Homework #8 **SOLUTION**
Geology 4113 (Remote Sensing)
Assigned Mar. 23, 2018
Due Friday Mar. 30, 2018

#1) The NASA/JAXA GPM mission (20 points). Yesterday, Thursday Feb. 27, 2014, the Japanese space agency (JAXA) and NASA successfully launched the Global Precipitation Measurement (GPM) satellite, which has two instruments, a "Dual-frequency Precipitation Radar" (DPR) and a "GPM Microwave Imager" (GMI) designed to measure the amount of rain and snow precipitation. Use the press kit available at
<`http://pmm.nasa.gov/sites/default/files/imce/GPM-Press-Kit_2014.pdf`>.
to answer the following questions.

a) Is this satellite in a geosynchronous, a sun synchronous, or some other type of orbit?

No. It is in an orbit with an inclination of approximately 60^O *at an altitude of 407 km, neither geosynchronous nor sun synchronous.*

b) The two wavelengths of the radar instrument are specified using the letter names for bands -- in this case two sub-parts of the K band. What are the name of those two bands? At what frequencies do they operate? (Note there is a typo in one figure where they repeat the name of the same band when they really mean to list both -- but from all the other information given you should be able to figure this out.) Finally, use the two frequencies they specify to find the wavelengths of those two bands.

The radar instrument operates in the Ka band 35.5 GHz and the Ku band at 13.6 GHz. Using $\lambda=c/\nu$ *these correspond to 0.00845 m and 0.022 m, or 8.45 mm and 2.2 cm, within the 0.8 to 2.4 cm range for K band listed in Sabins Table 6-2.*

c) They list a range and an azimuth resolution for the DPR? What are they? (Note they don't actually use the words "azimuth resolution" but from the diagrams they show, you should be able to tell which that is.

The azimuth resolution, as shown in the Figure on pg. 7, is 5 km. The DPS operates with two different pulse lengths, giving it a range resolution of 250 or 500 m.

d) They also list "pulses per second" for the two channels, and say that one of the two channels will emit both 250 and 500 meter length pulses -- the latter providing more sensitivity. (Note there is an inconsistency between these quoted pulse lengths and the range resolution quoted above, in that they are not including the two-way factor of 2 we discussed in class. They may just be simplifying the discussion in this press document -- but they also don't include the depression angle terms which partly compensate for the missing factor of two.) Convert the average "pulses per second" value into a time interval (in microseconds) between pulses. Similarly, convert the 500 meter pulse length into a pulse duration, in microseconds. The ratio between these two, at least assuming this is a simple system, gives the duty cycle, that is, the fraction of the time that the radar is actually transmitting a signal. What is that duty cycle?

They list "pulses per second" of 4100 to 4400, so for an average 4250 that is 0.00024 s = 240 µs between pulses. The 250 and 500 m pulse lengths correspond to pulse durations of Δt = Δl / c or 0.833 and 1.67 µs. That implies a duty cycle of 0.833/240 = 0.0035, and 1.67/240 = 0.070, or 0.35 % and 0.70 % .

e) They also list a (broad) range of frequencies which the microwave imager receives. What range of wavelengths does this correspond to?

They list 10-183 GHz which, using λ=c/ν, corresponds to 0.03 to 0.00164 m, or 3 cm to 1.64 mm. Note that even though this is much longer than the peak thermal wavelength (for room temperature) of 10 µm, the Planck blackbody curve falls much more slowly to long wavelengths than to short wavelengths, so there will be some thermal emission in the wavelengths seen by the GMI.

#2) Radar (10 points) The radar backscatter cross section (when measured in decibels) is defined by the following equation.

$$\sigma = 10\ \log\left(\frac{\text{Energy received}}{\text{Energy expected from isotropic scatterer}}\right)$$

Backscatter measurements over all of North America at 13.9 GHz, at 33^0 incidence angle, give an average backscatter cross section of -9.9 dB.

a) What wavelength is this radar operating at?

$$c = \lambda \times \nu \quad \text{or} \quad \lambda = \frac{c}{\nu} = \frac{3.0\times 10^8\,\text{m/s}}{13.9\times 10^9\,\text{s}^{-1}} = 2.16\times 10^{-2}\,\text{m} = 2.16\,\text{cm}$$

b) What is the Energy Ratio (i.e. Energy Received / Energy expected from isotropic scatterer) which corresponds to this cross section?

The above equation for the radar backscatter cross section can be inverted to give

$$\frac{\text{Energy received}}{\text{Energy expected from isotropic scatterer}} = 10^{(\sigma/10)} = 10^{(-9.9/10)} = 10^{-0.99} = 0.1023$$

#3) Radar Roughness (10 points) The PALSAR (Phased Array L band Synthetic Aperture Radar) system on ALOS (Advanced Land Observing Satellite) operated at a frequency of 1270 MHz. For the following, assume the depression angle γ is equal to 56º.

a) What is the wavelength of this radar?

$$\lambda = \frac{c}{\nu} = \frac{3.0\times10^{8}\,\mathrm{m/s}}{1270\times10^{6}\,\mathrm{s}^{-1}} = 0.236\,\mathrm{m} = 23.6\,\mathrm{cm}$$

b) Using the Rayleigh criteria, where, in centimeters, is the division between a rough and a smooth surface?

By the Rayleigh criterion the boundary between smooth and rough occurs at

$$h = \frac{\lambda}{8\sin(\gamma)} = \frac{23.6\,\mathrm{cm}}{8\sin(56^{o})} = \frac{23.6\,\mathrm{cm}}{8\times0.829} = 3.56\,\mathrm{cm}$$

c) Using the criteria by Peake and Oliver (pg. 200 in Sabins) who divide surfaces up into smooth, intermediate, and rough, categories, where is the division (again in cm) for rough vs. intermediate and for intermediate vs. smooth?

Using the Peak and Oliver criteria the boundary between smooth and intermediate occurs at

$$h = \frac{\lambda}{25\sin(\gamma)} = \frac{23.6\,\mathrm{cm}}{25\sin(56^{o})} = \frac{23.6\,\mathrm{cm}}{25\times0.829} = 1.14\,\mathrm{cm}$$

while the boundary between intermediate and rough occurs at

$$h = \frac{\lambda}{4.4\sin(\gamma)} = \frac{23.6\,\mathrm{cm}}{4.4\sin(56^{o})} = \frac{23.6\,\mathrm{cm}}{4.4\times0.829} = 6.47\,\mathrm{cm}$$