The University of British Columbia
Christen / GEOG 300, Section 101 / December 11, 2007
Microscale Weather and Climate

Sessional Examination

Name	Student #	
Signature	*for marking only* Score	Grade

Write answers directly into space provided. Additional pages are not allowed and will not be marked. There are 12 pages. Make sure you have all. Scores are indicated in square brackets. The total score is 100 (Part A: 24, Part B: 16, Part C: 24, Part D: 36). Read all instructions in the beginning of each part carefully. Time allowed: 90 min.

Rules governing formal examinations:

1. Each candidate must be prepared to produce, upon request, a UBCcard for identification;
2. Candidates are not permitted to ask questions of the invigilators, except in cases of supposed errors or ambiguities in examination questions;
3. No candidate shall be permitted to enter the examination room after the expiration of one-half hour from the scheduled starting time, or to leave during the first half hour of the examination;
4. Candidates suspected of any of the following, or similar, dishonest practices shall be immediately dismissed from the examination and shall be liable to disciplinary action;
    - Having at the place of writing any books, papers or memoranda, calculators, computers, sound or image players/recorders/transmitters (including telephones), or other memory aid devices, other than those authorized by the examiners;
    - Speaking or communicating with other candidates;
    - Purposely exposing written papers to the view of other candidates or imaging devices. The plea of accident or forgetfulness shall not be received;
5. Candidates must not destroy or mutilate any examination material; must hand in all examination papers; and must not take any examination material from the examination room without permission of the invigilator; and
6. Candidates must follow any additional examination rules or directions communicated by the instructor or invigilator.

Part A: Multiple choice questions

Solve <u>all</u> multiple choice questions. All questions have one correct answer. Total marks part A: 24.

1. How is albedo α defined? [2]

   ◯ $\alpha = K\downarrow / Q^*$ ◯ $\alpha = K\downarrow / K\uparrow$ ◯ $\alpha = K\uparrow / Q^*$ ◯ $\alpha = K\uparrow / K\downarrow$

2. Which one of the following features is typically observed in the nocturnal boundary layer? [2]

   ◯ thermal plumes ◯ inversion ◯ entrainment ◯ none of those

3. Which of the following equations describes the Reynolds analogy? [2]

   ◯ $u(t) = \overline{u} + u'(t)$ ◯ $\tau = \rho u_*^2$ ◯ $K_H = K_E = K_M$ ◯ $Re = u\,d/\nu$

4. Which of the following expressions describes the sensible heat flux density Q_H? [2]

   ◯ $\rho_a\, c_p\, \overline{w'T'}$ ◯ $\rho_a\, C_a\, \partial T/\partial z$ ◯ $\rho_a\, L_v\, \partial \rho_v/\partial z$ ◯ $L_v\, \overline{w'\rho_v'}$

5. Without further information, how would you estimate the roughness length z_0 for a uniform grass canopy of 0.3 m height? [2]

   ◯ $z_0 = 0.0003\,\mathrm{m}$ ◯ $z_0 = 0.002\,\mathrm{m}$ ◯ $z_0 = 0.03\,\mathrm{m}$ ◯ $z_0 = 0.2\,\mathrm{m}$

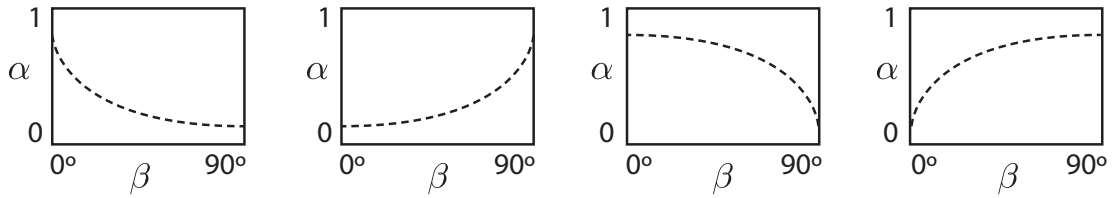
6. When we installed the eddy correlation system at Totem field - what exactly did we measure by calculating the term $\overline{w'\rho_c'}$? (ρ_c = concentration of carbon dioxide) [2]

   ◯ Soil respiration ◯ Net assimilation ◯ Potential photosynthesis ◯ Photosynthesis

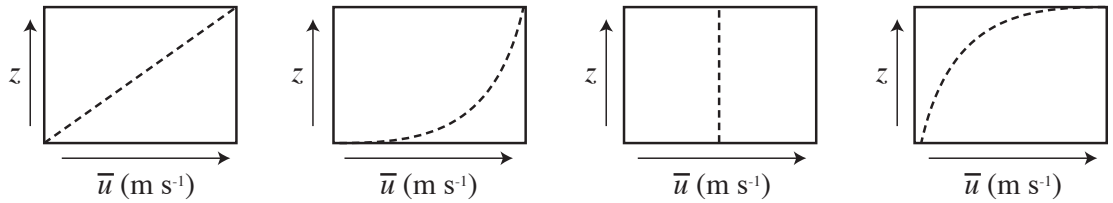
7. What means 'fetch'?
   ◯ Roughness change Δz_0 – difference in the roughness length between two different surfaces.
   ◯ Thickness δ – of an internal boundary layer.
   ◯ Area – field of view of a sensor (e.g. radiometer).
   ◯ Distance x – measured in the upwind direction.

8. Which of the following methods can <u>not</u> be used to determine the complete evapotranspiration of a forest ecosystem? [2]
   ◯ Penman-Monteith (Combination approach)
   ◯ Bowen-ratio Energy Balance approach.
   ◯ Porometry.
   ◯ Aerodynamic method.

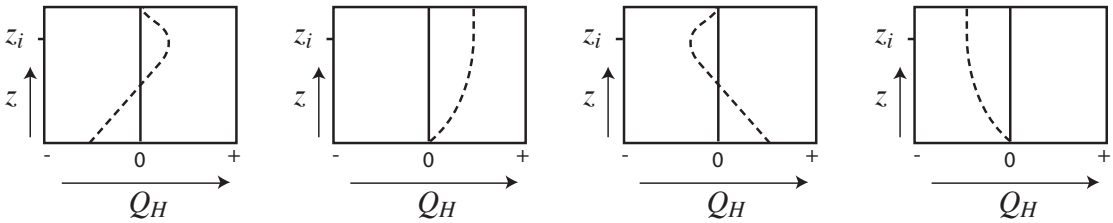
9. How does albedo α of a water surface change with changing solar altitude β under clear sky conditions? [2]



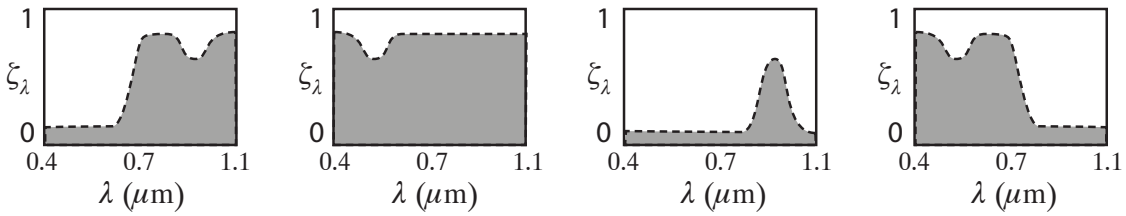
10. How does mean wind speed $\overline{u}$ change with height z over a smooth surface under neutral conditions? [2]



11. How does the sensible heat flux density Q_H change with height z in the daytime convective boundary layer (CBL)? z_i is the height of the CBL. For Q_H assume the micrometeorological sign convention we typically used in the course i.e an upward transport of sensible heat is positive. [2]



12. How does the spectral absorptivity ζ_λ of a green leaf change with wavelength in the short-wave part of the spectrum? [2]



Part B: Short answer questions

Answer all of the following short answer questions in one or a few words, or provide a formula. Total marks part B: 16.

1. How do we call the whole layer of the atmosphere where a diurnal course of meteorological variables (temperature, humidity, pollutants, ...) is measurable? [2]

2. Write down the name of an instrument that measures evapotranspiration from a soil monolith by tracking its weight? [2]

3. List a soil thermal property of your choice and provide its unit. [2]

4. In a turbulent flow, how do we call an event that transports momentum surplus from a high velocity region into a region with a low velocity? [2]

5. What is the 'Bowen ratio' (provide formula or alternatively words). [2]

6. List the name of a radiometer that measures short-wave irradiance in the soild angle 2π? [2]

7. Provide a formula of a flux-gradient approach of your choice using the K-Theory. [2]

8. Name a dimensionless number of your choice that can be used to describe dynamic stability. [2]

Part C: Comparison

Answer only four out of these six short answer questions. Note: the first four questions with any answer written into the space provided will be marked, hence solving more than four questions is not to your advantage. Total marks part C: 24.

1. Briefly explain the difference between *interception* and *transpiration*. [6]

2. Briefly explain the difference between a *stable boundary layer* and a *convective boundary layer*. [6]

3. Briefly explain the difference between *Reynolds stress* and *viscous shear stress*. [6]

4. Briefly explain the difference between the *zero plane displacement* z_d and the *roughness length* z_0.[6]

5. Briefly explain the difference between a *skimming flow* and a *isolated roughness flow* regime. [6]

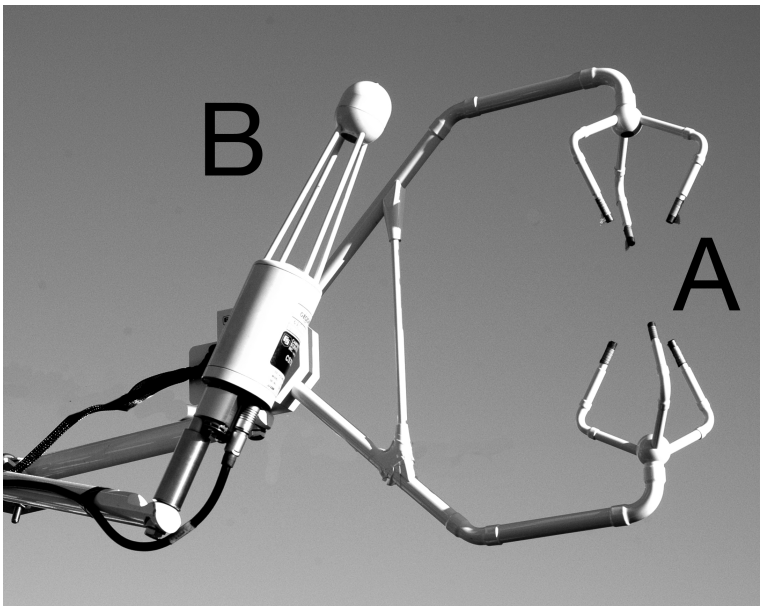
6. Briefly explain the difference in the energy balance between a *'warm' snow pack* ($T > 0°\text{C}$) and a *'cold' snow pack* ($T < 0°\text{C}$). [6]

Part D: Problem questions

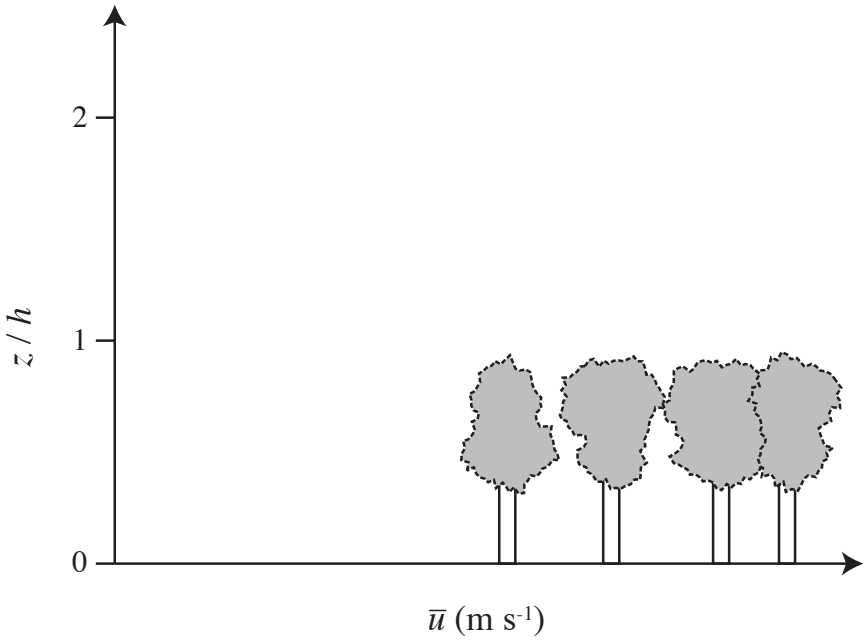
Answer only four out of the following six questions. Again: the first four questions with any answer written into the space provided will be marked, hence solving more than four questions is not to your advantage. Total marks part C: 36

1. Explain the Bowen Ratio energy balance approach to estimate evapotranspiration. List all sensors required for the Bowen Ratio energy balance approach. Discuss why this approach is typically preferred over the K-Theory from a practical point of view. [9]

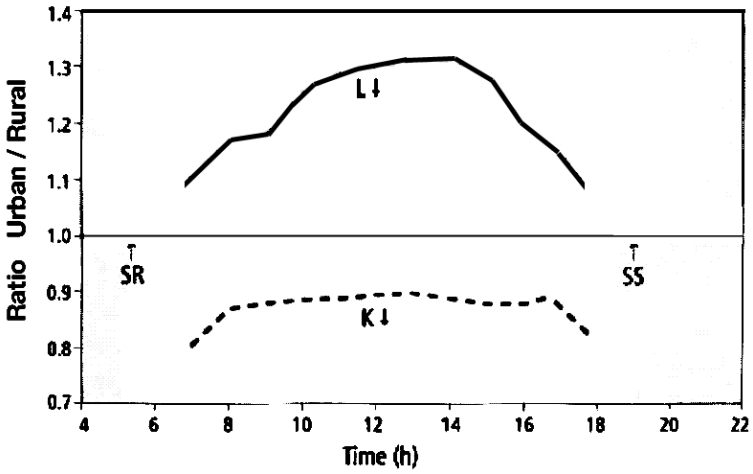
2. Provide the name of the meteorological sensor labelled ‘A’ on the photo below. Explain the principle of operation of ‘A’? Discuss why running ‘A’ side-by-side with instrument B is a very useful set-up. [9]



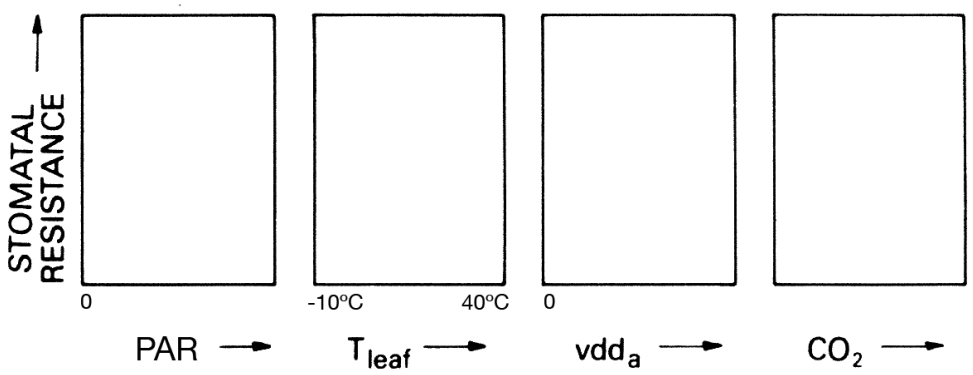
3. Sketch into the figure below how you expect mean horizontal wind $\overline{u}$ to change with height z within and above a forest canopy. Assume a forest with dense tree crowns but an open trunk space. Discuss your curve. Note, h is the height of the trees. [9]



4. The figure below illustrates the urban-rural ratio of incoming flux densities $K\downarrow$ and $L\downarrow$ measured in the industrialized center of Hamilton, ON and at a rural reference not influenced by the city. SR and SS refer to sunrise and sunset respectively. Explain how $K\downarrow$ and $L\downarrow$ are altered by the urban atmosphere and what are the physical processes that drive this urban climate 'modification'. Speculate why the ratio of $K\downarrow$ has its lowest value in the early morning and late evening. [9]



5. Sketch in the four graphs below how stomatal resistance r_{st} changes with increasing PAR, leaf temperature T_{leaf}, water vapour density deficit of the air vdd_a, and CO_2 concentration in the stomatal cavity. Briefly justify each of the four response curves. [9]



6. Explain in your own words what is the meaning of the friction velocity u_*. Why and where is it used in micrometeorology? [9]

[End of Exam - 12 pages]