You are allowed ten minutes before the start of the examination to acquaint yourself with the instructions below and to read the question paper.

Do not write anything until the invigilator informs you that you may start the examination. You will be given five minutes at the end of the examination to complete the front of any answer books used.

April 2014 **MTMG38**

Answer Book
Data Sheet
Any bilingual English language dictionary permitted
Only Casio-fx83 calculators are permitted

UNIVERSITY OF READING

Remote Sensing (MTMG38)

Two hours

Answer **ANY TWO** questions

The marks for the individual components of each question are given in [ ] brackets. The total mark for the paper is 100.

1.a (i) For sufficiently small particles with respect to the wavelength of the TRMM satellite Precipitation Radar (PR), how much difference in reflectivity (**in dB**) should we expect between liquid- and ice-phase particles? Explain your answer by discussing the scattering regime and the difference in backscattering of liquid/ice particles.

[10 marks]

(ii) A vertical profile of PR reflectivity for a particular location is shown in Fig. 1. For this location, we know that the freezing level height is 5,250 m and the liquid water path is 1,500 g m^{-2}. Let us assume that the cloud top is the uppermost level where the reflectivity exceeds 17 dBZ. Also, assume that the conversion time scales of liquid water path to surface rain rate are approximately **36** minutes for **cold rain** processes, and **65** minutes for **warm rain** processes. Please use Fig. 1 and all information here to estimate the near-surface rain rate (in mm h^{-1}) for this particular location.

[8 marks]

(iii) Using an empirical relationship $Z = 30 R^{1.33}$ and Fig. 1, estimate rain rate at the lowest cloud base height.

[8 marks]

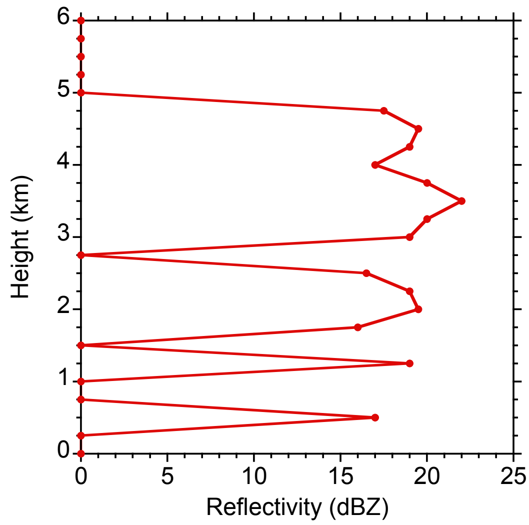

Fig. 1. A vertical profile of PR reflectivity.

(b) Sketch the relationship between cloud optical depth and reflectance at the top of the atmosphere for two droplet sizes. Use the sketch to describe the physical principle of how and what cloud properties can be retrieved from reflectance.

[14 marks]

(c) Explain how vegetation may cause overestimation or underestimation in soil moisture retrievals from passive satellite observations, and how the retrieval error could be minimised. [Hint: compare and contrast emissivity and polarisation as a function of wavelength (or frequency) for different surface types.]

[10 marks]

2.(a) List two radiative processes in remote sensing applications that result in polarization of radiation. [Note that these two processes need to be distinct.]

[8 marks]

(b) A strong absorption band occurs at 60 GHz in the microwave spectrum. Please sketch three curves of weighting functions for a zenith-viewing microwave radiometer that measures radiance at 53, 54 and 55 GHz.

(i) Please label your curves, x- and y-axis clearly, and explain why the shape and peak locations of the weighting functions should look like your sketch.

[18 marks]

(ii) Which gas causes this absorption band?

[2 marks]

(iii) Identify and explain which atmospheric parameter these weighting functions in your sketch can be used to retrieve.

[5 marks]

(c) Cirrus clouds were observed at Chilbolton on 13th November 2010 (as shown in Fig. 2). At 16 UTC, the cloud-base height is about 6 km and the cloud top is 10 km; the MODIS instrument on the NASA Aqua Satellite also passed over Chilbolton and took radiance measurements at Emissive Band 31 (10.8 μm) as summarised in Table 1. Assuming that the ice water content retrieved from Cloudnet in Fig. 2 is sufficiently accurate, please estimate the effective radius (**in μm**) of the cirrus clouds with a particle density of 0.9 g cm^3.

[For calculations, there is no need to be very accurate taking readings from Figure 2; labels shown along with the colour bars should be sufficient. For example, take ice water content reading at 10^{-6}, 10^{-5} kg m^{-3}, etc.]

[17 marks]

Table 1. Ancillary information and MODIS Measurements from NASA Aqua Satellite on 13th November 2010.

Parameter	Value
Solar zenith angle (°)	60
Sensor zenith angle (°)	50
Radiance (W m^{-2} μm^{-1} sr^{-1}) at 10.8 μm wavelength	3.50
Incident radiance at cloud base (W m^{-2} μm^{-1} sr^{-1})	6.63
Blackbody radiance at cloud temperature (W m^{-2} μm^{-1} sr^{-1})	2.91

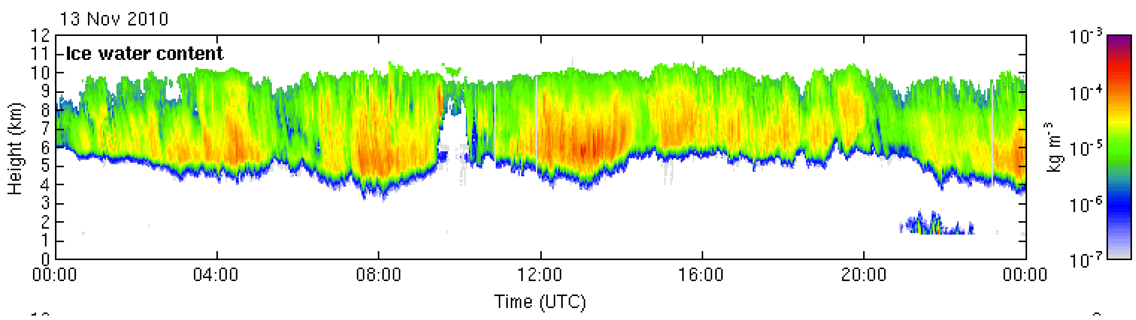

Fig. 2. Retrieved ice water content in kg m^{-3} at Chilbolton on 13th November, 2010 (courtesy of Cloudnet).

3. (a) The Aerosol Robotic Network (AERONET) operates a sunphotometer that measures transmittance at wavelengths of 440, 675, 870, and 1020 nm at a fixed location XX. When this sunphotometer was calibrated with the Langley plot method at Mauna Loa Observatory in Hawaii, the voltage extrapolated to the top of the atmosphere was V_0 = 2.0 and 1.0 volts for 440 and 870 nm, respectively.

One day when the solar zenith angle was 54°, NASA Terra Satellite overpassed Location XX and took the image as shown in Fig. 3a. The sunphotometer measured a voltage of V = 0.006 and 0.051 volts at wavelengths of 440 and 870 nm, respectively. It also measured an asymmetry factor of 0.65.

Based on these measurements, did Terra capture wildfires, dust plumes or clouds? Does the size distribution shown in Fig. 3b represent the event captured by Terra? Please support your statement by discussing all three types of particles and all the information provided here.

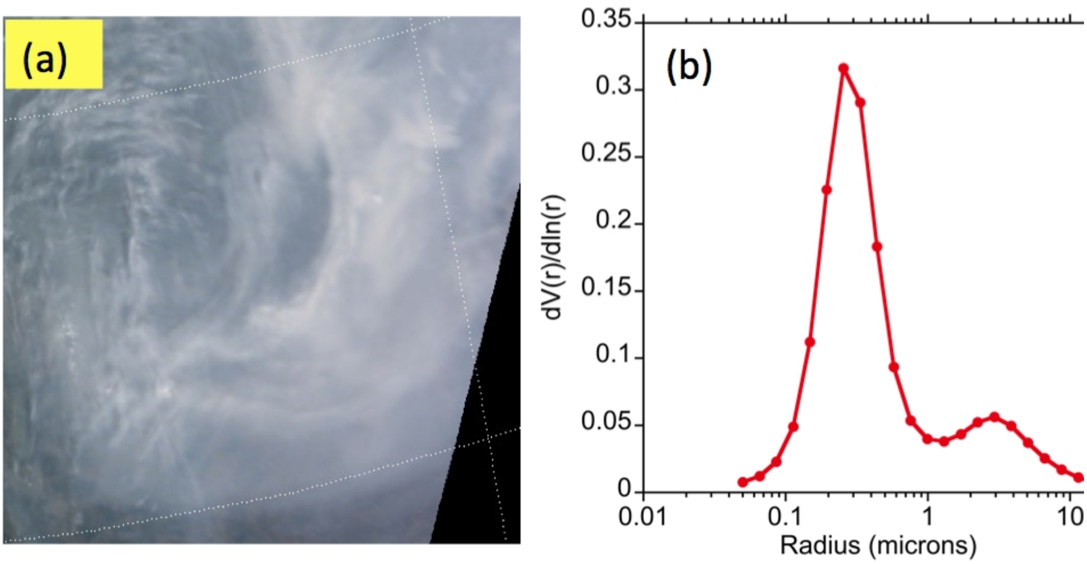

Fig. 3. (a) Image taken by NASA Terra Satellite on October 24, 2007, and (b) the corresponding particle size distribution measured by AERONET (courtesy of NASA).

[35 marks]

(b) Explain and contrast passive microwave brightness temperatures for snowpack in the following conditions:
1) shallow versus deep, and 2) dry newer versus moist older snowpack.

[15 marks]

(End of Question Paper)