Environmental Remote Sensing
GEOG 0027

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Course web page including details of practicals:

https://github.com/qwu-hab/GEOG0027/

Structure of Course

- First half of course introduces remote sensing
  - 8 lectures
    - Tuesday 10-11am, Pearson Building 110A
- Second half focuses on a practical example using remote sensing data
  - 6 practical sessions
    - Thursdays 11-1pm, Pearson Building 110A
  - 5 help sessions to work on coursework
    - extended practical project - all of the above times approximately from reading week onwards

Structure of Course

	Tuesday 10:00-11:00	Thursday 11:00-13:00
Week 1	14/1/2020 LECTURE 1 Introduction to course; Environmental Remote Sensing	16/1/2020 COMPUTING Image Display
Week 2	21/1/2020 LECTURE 2 Image Display and Enhancement	23/1/2020 COMPUTING Data download
Week 3	28/1/2020 LECTURE 3 Spatial Information	30/1/2020 COMPUTING 2 Spatial Filtering
Week 4	4/2/2020 NO LECTURE	6/2/2020 COMPUTING 3 Classification
Week 5	11/2/2020 LECTURE 4 Image Classification	13/2/2020 COMPUTING 3 Classification
Week 6	READING WEEK	
Week 7	25/2/2020 LECTURE 5 Spectral Information	27/2/2020 COMPUTING 3 Classification
Week 8	3/3/2020 LECTURE 6 Environmental Modelling: I	5/3/2020 COMPUTING 4 Project
Week 9	10/3/2020 LECTURE 7 Environmental Modelling: II	12/3/2020 COMPUTING 4 Project
Week 10	17/3/2020 LECTURE 8 Orbits, scale and trade-offs	19/3/2020 COMPUTING 4 Project
Week 11	24/3/2020 COMPUTING 4 Project	26/3/2020 COMPUTING 4 Project

Structure of Course

Assessment

100% coursework write-up on the extended practical

submission date – Friday 27st March (12:00) via moodle and Turn It In. Late penalties will apply.

Course webpage, including practical details and downloads

Course web pages: slides will be posted on Moodle and https://github.com/qwu-hab/GEOG0027/

Computer practices can be found at https://geog0027-environmental-remote-sensing.readthedocs.io/

Coursework/Project web page: https://geog0027-coursework.readthedocs.io/en/latest/

Lecture Plan

- Intro to RS
- Radiation Characteristics
- Spectral Information & intro to classification
- Spatial Information
- Classification
- *reading week*
- Spectral information
- Modelling I
- Modelling II
- Orbits, scale and trade-offs

Purpose of GEOG0027

- Enable practical use of remote sensing data through
  - Background theory & typical operations
    - Enhancement (spectral / spatial)
    - Classification
  - Practical example in environmental science
- Use ENVI and scripts on UNIX workstations
  - ENVI: widely-used, good functionality, easy to use (GUI)
  - Python: free, very flexible & useful for everything!
  - Others: R & Google Earth Engine (GEE)

Reading and browsing

Campbell, J. B. (2011) *Introduction to Remote Sensing (5th ed.)*, London: Guilford Press.

Jensen, J. R. (2006) *Remote Sensing of the Environment: An Earth Resource Perspective*, 2006, Prentice Hall, New Jersey, 2nd ed. (Excellent on RS but no image processing).

Jensen, J. R. (2005/2016, 3rd/4th ed.) *Introductory Digital Image Processing*, Prentice Hall, New Jersey. (Companion to above)

Lillesand, T. M., Kiefer, R. W. and Chipman, J. W. (2008, 6th ed.) *Remote Sensing and Image Interpretation*, John Wiley, New York.

Mather, P. M. (2004) *Computer Processing of Remotely-sensed Images*, 3rd Edition. John Wiley and Sons, Chichester.

Rees, W.G. (2001, 2nd ed). "Physical Principles of Remote Sensing", Cambridge Univ. Press

Jones, H. G and Vaughan, R. A. (2010) Remote Sensing of Vegetation, OUP, Oxford.

Reading and browsing

Tutorials

- http://geoinfo.amu.edu.pl/wpk/rst/rst/Front/overview.html
- http://step.esa.int/main/doc/tutorials/snap-tutorials/
- http://www.radartutorial.eu/index.en.html
- https://earth.esa.int/web/guest/home
- http://www.crisp.nus.edu.sg/~research/tutorial/image.htm
- http://www.nrcan.gc.ca/node/9309

Glossary

- http://www.nrcan.gc.ca/node/9483

Data sources etc.

- ESA Sentinel data: https://scihub.copernicus.eu/
- NASA data: https://glovis.usgs.gov/
- UK Environment Agency: https://data.gov.uk/publisher/environment-agency
- UK general environmental data: http://catalogue.ceda.ac.uk/uuid/55d1c9b6e7a4ce41b7a6f8416b7b6261

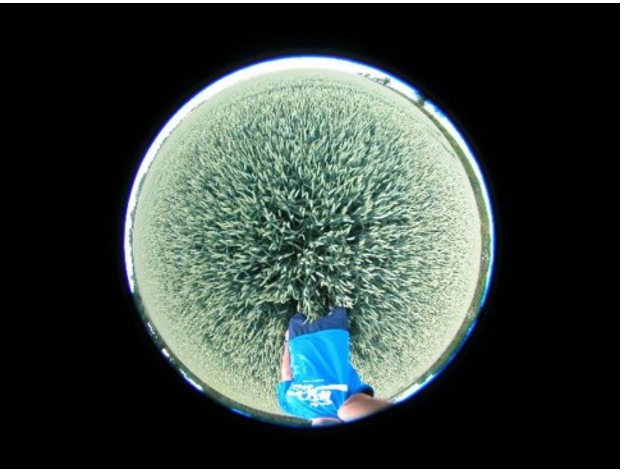
Agencies and Image galleries

- NASA: www.nasa.gov
- European Space Agency (ESA): http://earth.esa.int
- NASAs Visible Earth (source of data): http://visibleearth.nasa.gov/
- NOAA: www.noaa.gov
- Global Forest Watch: http://www.globalforestwatch.org/
- Daily Overview: http://www.dailyoverview.com/fiftyfive/
- UK National Centre for Earth Observation (NCEO): https://www.nceo.ac.uk/

Fundamentals

- Remote sensing is the acquisition of data, "remotely“
  - “The science technology and art of obtaining information about objects or phenomena from a distance (i.e. without being in physical contact with them” (Aronoff, 1995)
- Earth Observation / Remote Sensing (EO/RS)
  - For EO, "remotely" means using *instruments (sensors)* carried by *platforms*
  - Usually we will think in terms of satellites, but this doesn't have to be the case
    - aircraft, helicopters, ...

Remote Sensing: examples



- Not always big/expensive equipment
    - Photography (kite, aerial, helicopter…)
    - Field-based

Remote Sensing: examples

•Up to 9 large kites used to carry camera weighing 23kg.

Remote Sensing: examples

upscale

upscale

upscale

http://www-imk.fzk.de:8080/imk2/mipas-b/mipas-b.htm

- Platform depends on application
    - What information do we want?
    - How much detail?
    - What type of detail?

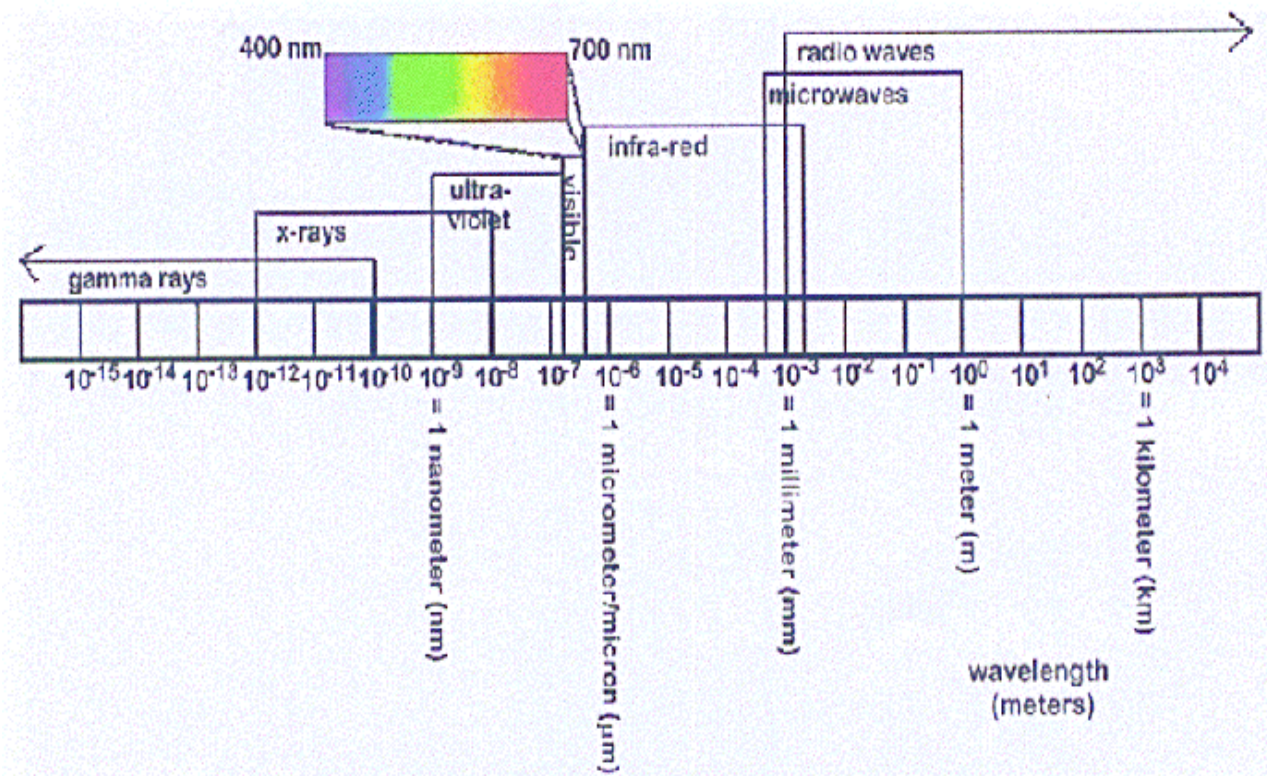
Why use satellite RS ?

- Source of spatial and temporal information
  - land surface, oceans, atmosphere, ice
- Monitor and develop understanding of environment
- Information can be **accurate**, **timely**, **consistent** and **large** (spatial) scale
- Some historical data (60s/70s+)
- Move to quantitative applications
  - data for climate (temperature, atmospheric gases, land surface, aerosols….)
- Some 'commercial' applications
  - Weather, agricultural monitoring, resource management

But….

- Remote sensing has various issues
  - Can be expensive
  - Can be technically difficult
  - NOT direct
    - measure surrogate variables
    - e.g. reflectance (%), brightness temperature ($Wm^{-2} \Rightarrow {}^{o}K$), backscatter (dB)
    - RELATE to other, more direct properties.

Basic Concepts: EM Spectrum



Sometime use frequency, $f=c/\lambda$,

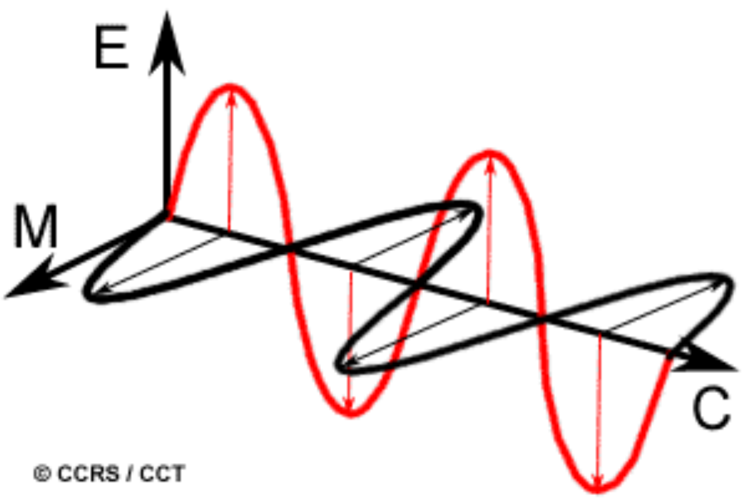
where $c=3\text{x}10^8$ m/s (speed of light)

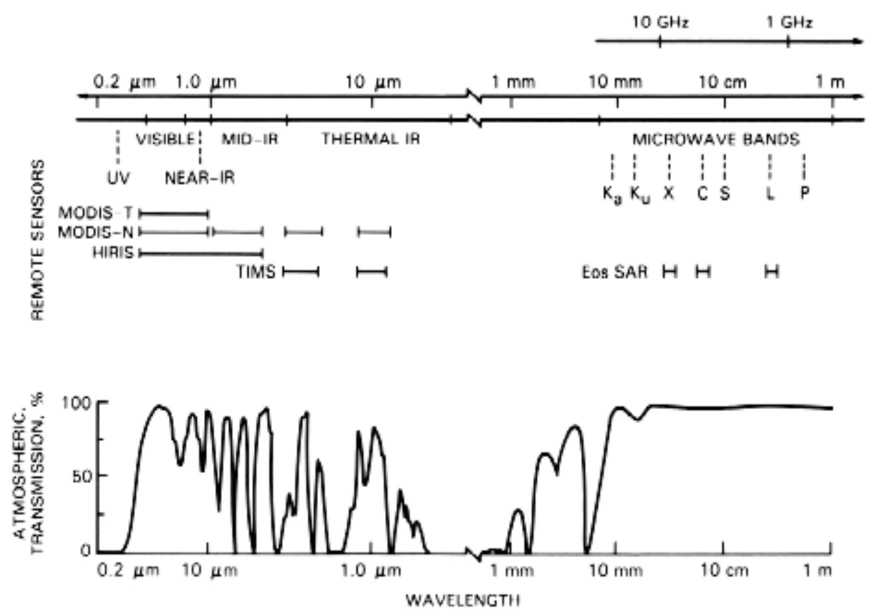
λ 1 nm, 1mm, 1m

f $3\text{x}10^{17}$ Hz, $3\text{x}10^{11}$ Hz, $3\text{x}10^8$ Hz,

Basic Concepts: 1

- **Electromagnetic (EM) radiation**
- **wavelengths**, atmospheric windows
  - visible / near infrared ('optical') (400-700nm / 700-1500 nm)
  - thermal infrared (8.5-12.5 μm)
  - microwave (1mm-1m)

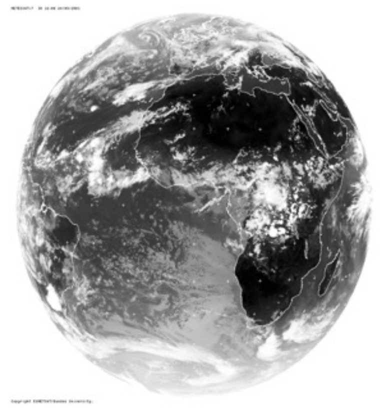




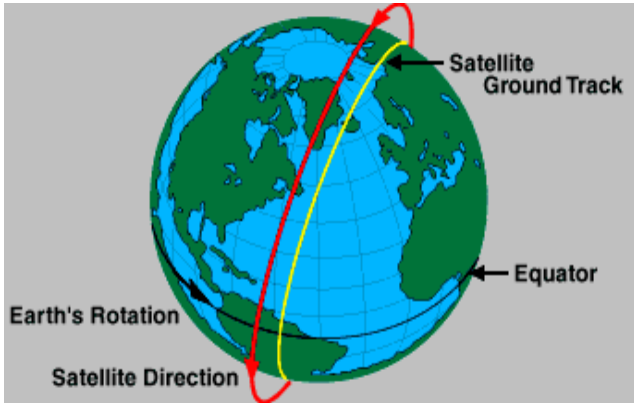
Basic Concepts: 2

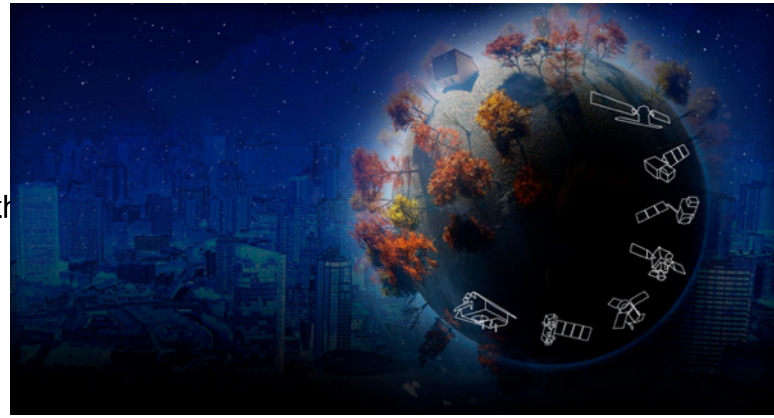
- **Orbits**
  - geostationary (36 000 km altitude)
  - polar orbiting (200-1000 km altitude)
- **Spatial resolution**
  - 10s cm (??) - 100s km
  - determined by altitude of satellite (across track), altitude and speed (along track), viewing angle
- **Temporal Resolution**
  - minutes to days
  - NOAA (AVHRR), 12 hrs, 1km (1978+)
  - MODIS Terra/Aqua, 1-2days, 250m++
  - Landsat TM, 16 days, 30 m (1972+)
  - SPOT, 26(...) days, 10-20 m (1986+)
  - **revisit** depends on
    - latitude
    - sensor FOV, pointing
    - orbit (inclination, altitude)
    - cloud cover (for optical instruments)

Major Programs



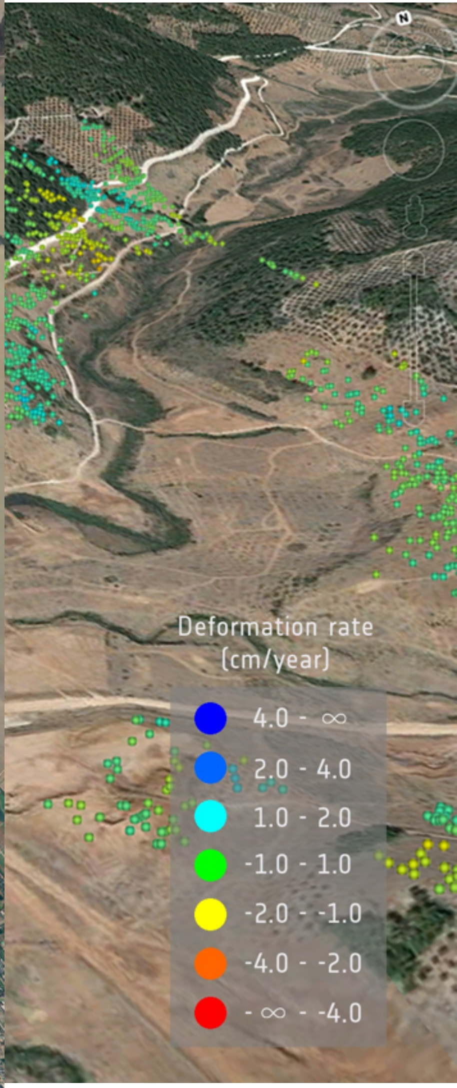
- Geostationary (Met satellites)
  - Meteosat (Europe)
  - GOES (US)
  - GMS (Japan)
  - INSAT (India)
  - Fengyun (China)
- Polar Orbiting
  - SPOT (France)
  - NOAA (US)
  - EOS/NPOESS, Landat, NOAA (US)
  - Copernicus: ESA Sentinels:
    - http://www.esa.int/Our_Activities/Observing_the_Earth





COPERNICUS:ESA Sentinels

- EU Copernicus: ”….provide accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.”
- Sentinel missions: 2014-++ (S1; S2, S3, S4, S5P, S5 ….)


Deformation rate
(cm/year)
4.0 - ∞
2.0 - 4.0
1.0 - 2.0
-1.0 - 1.0
-2.0 - -1.0
-4.0 - -2.0
- ∞ - -4.0

A Remote Sensing System

- Energy source
- Platform
- Sensor
- Data recording / transmission
- Ground receiving station
- Data processing
- Expert interpretation / data users

Physical Basis

- Measurement of EM radiation
  - scattered, reflected
- Energy sources
  - Sun, Earth
  - artificial
- Source properties
  - vary in intensity AND across wavelengths

EM radiation

- emitted, scattered or absorbed
- intrinsic properties (emission, scattering, absorption)
  - vary with wavelength
  - vary with physical / chemical properties
  - can vary with viewing angle

Data Acquisition

- RS instrument measures energy received
  - 3 useful areas of the spectrum:-

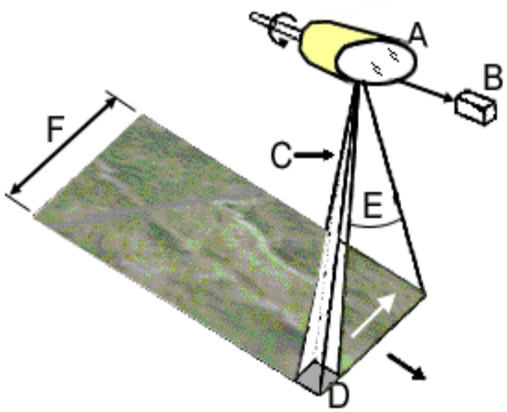
1) *Visible / near / mid infrared*
   - **passive**
     - solar energy reflected by the surface
     - determine surface (spectral) reflectance
   - **active**
     - LIDAR - active laser pulse
     - time delay (height)
     - induce florescence (chlorophyll)

2) *Thermal infrared*
   - energy measured - temperature of surface and emissivity

3) *Microwave*
   - **active**
     - microwave pulse transmitted
     - measure amount scattered back
     - infer scattering
   - **passive**
     - emitted energy at shorter end of microwave spectrum

Image Formation

- Photographic (visible / NIR, recorded on film, (near) instantaneous)
- *whiskbroom scanner*
  - visible / NIR / MIR / TIR
  - point sensor using rotating mirror, build up image as mirror scans
  - Landsat MSS, TM
- *Pushbroom scanner*
  - mainly visible / NIR
  - array of sensing elements (line) simultaneously, build
  - SPOT



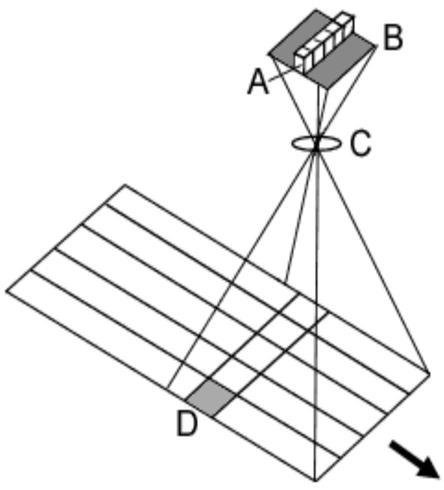
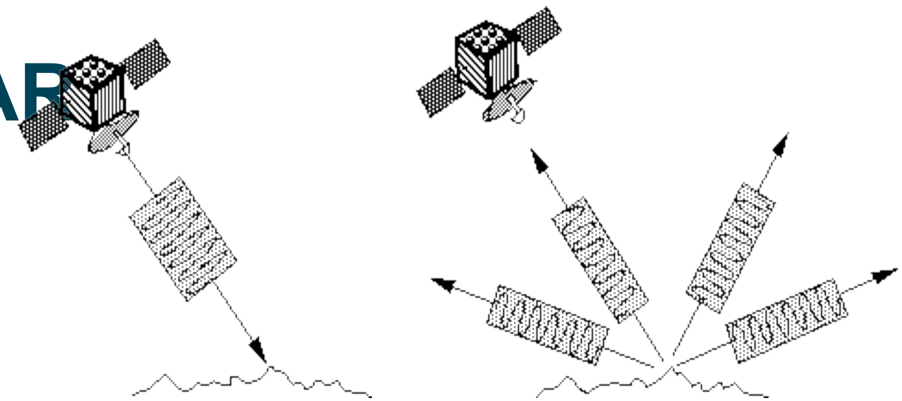
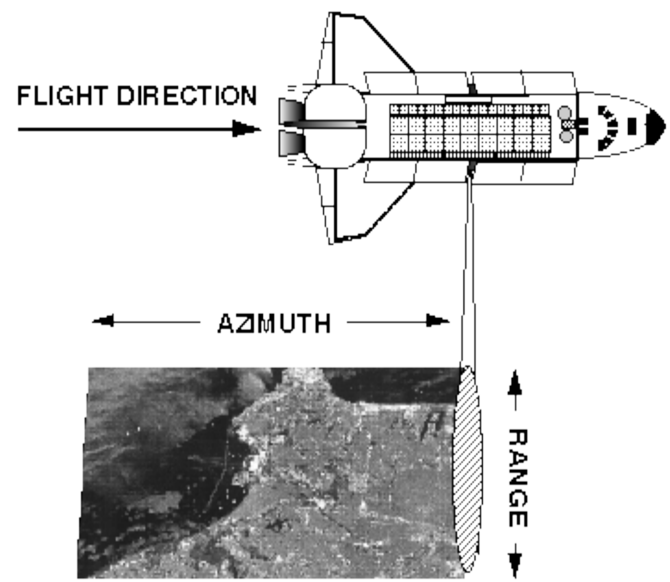


Image Formation: RADAR



- real aperture radar
  - microwave
  - energy emitted across-track
  - return time measured (slant range)
  - amount of energy (scattering)
- synthetic aperture radar
  - microwave
  - higher resolution - extended antenna simulated by forward motion of platform
  - ERS-1, -2 SAR (AMI), Radarsat SAR, JERS SAR

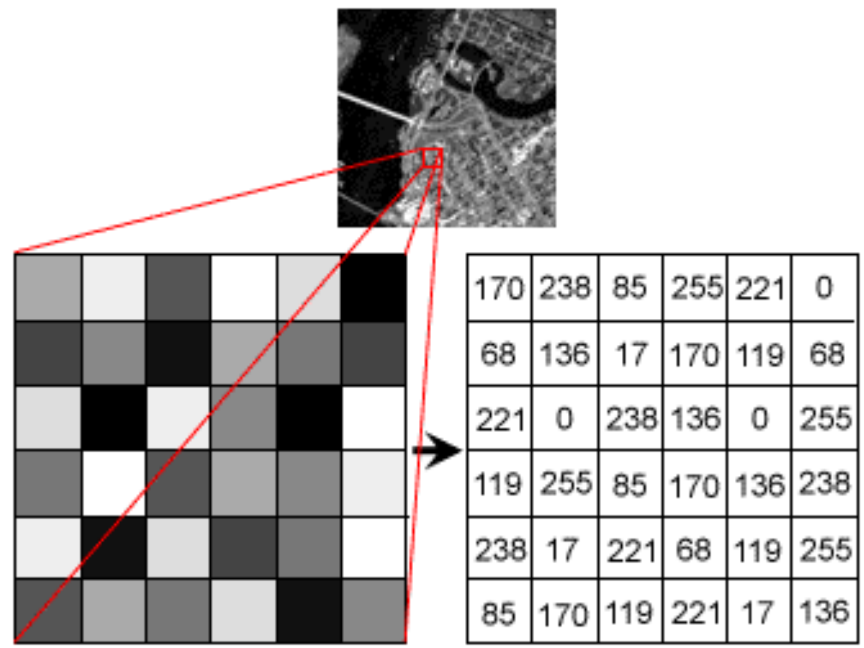


Quantization: digital data

- received energy is a continuous signal (analogue)
- quantise (split) into discrete levels (digital)
- Recorded levels called digital number (DN)
- downloaded to receiving station when in view
- 'bits'...
    - 0-1 (1 bit), 0-255 (8 bits), 0-1023 (10 bits), 0-4095 (12 bit)
- quantization between upper and lower limits (dynamic range)
    - not necessarily linear
- DN in image converted back to meaningful energy measure through *calibration*
    - account for atmosphere, geometry, ...
- relate energy measure to intrinsic property (reflectance)

Image characteristics

- pixel - DN
- pixels - 2D grid (array)
- rows / columns (or lines / samples)
- 3D (cube) if we have more than 1 channel
- dynamic range
  - difference between lowest / highest DN



Example Applications

- visible / NIR / MIR - day only, no cloud cover
  - vegetation amount/dynamics
  - geological mapping (structure, mineral / petroleum exploration)
  - urban and land use (agric., forestry etc.)
  - Ocean temperature, phytoplankton blooms
  - meteorology (clouds, atmospheric scattering)
  - Ice sheet dynamics

IKONOS-2 image of Venice
http://www.esa.int/esaEO/SEM44R0UDSG_index_1.html

Example Applications

- Thermal infrared - day / night, rate of heating / cooling
  - heat loss (urban)
  - thermal plumes (pollution)
  - mapping temperature
  - geology
  - forest fires
  - meteorology (cloud temp, height)

Urban heat island (ASTER surf. temp.) map of London, UK, Sep. 16, 2003

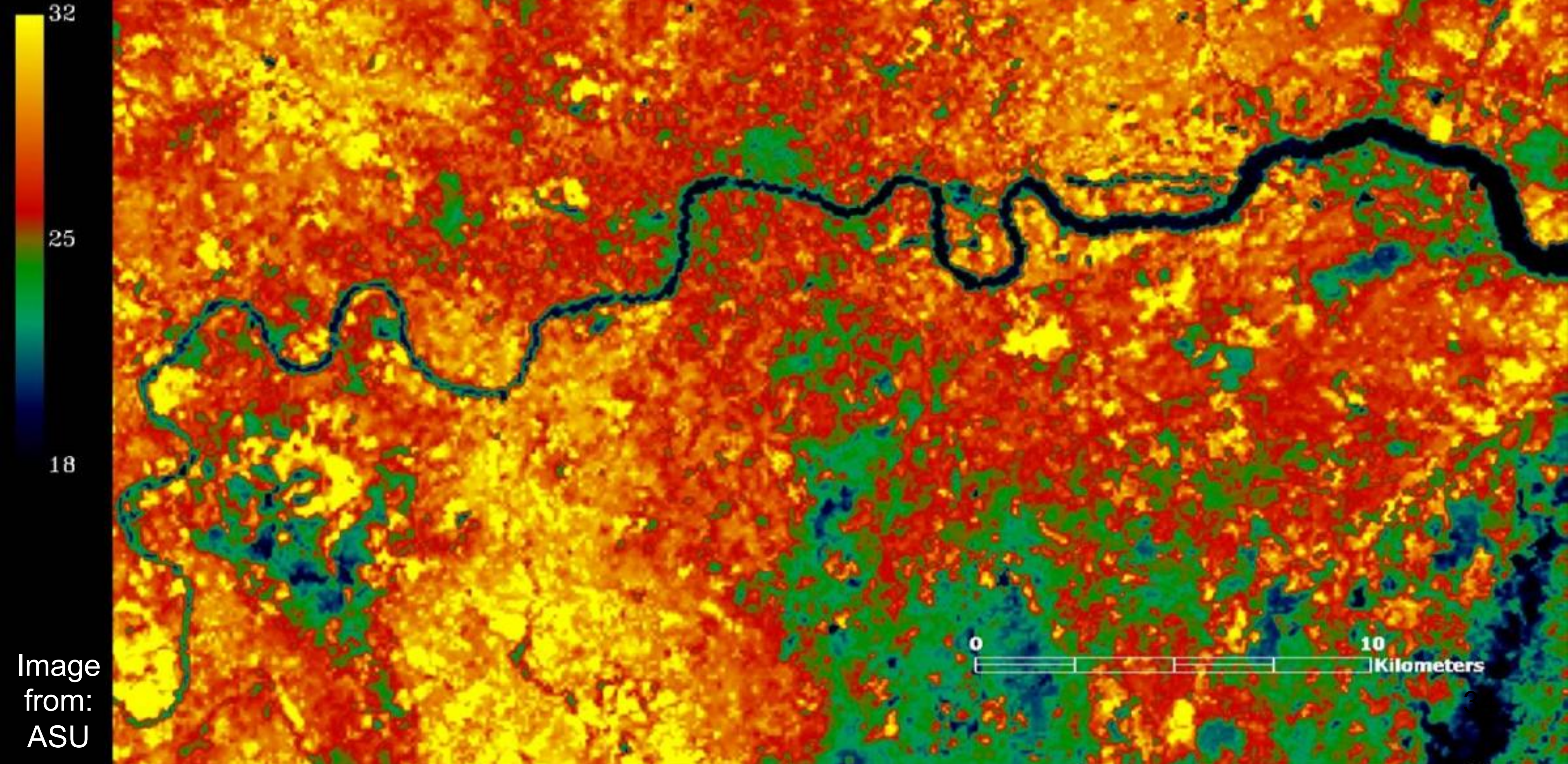
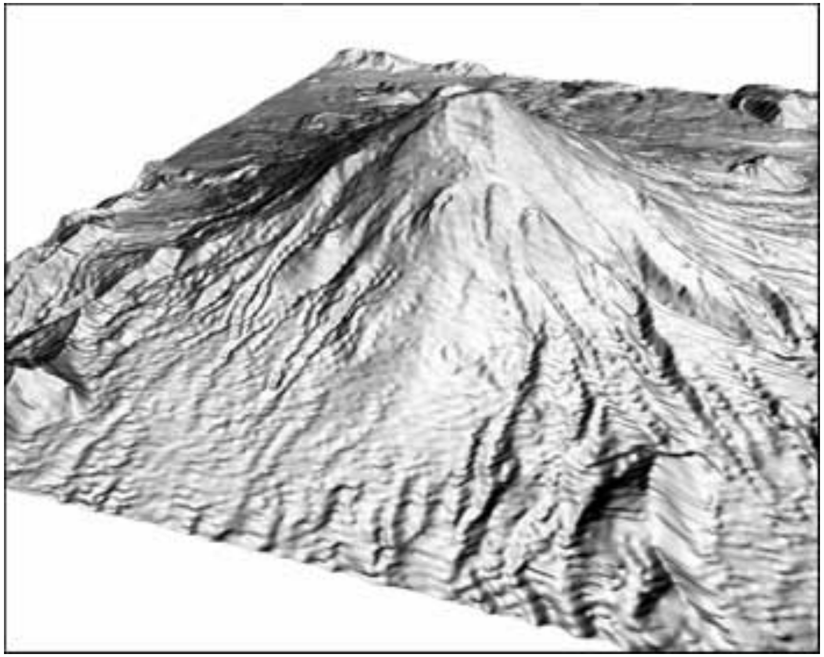


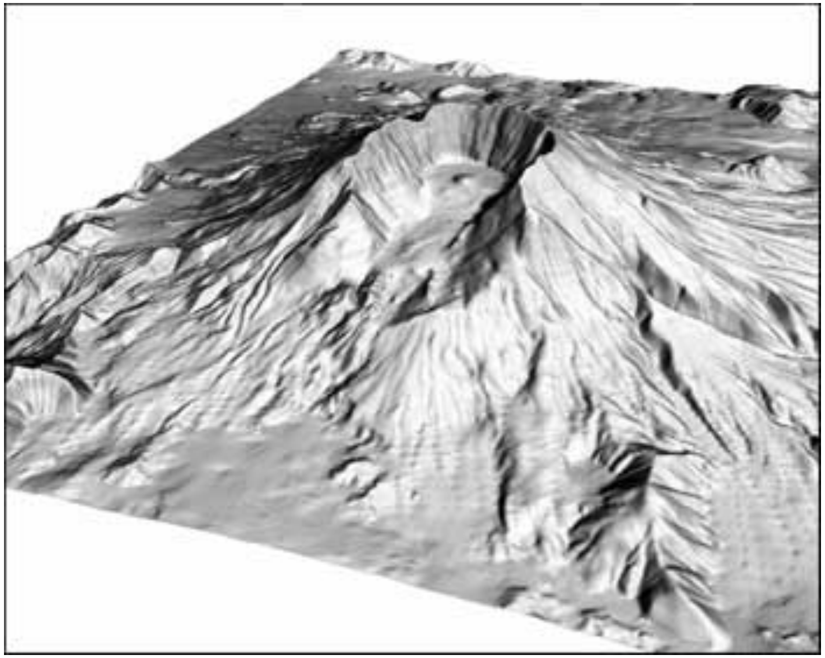
Image from: ASU

Example Applications

- Active microwave - little affected by atmospheric conditions, day / night
  - surface roughness (erosion)
  - water content (hydrology) - top few cms
  - vegetation - structure (leaf, branch, trunk properties)
  - Digital Elevation Models, deformation, volcanoes, earthquakes etc. (SAR interferometry)

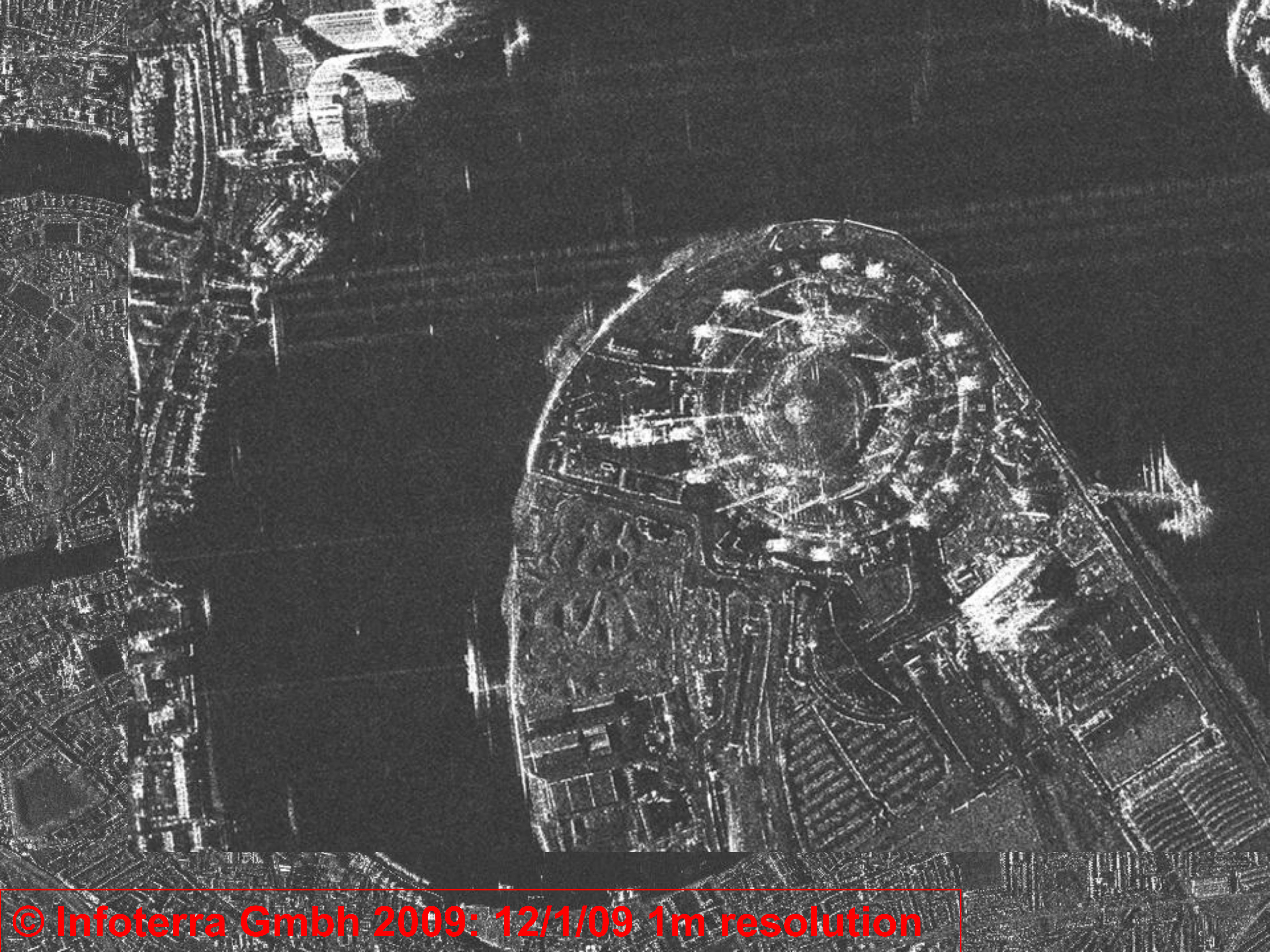
Example Applications





Mount St. Helens before 5/18/80 eruption **after 5/18/80 eruption**

Fly-through of Mt St. Helen generated from RADAR data:
http://www.youtube.com/watch?v=lUhFxDgqn6s



© Infoterra Gmbh 2009: 12/1/09 1m resolution

© Digital globe 12/1/10 0.5m resolution

Other sources, feeds

- http://www.esa.int/spaceinimages/Sets/Earth_observation_image_of_the_week
- http://www.satimagingcorp.com/gallery/geoeye-1/
- Instagram: @dailyoverview @nasa_eo @europeanspaceagency
- Twitter: @DOverview @NASA @NASAEarth @ESA @ESA_EO @mathiasdisney @NCEOscience
- Smart phone APPs: Copernicus Sentinel, Satellite Tracker, etc.