**GEOG3051: PRINCIPLES & PRACTICE OF REMOTE SENSING**

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**Personnel:** Dr. Mat Disney (MD)

Course web page:

www.geog.ucl.ac.uk/~mdisney/teaching/3051/GEOG3051.html

Moodle: GEOG3051

**Unit value:** 0.5 units  
**Year:** 3  
**Term:** 1

<table>
<thead>
<tr>
<th>Week</th>
<th>Date</th>
<th>Day/Time</th>
<th>Len</th>
<th>Class</th>
<th>Room</th>
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<tbody>
<tr>
<td>6</td>
<td>03/10</td>
<td>Tue 11:00</td>
<td>2</td>
<td>Introduction, Radiation Principles: I</td>
<td>PB G07</td>
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<tr>
<td>6</td>
<td>03/10</td>
<td>Tue 14:00</td>
<td>2</td>
<td>Radiation Principles: II</td>
<td>PB G07</td>
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<td>7</td>
<td>10/10</td>
<td>Tue 11:00</td>
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<td>NO LECTURES</td>
<td>PB G07</td>
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<tr>
<td>8</td>
<td>17/10</td>
<td>Tue 11:00</td>
<td>2</td>
<td>Spatial, spectral sampling</td>
<td>PB G07</td>
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<tr>
<td>8</td>
<td>17/10</td>
<td>Tue 14:00</td>
<td>2</td>
<td>Angular, temporal, radiometric sampling</td>
<td>PB G07</td>
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<td>9</td>
<td>24/10</td>
<td>Tue 11:00</td>
<td>2</td>
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<td>PB G07</td>
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<tr>
<td>10</td>
<td>31/10</td>
<td>Tue 11:00</td>
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<td>Pre-processing, ground segment</td>
<td>PB G07</td>
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<td>10</td>
<td>31/10</td>
<td>Tue 14:00</td>
<td>2</td>
<td>Poster seminar discussion</td>
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<td>07/11</td>
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<td>Reading Week</td>
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<td>12</td>
<td>14/11</td>
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<td>Active RS I: LIDAR intro</td>
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<tr>
<td>12</td>
<td>14/11</td>
<td>Tue 11:00</td>
<td>2</td>
<td>Active RS II: LIDAR applications</td>
<td>PB G07</td>
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<td>13</td>
<td>21/11</td>
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<tr>
<td>14</td>
<td>28/11</td>
<td>Tue 11:00</td>
<td>2</td>
<td>Active RS III: RADAR intro</td>
<td>PB G07</td>
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<tr>
<td>15</td>
<td>05/12</td>
<td>Tue 11:00</td>
<td>2</td>
<td>Active RS IV: RADAR interferometry</td>
<td>PB G07</td>
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<td>16</td>
<td>12/12</td>
<td>Tue 11:00</td>
<td>2</td>
<td>Revision &amp; problem class</td>
<td>PB G07</td>
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<td>16</td>
<td>12/12</td>
<td>Tue 14:00</td>
<td>2</td>
<td>Assessed poster presentation</td>
<td>PB G07</td>
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**NOTE:** text in red denotes PM sessions. Not all sessions are used. Note session on 31/10 will focus on EO applications for the assessed poster presentation on 12/12.

**Course description**

This course builds on the 2nd year module GEOG2021 and will provide an introduction to the concepts and principles of remote sensing in both the optical and microwave domains. The module will provide an introduction to the concepts and principles of remote sensing in both the optical and microwave domains. The first part of the course returns to the fundamental principles of remote sensing that were only touched upon in GEOG2021. The first 3 sessions cover the physical bases of the remote sensing signal: basic laws of electromagnetic radiation; absorption, reflection and emission in the optical and thermal domains; atmospheric effects; radiation interactions with the surface. Following this, we explore the application-specific instrument, orbit and data handling choices: spatial resolution; temporal resolution; sensor design considerations; orbits and swaths; applications of optical remote sensing, particularly of the terrestrial surface and vegetation. The course also provides an introduction to active remote sensing techniques including Lidar and RADAR. The Lidar session covers: lidar principles, discrete and waveform systems; example missions (proposed and flown); information from lidar; terrestrial laser scanning. The RADAR session covers: RADAR remote sensing instruments and techniques; RADAR interactions with the terrestrial surface; synthetic aperture RADAR; RADAR interferometry and applications.
There will also be a seminar-led component of the course which will focus on discussion of remote sensing applications, leading to an assessed poster presentation at the end of the module. There will also be occasional seminars from outside speakers on remote sensing applications in the commercial, NGO, government, and space agency sectors. I will advertise these via email and moodle.

**Intended learning outcomes**
Students will acquire knowledge and understanding of the fundamental concepts and principles underlying remote sensing in the optical and microwave domains, as well as the trade-offs used in instrument design and operation. Students will be able to discuss these fundamental principles in relation to various applications of remote sensing. They will be able to derive solutions to simple problems regarding the application of the various fundamental principles covered. Students will be expected to be able to present their assessment of a selected remote sensing application in the form of a scientific poster, and discuss the contents of the poster with the course convenor(s). Templates for the posters will be provided, and the expectations of what is required in a scientific poster will be discussed.

**Method of Teaching**
A combination of lectures, seminars and discussion sessions centred on current areas of remote sensing applications.

**Form of Assessment**
2 hour exam (70%) and assessed poster session (30%).

**Pre-requisites and Relationships to other Courses**
Students must have taken GEOG2021: Environmental Remote Sensing in their second year.

**Suggested Reading**

**Web resources:**
http://rst.gsfc.nasa.gov/Front/tofc.html
http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php
http://earth.esa.int/applications/data_util/SARDOCS/spaceborne/Radar_Courses/
http://ccrs.nrcan.gc.ca/glossary/index_e.php
Other resources
NASA www.nasa.gov
http://visibleearth.nasa.gov/
http://earthobservatory.nasa.gov/
European Space Agency www.esa.int
http://www.esa.int/esaEO/SEM9UELY17E_index_0.html

NOAA www.noaa.gov
Remote sensing and Photogrammetry Society UK www.rspsoc.org

Satellite Imaging Corp: http://www.satimagingcorp.com/gallery.html

**Journals**
Remote Sensing of the Environment (via Science Direct from within UCL):
http://www.sciencedirect.com/science?_ob=JournalURL&_cdi=5824&_auth=y&_acct=C000010182&_version=1&_urlVersion=0&_userid=125795&md5=5a4f9b8f79baba2ae1896ddabe172179
IEEE Transactions on Geoscience and Remote Sensing:

**Detailed outline; Introduction and Radiation principles I**

**Housekeeping**

What is remote sensing and why do we do it?
- Definitions of remote sensing
- Examples and applications
- Introduction to process
  - Collection of signal
  - Interpretation into information
- Experience of students?

Introduction to some terms and concepts
- EM Radiation
  - Solar properties
- Interaction with atmosphere
- Interaction with surface
- Resolution
  - Spatial
  - Spectral
  - Temporal
  - Angular
  - Radiometric

The remote sensing process
- Instrument design
- Mission
- Information collection and processing

Introduction to EM spectrum
- Conduction, convection, radiation (JJ29)
Wave model of EM radiation
- Properties of EM wave (JJ30)
- Concepts of wave velocity, wavelength, period etc. (JJ31)

Solar radiation
- Concept of blackbody (MU25)
  - Kirchoff's Law (JJ250)
- Radiant energy of sun/Earth (thermal emission)
- Stefan-Boltzmann law (MU25/JJ247)
- Wien's displacement law (MU25)
- Planck's law (MU26)
- Solar constant (MU36)
  - Implications of en. distribution for EO
  - Calculation of energy between given wavelengths
  - Implications for evolution of the eye, chlorophyll pigments etc. etc.

**Radiation principles II**
Particle model of EM radiation
- Photon energy (JJ35)
- Quantum energy and unit (MU27/JJ37)

Radiation geometry and interactions
- Radiant flux, and radiant flux density (MU28)
- Radiance/Irradiance, Exitance, Emittance (MU28/MU31)
- Flux from a point source and from a plane source (MU29/MU30)
- Cosine law for emission & absorption, Lambert's Cosine Law (MU29/MU30)

Interaction with the atmosphere
- Refraction (index of etc.), Snell's Law (JJ39)
- Scattering
  - Rayleigh, Mie, Non-selective (JJ41)
- Absorption (JJ42/MU39) and atmospheric windows
- Absorption (and scattering at the surface)
  - Examples of vegetation, soil, snow spectra
  - Spectral features and information
- Sun/Earth geometry, direct and diffuse radiation (MU40-42)

Interaction of radiation with the surface
- Reflectance, specular, diffuse etc.
- BRDF
- Hemispherical reflectance, transmittance, absorptance
- Albedo
- Surface spectra
  - Spectral features and information

**Detailed outline: data acquisition and sensor design considerations**
Resolution: concepts (JJ12-17)
• Spatial
• Spectral
• Temporal
• Angular
• Radiometric
• Time-resolved signals
  • RADAR, LiDAR (sonar)

Spatial:
• High v Med/Moderate v Low
  • E.g. IKONOS, MODIS/AVHRR, MSG
• IFOV and pixel size
• GRE/GRD/GSD (L&K 334)
• Point spread function
  • Mixed pixel, continuous v. Discrete, generalisation

Spectral
• Wavelength considerations
• Optical
  • Photography, scanning sensors, LiDAR et.
• Microwave (active/passive)
  • RADAR
  • Thermal
  • Atmospheric sounders

Temporal/Angular
• Orbits
• Kepler's Laws
• Orbital period, altitude
• Polar, equatorial and Geostationary (L&K 397-9; JJ187-9 and 201)
• Advantages/disadvantages of various orbits
  • Coverage of surface
  • Solar crossing time/elevation
  • Broad swath instruments
    • AVHRR/POLDER/MODIS etc.
  • v Narrow swath
    • Landsat ETM+, IKONOS, MISR etc.

Radiometric
• Precision v accuracy
• Digital v analogue
• Signal to noise

Processing stages
• Transmission
• Storage and dissemination
• Ground segment
• Overview of pre-processing stages
  • Geometric, radiometric, atmospheric correction

Multi/hyperspectral scanners
• Heritage
  • Landsat, AVHRR (NOAA), EOS/NPOESS (NASA), ESA (Envisat, Explors etc.)
• Discrete detectors and scanning mirrors (JJ183)
• Pushbroom/whiskbroom linear arrays (JJ184)
  • Across track scanning (L&K 331, 337)
• Digital frame camera area arrays
• Detector types (CCD, L&K 336)
• Hyperspectral area arrays
• Examples of the different systems

**Detailed outline: Introduction to Lidar principles**

Lidar:
• Time-resolved signal
  • Why lidar? Time-resolved, near direct
• Lidar principles
• Wavelengths
• Types of system:
  • discrete
  • waveform
• Platforms and scanning
• Small-footprint systems
• Confounding effects (slope)
  • Waveform modelling
  • GLAS/ICESAT

Lidar missions & examples
• SLICER, MOLA GLAS
• Single scattering, multiple scattering
• VCL, CARBON-3D concept

Information extraction
• Direct, indirect
• Caveats
• Vertical distribution
• Empirical allometric relationships
• Canopy cover, tree number density

Ground-based terrestrial laser scanning (TLS)
Why?
• Systems
• Scanning
• Multi-wavelength? ECHIDNA, DWEL, SALCA
**Detailed outline: Introduction to RADAR**

**RADAR: Definitions**
- SLAR, SAR, IfSAR
- Principles
  - Ranging and imaging
  - Geometry
  - Wavelengths
- SAR principles
- Resolution
  - Azimuth, range
  - ERS1 & 2 examples

**Radiometric effects**
- Speckle
- RADAR equation

**Geometric effects**
- Shadow
- Foreshortening
- Layover

**Surface interactions**
- Moisture
- Types of interaction

**The RADAR equation**
- Measurable quantities
- Calibration

**Interferometric SAR (InSAR)**
- Principles
  - Phase information
  - Coherence
  - Phase unwrapping
- Interferograms, fringes, DEMs
- Sources
- Problems
  - Geometry
  - Decoherence
  - Accuracy
- Differential InSAR