On admission to the examination room, you should acquaint yourself with the instructions below. You must listen carefully to all instructions given by the invigilators. You may read the question paper, but must 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.

DO NOT REMOVE THIS QUESTION PAPER FROM THE EXAM ROOM.

April 2016 **MTMG38/ 2015/16 A001**

Answer Book

Any bilingual English language dictionary permitted
Any non-programmable calculator is 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) 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.

[25 marks]

(b) For radar at 85.50 GHz detecting raindrops, which scatter regime can be applied? Show your calculation of size parameter to support your conclusion.

[10 marks]

(c) A Z–R relationship $Z = 2.0\ R^{0.7}$ has been used to estimate drizzle rate (mm d^{-1}) for spaceborne cloud radar observations. An overpass over the Atlantic Ocean shows a shallow precipitating cloud system with reflectivity of 15 dBZ. Use this Z–R relationship to estimate drizzle rate (in mm d^{-1}) for this particular precipitation system.

[10 marks]

(d) For the precipitation system in (c) over the ocean, do you expect to see any polarisation difference in satellite passive microwave observations for the 85.50 GHz channel? Explain why or why not.

[5 marks]

[Total 50 marks]

2. (a) Cloud retrievals from a ground-based radar at Chilbolton on 3rd March 2010 are shown in Fig. 1. The cloud-base height is about 4 km, and the cloud geometric thickness is 4 km. At 11 UTC, the MODIS instrument on the NASA Terra Satellite passed over Chilbolton and took radiance measurements at Emissive Band 31 (10.8 μm); the corresponding measurements are summarized in Table 1.

Assume the cloud incident radiation brightness temperature is 260 K and cloud temperature is the same as the ambient environment at 6 km. Retrieve the optical depth of the cloud using the MODIS data. [Hint: Use Planck's function below, where λ is the wavelength; T is the temperature, c_1 is 1.191 x 10^8 W m^{-2} μm^{-4} sr^{-1}; and c_2 is 1.43 x 10^4 K μm.]

$$B_\lambda(T) = \frac{c_1}{\lambda^5 (e^{c_2/\lambda T} - 1)}$$

[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 230, 240, 250 K, etc.; ice water content reading at 10^{-6}, 10^{-5} kg m^{-3}, etc.]

[20 marks]

Table 1. MODIS Measurements from NASA Terra Satellite.

Parameter	Value
Solar zenith angle (°)	60
Sensor zenith angle (°)	30
Radiance (W m^{-2} μm^{-1} sr^{-1}) at 10.8 μm wavelength	3.5

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

[12 marks]

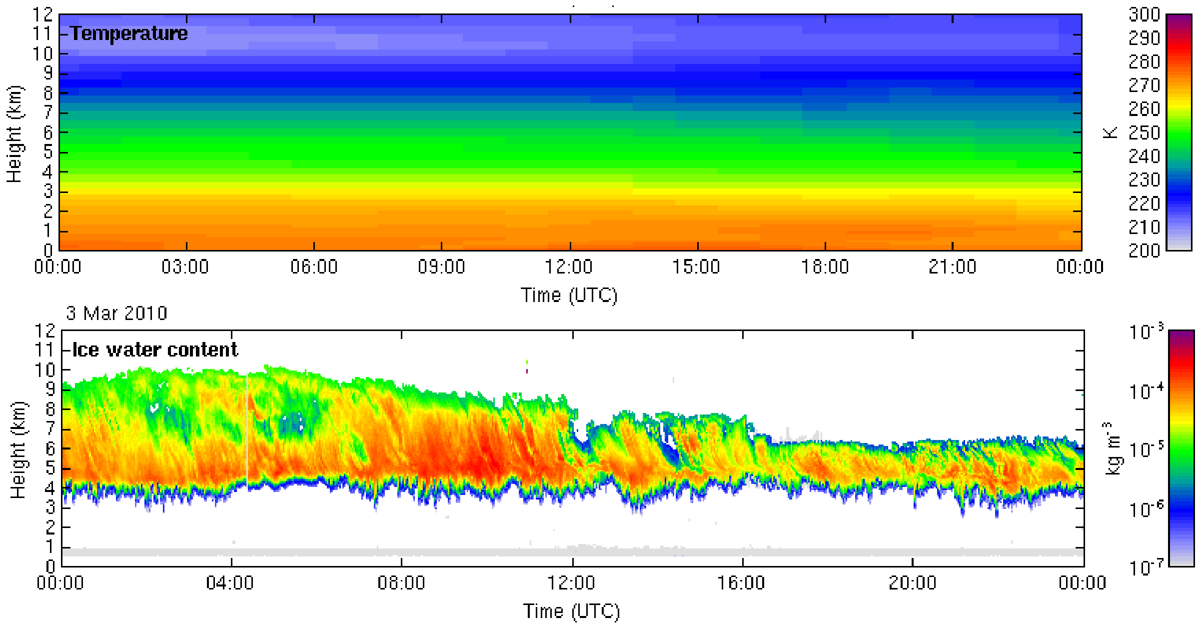

Figure 1. ECMWF temperature in K (top) and retrieved ice water content in kg m^{-3} from ground-based radar observations (bottom) at Chilbolton on 3rd March 2010. (courtesy of Cloudnet)

(c) Figure 2 is the weighting function calculated for an instrument that capitalises on a strong absorption band at 60 GHz. Which of the following is this instrument likely to be, the Special Sensor Microwave Imager (SSM/I), The Advanced microwave sounding unit (AMSU), The Atmospheric Infrared Sounder (AIRS) or a ground-based microwave radiometer? Explain your reasoning.

[5 marks]

Focusing on Channel 1 and Channel 2, identify which channel is more likely to be 51.8 GHz and which one is more likely to be 54.8 GHz? Explain your reasoning.

[7 marks]

Identify and explain which atmospheric parameter Channel 1 and Channel 2 can help retrieve.

[6 marks]

[Total 50 marks]

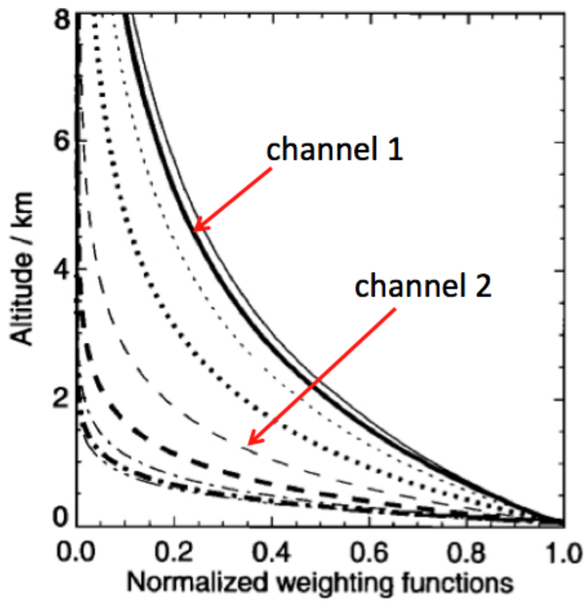

Figure 2. Weighting functions for an instrument of interest.

3. (a) The Aerosol Robotic Network (AERONET) operates a sunphotometer at location ‘Secret_Site (at an elevation of 2 km), which measures transmittance at wavelengths of 440, 675, 870, and 1020 nm.

Rayleigh optical depth (τ_R), a function of wavelength (λ; μm) and altitude (z; km), can be parameterized as:

$\tau_R = 0.009 \cdot \lambda^a \cdot \left[e^{-0.1z-0.001z^2}\right]$. (Eq. 1)

Provide the value for coefficient *a* and calculate Rayleigh optical depth at wavelengths of 440 nm.

[6 marks]

(b) 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 2.0 mV for 440 nm.

The sky on 2nd May 2002 was cloudless. When the solar zenith angle was 30°, the sunphotometer measured a voltage of V = 0.72 mV at wavelengths of 440 nm. At the same time, a 0.5 km thick layer of aerosols from the surface was identified by a micropulsed lidar.

Calculate the corresponding aerosol optical depth and the average volume extinction coefficient.

[14 marks]

(c) At the same time, NASA Terra Satellite took the image below (Fig. 3). Based on MISR official aerosol products, the aerosol optical depth at 558-nm wavelength at location 'Secret_Site' was about 0.5. Based on the information provided in (b) and (c), did Terra capture polluted continental particles, dust plumes, or clouds? Approximately, what particle size (in μm) did Terra likely observe? Support your statements by discussing all the information provided throughout Question 3.

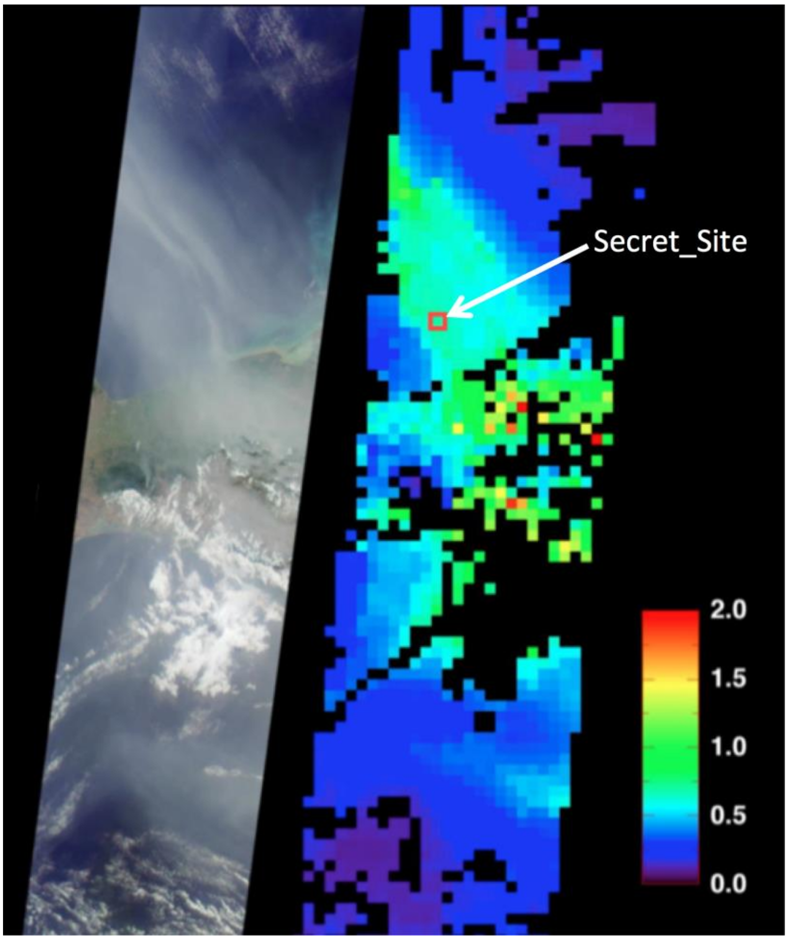

Figure 3. MISR image (left) and the corresponding retrieved aerosol optical depth at 558-nm wavelength (right) for 2nd May 2002. The red square represents the location 'Secret_Site.

[16 marks]

(d) Briefly describe the physical principle of how MISR measurements can be used to retrieve aerosol optical depth, by sketching relationships between aerosol optical depth (x-axis) and the observable (y-axis). Make sure to label what the observable is, and the ranges of x- and y-axis.

[14 marks]

[Total 50 marks]

(End of Question Paper)