The Royal Photographic Society

University of Brighton

Pictures From Space; - An Introduction To Multi-Spectral Remote Sensing

Dr. Graeme Awcock CEng MIET PhD
School of Environment & Technology
University of Brighton
G.J.Awcock@BRIGHTON.AC.UK

1910 infrared 100 2010

Graeme Awcock | *Pictures From Space; - An Introduction to Multi-spectral Remote Sensing* | University of Brighton

Presentation Overview

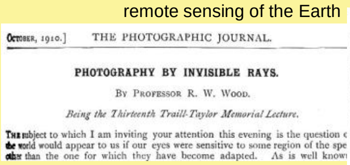
1910 infrared 100 2010

- *Anticipation of 'Infrared 100'*
- *Why multi-spectral sensing?*
  - *Atmospheric 'windows'*
  - *A case study of energy/target interaction*
    - ***Vegetation***
- *A brief history of multi-spectral imaging*
- *Case study of 'Landsat programme'*
  - *Systematic global monitoring 1972 – date*
  - *'Thematic' capability*
    - ***Each spectral band has a specific role...***
- *A change-detection application...*

Graeme Awcock | *As We Approach 'IR100'...* | University of Brighton

1910 infrared 100 2010

- Actually it is very fitting to be looking at multi-spectral remote sensing in this context
  - Since we are on the brink of a year of events from the RPS to celebrate the 100th Anniversary of ***infrared photography***
    - Which is fundamental to most of the achievements of remote sensing of the Earth

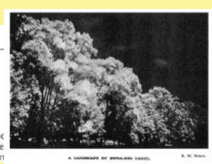

October, 1910.] THE PHOTOGRAPHIC JOURNAL.

PHOTOGRAPHY BY INVISIBLE RAYS.

By Professor R. W. Wood.

Being the Thirteenth Traill-Taylor Memorial Lecture.

The subject to which I am inviting your attention this evening is the question o
the world would appear to us if our eyes were sensitive to some region of the spe
other than the one for which they have become adapted. As is well know

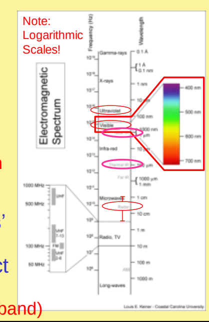


---

http://en.wikipedia.org/wiki/File:Electromagnetic-Spectrum.png

Graeme Awcock | *Electromagnetic Spectrum* | University of Brighton

- The range of wavelengths occupied by e/m waves is called the 'e/m spectrum'
  - All the way from...
    - Long-wave radio; $\lambda \approx 1000$ m
  - To...
    - Gamma-rays; $\lambda \approx 0.01$ nm
  - A spread of 100 million, million times (10^{14})
- Human visual response ***defines*** 'visible wavelengths'
  - 380 – 740 nm ***ONLY***
- Typically, RS satellites detect ultraviolet – microwave
  - ≈250 nm (UVB) - ≈100 cm (P-band)

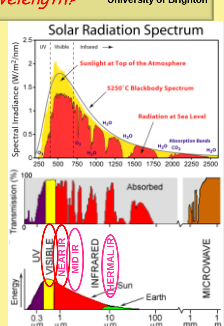


Canada Centre for Remote Sensing: *The Fundamentals of Remote Sensing*, Chapter 1

http://en.wikipedia.org/wiki/File:Solar_Spectrum.png

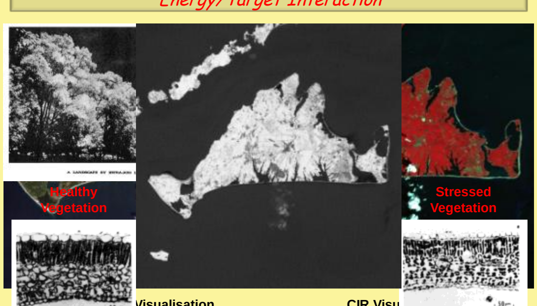
Graeme Awcock | *Why Use THAT Wavelength?* | University of Brighton

- The Sun emits its own spectrum of wavelengths
  - Which peak in the 'visible'
    - (Isn't evolution wonderful!)
- BUT, not all of it reaches the Earth's surface
  - Ozone (O_3), Water Vapour (H_2O) & Carbon Dioxide (CO_2) in the atmosphere absorb specific wavelengths
- BUT, note, the atmosphere has transparent 'windows':
  - We have to ***exploit*** these transparent windows with matching sensing capability



After Figures 2-28 & 2-29, Floyd F. Sabins, Remote Sensing Principles and Interpretation (3rd Edition)

Graeme Awcock | *Vegetation Case Study of Energy/Target Interaction* | University of Brighton



See http://history.nasa.gov/SP-168/section3a.htm for more images and appraisals

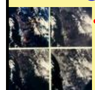
Graeme Awcock *Food For Thought...* University of Brighton

- "For centuries man has looked on the Nile Valley as one of the cradles of civilization,"
  - Astronaut FRANK BORMAN noted
- "Generations have explored, excavated, and interpreted the significance of the Nile and its delta, but it was not until 1965 that the world received its first panoramic view of this sprawling spectacle on the northern coast of Africa."
- "This picture revealed, for the first time as an entity, the 500 000-square-mile delta with its collar of wind-whipped rock and desert.
  This photograph became an important data point in man's quest to understand his environment."

Taken by Gemini IV Astronauts, 1965

Graeme Awcock *History of Multi-Spectral Imaging* University of Brighton

- Apollo 9 astronauts conducted first multi-spectral photography experiments

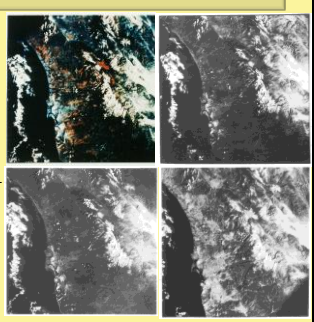


  - To capture Red, Green and Infrared channels
    - Which facilitated discrimination of Earth features
    - 140 sets of imagery covering southern US, Mexico...
- MSS-equipped Earth Resources Technology Satellites (ERTS) experiment launched in 1972
- In 1973 Skylab astronauts took 35,000 images
  - Earth Resources Experiment Package (EREP)
    - Film **AND** ***electronic*** imaging with 6-cameras
- In 1975 ERTS was renamed 'Landsat'...

See http://rst.gsfc.nasa.gov/Intro/Part2_14.html#I-18 & http://rst.gsfc.nasa.gov/Sect12/Sect12_2.html#12-5

Graeme Awcock *Apollo 9 Multi-Spectral Photography* University of Brighton

- The first multispectral photography from space happened during the 1968 Apollo 9 mission
- Four Hasselblad cameras were mounted in a holder such that they all aimed at the same target
  - an astronaut triggered their shutters simultaneously
- The montage of 4 photos that cover San Diego and the California / Mexico peninsular ranges includes the following filters:
  - Upper left: false colour infrared;
  - Upper right: green filter;
  - Lower left: red filter;
  - Lower right: B&W infrared



[1] Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6*

Graeme Awcock *Landsat; - Specified for Land Monitoring* University of Brighton

- Landsat is very important, as the first satellite programme ***optimised*** for Earth Monitoring
  - Moderate spatial resolution
    - Defined as[1] 4m – 60m width per pixel side
      - **Landsat 2-3 (MSS); 4 bands @82m, Thermal-IR @240m**
      - **Landsat 4-5 (TM); 6 bands @30m, Thermal-IR @120m**
  - \+ Also Allows coverage to repeat every 16 days
    - 7 days between adjacent 'swathes'; - each 185 km wide
  - \+ Sun-synchronous orbit (data for Landsat 4, 5)
    - Ensures that satellite crosses equator at same local sun time on every orbit; ≈ 9:45 am → clearer skies
      - **inclination 98.2°, altitude 705 km, orbital period 98.2 mins**
  - \+ Multi-spectral capability; - multiple 'bands'
    - **Visible** + **N**ear **IR** + **S**hort **W**ave **IR** + **T**hermal **IR** bands
      - **Landsat 4-5 TM; Blue, Green, Red, NIR, SWIR1, SWIR2, TIR**

[2] Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6*

Graeme Awcock *Moderate Resolution Means...* University of Brighton

- Landsat Thematic Mapper (TM) images at 30/120 m resolution
  - 30 m per pixel side for visible, NIR & MIR bands
  - 120 m per pixel side for Thermal IR band

Landsat TM images of suburban Madison, Wisconsin[2]

Red, visible band 3 (λ = 0.63 - 0.69 μm)

TIR, band 6 (λ = 10.4 - 12.5 μm)

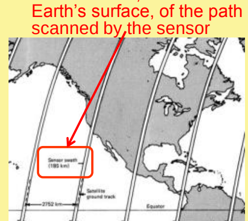
Google maps image of approx. area *Note scale*

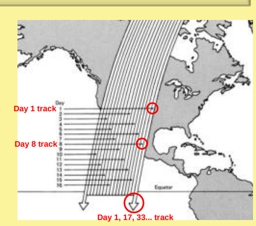
...'Cultural Features' Are Clearly Visible At 30m Resolution; -Roads, Fields, Urban Areas...

Images: Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6*

Graeme Awcock *Swathe (=UK Spelling of Swath)* University of Brighton

- Landsat 'Swathe' width is 185 km
  - i.e. The width, on the Earth's surface, of the path scanned by the sensor



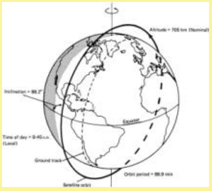


... Complete Coverage
... At 'Frequent' Intervals
- Adjacent swathes 7 days apart
- **'Revisit Period'** is 16 days
- Monitoring, NOT responsive

Images: Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6*

Graeme Awcock — **Sun-Synchronous Polar Orbit (SSPO)** — University of Brighton

- Satellite crosses equator at the SAME local time on EVERY orbit
  - Ensures same illumination
    - Vital for change monitoring



Landsat 5 orbit parameters shown

Orbital descent at 09:45 gives best chance of clear skies

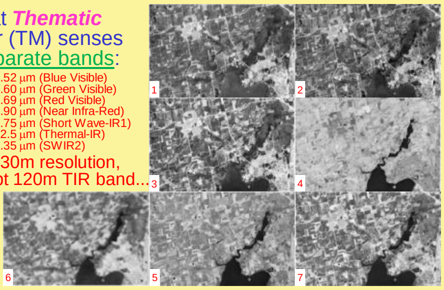
- During orbit period of ≈100 mins the Earth rotates ≈ 25°
  - 2752 km west for Landsat5
- SSPO is ***PREFERRED*** orbit for:
  - Earth Mapping, Earth Observation, Reconnaissance & Some Weather Satellites

Images: Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6*

Graeme Awcock — **Multi-Spectral Means…** — University of Brighton

- Landsat ***Thematic*** Mapper (TM) senses in 7 separate bands:
  1. 0.45-0.52 μm (Blue Visible)
  2. 0.52-0.60 μm (Green Visible)
  3. 0.63-0.69 μm (Red Visible)
  4. 0.76-0.90 μm (Near Infra-Red)
  5. 1.55-1.75 μm (Short Wave-IR1)
  6. 10.4-12.5 μm (Thermal-IR)
  7. 2.08-2.35 μm (SWIR2)
  - All at 30m resolution, except 120m TIR band…

Landsat TM images of suburban Madison, Wisconsin



… So land-cover can be classified into ***'Themes'***

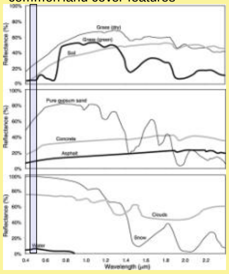
Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6 & 1 resp.*

Graeme Awcock — **Each Spectral Band Has A Role… 1** — University of Brighton

Table 6.3 Thematic Mapper Spectral bands

Band	Wavelength (μm)	Nominal Spectral	Principal Applications
1	0.45–0.52		Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest-type mapping, and cultural feature identification.

Figure 1.9 Spectral reflectances of common land cover features



… In The Thematic Classification of Land-Cover

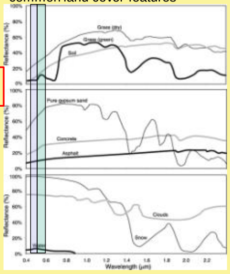
Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6 & 1 resp.*

Graeme Awcock — **Each Spectral Band Has A Role… 2** — University of Brighton

Table 6.3 Thematic Mapper Spectral bands

Band	Wavelength (μm)	Nominal Spectral	Principal Applications
1	0.45–0.52		Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest-type mapping, and cultural feature identification.
2	0.52–0.60		Designed to measure green reflectance peak of vegetation (Figure 1.9) for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.

Figure 1.9 Spectral reflectances of common land cover features



… In The Thematic Classification of Land-Cover

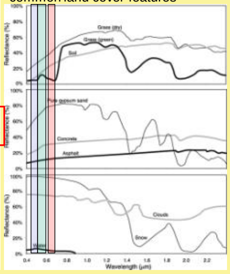
Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6 & 1 resp.*

Graeme Awcock — **Each Spectral Band Has A Role… 3** — University of Brighton

Table 6.3 Thematic Mapper Spectral bands

Band	Wavelength (μm)	Nominal Spectral	Principal Applications
1	0.45–0.52		Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest-type mapping, and cultural feature identification.
2	0.52–0.60		Designed to measure green reflectance peak of vegetation (Figure 1.9) for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.
3	0.63–0.69		Designed to sense in a chlorophyll absorption region (Figure 1.9) aiding in plant species differentiation. Also useful for cultural feature identification.

Figure 1.9 Spectral reflectances of common land cover features

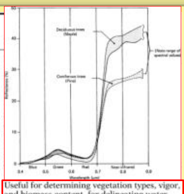


… In The Thematic Classification of Land-Cover

Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6 & 1 resp.*

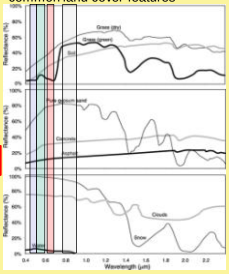
Graeme Awcock — **Each Spectral Band Has A Role… 4** — University of Brighton

Band	Wavelength (μm)	Nominal Spectral
1	0.45–0.52	
2	0.52–0.60	
3	0.63–0.69	
4	0.76–0.90	



Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.

Figure 1.9 Spectral reflectances of common land cover features



… In The Thematic Classification of Land-Cover

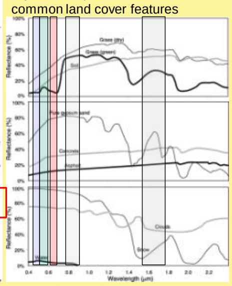
Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6 & 1 resp.*

Graeme Awcock — **Each Spectral Band Has A Role... 5** — University of Brighton

Table 6.3 Thematic Mapper Spectral bands

Band	Wavelength (μm)	Nominal Spectral	Principal Applications
1	0.45–0.52		Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest-type mapping, and cultural feature identification.
2	0.52–0.60		Designed to measure green reflectance peak of vegetation (Figure 1.9) for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.
3	0.63–0.69		Designed to sense in a chlorophyll absorption region (Figure 1.9) aiding in plant species differentiation. Also useful for cultural feature identification.
4	0.76–0.90		Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.
5	1.55–1.75		Indicative of vegetation moisture content and soil moisture. Also useful for differentiation of snow from clouds.

Figure 1.9 Spectral reflectances of common land cover features



... In The Thematic Classification of Land-Cover

Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6 & 1 resp.*

Graeme Awcock — **Each Spectral Band Has A Role... 7** — University of Brighton

Band	Wavelength (μm)	Nominal Spectral	Principal Applications
1	0.45–0.52		
2	0.52–0.60		
3	0.63–0.69		
4	0.76–0.90		
5	1.55–1.75		
7[a]	2.08–2.35		Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

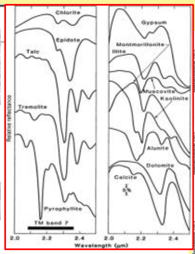
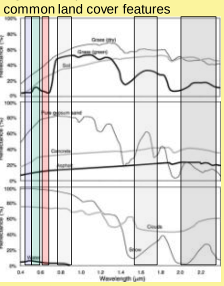


Figure 1.9 Spectral reflectances of common land cover features



... In The Thematic Classification of Land-Cover

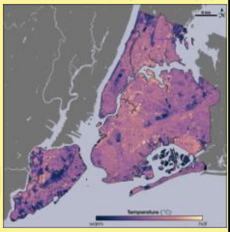
Lillesand, T.M. et al (2008) *Remote Sensing & Image Interpretation (6th Edn), Chapter 6*

Graeme Awcock — **Each Spectral Band Has A Role... 6** — University of Brighton

Table 6.3 Thematic Mapper Spectral bands

Band	Wavelength (μm)	Nominal Spectral	Principal Applications
1	0.45–0.52		Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest-type mapping, and cultural feature identification.
2	0.52–0.60		Designed to measure green reflectance peak of vegetation (Figure 1.9) for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.
3	0.63–0.69		Designed to sense in a chlorophyll absorption region (Figure 1.9) aiding in plant species differentiation. Also useful for cultural feature identification.
4	0.76–0.90		Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.
5	1.55–1.75		Indicative of vegetation moisture content and soil moisture. Also useful for differentiation of snow from clouds.
6[a]	10.4–12.5		Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7[a]	2.08–2.35		Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

Thermal map of New York City during a heat wave on 14th August 2002
http://earthobservatory.nasa.gov/Features/GreenRoof/greenroof2.php



... In The Thematic Classification of Land-Cover

Graeme Awcock — **The Landsat Legacy** — University of Brighton

- 7 Landsat Missions Were Launched:
  - ERTS-1/Landsat 1: NASA Experimental; Functional 1972-78
  - Landsat 2: NASA Experimental; Functional 1975-82
  - Landsat 3: NASA Improved/Exp; Functional 1978-83
    - Declared operational in 1979; Transferred to NOAA for operational control
  - Landsat 4: Improved Design With TM; Functional 1982-2001
    - In 1984-1999, operations were commercialised via EOSAT
  - Landsat 5 : Same Design As LS 4; Functional 1984-*date*
  - Landsat 6: Improved Design With ETM; Launch Failure 1993
  - Landsat 7: Improved Design With ETM+; Funct'n'l 1999-*date*
    - 1992 Land Remote Sensing Act Required NASA & USGS to ENSURE operations after Landsat 7
      - **Landsat operations returned to government control**
  - Landsat Data Continuity Mission (LDCM); Earliest Launch 2011
- This legacy supports long-term change detection...

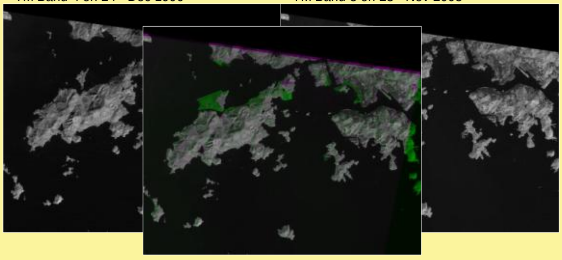
Graeme Awcock — **Some Concluding Thoughts** — University of Brighton

1910 infrared 100 2010

- Remote Sensing imagery is a genuine successor of R. W. Wood's 1910 heritage
  - It is fundamentally dependent on "*imaging* by invisible rays"
- This multi-spectral imagery is VITAL to helping us understand our threatened planet
- You are now aware of some fantastic camera systems, working 24/7
  - Which none of us could normally afford!
    - BUT a tremendous legacy of data, from all around the globe, is available free of charge to all of us...
  - I thoroughly recommend exploration of the Landsat data archive; - for example...

Graeme Awcock — **Change Detection in Hong Kong** — University of Brighton

Hong Kong Islands Observed by Landsat 4 TM Band 4 on 24th Dec 1990 | Hong Kong Islands Observed by Landsat 5 TM Band 5 on 23rd Nov 2005



Change Visualisation of Hong Kong Islands 1990-2005
Magenta=1990 ONLY; Green=2005 ONLY; Grey=Both


Graeme Awcock
Thanks For Your Attention
University of Brighton
• Any Questions?