GEOGG141
Principles & Practice of Remote Sensing (PPRS)
Revision

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Revision

• GEOGG141: Exam 3 hrs, answer 4 from 7
• Types of question based on PREVIOUS material be similar each year (not surprisingly!)
  – Planck function, orbital calculations, definitions of terms, pre-processing stages
  – Factors controlling measured signal from vegetation across vis/SWIR, or angular behaviour
  – RADAR principles eg RADAR equation, resolutions
  – Principles of SAR interferometry and applications
  – General questions - systems to address a given problem
    • KEY: address that problem
    • Does Q give scope for moving beyond one platform or wavelength? If so then DO SO…
Revision

- GEOG30501: Exam 3 hrs, answer 3 from 9 (!)
- As above – see previous papers
- Key differences to GEOGG141:
  - I DON’T ask you to derive/reproduce equations (eg Planck function or orbital period etc)
  - I often (always?) ask you to eg draw Planck function, and explain why it’s important, & how eg SB & Wien’s Law relate to the shape you draw
  - Sketch and explain things:
    - E.g. pros and cons of RADAR, examples of how lidar works, how SAR works, scattering properties of a surface at optical or microwave region
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• Both
  – EM spectrum
  – Key properties – where the visible (0.4-0.7), NIR (~0.7-1 or 2 ish) and SWIR (~400-2500)
  – Atmospheric windows – where, why?
  – Implications of Planck plus atmospheric windows?
  – Types of atmospheric scattering?
    • Rayleigh, Mie, non-selective
    • Note the wavelength and angular dependence here
Revision

• Both
  – Planck Function – shape and properties – remember to label axes correctly depending on how you plot
    • Log-log easiest, but could do log-linear
    • SB Law - total emitted ($\sigma T^4$) i.e. area under the curve
    • Wien’s Law – location of max emittance – reduces linearly with T IF we look in log-log space
  – Importance of Planck function is we can calculate energy between any 2 wavelengths

• GEOGG141:
  – Show Planck function & calculate energy between wavelengths (interpolation – see examples)
Revision

• Both
  – Surface scattering behaviour
  – BRDF: What is it? Relation to albedo?
  – BRDF of vegetation
    • Upward bowl-shape (volume scattering), downward-bowl shape and asymmetry (shadowing), and hot-spot peak (view/illumination coincident)
  – Lambertian surface? Non-Lambertian? Specular?
Revision

• Resolution / sampling
  – Distinguish these: resolution – smallest thing we can determine (spatial, spectral interval, angular IFOV, time-slice); sampling – usually angular or temporal, but can be spectral i.e. the INTERVAL between samples (eg every 16 days is temporal sampling NOT resolution)
  – Understand difference between moderate & high spatial for eg and be able to give specific examples

• Trade-offs
  – Why do we want high spatial, temporal, spectral?
  – What do we lose by going to higher resolution, sampling?
  – How do we choose how to optimise?
Revision

• Orbits, swaths etc
  – Know types of orbit
    • Near-Earth: near-polar, polar equatorial – orbital period? Sun-synchronous?
    • Geostationary: How far away, why? Trade-offs again
  – GEOGG141: derive orbital period from altitude, or vice-versa, maybe also revisit time
  – Trade-offs again
    • Specific applications and eg multi-platform examples like Sentinels
Revision

• Pre-processing
  – Radiometric calibration – turn raw DN into radiance – need to know detector properties
  – Radiometric correction – account for detector variations, destriping/denoising etc
  – Geometric – remove distortion & put in some sort of coordinate system
  – Atmospheric – remove atmospheric effects
    • Simple empirical using stable dark/bright targets
    • Or using atmospheric radiative transfer models – GEOGG141: expect you to be able to discuss in much more detail
Revision

• LiDAR
  – Main types of lidar system
  – Principles of lidar remote sensing
  – What is it good for and limitations
  – Example applications
    • Height/DEMs (hydrology, coastal surveying, urban etc etc), ice sheet thickness and dynamics (IceSAT), canopy height & hence biomass, veg structure
Revision

- **RADAR**
  - Why do we use it? Pros and cons?
  - Main types of system – side-looking airborne, real aperture, synthetic aperture
  - Principles of RADAR
    - GEOGG141: RADAR equation – terms and meaning
    - Backscatter: dielectric properties, geometry of surface – very sensitive to roughness, specular surfaces
  - What is it good for and limitations
  - Example applications
    - Flood mapping, agriculture (irrigation, amount), detection (shipping, military), oil slick mapping
    - Altimetry: DEMs, ice sheet, sea ice, wave height etc
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• RADAR - SAR
  – Synthesise large aperture various ways (2 sensors, repeat pass etc)
  – Use phase information (Doppler shift) to infer distance, hence small height changes/differences
  – Must have coherent signal – affected by …?
  – Example applications
    • Very accurate DEMs, earthquakes, landslides, subsidence volcanoes; oil and mineral exploration; ice sheet dynamics
    • DiffInSAR – (difference of differences) – v sensitive to small changes over time
Revision

- GEOGG141: Radiative Transfer modelling
  - Basis of RT model – building blocks?
    - 3 main parts: canopy architecture (LAI, height, arrangement & orientation of leaves – primarily structure not spectral), leaf scattering properties (within leaf, structure AND spectral), soil scattering (structure – roughness & spectral – moisture, type)
  - Scalar RT equation
    - what do terms mean?
    - How can we go about solving? Key approximations (eg LAD, leaf size and distribution)
    - Simplify to eg linear BRDF model approach of isotropic + volume + GO scattering terms
Revision problems: Planck’s Law

• Fractional energy from 0 to \( \lambda \) \( F_{0 \rightarrow \lambda} \)? Integrate Planck function

• Note \( E_{b\lambda}(\lambda, T) \), emissive power of bbody at \( \lambda \), is function of product \( \lambda T \) only, so....

\[
F_{0 \rightarrow \lambda}(\lambda, T) = \frac{E_{0 \rightarrow \lambda}(\lambda, T)}{\sigma T^4} = \int_0^{\lambda T} d(\lambda, T) \frac{E_{b\lambda}(\lambda, T)}{\sigma T^5}
\]

Radiant energy from 0 to \( \lambda \)

Total radiant energy
for \( \lambda = 0 \) to \( \lambda = \infty \)
**Q:** what fraction of the total power radiated by a black body at 5770 K fall, in the UV (0 < \(\lambda\) ≤ 0.38 \(\mu\)m)?

- Need table of integral values of \(F_{\lambda}\)
- So, \(\lambda T = 0.38 \mu m \times 5770 K = 2193 \mu mK\)
- Or 2.193x10^3 \(\mu mK\) i.e. between 2 and 3
- Interpolate between \(F_{\lambda}(2 \times 10^3)\) and \(F_{\lambda}(3 \times 10^3)\)

\[
\frac{F_{\lambda}(3 \times 10^3) - F_{\lambda}(2 \times 10^3)}{F_{\lambda}(3 \times 10^3) - F_{\lambda}(2 \times 10^3)} = \frac{2.193 - 2}{3 - 2} = 0.193
\]

\[
\frac{F_{\lambda}(0.38) - 0.067}{0.273 - 0.067} = 0.193
\]

- Finally, \(F_{0.38} = 0.193 \times (0.273 - 0.067) + 0.067 = 0.11\)
- i.e. ~11% of total solar energy lies in UV between 0 and 0.38 \(\mu m\)
Orbits: examples

• Orbital period for a given instrument and height?
  – Gravitational force $F_g = \frac{GM_E m_s}{R_{SE}^2}$
    • where $G$ is universal gravitational constant ($6.67 \times 10^{-11}$ Nm$^2$kg$^{-2}$); $M_E$ is Earth mass ($5.983 \times 10^{24}$kg); $m_s$ is satellite mass (?) and $R_{SE}$ is distance from Earth centre to satellite i.e. $6.38 \times 10^6 + h$ where $h$ is satellite altitude
  – Centripetal (not centrifugal!) force $F_c = \frac{m_s v_s^2}{R_{SE}}$
    • where $v_s$ is linear speed of satellite ($= \omega_s R_{SE}$ where $\omega$ is the satellite angular velocity, rad s$^{-1}$)
  – for stable (constant radius) orbit $F_c = F_g$
  – $\therefore GM_E m_s / R_{SE}^2 = m_s v_s^2 / R_{SE} = m_s \omega_s^2 R_{SE}^2 / R_{SE}$
  – so $\omega_s^2 = GM_E / R_{SE}^3$

From:http://csep10.phys.utk.edu/astr161/lect/history/kepler.html
Orbits: examples

• Orbital period $T$ of satellite (in s) = $\frac{2\pi}{\omega}$
  – (remember $2\pi = \text{one full rotation, 360}^\circ, \text{in radians}$)
  – and $R_{sE} = R_E + h$ where $R_E = 6.38 \times 10^6$ m
  – So now $T = 2\pi[(R_E+h)^3/GM_E]^{1/2}$

• Example: geostationary altitude? $T = ??$
  – Rearranging: $h = [(GM_E/4\pi^2)T^2]^{1/3} - R_E$
  – So $h = [(6.67 \times 10^{-11} \times 5.983 \times 10^{24} / 4\pi^2)(24 \times 60 \times 60)^2]^{1/3} - 6.38 \times 10^6$
  – $h = 42.2 \times 10^6 - 6.38 \times 10^6 = 35.8$ km
Orbits: examples

• Example: polar orbiter period, if $h = 705 \times 10^3$ m
  – $T = 2\pi[(6.38 \times 10^6 + 705 \times 10^3)^3 / (6.67 \times 10^{-11} \times 5.983 \times 10^{24})]^{1/2}$
  – $T = 5930.6$ s = 98.8 mins

• Example: show separation of successive ground tracks ~3000 km
  – Earth angular rotation = $2\pi/24 \times 60 \times 60 = 7.27 \times 10^{-5}$ rads s$^{-1}$
  – So in 98.8 mins, point on surface moves $98.8 \times 60 \times 7.27 \times 10^{-5} = .431$ rads
  – Remember $l = r \theta$ for arc of circle radius $r$ & $\theta$ in radians
  – So $l = (\text{Earth radius} + \text{sat. altitude}) \theta$
  – $= (6.38 \times 10^6 + 705 \times 10^3) \times 0.431 = 3054$ km