Lesson 4b – Remote Sensing
and geospatial analysis to integrate observations over larger scales

- We have discussed static sensors, human-based (participatory) sensing, and mobile sensing.
- **Remote sensing**: Satellite or aircraft; Capacity to observe at large scales (and increasingly high spatial resolution!)
Looking at data spatially
historical perspective

• In 1854, a major cholera outbreak in London had already taken hundreds of lives.
• Early theories blamed the infection on noxious air quality.
• Dr. John Snow believed that if the air caused cholera, the cases should be uniformly distributed along streets.
• By plotting each known cholera case on a street map, Snow could see that the cases occurred almost entirely among those who lived near the Broad Street water pump.
• This pump belonged to a company, which drew water polluted with London sewage from the lower Thames River.
Remote Sensing

- **Remote Sensing** - collecting data about objects or landscape features without coming into direct physical contact with them. It can be anything from: visual assessment of ones surrounding area, using a hand held camera, aerial photography, satellite imagery.

- These days, remote sensing means electro-optical data collection of **reflected electromagnetic radiation (EMR)**

- Ranging from the simple photographs (visible spectrum) to **hyperspectral** (wide range of EMR)

- **Lidar (Light Detection and Ranging)** has arisen recently as an exciting method for measuring elevation properties
Remote Sensing – past and present
Overview of useful EMR bands

- The atmosphere is efficient at absorbing some wavelengths
  - This is a function of the molecules in the atmosphere
  - However, the range of possibilities is great, and optics technology continues to improve
Remote Sensing data analysis

- All remote sensing data requires significant processing before it is usable.
- **Geo-referencing** is critical due to atmospheric distortion of the EMR.
  - This corrects the earth surface position with the signal.
- **Signal calibration** is also important because atmospheric conditions (e.g., air pollution) affects the signal.
  - Typically calibration surfaces of known properties (e.g., road surfaces or bare earth areas).
- **Visualization and classification** — The resulting product is usually viewed as an image and different characteristics or EMR band values (from pixels) are classified according to environmental properties.
  - Major software has developed in the area of geospatial analysis (known as **Geographical Information System (GIS)** software).
Geospatial technologies

- We refer to remote sensing, spatial analysis and visualization as geospatial technologies.
- Geospatial technologies are integrated as follows:
  - **GIS** for data collection, storage and analysis.
  - **GPS** to capture precise and accurate spatial data from the field.
  - **Remote sensing** to give a synoptic and timely view of landscape change.
  - **Spatial analysis** to discern patterns in the data, and to understand underlying physical and social processes.
  - **Visualization** to impart results to the public.

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Remote Sensing Resolution

- **AVHRR**
- **Landsat 1**
- **Landsat 4**
- **SPOT**
- **Landsat 7**
- **IKONOS**
- **Quickbird**
- **ADAR**

**Spatial Resolution**

- 1 km
- 100 m
- 10 m
- 1 m

**Time**

- 1970
- 1980
- 1990
- 2000
- 2010

**Number of Bands**

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Spatial Resolution Example

30m X 30m

1m x 1m per pixel
Geospatial Analysis Challenges

Our ability to analyze data has increased significantly over time. The amount of data available has grown exponentially, especially after the introduction of Aqua and Terra satellites. This growth has challenged our ability to handle and analyze the data effectively.

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Remote Sensing and Water Quality

- Aircraft-based multispectral imaging to achieve necessary spatial resolution
- Turbidity, TSS, chlorophyll-a, CDOM
- There is more potential here

Brezonik and co-workers
See: http://water.umn.edu/pres_pubs.html
Other air/ground-based remote sensing

- Lidar – high resolution DEM, vegetation topology, snow/ice cover
- Thermal infrared remote sensing – thermal gradients, mixing phenomena, pollution sources
- CUAHSI Hydrologic Measurement Facility (http://www.cuahsi.org/hmf.html)
  - Geophysical: electromagnetic toolbox (em induction, ground-penetrating radar, electrical resistivity imaging)
  - Evapotranspiration Suite
    - Integrated Cavity Output Spectroscopy (ICOS) – water vapor isotopes for quantifying and partitioning large scale ET fluxes
    - Large Aperture Scintillometer (LAS) – large-scale sensible heat fluxes, atmospheric turbulence
- Codar – HF radar – large scale surface water velocity, wave action

Bonner, Maidment, Minsker, et al.
WATERS Test Bed Site at Corpus Christi Bay
Land Cover Classification
Land cover monitoring

Deforestation and emergence of agriculture in Bolivia

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Airborne ADAR Image Over DEM
(Bands: Blue, Green, Red, NIR; 1 meter resolution)
Mortality Visualization

North facing slopes show moderate mortality on several different slopes and elevations.

South facing slopes show little mortality.
As we learn what the data mean, we can provide clear information to policy and decision-makers.

We can also combine our data with participatory (community) observations.
Lidar: Major advancements in recent years

Aircraft and ground-based Lidar is now providing resolution of > 9 elevations per m²
Virtually reproducing forests and snow depth

- Summer lidar flight to measure ground elevation (DEM) and tree geometry
- Winter lidar flight can then be used to produce a “snow” DEM
Remote sensing products are enabling us to observe changes over large spatial scales; these would be difficult to assess on-the-ground.

However, there are many things remote sensing platforms cannot sense (e.g., various environmental properties and most subsurface properties).

Therefore, integrating ground-based with remote sensing approaches is the ultimate pathway to systems monitoring water sustainability.