Environmental Remote Sensing
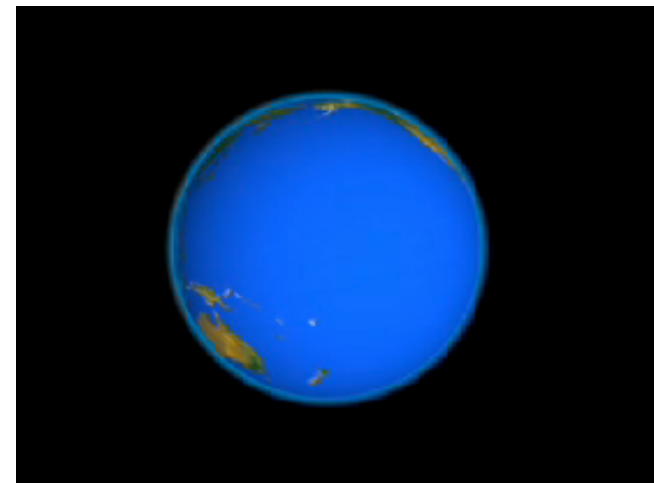## *GEOG 2021*

Lecture 8

Orbits, scale and trade-offs, revision

Orbits: trade-offs / pros and cons

- ## Polar orbiting
  - Polar (or near-polar) orbit – inclined 85-90° to equator
  - Typical altitude 600-700km, orbital period ~100 mins so multiple (15-20) orbits per day
  - Majority of RS instruments e.g. MODIS, AVHRR, Landsat, SPOT, Ikonos etc.

Orbits and trade-offs: polar

- Advantages
  - Higher spatial resolution (<m to few km), depending on instrument and swath width
  - Global coverage due to combination of orbit path and rotation of Earth
- Disadvantages
  - Takes time to come back to point on surface e.g. 1 or 2 days for MODIS, 16 days for Landsat

Orbits: trade-offs / pros and cons

- Geostationary
  - Orbit over equator, with orbit period (by definition) of 24 hours
  - <u>Always in same place over surface</u>
  - 36,000km altitude i.e. MUCH further away then polar

Orbits and trade-offs: Geostationary

- Advantages
  - Always look at same part of Earth
  - Rapid repeat time (as fast as you like) e.g. Meteosat every 15 minutes - ideal for weather monitoring/ forecasting
- Disadvantages
  - Much higher (36000km) altitude means lower resolution
  - Not global coverage – see same side of Earth

Orbits and trade-offs: Geostationary

METEOSAT 2nd Gen (MSG)
(<u>geostationary orbit</u>)
    1km (equator) to 3km
    (worse with latitude)
    Views of whole Earth disk
    every 15 mins
    30+ years METEOSAT
    data
MSG-2 image of Northern
Europe
"Mostly cloud free"

Remember, we always have trade-offs in space, time, wavelength etc. – determined by application

- Global coverage means broad swaths, moderate-to-low resolution
  - Accept low spatial detail for global coverage & rapid revisit times
  - Land cover change, deforestation, vegetation dynamics, surface reflectance, ocean and atmospheric circulation, global carbon & hydrological cycle
  - E.g. MODIS (Terra, Aqua) (near-polar orbit)
    - 250m to 1km, 7 bands across visible + NIR, swath width ~2400 km, repeat 1-2 days
  - MERIS (near-polar orbit)
    - ~300m, 15 bands across visible + NIR, swath width ~1100 km, repeat time hours to days

Remember trade-offs in space, time, wavelength etc.

- Sea-WIFS

  - Designed for ocean colour studies
  - 1km resolution, 2800km swath, 16 day repeat (note difference)
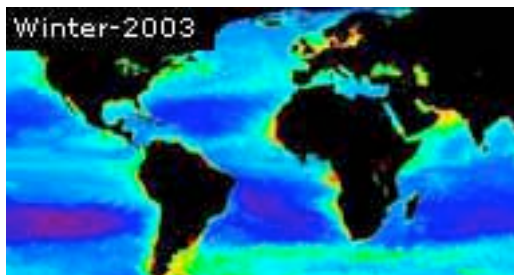
Remember trade-offs in space, time, wavelength etc.

MERIS image of Californian
fires
October 2007

Remember trade-offs in space, time, wavelength etc.

- ## Local to regional
  - Requires much higher spatial resolution (< 100m)
  - So typically, narrower swaths (10s to 100s km) and longer repeat times (weeks to months)
  - E.g. Landsat (polar orbit)
    - 28m spatial, 7 bands, swath ~185km, repeat time nominally 16 days BUT optical, so clouds can be big problem
  - E.g. Ikonos (polar orbit
    - 0.5m spatial, 4 bands, swath only 11 km, so requires dedicated targeting

Remember trade-offs in space, time, wavelength etc.

- SPOT 1-4
  - Relatively high resolution instrument, like Landsat
  - 20m spatial, 60km swath, 26 day repeat

Seville (Spain)   Mojave desert (USA)   Vancouver (Canada)
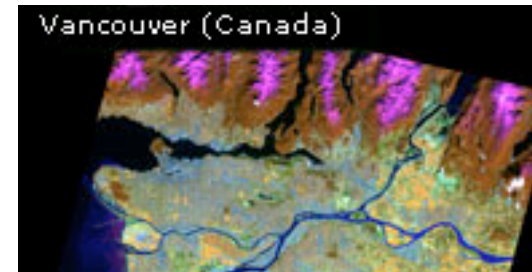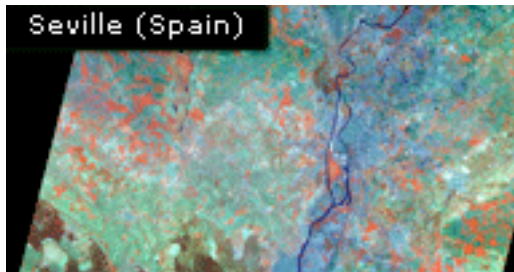
- IKONOS, QuickBird
  - Very high resolution (<1m), narrow swath (10-15km)
 - Limited bands, <u>on-demand acquisition</u>

Summary

- Instrument characteristics determined by application
  - How often do we need data, at what spatial and spectral resolution?
  - Can we <u>combine</u> observations??
  - E.g. optical AND microwave? LIDAR? Polar and geostationary orbits? Constellations?
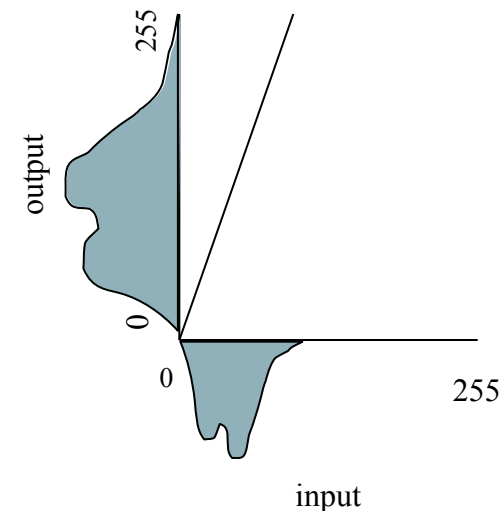
Revision

- Lecture 1: definitions of remote sensing, various platforms and introduction to EM spectrum, atmospheric windows, image formation for optical and microwave (RADAR)
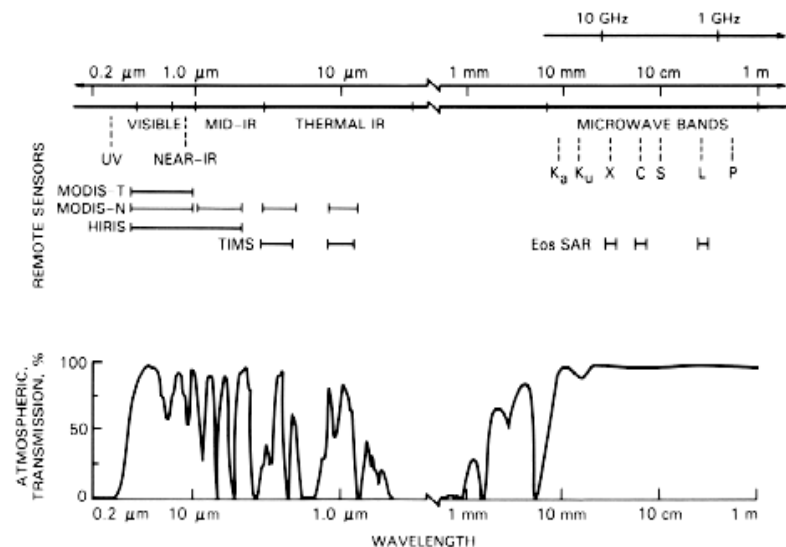
Revision

- Lecture 2: image display and enhancement
  - To aid image interpretation
    - Histogram manipulation: linear contrast stretching, histogram equalisation, density slicing
    - Colour composite display: e.g. 'real' (R, G, B); 'false' (FCC – NIR, R, G); pseudocolour
    - Feature space plots (scatter of 1 band against another)
  - Image arithmetic
    - Reduce topographic effects
      - dividing;
      - average out noise by adding bands;
      - masking by multiplication
    -

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Cloud of reflectance points in NIR-red waveband space for agricultural crops observed throughout the growing season.

CORN

COTTON

SOIL

ALFALFA

WHEAT

Water
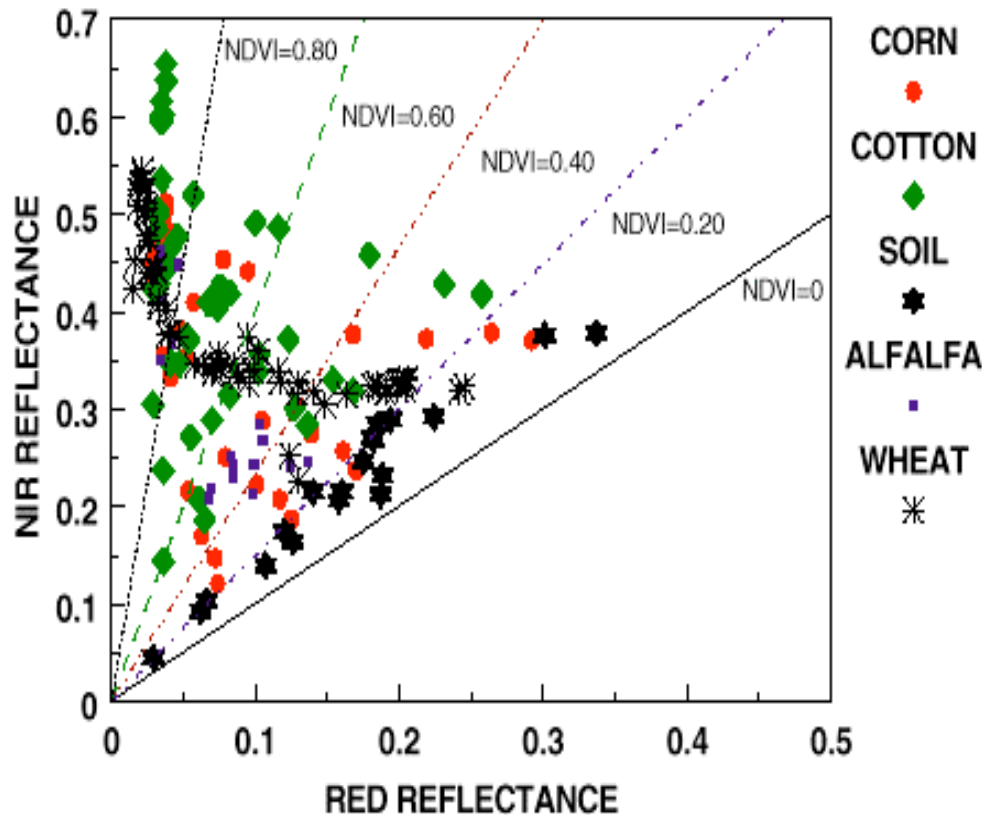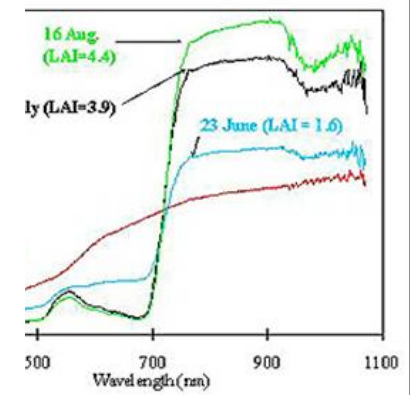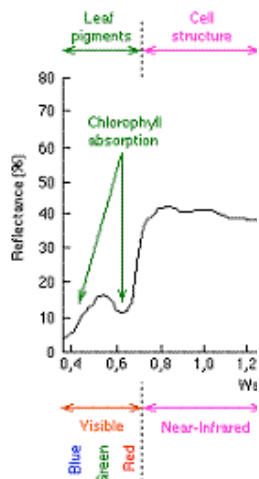
Revision

- Lecture 4: classification
  - Producing thematic information from raster data
  - Supervised (min. distance, parallelepiped, max likelihood etc.)
  - Unsupervised (ISODATA) – iterative clustering
  - Accuracy assessment: confusion matrix
    - Producers accuracy: how many pixels I know are X are correctly classified as X? Errors of omission (val/col total)
    - Users accuracy: how many pixels in class Y that I know don't belong there? Errors of comission (val/row total)

Revision

- L5: spatial operators, convolution filtering
  - 1D examples e.g. mean filter [1,1,1] smooths out (low pass filter)
    - 1st differential (gradient) [-1,0,1] - detects edges (high pass filter)
    - 2nd differential (2nd order gradient) [1,-2,1] detects edges of edges (high pass)
  - Applications:
    - Low-pass filter to smooth RADAR speckle
    - High-pass to detect edges of field boundaries, or directions of edges e.g. roads in an image;
    - Or slope (gradient) and aspect (direction) e.g. apply 1 in x direction and 1 in y direction – result direction vector = aspect; size = steepness (slope)

- Consider the following one-dimensional signal (a) and digital convolution filter (b):

  (a) 1 1 2 4 5 5 5 5 4 2 1 1 -1 -1 -1 -1

  (b) -1 0 1

  Answer the following parts. using illustrations where appropriate:

  (i) Convolve the filter in (b) with the signal in (a). identify the type of filter, and discuss the impact of the filter on the features of the signal. (25%)

  (ii) Convolve the signal resulting from part (i) with the filter in (b), identify the filter resulting from two convolutions with filter (b) and discuss the impact of the filter on the (original) signal (a). (25%)

  (iii) Describe how you could have achieved the result in (ii) with a single convolution filter. (10%)

  (iv) Describe how you would use filters of the type given in (b) to determine characteristics of a digital elevation model (DEM) pertinent to EITHER A: hydrological modelling OR B: estimating incident shortwave radiation over the area of the DEM. (40%)

Previous exam Qs: 2009

- i) Remember, as this is not a mean filter you don't have to divide by the number of elements in the filter (5 here). It doesn't really matter to the result if you do - in an exam we only take a mark or two off for this, but it will alter the numerical values below - so scale numbers accordingly:

  IN: 1 1 2 4 5 5 5 5 4 2 1 1 -1 -1 -1 -1
  OUT: 1 3 3 1 0 0 -1 -3 -3 -1 -2 -2 0 0

  First order differential i.e. gradient or edge detection (high-pass) filter. Positive when gradient increasing, negative when gradient decreasing, flat elsewhere, although as the signal is a bit noisy the resulting edges aren't particularly strongly defined.

- ii) IN: 1 3 3 1 0 0 -1 -3 -3 -1 -2 -2 0 0
  OUT: 2 -2 -3 -1 -1 -3 -2 2 1 -1 2 2

- Detects the edges of edges - although even noisier now. This is 2nd derivative filter. 'Edges' in the signal that are actually noise will also be enhanced, so the noisier the original signal the less clear the real edges will be.

- iii) 1 -2 1

- iv) For A you are more interested to find where there are low points (edges) in the DEM i.e. valleys, which indicate downward flow, as well as the direction of those slopes. For B it is more about finding the projected area in the direction of the sun to work out how much energy is arriving, so slope and aspect (direction of slope) required.

Previous exam Qs: 2010

- 2010: Consider the one-dimensional digital convolution filter, F:
F = -1 -2   0   1   2
    and the one-dimensional signal, S:
S = 11 10   14   11   13   11   24   21   22   21   23   20
and note that convolution results at the edges of a signal depend on what the signal is assumed to be outside of what is given (i.e. before and after). Two options are: (a) assume the signal outside of what is defined to be zero; (b) assume the signal to continue with the last defined value (i.e. 11 for data before the sequence and 20 for data after the sequence in signal S above.

Answer the following questions:
(i)   Describe the type of filter represented by F, explain its impact, and give an example of an application where such a filter would be useful. [20%]
(ii)   Give the result of convolving the filter F with the signal S under the two assumptions above, showing your working for each.   [50%]
(iii)   Explain which of these two assumptions would be preferable for interpreting the signal.   [20%]
(iv)   Give one other reasonable assumption that might be made about the signal outside of the defined region and explain its relative advantages and disadvantages over the two assumptions given above.   [10%]

Previous exam Qs: 2010

- i) : High-pass, edge detection filter (slight difference is it's non-symmetric but doesn't really make much difference). See above re not needing to divide by 5.

- ii) IN: 0 0 0 0 0 0 0 0 0 0 11 10 14 11 13 11 24 21 22 21 23 20 0 0 0 0 0 0
  OUT: 0 0 0 0 0 0 22 31 38 14 6 -3 23 29 30 5 1 -2 -44 -67 -63 -20 0 0 ....

- IN: 11 11 11 11 11 11 11 11 11 11 11 10 14 11 13 11 24 21 22 21 23 20 20 20 20 20 20 20
  OUT: 0 0 0 0 0 0 0 -2 5 3 6 -3 23 29 30 5 1 -2 -4 -7 -3 0 0 0

- iii) Second assumption preferable , as in that case there is only one change in the signal, which is the one we're interested in, in the middle rather than changes at both ends as well.

- iv) Perhaps a mirror image of the signal we have already - as we have seen a change from low to high. Same problem as before i.e. we have no info. that this is any better, but at least we know we have definitely seen these values over this spatial scale before.

Revision

- L6: Modelling 1 - types of model
  - Empirical – based on observations; simple, quick BUT give no understanding of system, limited in application e.g. linear model of biomass as function of NDVI
  - Physical - represent underlying physical system; typically more complex, harder to invert BUT parameters have physical meaning e.g. complex hydrological model

Revision

- ## Lecture 7: Modelling 2
  - Model vs obs: e.g. 'best fit' in root mean square error (RMSE)
  - Forward modelling
    - Provide parameter values, use model to predict state of system - useful for understanding system behaviour e.g. backscatter = f(LAI), can predict backscatter for given LAI in forward direction
  - Inverse modelling
    - Measure system, and invert parameters of interest e.g. LAI = f^{-1}(backscatter)

- ## Today – spatial coverage: local v global?

Previous exam Qs: 2010

- The Normalised Difference Vegetation Index (NDVI) (unitless), a surrogate for the proportion of shortwave radiation intercepted by a vegetation canopy, can be related to the productivity of a grassland P (units kg of dry matter/m^2) via:

- $P = e \times I \times NDVI \times t$

- where I is the insolation at short wavelengths incident on the surface (units of W/m^2) and e is an efficiency term (the efficiency of conversion of solar energy to grass biomass, accounting for losses due to respiration) (units kg of dry matter/W/month) and t represents time (units months).

- The following is a series of red and near infrared (NIR) percent reflectance data for one year over a grassland site:

-

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Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Red	60	12	12	11	9	8	5	3	8	14	12	15
NIR	30	13	14	13	24	31	40	45	20	17	15	15

- Answer the following questions:
- Calculate the annual grassland production (kg dry matter) assuming the ground resolution dimension of the pixel is 500 m and that the pixel is square. You may assume that I is constant, with a value of 1366 W/m^2 and that e has a constant value of 9.15 x10^{-4} kg/W/month.   [40%]
- Identify which month the vegetation starts to grow.   [10%]
- The data for one of the months shows different behaviour to the others. Identify which one and explain why it might it might have occurred.   [15%]
- Explain what modifications would be needed to use this simple model to estimate global vegetation production.   [35%]

Previous exam Qs: 2008

6. A simple model relating $NDVI$ to canopy vegetation cover c is:

$$NDVI = cNDVI_{veg} + (1-c)NDVI_{soil}$$

where $NDVI_{veg}$ is the NDVI of vegetation and $NDVI_{soil}$ is the NDVI of bare soil. A simple model between canopy cover and leaf area index (LAI) is:

$$c = 1 - e^{-kLAI}$$

where k is an extinction coefficient with a value between 0.7 and 1.4 for different cover types.

(i) Provide a critical evaluation of the two models, explaining any physical basis for the models and likely causes of uncertainty in the modelled relationships. (40%)

(ii) Explain how these two models could be used with appropriate EO data to monitor LAI at a monthly time-step at a continental scale. Your answer should include a discussion of likely data sources and any complicating factors. (60%)

References

- Global land cover & land cover change
- http://glcf.umiacs.umd.edu/services/landcoverchange/
- B. L. Turner, II*, , Eric F. Lambin , and Anette Reenberg The emergence of land change science for global environmental change and sustainability, PNAS 2007, http://www.pnas.org/cgi/content/full/104/52/20666
- http://lcluc.umd.edu/
- http://visibleearth.nasa.gov/view_rec.php?id=3446
- Deforestation
- http://visibleearth.nasa.gov/view_set.php?categoryID=582

Previous exam Qs

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