

Integration of Remote Sensing and GPS

AITRS Workshop on Integration of Geospatial and
Statistical Data

February 16 – 19, 2015

Use of Remotely Sensed Imagery

- Satellite imagery and aerial photography can be powerful datasets
- An understanding of some basic terms and differences between the two will allow you to make better decisions about when and how to use remotely sensed imagery
- The ability to automatically extract objects from imagery, whether point or linear, is appealing but is also a considerable technical challenge

Remote Sensing Terminology

- **Satellite Image:** Data based on reflected or emitted electromagnetic radiation collected from orbit that can be used to create photograph-like representations.
- **Aerial Image:** Data based on reflected or emitted electromagnetic radiation collected from a sub-orbital platform, most commonly an airplane, which can be used to create photograph-like representations.
- **Sensor:** A particular instrument used to collect either satellite images or aerial photographs with a set resolution and sensitive to particular bands.

Remote Sensing Terminology

- **Band:** A range of values in the electromagnetic spectrum (e.g., visible light) to which a sensor is sensitive.
- **Color Composite:** An image created from a combination of bands using the Red, Green, and Blue channels. If the red, green, and blue bands are in the red, green, and blue channels the image is referred to as a true-color composite.
- **Pixel:** The lowest resolvable unit in any remotely sensed image, the dimensions of which are referred to as the resolution of the image.

Combining GPS and Remote Sensing

- Field-validation of EA boundaries that were created in the NSO's GIS lab from prior digitization, including sketch maps.
- May be the primary source for EA digitization if other sources, such as sketch maps, are not available or interpretable.
- Mobile data collection can be used to verify both the geolocation and attributes of data collected using remotely sensed imagery

Primary NSO Uses for GPS

- **Building point collection** – These points can includes individual housing units, collective housing, and landmarks used for enumerator navigation.
- **Physical feature digitization** – Some physical features may not be apparent in imagery but are useful for a census geographic database.
- **Statistical boundary verification** – Imagery should be used for primary digitization, however GPS can be used for detailed boundary edits, especially in cases of annexed or newly created areas.

Challenges with GPS

- **Signal strength** – Topography, both natural and of the built environment strongly affect GPS signal and accuracy.
- **Connectivity** – Availability of WiFi networks can have an effect on accuracy of geolocations.
- **Collection Instrument and Integration**– Handheld units can be used offline in a carefully managed verification program. Centralized solutions require enterprise data management and application development.

Remote Sensing Approach

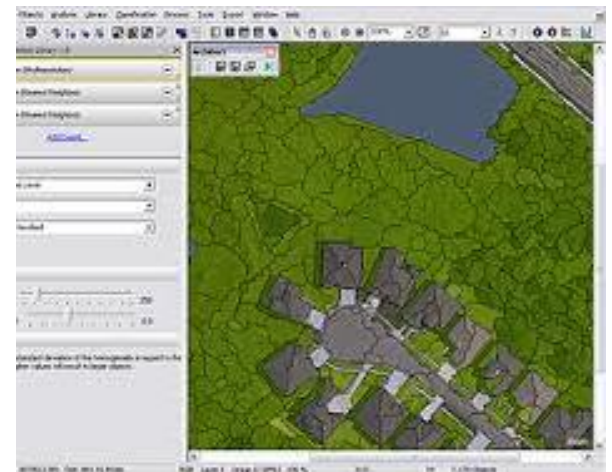
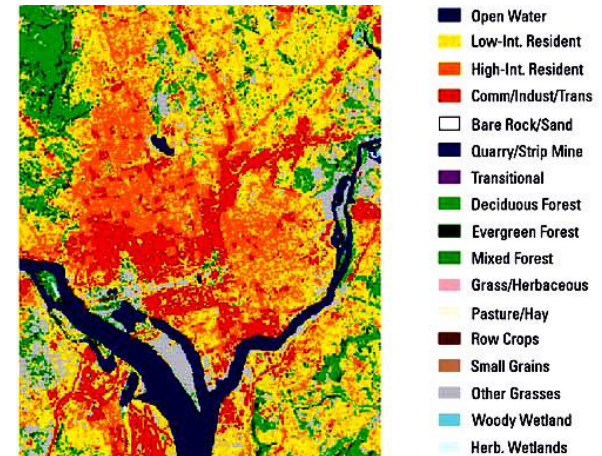
- Through integration of satellite imagery, analysts and census planners can identify areas that require additional fieldwork, for instance to account for new growth in areas surrounding cities.
- Imagery can be used to track areas of high-growth or leap-frog growth, where a new settlement cluster has appeared beyond the urban boundary
- Change-detection can mean visual or automated tracking of newly-settled area. Change detected via satellite imagery must be field verified.

Working with Remotely Sensed Imagery

- Imagery Integration and Verification:
 - Photo-like Images – Manual interpretation and adjustment only
 - Desktop GIS software able to open images
- Imagery Analysis:
 - Spatial analyst in ArcGIS, ERDAS Imagine, ENVI, GRASS/QGIS (open-sources)
 - Multi-band – Classification, automation, and analysis

Classifying and Interpreting Satellite Data

- Multi-Spectral Classification
 - Based on how light reflects off of different surfaces
- Object-based classification
 - Based on reflecting light and geometric properties of objects
- Photo-interpretation
 - Human interpretation (digitization) of features



Using Imagery to Field-Verify EA Maps (Photo Interpretation)

- R/S imagery can be used to update EA boundaries as physical boundaries are clearly visible. Areas of new or increased settlement may also be identified for the splitting or creations of new EAs.

EA boundaries delineated atop
a **panchromatic** satellite image



Using Imagery to Field-Verify EA Maps

- Resolution of remote sensing data
 - Only high-resolution products are useful for most NSO applications, such as Quickbird (0.82m), Ikonos (1m), IRS (5.8 m pan), Orbimage 3 and 4 (1m), and SPOT 5 (2.5m). Ikonos was launched in 1999 and Quickbird was launched in 2001.
 - For most census applications, 5m or better spatial resolution is needed to identify housing units and the spread of population settlements, with multi-spectral imagery less absolutely necessary.

Using Imagery to Field-Verify EA Maps

- **Advantages:**

- Up-to-date coverage of very large areas at relatively low cost with lower spatial resolution images. Streaming services have made high-resolution imagery available for photo-interpretation.
- High spatial resolution images offer the ability to cover areas at a level of detail sufficient for EA delineation, provided population estimates exist for the areas delineated.
- Imagery can permit mapping of inaccessible or hard to reach areas.
- Imagery can serve as an independent check on field verification.
- Identification of settlements and settled areas that are not indicated on other source maps.

Using Imagery to Field-Verify EA Maps

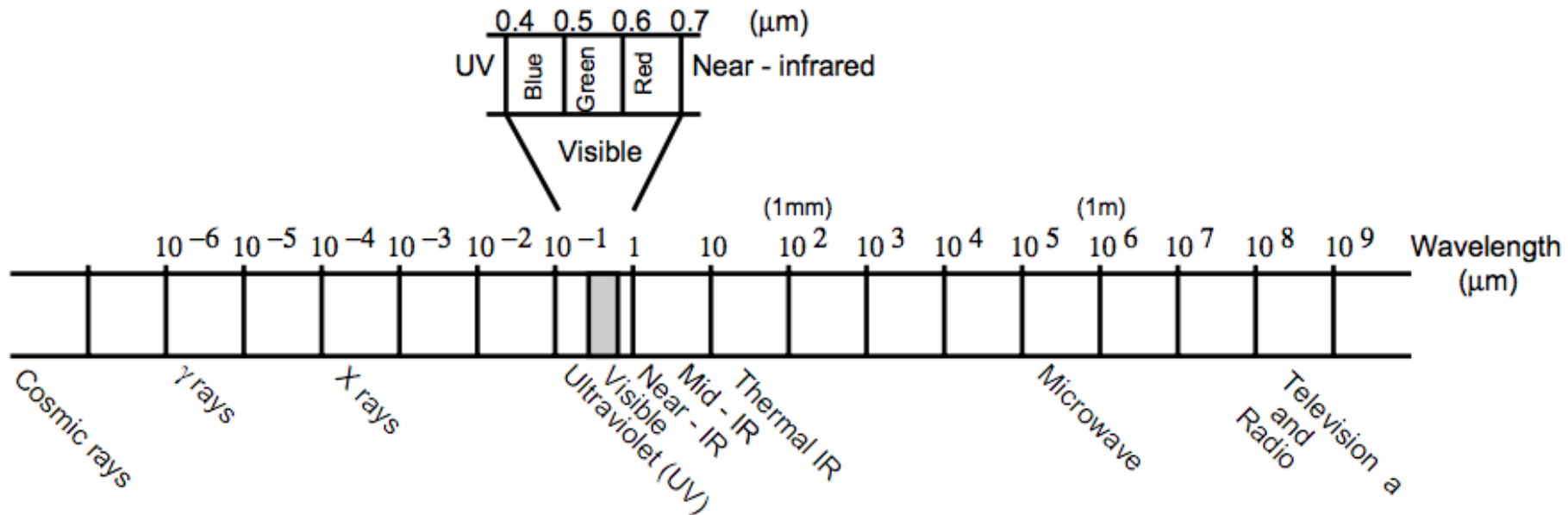
- **Disadvantages**

- The spatial resolution of many systems, especially low cost ones, is not sufficient for most census applications (though can still be useful for change detection).
- In the case of optical sensors, cloud and vegetation cover restricts image interpretation (though advanced processing techniques exist to mitigate these challenges).
- The problem of low contrast between features — e.g., dirt roads and traditional building materials in rural areas — makes their delineation particularly difficult in developing world contexts and arid environments.
- Image processing (a requirement for all automated uses of remotely sensed data) requires a high level of expertise – which may not be available at the NSO.

Background on Remotely Sensed Data and Sources

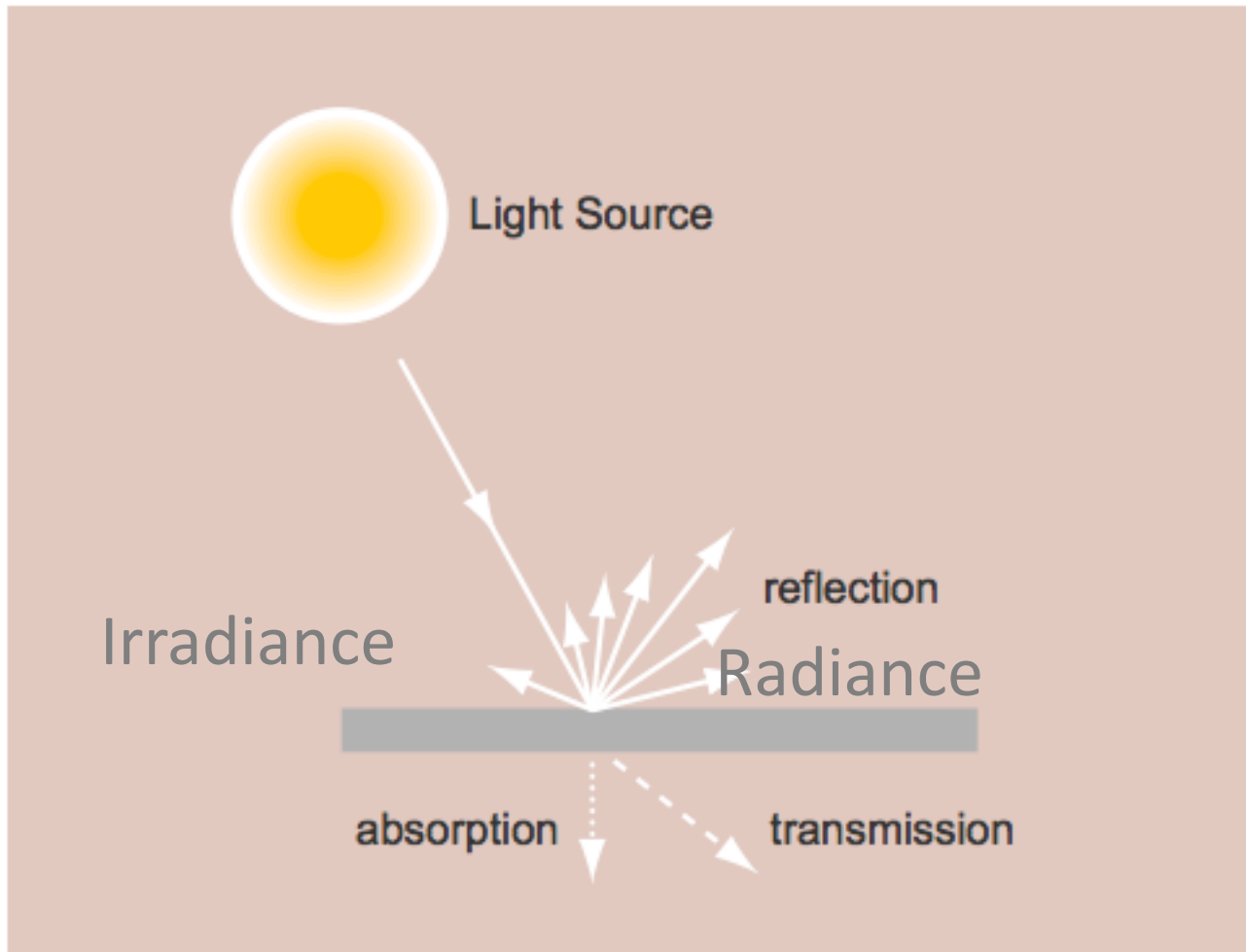
Wavelengths

- Electromagnetic spectrum



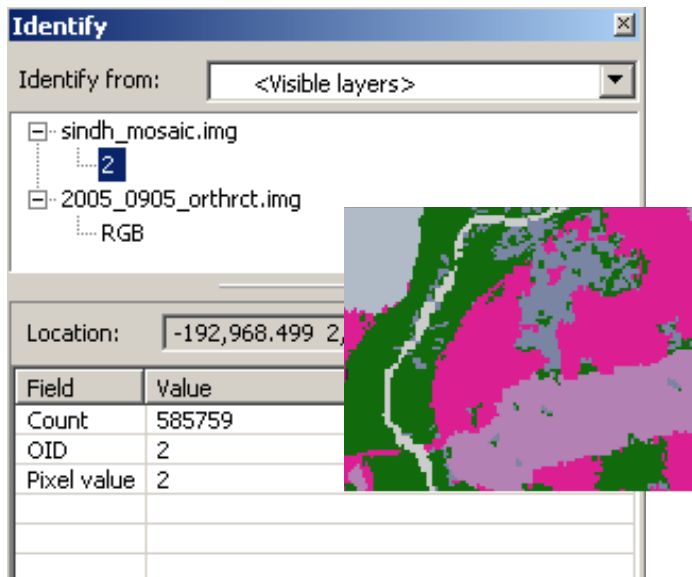
From Lillesand and Kiefer 1987

Spectral Response



Raster Representation

The images show the same area in a categorical and image-like raster.



Identify

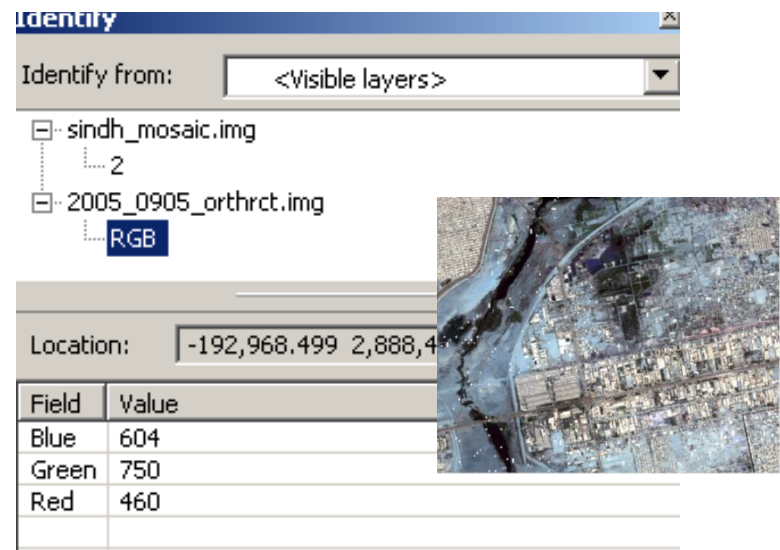
Identify from: <Visible layers>

- sindh_mosaic.img
 - 2
- 2005_0905_orthrct.img
 - RGB

Location: -192,968.499 2,888.4

| Field | Value |
|-------------|--------|
| Count | 585759 |
| OID | 2 |
| Pixel value | 2 |

Categories represented by a number.



Identify

Identify from: <Visible layers>

- sindh_mosaic.img
 - 2
- 2005_0905_orthrct.img
 - RGB

Location: -192,968.499 2,888.4

| Field | Value |
|-------|-------|
| Blue | 604 |
| Green | 750 |
| Red | 460 |

3 band combination that may be integer or continuous (floating point).

Raster Formats

- There are several types of raster formats.
 - Ex: BMP, GIF, ERS, MrSID, NITF, IMG.
- Most commonly used: TIFs, IMGs, JPGs, Binary files, GRIDS.
- The IMG format works best as an interchange file between ESRI and other proprietary software.
- What is a GRID file?
 - A grid is a raster data storage format native to ESRI. There are two types of grids: integer and floating point.
 - Integer grids are used to represent discrete data.
 - Floating-point grids represent continuous data.

Discrete and Continuous Data

- **Discrete:** A geographic feature with a discernible boundary. For example a house, road, or tree stand. Represented by a vector or raster.
- **Continuous:** A geographic field that varies over space without a clear defined boundary. For example elevation, population density, or rainfall. Nearly always represented by a raster, or contour lines.

Integer and Floating Data

- **Integer:** Always used when representing discrete data in raster format (categories). Can also be used to represent continuous data on a compressed histogram.
- **Floating Point:** Each pixel can have a positive or negative real number value. Processor intensive during analysis. Files can be large.

Integer Datasets

- Categorical rasters are stored as discrete integer values.
- Image like rasters (combinations of colored bands) rasters may also have discrete values.

| Bit Value | Possible Integer Values |
|-----------|-------------------------|
| 1 | 0 - 1 |
| 8 | 0 - 255 |
| 16 | 0 - 6,535 |
| 32 | 0 - 4,294,967,295 |

Halved for signed values.

Types of Sensors

- Active
 - RADAR
 - LiDAR
- Passive (optical)
 - ASTER
 - AWiFS
 - CBERS
 - IKONOS
 - Landsat
 - MODIS
 - SPOT
 - Quickbird
 - WorldView

Landsat 8 – OLI

Launched February, 2013

■ Operational Land Imager

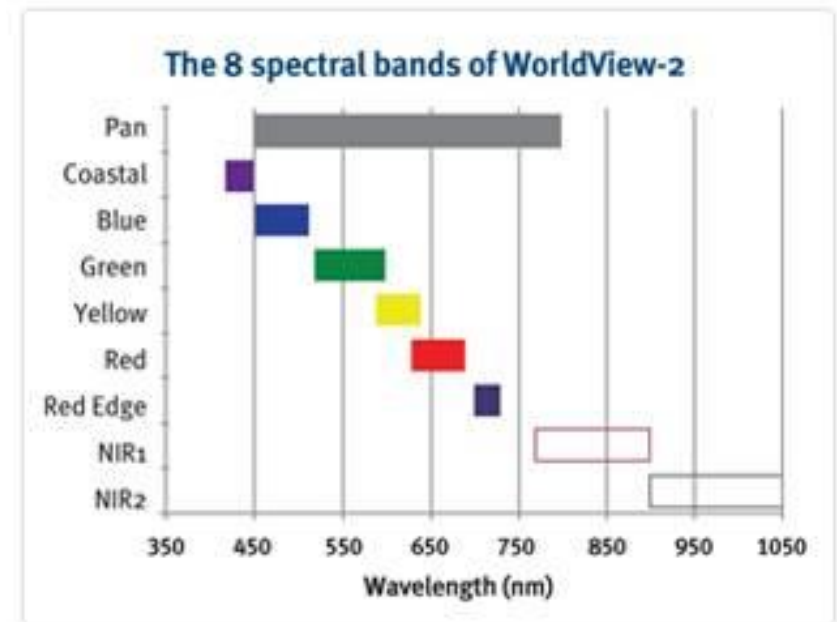
| Spectral Band | Wavelength | Resolution |
|----------------------------|-----------------------------|------------|
| Band 1 - Coastal / Aerosol | 0.433 - 0.453 μm | 30 m |
| Band 2 - Blue | 0.450 - 0.515 μm | 30 m |
| Band 3 - Green | 0.525 - 0.600 μm | 30 m |
| Band 4 - Red | 0.630 - 0.680 μm | 30 m |
| Band 5 - Near Infrared | 0.845 - 0.885 μm | 30 m |
| Band 6 - MIR | 1.560 - 1.660 μm | 30 m |
| Band 7 - MIR | 2.100 - 2.300 μm | 30 m |
| Band 8 - Panchromatic | 0.500 - 0.680 μm | 15 m |
| Band 9 - Cirrus | 1.360 - 1.390 μm | 30 m |

- 12 Bit Radiometric Resolution
- Pushbroom vs. Whiskbroom sensor



WorldView 2 – Digital Globe

- Launched October 8th 2009
- 1.8 m Multispectral
 - 8 Bands
- .46 m panchromatic
- 11 bit
- 16.4 km swath width
- 1.1 day repeat



Ikonos

- Spectral/Spatial resolutions:
 - 4 Multispectral bands (4m)
 - Blue, Green, Red, NIR
 - 1 panchromatic band (1m)
 - Swath 11 km
- Temporal resolution: < 3 days
- Radiometric resolution: 11-bits

QuickBird

- Spatial/Spectral Resolution
 - 0.6m, Panchromatic
 - 2.4m, multi-spectral (1-B, 2-G, 3-R, 4-NIR)
 - 16.5 km swath width
- Radiometric
 - 11 bit
- Temporal
 - 1-3.5 day Revisit Frequency

Others

- Formosat 2
 - Taiwan's National Space Organization
 - 2 meter pan, 8 m vis-NIR
 - Cosmos KVR-1000
 - 2 m pan - Russian
 - Eros
 - Earth Resources Observation Satellite, Israel
 - 1.8 m pan
 - Indian Remote Sensing (IRS)
 - 5.8 m pan, 23 m vis-NIR
 - Kompsat 2
 - KOREAN MultiPurpose SATellite
 - Panchromatic : 1 m
 - Multispectral (B, G, R, NIR) : 4 m
 - Worldview 1, 2, 3
 - Geoeye 1, 2
 - Rapid Eye
- <http://www.satimagingcorp.com/satellite-sensors.html>

Storage and Retrieval

- Storage
 - Remotely-sensed datasets tend to be large
 - 500 MB-3 GB for high-resolution (QB, 18 km x 16.4 km)
 - 1 GB Landsat-8 (170 km x 183 km)
- Retrieval
 - Image catalogs can be confusing, staff time often lost trying to find correct image
- ERDAS Apollo (Hexagon), ArcGIS Image Extension for ArcGIS Server (esri)

Conclusion

- Remote sensing cannot replace field work with GPS-enabled devices, but it can save a significant amount of staff time and thus expenses
- The benefits of remotely sensed data can be accessed even with a minimum amount of staff experience and exposure (photo interpretation)