UNIVERSITY OF KWAZULU-NATAL
SCHOOL OF AGRICULTURAL, EARTH & ENVIRONMENTAL SCIENCES
DISCIPLINE OF AGROMETEOROLOGY
EXAMINATION: Tuesday 3rd JUNE 2014 2 pm
SUBJECT, COURSE & CODE: Agrometeorology and Environmental Biophysics, AMET210

DURATION: 3 HOURS **TOTAL MARKS: 150**

External Examiner: Dr M. G. Mengistu
Internal Examiners: Mr A. D. Clulow and Professor M. J. Savage

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NOTE: THIS PAPERS CONSISTS OF TEN (10) PAGES, PLEASE SEE THAT YOU HAVE THEM ALL.

Note:
1. Students are requested, in their own interests to write legibly.
2. **Non-programmable calculators** are permitted.
3. Attempt all sections. All answers should be presented in your answer book.

Symbols used are as used in lectures. Some constants given below are approximate.

4. Useful information
   - 0 ^{o}C = 273.15 K; density of water ρ_{water} is 1000 kg m^{-3}; molecular mass of water m_w is 18 g mol^{-1}; specific heat capacity of liquid water $c_{p.water}$ is 4180 J kg^{-1} K^{-1}; specific latent heat of fusion for water L_f is 0.33 MJ kg^{-1}; specific latent heat of vapourisation for water L_v is 2.43 MJ kg^{-1}.
   - Specific heat capacity of air is 1030 J kg^{-1} K^{-1}.
   - Stefan-Boltzmann constant σ = 5.6704 x 10^{-8} W m^{-2} K^{-4}; Wien's constant $k = 2.8978 \times 10^{-3}$ m K; Universal gas constant $R =$ 8.31451 J mol^{-1} K^{-1}; $e = \rho_w RT / m_w$.
   - Dry adiabatic lapse rate is – 0.01 K m^{-1}.
   - Saturated adiabatic lapse rate is – 0.005 K m^{-1}.
   - Ohm's Law constant for r_i, r_{av} and stomatal resistance r_s is $\rho_{air} c_p / \gamma$.
   - Ohm's Law constant for aerodynamic resistance r_{ah} is $\rho_{air} c_p$.
   - Fick's Law constant for sensible heat flux density is $\rho_{air} c_p K_h$.
   - Fick's Law constant for latent energy flux density is $\rho_{air} c_p K_w / \gamma$.
   - $L_v F_w = -(I_{net} + F_s)/(1+\beta)$ when using the shortened energy balance convention $I_{net} + L_v F_w + F_h + F_s = 0$ or
     $L_v F_w = (I_{net} - F_s)/(1+\beta)$ when using the convention that $I_{net} = L_v F_w + F_h + F_s$
     where $\beta = \gamma \cdot (T_2 - T_1)/(e_2 - e_1)$.
   - Fundamental evaporation equation is: $\alpha = [\Delta \cdot r_a + \gamma \cdot r_i]/[\gamma \cdot (r_a + r_s) + \Delta \cdot r_a]$ where Δ / γ = 1, 2, or 3 for temperatures of 6, 18 or 26 ^{o}C respectively where γ = 0.066 kPa K^{-1}.

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Attempt all sections.
Section A: 60 marks (Question 1 – 10 marks; Question 2 – 50 marks); 72 min
Section B: 60 marks (three questions out of five – 20 marks for each question); 72 min
Section C: 30 marks (all questions); 36 min

Section A

Answer Questions 1 and 2. Total marks for this section is 60 and the suggested time is 72 minutes.

Questions 1 and 2 are compulsory

Question 1

Define, using diagrams where appropriate, any ten of the following twelve:

(a) air temperature anomaly
(b) cost loss ratio
(c) water vapour pressure deficit
(d) quantum sensor
(e) radiation error
(f) diffuse irradiance
(g) specific heat capacity
(h) civil twilight time
(i) southern oscillation
(j) cloud condensation nuclei
(k) supersaturation
(l) Dobson unit

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Question 2

Note: Symbols used here are as used in lectures.

(a) State Fick's law for sensible heat flux density and latent energy flux density. Aid: see front page of this examination paper. **3**

(b) State the Similarity Principle. **2**

(c) Define the Bowen ratio. **3**

(d) In Chapter 4, we discussed many different methods of measuring evaporation – for example a class-A pan, a lysimeter, etc. Using a diagram if necessary, describe any one of these methods. **3**

Penman/Penman-Monteith evaporation

(e) Use a diagram to show the Penman approach for estimating open water evaporation. What is the essential difference in approach between Penman and Penman-Monteith? **4.5**

(f) Present an annotated model for the transfer of sensible and latent energy flux density for the so-called big-leaf. **8**

(g) Write down expressions for the three resistances shown in your diagram of Question 2 (f). **3**

(h) State how these three expressions in Question 2 (g) were combined, the rationale for combining them and state which two equations were combined. **3**

(i) State the other two equations that were used in conjunction with the equations of Question 2 (g) when deriving the Penman-Monteith equation. **2**

(j) The quasi-resistance r_i, unlike the r_a and r_s resistances, cannot be depicted in the resistance model diagram for a leaf. How can r_i be depicted in a diagram? **2**

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Alpha

(k) Define α in terms of sensible and latent energy flux density. **2**

(l) In lectures, we considered the influence of environmental conditions on evaporation. We considered a number of environmental cases. Define in words the conditions for each of the following cases:

- 1. potential evaporation;
- 2. the Priestley-Taylor evaporation case;
- 3. the desert case;
- 4. the oasis case. **8**

(m) Derive an expression for α for the equilibrium evaporation case. **3**

(n) Explain what is meant by the clothesline effect. What is the effect meant to typify? Give an example. **3.5**

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Section B

Answer any three questions from Questions 3, 4, 5, 6 and 7. Total marks for this section is 60 and the suggested time is 72 minutes. Note that if more than three are attempted, **only the first three will be marked**.

Question 3

Write short notes using diagrams and giving examples if necessary, to illustrate your understanding, of any five of the following topics discussed in lectures. Note that more than just a definition of the topic is required. If more than five are attempted, **only the first five will be marked**:

(a) shrinking of the cryosphere;
(b) global dimming;
(c) arctic amplification;
(d) urban heat island effect;
(e) 4P principle – you must also state what 4P stands for;
(f) UVA, UVB and UVC and their effects on humans;
(g) greenhouse gases and their impacts.

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Question 4

(a) What are the two main categories of frost? **2**

(b) What is the problem with using a standard AWS air temperature measurement for predicting frost? **3**

(c) Show by making one assumption (which you must state) that when water freezes it expands in volume. Hint: Compare the density of ice relative to liquid water. **2**

(d) Show, using a diagram, the inversion of air temperature during a radiative frost. **3**

(e) Discuss the role that atmospheric water vapour pressure plays in determining surface temperature. **2**

(f) Is it possible for the dew point temperature to be negative? Why is this so and what is the consequence of this as far as frost is concerned? **2**

(g) Give three inequations for the possible temperature conditions on a frost morning? **6**

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Question 5

(a) Define remote sensing. **1**

(b) Derive an expression for the surface temperature of a canopy as a function of the infrared thermometer temperature. Use an annotated diagram as an aid to your derivation. **6**

(c) What is ground truth data? **2**

(d) If an infrared thermometer is aimed at a river from above, what would it be sensing? **1**

(e) Canopy surface temperatures, alone, are of little use for the determination of crop water status. What other temperatures are compared with canopy surface temperature for determining crop water status? **3**

(f) What is the disadvantage of using remote sensing for determining soil water status? **1**

(g) Using the reflection measurements for a fertigated maize canopy shown in Table 1 for days 1 and 10, obtain the NDVI values before and after fertigation.

Table 1. **The reflectance values for a fertigated maize canopy for the red and near-infrared regions at midday on two cloudless days**

	Reflection in the red region	**Reflection in the near-infrared region**
Day 1 (before fertigation)	0.37	0.48
Day 10 (after fertigation)	0.10	0.37

6

[20]

Question 6

Below is a list of physical laws/equations:

1. $L_u = \varepsilon \sigma T^4$
2. $L_d = \sigma T^4 [0.44 + 0.08 \cdot \sqrt{e_{air}/100}]$
3. $I = I_o \exp(-kx)$
4. $a_\lambda = \varepsilon_\lambda$
5. $I_{net} = I_s - r I_s + L_d - L_u$

(a) Name each law/equation involved and describe its use in one sentence. **15**

(b) Use diagrams to illustrate any two of the laws/equations. **5**

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Question 7

(a) Using diagrams, write a short paragraph on the Bergeron process. **2**

Coriolis force

(b) In your answer book, complete the sentence:
The earth rotates on its axis from_____. **1**

(c) When viewed from the south pole, the rotation of the earth, a moving object in the southern hemisphere is deflected to the (c 1) _____ of its path of motion. This deflecting force is referred to as (c 2) _____ . **1**

(d) Using a diagram for southern Africa, show the application of this force (from 7c) to ocean currents. Name the important ocean currents in your diagram and indicate whether they are warm or cool currents. **3**

(e) Use two diagrams to illustrate the action of this force (from 7c) on high and low pressure systems in the southern hemisphere. **2**

(f) In lectures we considered the descent of cloud droplets and the growth of clouds. What important aspects about the size of droplets causes clouds to grow? Discuss. **3**

(g) What is an adiabatic process? Discuss giving its significance. **2**

(h) What adiabatic conditions usually occur during the night and early morning hours in Pietermaritzburg winters? Discuss in terms of vertical atmospheric motions. **2**

(i) Using two cross sectional diagrams, show a cold air mass overtaking a warm air mass and a second diagram showing a warm air mass overtaking a cold air mass. Beneath each diagram give reasons for the shape of the front. You must indicate the typical horizontal extent for each frontal system. **4**

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Section C

Answer all questions. Total marks for this section is 30 and the suggested time is 36 minutes.

Questions 8, 9, 10 and 11 are compulsory

Question 8

Suppose that the optimum range for relative humidity (RH) for the preservation of paintings in an art gallery is between 48 and 67 %. Suppose that the dry bulb temperature measured is 25.3 ^{o}C.

(a) For the dry bulb and range in RH given above, what is the acceptable range in wet bulb temperature. (Use the psychrometric chart provided on page 10 of this examination paper). **3**

(b) What is the "safe" range in water vapour pressure? **2**

(c) Calculate the dewpoint temperature corresponding to 48 % RH and that corresponding to 67 % RH. **2**

(d) Suppose that a visitor to the gallery caused the fire sprinklers inside the gallery to go on. As a result dry bulb temperature reduces to 22.4 ^{o}C. Calculate the RH and water vapour pressure as a result of this event. **3**

(e) In your practical, you used a sling psychrometer. Describe the procedures followed for obtaining the wet and dry bulb temperatures. **3**

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Question 9

A radiosonde measures an air temperature of 9.25 ^{o}C at an altitude of 2050 m and 9.02 ^{o}C at 2080 m.

(a) What is the adiabatic state of the atmospheric layer between these two heights with respect to the dry adiabatic lapse rate? **2**

(b) What is the adiabatic state of the atmospheric layer with respect to the saturated adiabatic lapse rate? **2**

(c) What is the likelihood of rain? **1**

[5]

Question 10

A student calibrates a spoongauge used at the Agrometeorology Instrumentation Mast (AIM) system by pouring in at a fixed rate known amounts of water using a syringe and noting the number of tips recorded. The AIM spoongauge receiving area has a length of 100 mm and breadth of 50 mm. Assuming that no water added yields no tips, calculate the depth of water (mm) per tip if adding 75 mL results in 16 tips. **[4]**

Question 11

(a) Suppose that the additional thermal time requirement for maturation of a maize crop, with a base temperature of 10 ^{o}C, is 60 ^{o}C day.

1. In your answer book, complete a table for only the last three columns shown below.
2. On which day will the crop mature? Justify your answer.

Day	Minimum air temperature (^{o}C)	Maximum air temperature (^{o}C)	Day	Thermal time (^{o}C day)	Daily accumulated thermal time (^{o}C day)
1	16.4	34.2	1		
2	14.3	36.5	2		
3	13.8	29.4	3		
4	11.0	24.4	4		

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