Environmental Remote Sensing
GEOG 2021

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Course web page including details of practicals:

http://proflewis.github.io/geog2021/

Structure of Course

First half of course introduces remote sensing

Second half focuses on a practical example using remote sensing data

8 lectures

Mondays 09-10am, G22 Pearson Building

7 practicals

Thursdays 11-1pm, in PB UNIX computer lab (room 110a)

help sessions (PB UNIX lab 110a)

- extended practical project - all of the above times approximately from reading week onwards

Structure of Course

Assessment

100% coursework write-up on the extended practical

submission date – Weds 22nd March (12:00) via moodle and Turn It In. Late penalties will apply.

Course webpage, including practical details and downloads

- http://proflewis.github.io/geog2021/

Lecture Plan

Intro to RS

Radiation Characteristics

Spectral Information & intro to classification

Spatial Information

Classification

Modelling I

reading week

Modelling II

Purpose of 2021

Enable practical use of remote sensing data through

- background theory & typical operations
  - enchancement (spectral / spatial)
  - classification
- practical example in environmental science

Use ENVI and Python on UNIX workstations

- ENVI: widely-used, good functionality, easy to use (GUI)
- Python: free, very flexible & useful for everything!

Reading and browsing

Campbell, J. B. (1996) Introduction to Remote Sensing (2nd Ed), London:Taylor and Francis.

R. Harris, 1987. "Satellite Remote Sensing, An Introduction", Routledge & Kegan Paul.

Jensen, J. R. (2000) *Remote Sensing of the Environment: An Earth Resource Perspective*, 2000, Prentice Hall, New Jersey. (Excellent on RS but no image processing).

Jensen, J. R. (2005, 3rd ed.) *Introductory Digital Image Processing*, Prentice Hall, New Jersey. (Companion to above) BUT mostly available online at http://www.cla.sc.edu/geog/rslab/751/index.html

Lillesand, T. M., Kiefer, R. W. and Chipman, J. W. (2004, 5th ed.) *Remote Sensing and Image Interpretation*, John Wiley, New York.

Mather, P. M. (1999) *Computer Processing of Remotely-sensed Images*, 2nd Edition. John Wiley and Sons, Chichester.

W.G. Rees, 1996. "Physical Principles of Remote Sensing", Cambridge Univ. Press

Reading and browsing

- Web
- *Tutorials*
- http://rst.gsfc.nasa.gov/
- http://earth.esa.int/applications/data_util/SARDOCS/spaceborne/Radar_Courses/
- http://www.crisp.nus.edu.sg/~research/tutorial/image.htm
- http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php
- http://octopus.gma.org/surfing/satellites/index.html

- Glossary of alphabet soup acronyms!
  http://www.ccrs.nrcan.gc.ca/glossary/index_e.php

- Other resources
- NASA www.nasa.gov
- NASAs Visible Earth (source of data): http://visibleearth.nasa.gov/
- European Space Agency earth.esa.int
- NOAA www.noaa.gov
- Remote sensing and Photogrammetry Society UK www.rspsoc.org
- IKONOS: http://www.spaceimaging.com/
- QuickBird: http://www.digitalglobe.com/

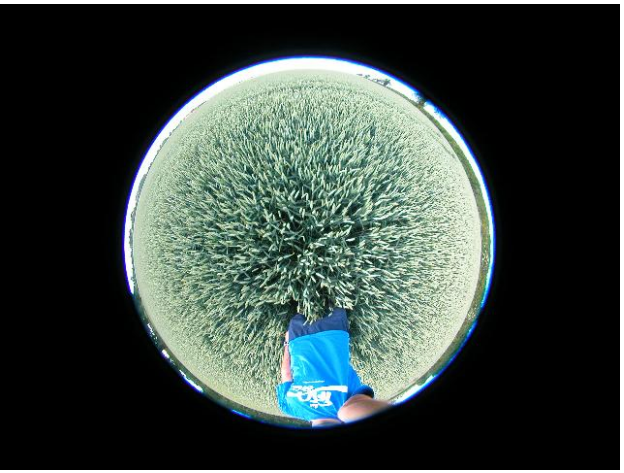
Free data sources on the web

- GLOVIS (USGS Global Visualisation Viewer)
  - http://glovis.usgs.gov/
  - All global Landsat data now available – hugely useful resource
  - Plus ASTER, MODIS (moderate/coarse resolution but global coverage)
- NASA Distributed Active Archive Centres – huge range of free NASA data:
  - http://nasadaacs.eos.nasa.gov/about.html (overview)
  - https://lpdaac.usgs.gov/ (land)
  - http://podaac.jpl.nasa.gov/ (oceans)
  - http://www.nsidc.org/daac/ (snow and ice)
- UK/NERC
  - NERC National Centre for Earth Observation (NCEO)
  - http://www.nceo.ac.uk
  - Earth Observation Data Centre
  - http://www.neodc.rl.ac.uk/ (UK/European focused, with ESA data, airborne, various campaign surveys etc. – may require registration)

Fundamentals

- Remote sensing is the acquisition of data, "remotely"
- 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

upscale

upscale

upscale

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

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

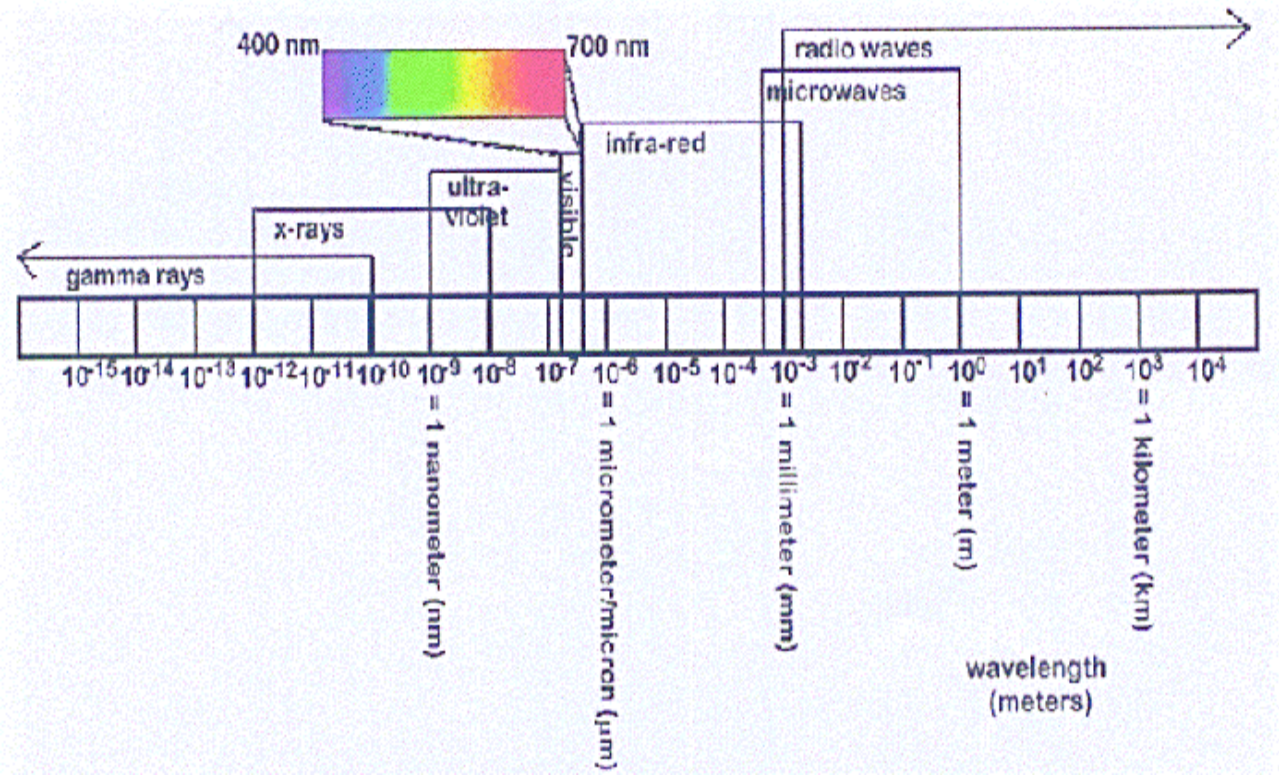
Why use satellite RS ?

- 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, $f=c/\lambda$,

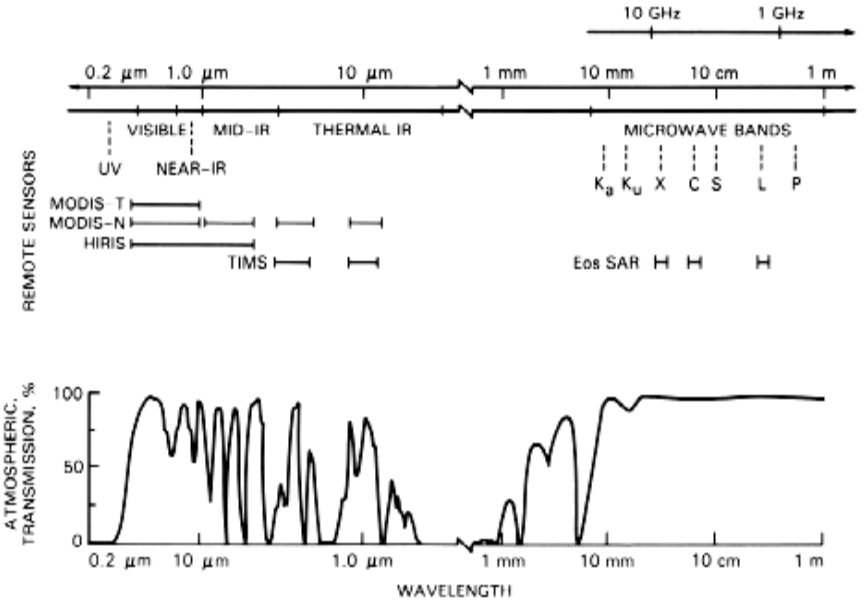
where $c=3\times10^8$ m/s (speed of light)

λ 1 nm, 1mm, 1m

f 3×10^{17} Hz, 3×10^{11} Hz, 3×10^8 Hz,

Basic Concepts: 1

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

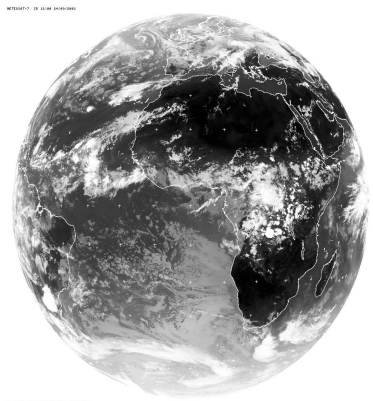


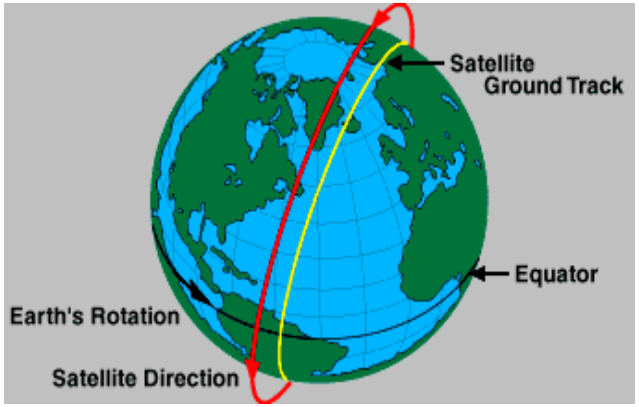
Basic Concepts: 2

- **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)
- Polar Orbiting
  - SPOT (France)
  - NOAA (US)
  - EOS/NPOESS, Landat, NOAA (US)
  - Copernicus: ESA Sentinels:
  - http://www.esa.int/Our_Activities/Observing_
    w4





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:-

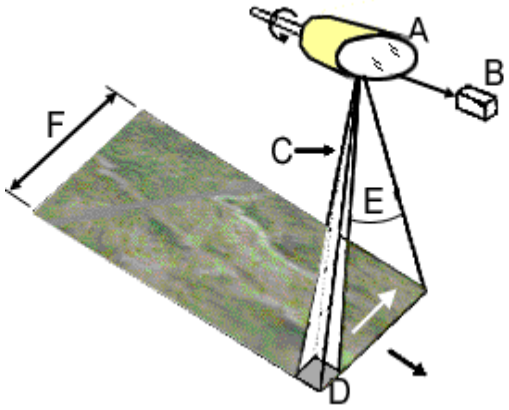
1) *Visible / near / mid infrared*
   - **passive**
     - solar energy reflected by the surface
     - determine surface (spectral) reflectance
   - **active**
     - LIDAR - active laser pulse
     - time delay (height)
     - induce florescence (chlorophyll)

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



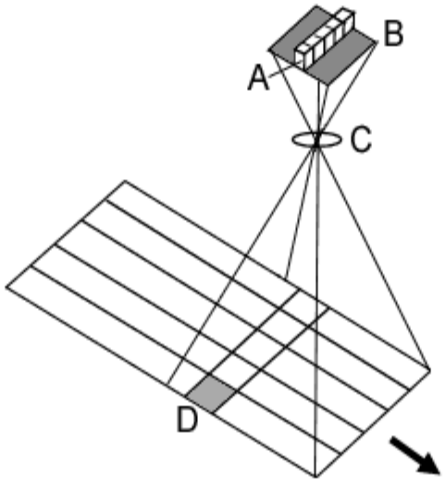
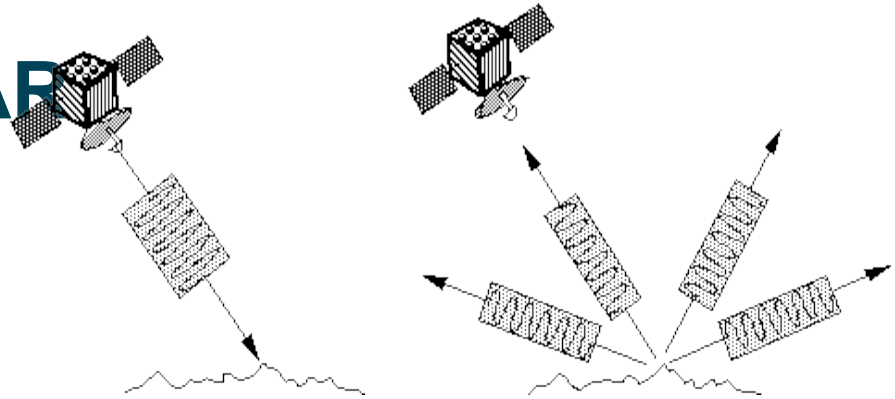
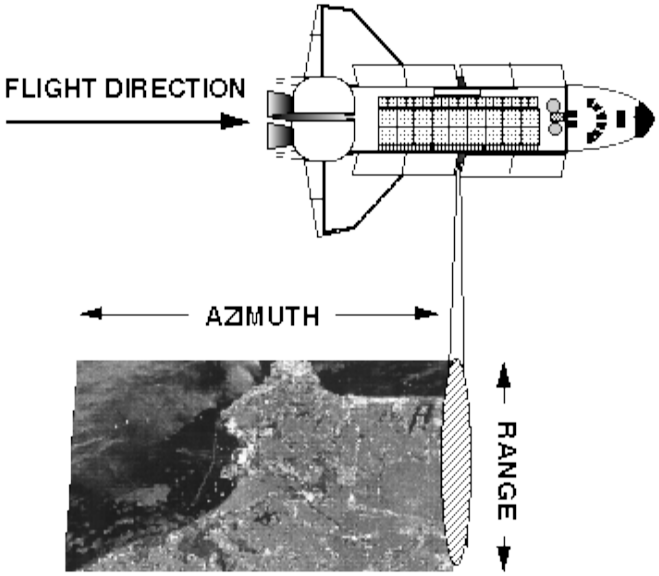


Image Formation: RADAR



- 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

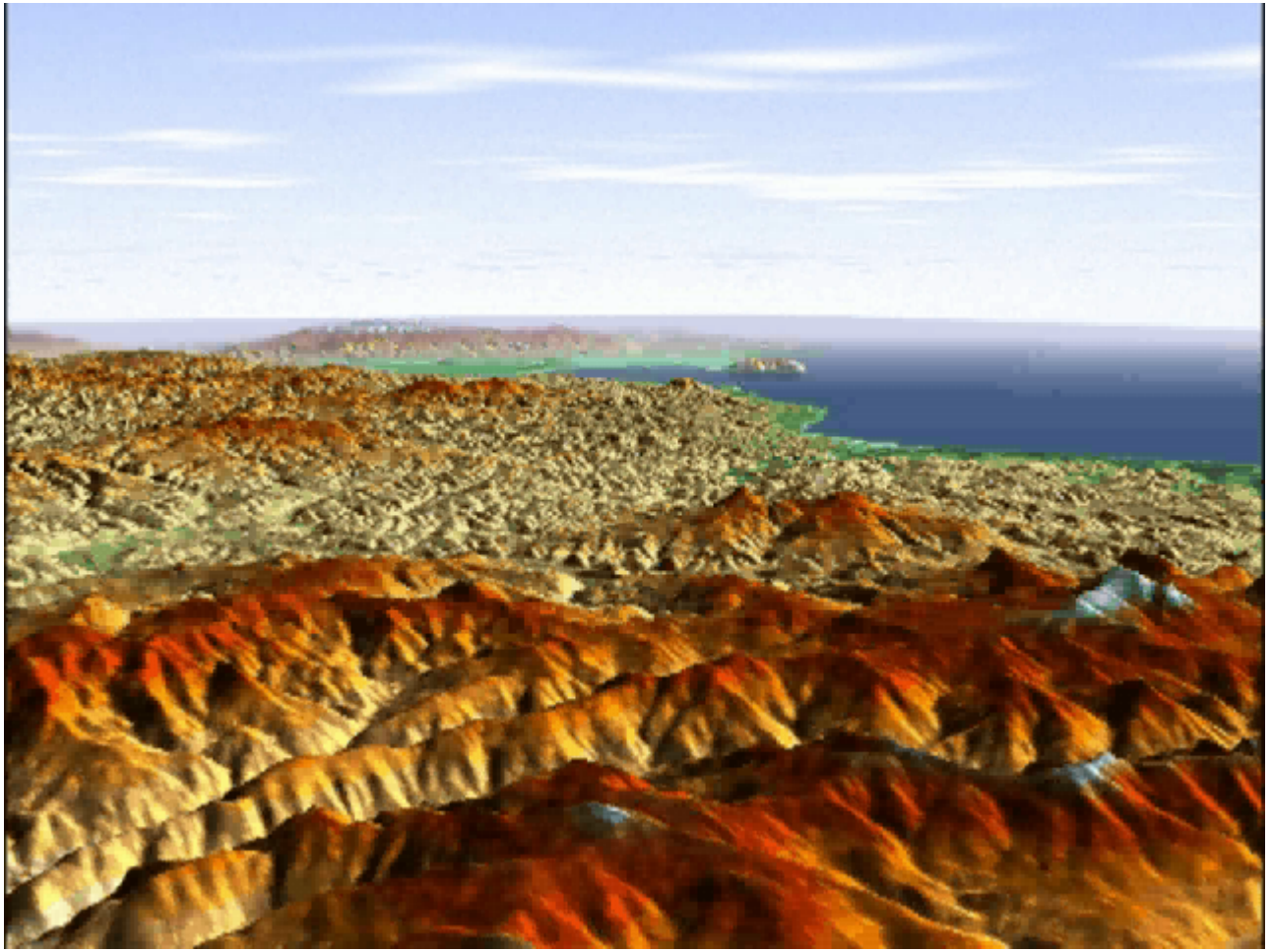
- Thermal infrared - day / night, rate of heating / cooling
  - heat loss (urban)
  - thermal plumes (pollution)
  - mapping temperature
  - geology
  - forest fires
  - meteorology (cloud temp, height)

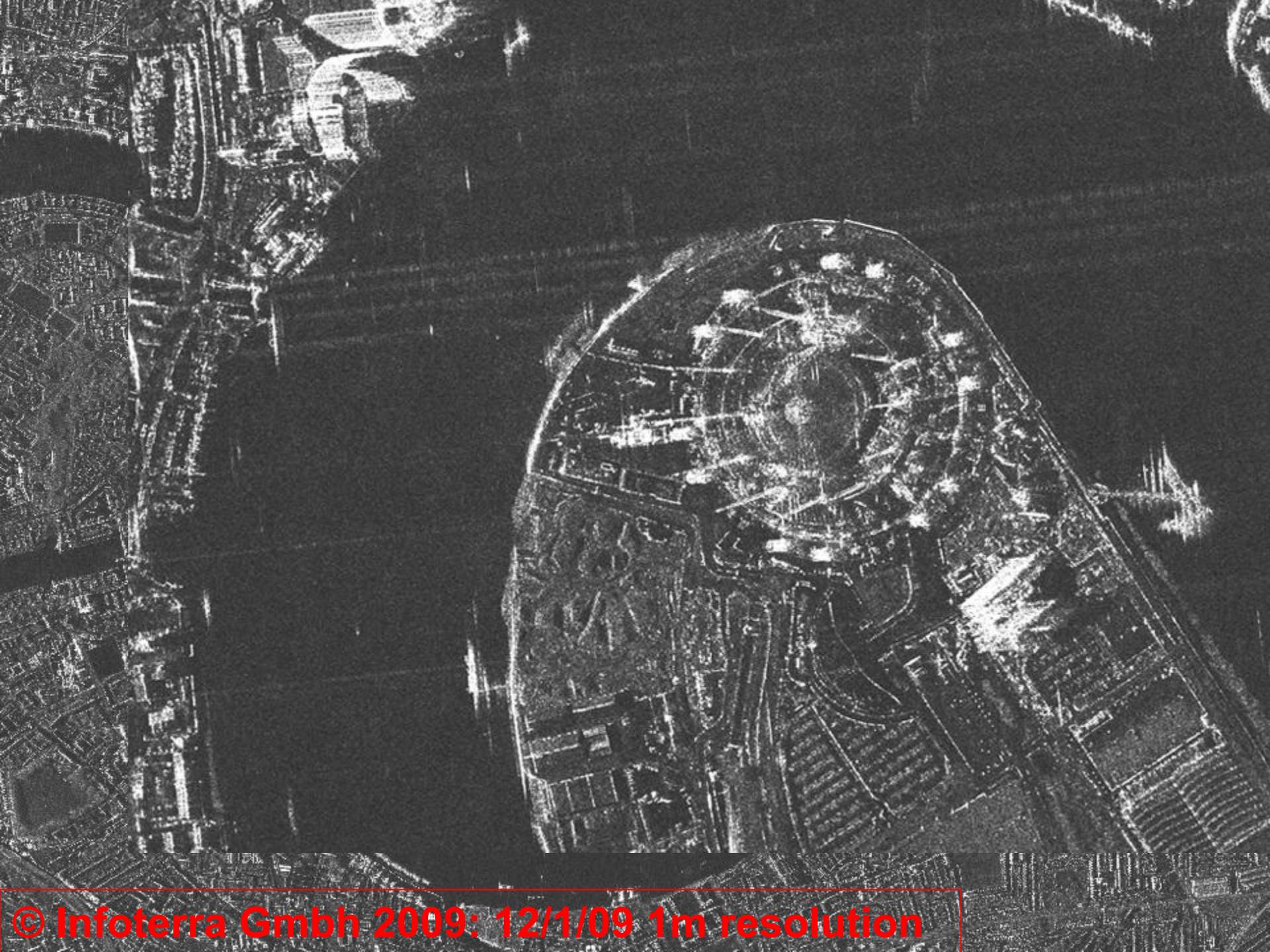
Example Applications

- 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

Fly-through of Mt Hokaido generated from SRTM (Shuttle RADAR Topographic Mapping data)




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

© Digital globe 12/1/10 0.5m 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