Introduction of Remote Sensing and Earth Environments

Department of Geosciences, National Taiwan University
• Course FTP site:
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Remote Port: 317
Introduction

What is remote sensing?

- Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation.
Electromagnetic Remote Sensing of Earth Sources

GIS: Geographic Information System
GPS: Global Positioning System
An Ideal Remote Sensing System

• A uniform energy source
• A noninterfering atmosphere
• A series of unique energy-matter interactions at the earth’s surface
• A supersensor
• A real time data processing and supply system
• Multiple data users
Components of an ideal remote sensing system

(1) Uniform energy source

(2) Noninterfering atmosphere

(3) Unique energy interactions at earth’s surface features

(4) Super sensor

(5) Real-time (instantaneous) data handling system

(6) Multiple data users
Visible band

Blue: 0.4 – 0.5 µm, Green: 0.5 – 0.6 µm, Red: 0.6 – 0.7 µm
Infrared (IR) Terminology

- Near IR: 0.7 - 1.3 μm
- Mid IR: 1.3 - 3 μm
- Thermal IR: Beyond 3 to 14 μm

- Photographic IR 0.7 - 0.9 μm
- Very near IR 0.7 - 1.0 μm
- Reflected IR 0.7 - 3.0 μm
- Near IR 0.7 - 3.0 μm
- Thermal IR 3.0 – 1000 μm
## Radio Frequency Bands

<table>
<thead>
<tr>
<th>Band Designation</th>
<th>Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF (high frequency)</td>
<td>3-30 MHz</td>
</tr>
<tr>
<td>VHF (very HF)</td>
<td>30-300 MHz</td>
</tr>
<tr>
<td>UHF (ultra HF)</td>
<td>300-1000 MHz</td>
</tr>
<tr>
<td>L</td>
<td>1-2 GHz</td>
</tr>
<tr>
<td>S</td>
<td>2-4 GHz</td>
</tr>
<tr>
<td>C</td>
<td>4-8 GHz</td>
</tr>
<tr>
<td>X</td>
<td>8-12 GHz</td>
</tr>
<tr>
<td>K_u</td>
<td>12-18 GHz</td>
</tr>
<tr>
<td>K</td>
<td>18-27 GHz</td>
</tr>
<tr>
<td>K_a</td>
<td>27-40 GHz</td>
</tr>
<tr>
<td>V</td>
<td>40-75 GHz</td>
</tr>
<tr>
<td>W</td>
<td>75-110 GHz</td>
</tr>
<tr>
<td>Mm (millimeter)</td>
<td>110-300 GHz</td>
</tr>
</tbody>
</table>
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Characteristics of remotely sensed data

Different remote sensing systems acquire different types of data which are often categorised according to three different types of `resolution`

1. Spatial resolution: the ability to distinguish between adjacent objects on the ground.

30-m pixels

5-m pixels
Characteristics of remotely sensed data

2. Temporal resolution: How often are the data collected?

AVHRR - 1 km pixels - 12 hour repeat
SPOT - 10m pixels - 26 day repeat

Temporal and spatial resolution generally inversely related
3. Spectral resolution: how many wavebands of data are collected?
Determines ability to exploit differences in spectral signature

Higher spectral resolution = better ability to exploit differences in spectral signatures
Course goals

1. To be able to evaluate remote sensing literature in the context of a understanding of RS principles and technology
2. You must know the difference between GPS, GIS, and RS
3. To be able to perform basic remote sensing research (project design, data collection, image acquisition, image analysis)
**Nimbus’ 40th Anniversary:** On August 28, 2004, NASA celebrated the 40th anniversary of the launch of the Nimbus-1 Earth-observation satellite. Starting in 1964 and for the next twenty years, the Nimbus series of missions was the United States’ primary research and development platform for satellite remote-sensing of the Earth.
NASA mission

EOS (Earth Observing System) TERRA
EOS AQUA
EOS AURA...

MODIS: Moderate Resolution Imaging Spectroradiometer
TRMM: Tropical Rainfall Measuring Mission
CZCS: Coastal Zone Color Scanner
AVHRR: Advanced Very High Resolution Radiometer
AIRS: Atmospheric Infrared Sounder
SeaWiFS: Sea-viewing Wide Field-of-view Sensor
SORCE: Solar Radiation and Climate Experiments
UARS: Upper Atmosphere Research Satellite
TOMS: Total Ozone Mapping Spectrometer
The great floods

The great floods of 1993 inundated 80,000 square kilometers (20,000,000 acres) of land along the Missouri and Mississippi Rivers. This aerial photograph of a flooded power plant along the Mississippi only hints at the extent of the disaster.
Urban Heat Island
On May 11-12, 1997, NASA used a specially outfitted Lear Jet to collect thermal data on metropolitan Atlanta, Georgia. Nicknamed “Hot-Lanta” by some of its residents, the city saw daytime air temperatures of only about 26.7 degrees Celsius (80 degrees Fahrenheit) on those days, but some of its surface temperatures soared to 47.8 degrees Celsius (118 degrees Fahrenheit).
規模 (Magnitude, Mw): 9.0
格林威治時間: Sunday, December 26, 2004 at 00:58:53 (UTC)
當地時間: Sunday, December 26, 2004 at 6:58:53 AM (Local Time at epicenter)
震央位置: 3.307 N, 95.947 E
震源深度: 30 km
2004年12月26日蘇門答臘地震與海嘯傷亡統計

資料來源：CNN, January 13, 2005
Sri Lanka: Kalutara Beach Detail

Area showing beach before tsunami
Imagery collected January 1, 2004

DigitalGlobe
Sri Lanka: Kalutara Beach Detail

Receding waters and beach damage from tsunami
Imagery collected December 26, 2004

DigitalGlobe
Meluaboh Overview

Imagery collected May 18, 2004
Imagery collected January 7, 2005

DigitalGlobe
Banda Aceh South Overview

Imagery collected April 12, 2004
Imagery collected January 2, 2005

DigitalGlobe
Gleebruk Village

Imagery collected April 12, 2004

Imagery collected January 2, 2005

DigitalGlobe
In eastern Columbia (left) and northern Venezuela (right), a vast stretch of plains called the Llanos rests at the foothills of the Andes Mountains. The Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra satellite detected numerous fires (red dots).
Multispectral, Thermal, and Hyperspectral Sensing

This computer-generated image shows the Terra spacecraft, with the MISR instrument on board, orbiting Earth. Direction of flight is toward the lower left. The actual locations imaged by the 9 cameras, each with 4 color bands, along Earth's surface are illustrated here with translucent surfaces.
Incident EM radiation may be reflected, transmitted or absorbed. Amount and spectral composition of energy reflected depends on the nature of the surface - different surfaces have different `spectral signatures`.
Spectral signatures

Visible photograph

Infrared photograph

University of Wisconsin-Madison
Typical spectral reflectances of various materials in visible and near-infrared regions

s: snow; c: cloud; rw: ripe wheat; uw: unripe wheat; l: limestone; ds: dry soil; ms: moist soil; tw: turbid water; cw: clear water.
Microwave and LiDAR Sensing

Laser profiling (laser altimetry) is the simplest application of the lidar (Light Detection And Ranging) technique. A short pulse of ‘light’ (visible or near-infrared radiation) is emitted towards the earth’s surface by the instrument, and its ‘echo’ is detected some time later.
太空梭雷達地形測量任務
Shuttle Radar Topography Mission (SRTM)
2002年2月11日，NASA太空梭Endeavour (奮進號)載著SRTM儀器，飛上地球上空233公里，對地表進行11天的掃瞄，掃過了80%的陸地 (北緯60°至南緯54°)。太空梭伸出60公尺長的支架，兩端各一座天線，利用合成孔徑雷達 (SIR-C/X-SAR) ，為地球繪製30公尺DEM。這些資料，對觀察地震斷層、熔岩和冰河流動、山脈的形成等自然現象，及河流和森林的變化，很有幫助；同時，在軍事上，更可以提供非常有用的資料。
Why Map the World with Radar?

一 你曾經看過一張地圖不但可以展示出地球上的區域特徵，而且顯示出他們的高低起伏。此訊息已知稱為地形學，且顯示高度訊息的地圖稱為地形圖。

二 人們使用地形資料在於許多方面:動、植物研究、土壤類型、地形、城市計畫、飛行器導航、軍事等....。

三 對世界的不同地區，地球上的地形圖是有限、不確定、或不存在。
Why Map the World with Radar?

四 SRTM 使用雷達設備盡可能且更詳細去收集全球地形圖的資料。

五 對此應用，雷達是較好工具。因其可每日運作並穿透雲層，在太空梭上的雷達更意味著物理途徑到達位置不再是問題。

六 使用干涉計（interferometry）的科技，SRTM收集地球陸地上大部分超過80% 的資料，近95%的世界人口。

七 所有的雷達資料收集在單一、11天太空梭任務並且處理至相同的規格，SRTM產生地形圖將有相同特徵。
What is SRTM?

• 計畫：National Imagery and Mapping Agency (NIMA) 和 National Aeronautics and Space Administration (NASA) 之間的聯合計畫。

• 目的：產生 80% 地球陸地表面的數值地形資料 (digital topographic data)。

• 背景：Interferometric Synthetic Aperture Radar (IFSAR)
What is SRTM?

- **範圍**: 在緯度60°以北與56°以南之間
- **解析度**: 在橫或縱網格上，分為1弧秒與3弧秒兩種，約相當30公尺與90公尺的空間解析度，分別稱為SRTM-1與SRTM-3數據。
- **絕對垂直高度資料的精確度**: 16公尺。
- **人類史上第一次使用單一感測器與單一處理標準產製全球涵蓋的DEM**
圖一：SRTM 裝置圖 [Rabus et al, 2003]
表一：SRTM 諸元簡表

<table>
<thead>
<tr>
<th></th>
<th>觀測時間</th>
<th>航高</th>
<th>解析度</th>
<th>高程精度</th>
<th>水平精度</th>
<th>平面系統</th>
<th>高程系統</th>
<th>描述</th>
<th>表面</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRTM</td>
<td>2000/02</td>
<td>223000m</td>
<td>30m/90m</td>
<td>16m</td>
<td>20m</td>
<td>WGS84</td>
<td>EGM96</td>
<td>DSM</td>
<td></td>
</tr>
</tbody>
</table>

Major specification of SIR-C/X-SAR

美國C 波段系統SIR-C
德國/義大利的X 波段系統X-SAR
<table>
<thead>
<tr>
<th>Item</th>
<th>SIR-C Spaceborne Imaging Radar-C</th>
<th>X-SAR X-band Synthetic Aperture Radar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main antenna</td>
<td>12.0m X 3.5m</td>
<td>12.0m X 0.5m</td>
</tr>
<tr>
<td>Outboard antenna</td>
<td>8.1m X 0.9m</td>
<td>6m X 0.4m</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>5.3GHz</td>
<td>9.6GHz</td>
</tr>
<tr>
<td><strong>Wavelength</strong></td>
<td>5.8cm</td>
<td>3.1cm</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>30m</td>
<td>30m</td>
</tr>
<tr>
<td>Vertical</td>
<td>16m</td>
<td>16m</td>
</tr>
<tr>
<td><strong>Altitude</strong></td>
<td>233km</td>
<td>233km</td>
</tr>
<tr>
<td><strong>Swath width</strong></td>
<td>225km *2</td>
<td>50km</td>
</tr>
<tr>
<td><strong>Polarization</strong></td>
<td>HH,HV,VH,VV</td>
<td>VV</td>
</tr>
<tr>
<td><strong>Off nadir</strong></td>
<td>23 - 63 degree *2</td>
<td>52 degree</td>
</tr>
</tbody>
</table>
How it was done?

- SRTM 使用的科技稱為雷達干涉計（radar interferometry）。在雷達干涉計中，兩張雷達影像從些微不同位置獲得。影像之間的不同允許去計算地表高程或變化。
- 使用InSAR 技術由兩張涵蓋相同地區的SAR影像利用同一目標物的雷達回訊係數做干涉處理，可由相位差計算地物高程。
- 同時使用兩組成像雷達觀測同時取得SAR 像對，屬於一次通過干涉(single-pass interferometry)，解決了重複通過干涉的問題。
干涉圖像(interference patterns)的研究由結合兩組雷達訊號所產生fixed-baseline interferometry mission
Characteristics of SAR images

Different types of surfaces and their corresponding radar image characteristics:
- Rat Surface
- Forest
- Cropland
- Mountains
- Rough Surface
- City
Strong microwave backscatter: corner reflector or permanent scatters

Radiation is reflected by two perpendicular planes so that it returns along the incidence direction. This is an important contribution to the strong microwave backscatter from urban areas.
Like oil interferogram
Or fringe map

Portion of SIR-C Interferogram, Ft. Irwin, California
SAR image

Optical sensor image
SRTM available global DTM
Data download

http://seamless.usgs.gov/

View and Download United States Data

View and Download International Data
SRTM of Taiwan
LIDAR (Light Detection And Ranging)
空載雷射掃描儀
Uses for high-resolution topography

• Finding faults (earthquake frequency, kinematics)
• Geologic mapping
• Landslide hazards
Multiple reflections for each laser pulse

1st return from tree top

2nd return from branches

3rd return from ground

1st (and only) return from ground
Components of an airborne scanning lidar system
High resolution is much better..

10 m DEM from contour 12 ft DEM from LIDAR

Haugerud and Weaver, USGS
Earthquake-Induced Land Slide
Jeou-Fen-Ell-San, Taiwan
Vegetation Removal
Jeou-Fen-Ell-San, Taiwan
龜山島分析成果

龜山島DSM模擬日照陰影圖
火山地質地形分析 -- 火山口

從火山錐與火山口地形判斷大屯火山群共具有 43 個火山
Grand LiDAR
Grund LiDAR
Applications of radar altimetry

- Sea-surface topography
- Sea-surface roughness
- Land and ice-sheet topography
Topex-Poseidon

From its vantage point 1336 kilometers (830 miles) above the Earth, TOPEX/Poseidon can measure the height of the ocean surface directly underneath the satellite with an accuracy of 4-5 centimeters (better than 2 inches). Traveling in excess of 7 kilometers (4 miles) every second as it traces out its orbit, TOPEX/Poseidon covers the global oceans every 10 days (the "repeat period" of the satellite orbit).
El Nino/La Nina & Pacific Decadal Oscillation

25 MAY 97

23 OCT 97

sea level in millimeters
El Niño/La Niña & Pacific Decadal Oscillation

25 MAR 97

25 APR 97

Sea level in millimeters

-120 -80 -40 0 40 80 120
El Nino

TOPEX / POSEIDON

AVHRR PATHFINDER

Oct 6 - 13 1997

sea level anomaly (cm)

sst anomaly (°C)
The Global Positioning System: GPS
Continuous GPS station
Survey Mode GPS
Application of GPS in plate motion and crustal deformation
Application of GPS in plate motion and crustal deformation
Coseismic deformation of Chengkung Earthquake