Candidates are admitted to the examination room ten minutes before the start of the examination. On admission to the examination room, you are permitted 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 2013 **MTMG38**

Answer Book
General Data Sheet
Figures and Tables
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) The rainfall rate, R, in mm h^{-1} could be estimated using an empirical relationship: $Z = 300\ R^{1.4}$. If the observed radar reflectivity is 10 dBZ what rainfall rate is estimated?

[8 marks]

(b) Is radar reflectivity dominated by smaller or larger particles? Explain your answer using quantitative calculations. [Hint: Make assumptions on the number concentration and particle size, and calculate the reflectivity. Then, give an example of how this calculated reflectivity can correspond to a different combination of the number concentration and particle size.]

[10 marks]

(c) A ground-based radar observed cirrus clouds at the Atmospheric Radiation Measurement Program Oklahoma site on November 22, 2007 (as shown in Fig. 1). The cloud-base height is about 8 km, and the cloud geometric thickness is 2 km. At 20 UTC, the MODIS instrument on the NASA Aqua Satellite passed over the Oklahoma site and took radiance measurements at Emissive Band 31 (10.8 μm); the corresponding measurements are summarized in Table 1.

[For these calculations, there is no need to be very accurate taking readings from Figure 1; labels along with the colour bars shown should be sufficient. For example, take temperature reading at 210, 220 K, etc.; ice water content reading at 10^{-6}, 10^{-5} kg m^{-3}, etc.]

(c.1) Assume the cloud incident radiation brightness temperature is 275 K and cirrus cloud temperature is the same as the ambient environment at 8–9 km. Please retrieve the optical depth of the cirrus clouds using the MODIS data. [Hint: Use Planck's function below, where λ is the wavelength; T is the temperature, c_1 is 1.191×10^8 W m^{-2} μm^{-4} sr^{-1}; and c_2 is 1.43×10^4 K μm.]

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5\left(e^{hc/k_B\lambda T} - 1\right)} = \frac{c_1}{\lambda^5\left(e^{c_2/\lambda T} - 1\right)}$$

[20 marks]

(c.2) Assuming that the ice water content retrieved from Cloudnet (the middle panel in Fig. 1) and the cloud optical depth from Part (c) are both sufficiently accurate, please estimate effective radius (**in μm**) of the cirrus clouds with a particle density of 0.9 g cm^{-3}.

[12 marks]

1. (continued)

Table 1. MODIS Measurements from NASA Aqua Satellite.

Parameter	Value
Solar zenith angle (°)	60
Sensor zenith angle (°)	55
Radiance (W m^{-2} μm^{-1} sr^{-1}) at 10.8 μm wavelength	5

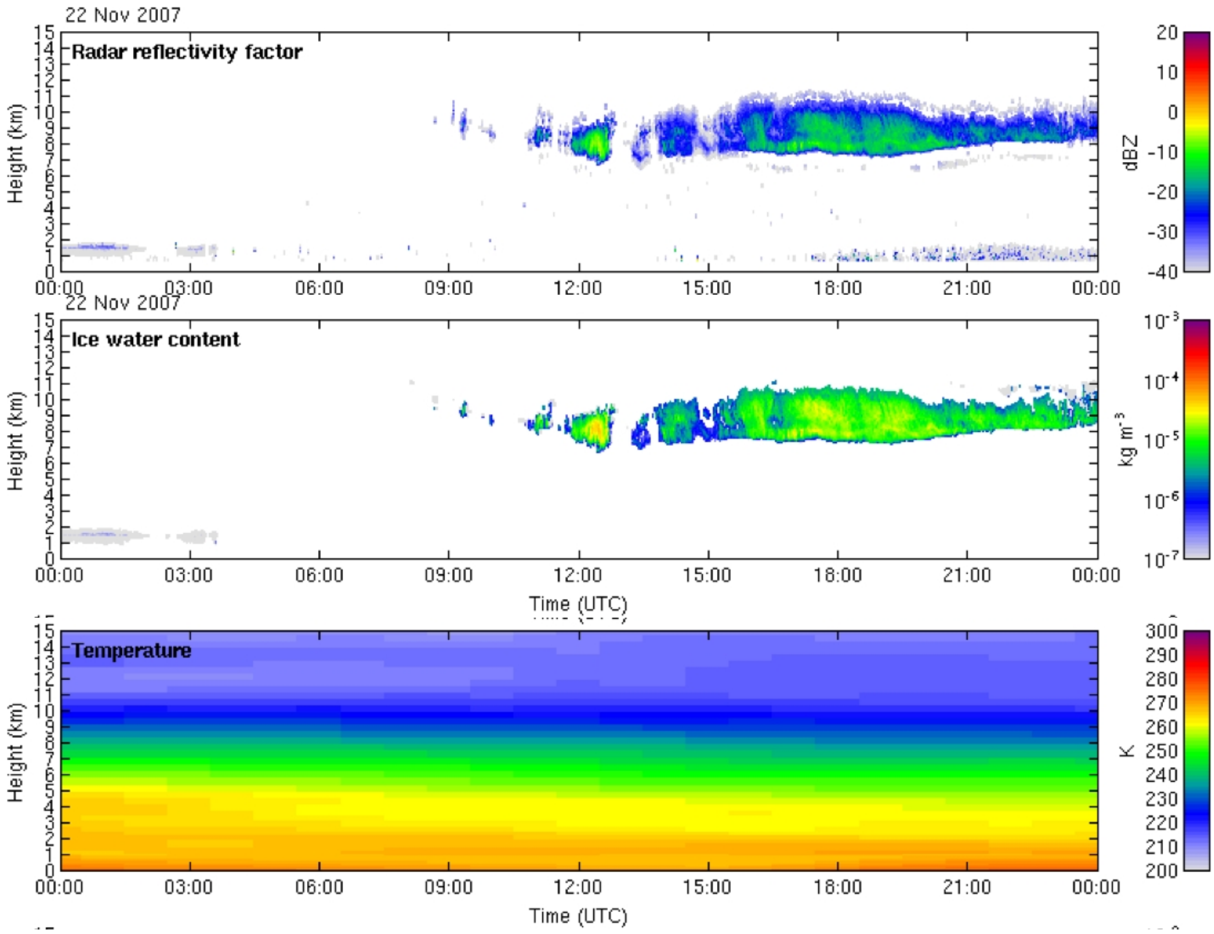

Fig. 1. Measurements at the Oklahoma site on November 22, 2007 for ground-based radar reflectivity in dBZ (top), retrieved ice water conent in kg m^{-3} from Cloudnet (middle), and ECMWF temperature in K (bottom).

2.

(a) Figure 2 illustrates a set of weighting functions for various atmospheric parameters, including pressure, temperature, water vapour and cloud water <u>for a single instrument</u>. Each curve represents the response of the instrument to a unit change in the respective atmospheric parameter at various altitudes (km) and at a given frequency (GHz).

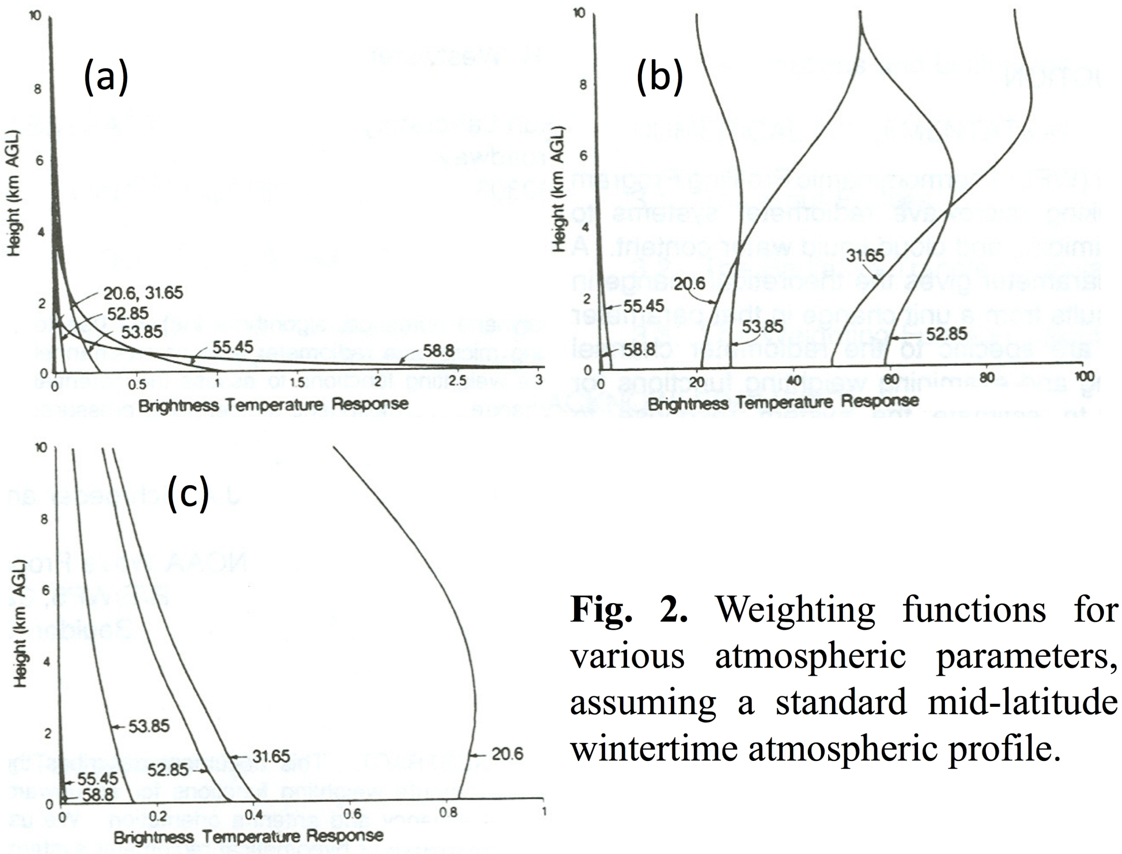

Fig. 2. Weighting functions for various atmospheric parameters, assuming a standard mid-latitude wintertime atmospheric profile.

(a.1) Explain whether these weighting functions represent a typical nadir or zenith sounding.

[4 marks]

(a.2) Identify and explain which instrument these weighting functions might be provided for. [Your answer should include information on flux versus radiance, and spectral regions.]

[9 marks]

(a.3) Identify and explain which atmospheric parameter these weighting functions in Fig. 2. (a) – (c) respectively correspond to.

[18 marks]

2. (continued)

(b) NASA Terra Satellite took the image below (Fig. 3) on October 24, 2007. Based on MODIS official aerosol products, the aerosol optical depth was about 0.516, 0.421 and 0.212 at wavelengths of 470, 550 and 860 nm, respectively. Asymmetry factors were in the range between 0.65 – 0.75. Based on the overall information, did Terra capture wildfires, dust plumes, or clouds? What range of the particle size (**in μm**) did Terra likely observe? Please support your statements by discussing all the information provided here.

Fig. 3. Image taken by NASA Terra Satellite on October 24, 2007 (courtesy of NASA).

[19 marks]

3.

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

[10 marks]

(b) Sketch relationships between oceanic vertically/horizontally polarized brightness temperatures and rain rate, using 19.35, 37.00 and 85.50 GHz as examples. Summarize key points shown in your plot.

[22 marks]

(c) Give a ground-based remote sensing application that measures parameters of interest using extinction methods. Please clearly define the parameter of interest and briefly describe the physical principles.

[18 marks]

(End of Question Paper)