*The University of British Columbia*
Christen / GEOB 300, Section 101 / December 13, 2013
Microscale Weather and Climate

# Sessional Examination

| Name | Student # | |
|---|---|---|
| Signature | *for marking only*<br>Marks | Grade |

Write answers directly into space provided. Additional pages are not allowed and will not be marked. There are 10 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: 20, Part D: 40). Read all instructions in the beginning of each part carefully. Time allowed: 120 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. Check only one box per question. If you check none or multiple boxes, your answer will be invalid. Total: 24 marks (24% of exam).*

1. Name the ratio $K_{\uparrow}/K_{\downarrow}$? [2]

   ◯ Albedo ◯ Net all-wave radiation ◯ Net short-wave radiation ◯ Reciprocal of albedo

2. Which expression describes the sensible heat flux density $Q_H$? [2]

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

3. Which dimensionless number is used to determine whether a flow is laminar or turbulent? [2]

   ◯ Renynolds number ◯ Knudsen number ◯ Obukhov number ◯ Richardson number

4. What is 'extraterrestrial irradiance'? [2]
   ◯ The total cosmic background radiation reaching Earth in W from outside our solar system.
   ◯ Radiative flux density in $\mathrm{W\,m^{-2}}$ reaching Earth's surface that comes from all non-terrestrial sources.
   ◯ Short-wave radiant flux density in $\mathrm{W\,m^{-2}}$ received at the top of the Earth's atmosphere from the Sun.
   ◯ Total short-wave radiant flux emitted by the sun in W.

5. Which term describes the standard deviation of turbulent temperature variations $T$? [2]

   ◯ $\overline{\left(\sqrt{T'}\right)}$ ◯ $\sqrt{\overline{T'^2}}$ ◯ $\sqrt{\overline{T'}^2}$ ◯ $\sqrt{\overline{T}^2}$

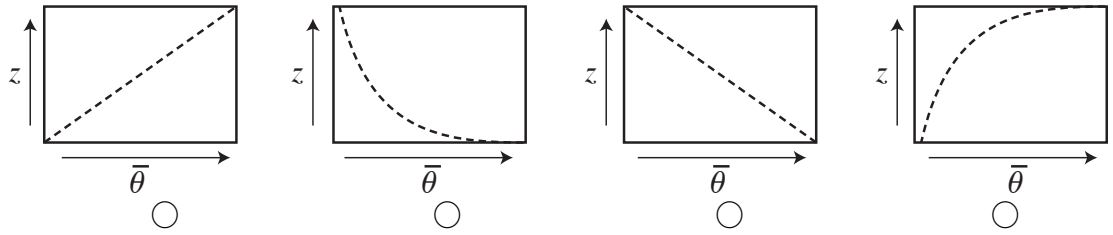
6. UBC researchers have installed the following instrumentation above a forest clear-cut. What is this? [2]

   ◯ Eddy-covariance system ◯ Lysimeter ◯ Interceptor ◯ Penman-Monteith Apparatus

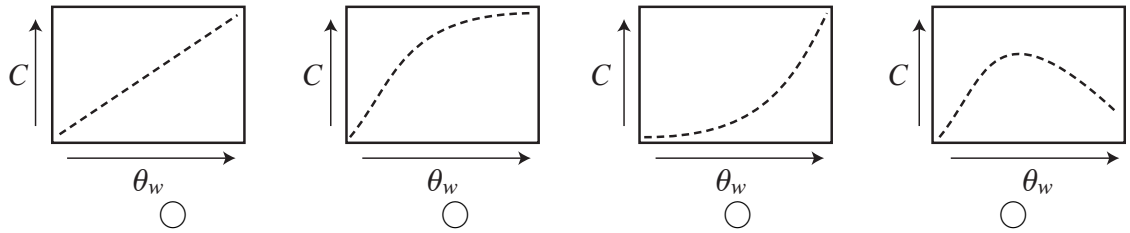
7. Which of the following terms can the instrumentation shown on the photo <u>not</u> measure? [2]

   ◯ $Q^*$ ◯ $Q_E$ ◯ $Q_H$ ◯ $\tau$

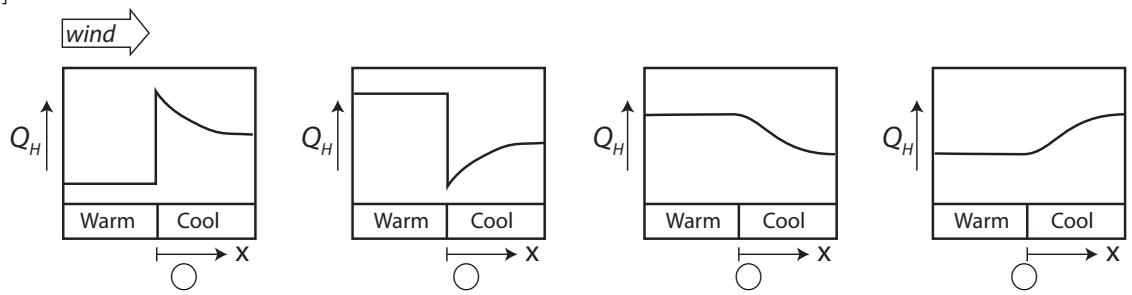
8. How does potential temperature $\theta$ change with height $z$ in the lowest 100 m above ground on a sunny day? [2]



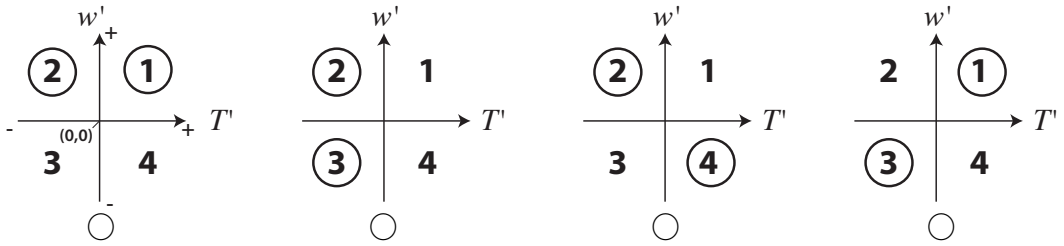

9. How does soil heat capacity $C$ change with increasing soil volumetric water content $\theta_w$. [2]




10. How does $Q_H$ at a height of 1 m above the surface change as an air mass flows first over a warm patch then over a cool patch? Wind is blowing from left to right, and $x$ is the 'fetch'. [2]




11. Above a bare soil, which two quadrants (combinations) of the joint probability distribution between vertical wind $w'$ and air temperature fluctuation $T'$ are the two most likely ones to occur in the late evening (after sunset)? Assume clear-skies. [2]




12. Which statement on turbulent kinetic energy (TKE) is generally true in the surface layer, if everything else is kept constant? [2]
   - ◯ TKE decreases with increasing net all-wave radiation.
   - ◯ TKE decreases with increasing surface roughness.
   - ◯ TKE decreases with increasing wind speed.
   - ◯ TKE decreases with increasing stability.

## Part B: One-word questions

*Answer all of the following short answer questions in one or a few words, or provide a formula. Total: 16 marks (16% of exam).*

1. Name a term of your choice that is part of the water balance equation for a land surface. [2]

2. What does 'PAR' stand for? [2]

3. Write out the name of the variable $u_*$. [2]

4. Name an instrument of your choice that measures shortwave radiation. [2]

5. Name an approach that is used to model directly or indirectly turbulence in the atmosphere. [2]

6. List an atmospheric variable of your choice that controls stomatal aperture. [2]

7. List a method of your choice that can be used to measure evapotranspiration of a crop. [2]

8. Name the amount of precipitation (in mm) in a canopy that does not reach the ground, but remains on the canopy structure (leaves, branches etc.) [2]

## Part C: Short answer questions

*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: 20 marks (20% of exam).*

1. Briefly explain the difference between the *energy balance* and the *energy cascade*. [5]

2. Briefly explain the difference between a *turbulent* and a *laminar* flow. [5]

3. Briefly explain the difference between *photosynthesis* and *transpiration*. [5]

4. Briefly explain the difference between *eddy diffusivity* and *molecular diffusivity* for sensible heat.[5]

5. Briefly explain the difference between *form drag* and *skin drag*. [5]

6. Briefly explain the difference between the *roughness length* and the *Obukhov length*. [5]

## Part D: Problem questions

*Answer only four out of the following six questions and provide explanations of your interpretation steps. 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: 40 marks (40% of exam).*

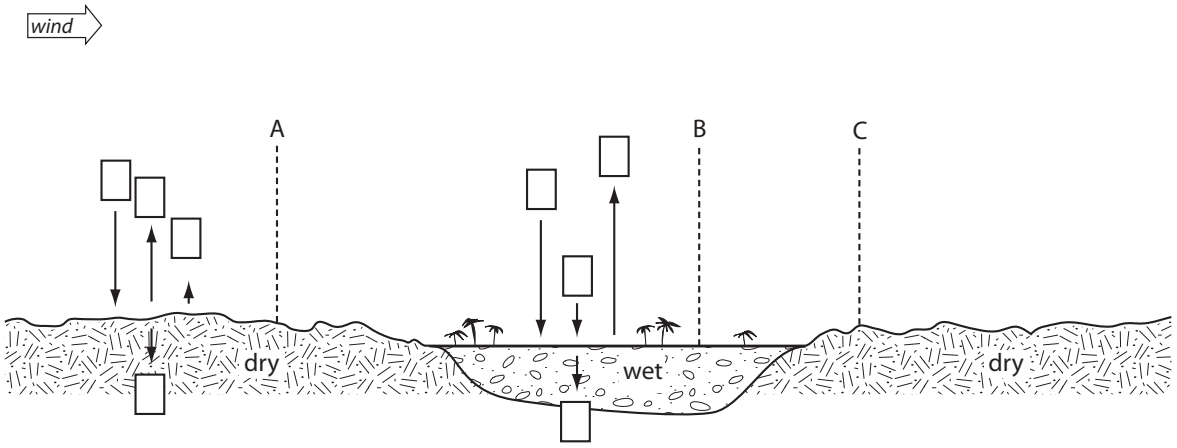
1. Sketch a schematic vertical profile of mean potential temperature $\overline{\theta}$ along with a profile of the sensible heat flux density $Q_H$ through the entire daytime convective boundary layer (CBL). Label all layers of interest and describe two important processes that relocate sensible heat in the CBL. [10]

2. $Rf$ is widely used in micrometeorology. (a) What is the name of $Rf$ and what is it used for? (b) what does the ratio $\frac{g}{\overline{\theta}}\overline{w'T'}$ to $\overline{u'w'}\,\frac{\partial \overline{u}}{\partial z}$ physically describe? (c) What can we say about the atmosphere if $Rf$ is $> 0$? [10]

$$Rf = \frac{\frac{g}{\overline{\theta}}\overline{w'T'}}{\overline{u'w'}\,\frac{\partial \overline{u}}{\partial z}}$$

3. Explain why it might be important to add a zero-plane displacement length $z_d$ into the wind profile equation. In which situations is $z_d$ important? How do you modify the wind profile equation when $z_d$ needs to be included? [10]

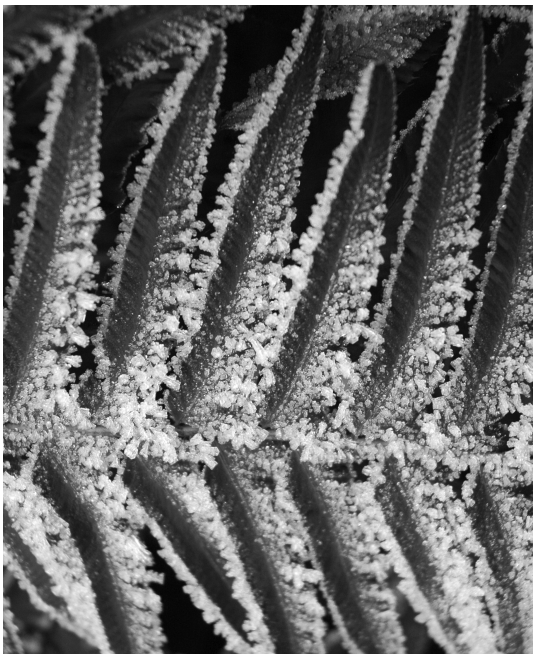
4. The following sketch shows a cross-section through a dry landscape with small wet patch (e.g. oasis). The vertical arrows indicate flux densities of the surface energy balance over a representative part of the dry landscape and the wet patch. The direction of the arrows indicates the direction of energy transfer and the length of the arrows is the relative magnitude of the flux density. (a) name all flux densities (i.e. write symbols in empty boxes). (b) sketch vertical profiles of mean potential temperature $\overline{\theta}$ at locations $A$ and $B$ from ground to about 10 m above ground. (c) Where do you expect highest (most positive) $Q_H$? At $A$, $B$, or $C$? [10]



5. Each year, a substantial fraction of the world's tropical forests are logged and many logged areas are permanently transformed into pasture /rangeland. This will change the regional and global surface energy balance. (a) In the table below, compare selected flux densities and surface properties over a mature tropical forest and a pasture / rangeland and fill-in the boxes below with (=,<, or >). Briefly explain each postulated change (or explain why no change is expected). (b) What is globally the expected net effect of tropical deforestation on the troposphere - warming, cooling or no influence? [10]

| tropical forest | | pasture | brief explanation |
|---|---|---|---|
| $K\uparrow$ | ☐ | $K\uparrow$ | ..... |
| $L\uparrow$ | ☐ | $L\uparrow$ | ..... |
| $Q^*$ | ☐ | $Q^*$ | ..... |
| $Q_H$ | ☐ | $Q_H$ | ..... |
| $Q_E$ | ☐ | $Q_E$ | ..... |
| $\beta$ | ☐ | $\beta$ | ..... |
| $z_0$ | ☐ | $z_0$ | ..... |

6. The following photo shows hoar frost on leaves. Discuss the energy and/or mass transfer mechanisms required in the formation of hoar frost and explain physically why the ice formation occurs preferentially at the edges of the leaves. [10]



[End of Exam - 10 pages]