The University of British Columbia
Christen / GEOB 300, Section 101 / December 17, 2011
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: 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. What is the dominant heat transfer mechanism in the planetary boundary layer? [2]

   ◯ Conduction ◯ Convection ◯ Diffusion ◯ Dissipation

2. Name the layer of the atmosphere from the surface to the level where the frictional influence of the surface is absent. [2]

   ◯ Planetary boundary layer ◯ Residual layer ◯ Troposphere ◯ Laminar boundary layer

3. What is the name of the characteristic vertical mixing distance which occurs in a turbulent flow? [2]

   ◯ Roughness length ◯ Free molecular path length ◯ Obukhov length ◯ Mixing length

4. The pathway of water vapour from the stomatal cavity of a leaf to the surface layer can be described by a series of resistances – the stomatal resistance r_s, the laminar boundary layer resistance r_b, and the aerodynamic resistance r_a. What is the total resistance r_t of the entire system? [2]

   ◯ $r_t = r_s + r_b + r_a$ ◯ $r_t = \dfrac{1}{r_s + r_b + r_a}$ ◯ $r_t = \dfrac{r_s + r_b + r_a}{3}$ ◯ $r_t = r_s \times r_b \times r_a$

5. How is net long-wave radiation L^* defined? [2]

   ◯ $L^* = L\downarrow / L\uparrow$ ◯ $L^* = L\uparrow / L\downarrow$ ◯ $L^* = K\downarrow + L\downarrow$ ◯ $L^* = L\downarrow - L\uparrow$

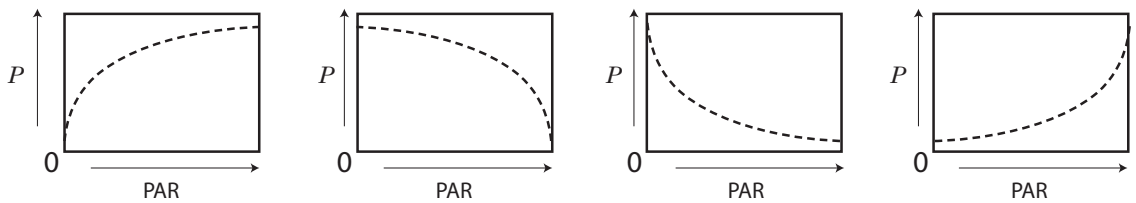
6. Which condition is typical for an oasis effect? [2]

   ◯ $Q^* < Q_H$ ◯ $Q^* > Q_E$ ◯ $\beta < 0$ ◯ $Q^* < 0$

7. What is the unit of the variance of the vertical wind velocity w? [2]

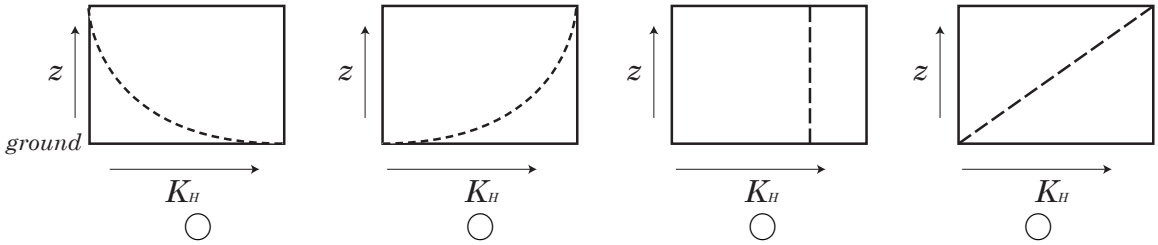
   ◯ $\mathrm{m\,s^{-1}}$ ◯ $\mathrm{m\,s^{-2}}$ ◯ $\mathrm{m^2\,s^{-2}}$ ◯ $\mathrm{m^2\,s^{-1}}$

8. How does the rate of photosynthesis P (in g C $\mathrm{m^{-2}\ s^{-1}}$) respond to incident photosynthetically active radiation PAR? [2]



◯ ◯ ◯ ◯

9. How does the eddy diffusivity for sensible heat K_H change with height above ground z in the surface layer? [2]



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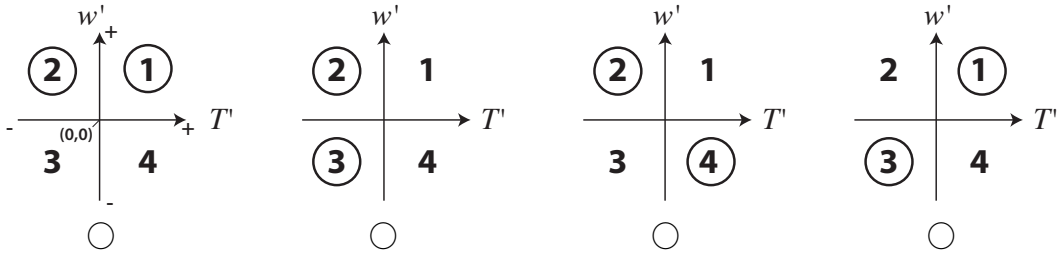
10. In the surface layer, which two quadrants (combinations) of the joint probability distribution between vertical wind w' and air temperature fluctuation T' are the two most likely ones to occur in the late evening (after sunset)? [2]



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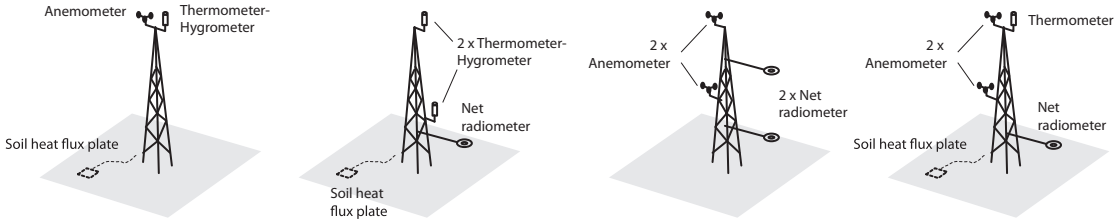
11. Which statement about the laminar boundary layer (LBL) thickness is <u>incorrect</u>? [2]
○ The LBL thickness shrinks with increasing object size.
○ The LBL thickness shrinks with increasing wind speed.
○ The LBL thickness shrinks with increasing buoyancy.
○ The LBL thickness shrinks with increasing roughness of the surface.

12. Which experimental set-up allows a quantitative determination of all terms of the surface energy balance above an extensive, flat land-surface under all atmospheric conditions? [2]



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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 the term Q_E in the surface energy balance. [2]

2. Name the ratio of the amount of the sky actually 'seen' from a given point to that potentially available (i.e. the entire upper hemisphere)? [2]

3. Write down the Reynolds decomposition for any variable of your choice. [2]

4. Write down the name of an instrument that reports wind at high frequency by measuring of the speed of sound. [2]

5. Name a number or parameter that describes the dynamic stability of the atmosphere. [2]

6. List an approach you can use to measure evapotranspiration from an ecosystem. [2]

7. Write down a covariance of your choice. [2]

8. Write down the formula *or* the name of a physical law that relates a temperature gradient in a soil to the soil heat flux density. [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 *Evaporation* and *Transpiration*. [5]

2. Briefly explain the difference between a *cold* and a *wet* snowpack from an energetic point of view. [5]

3. Briefly explain the difference between *Photosynthesis* and *Respiration*. [5]

4. Briefly explain the difference between *anabatic* and *katabatic* winds.[5]

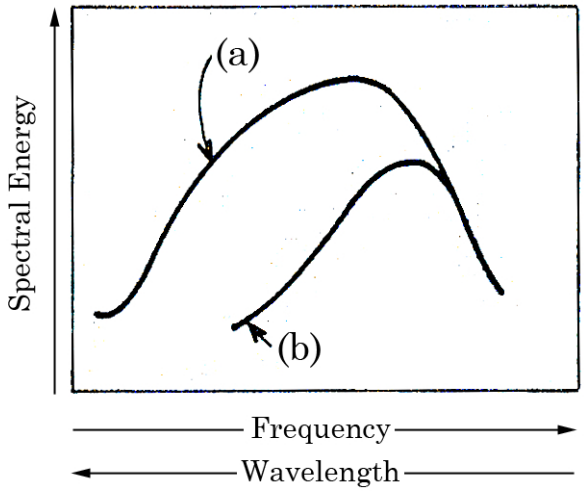
5. Briefly explain the difference between a *Lysimeter* and a *Pyranometer.* [5]

6. Briefly explain the difference between the *Reynolds number* and *Reynolds analogy.* [5]

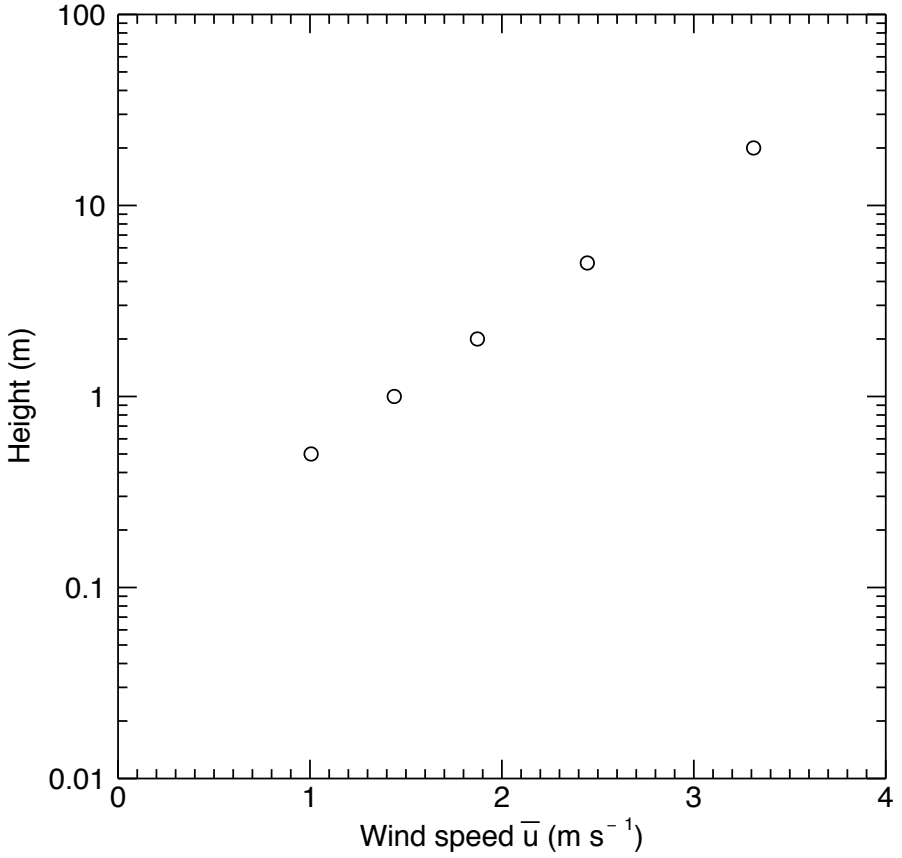
Part D: Problem questions

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).

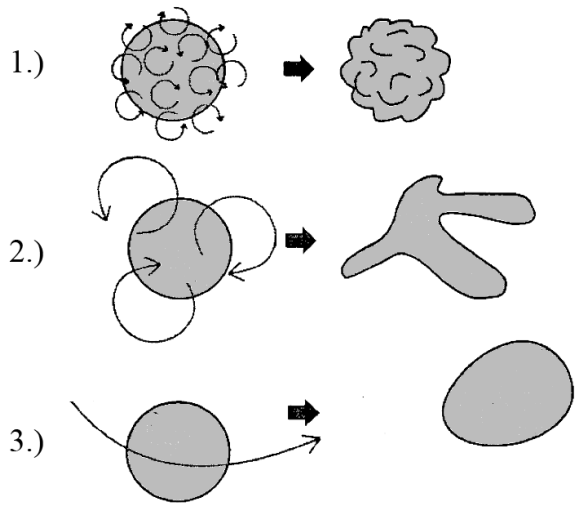
1. The graph below shows two spectra of atmospheric turbulence. They were calculated from data measured at the same location and same height but at different times. One is from a windy, overcast day when differences in surface temperatures in the surrounding of the measurement site are minimal, the other was measured during a clear-sky (summer) day when differences in surface temperatures in the surrounding of the measurement site are large. Attribute the curves to those two cases and explain your choice. [10]



2. The following graphs shows measured wind speed (x-axis) as a function of height above ground (y-axis) in the atmospheric surface layer. Note that the y-axis is logarithmic. (a) What can you say about the dynamic stability of the surface layer at the time the measurements were made [3]? (b) Can you estimate the roughness length z_0 from this graph? If so, what is the approximate value of z_0 [4]? (c) Sketch the profile that you would expect under the same dynamic stability, the same z_0 but with a substantially increased friction velocity u_* [3].

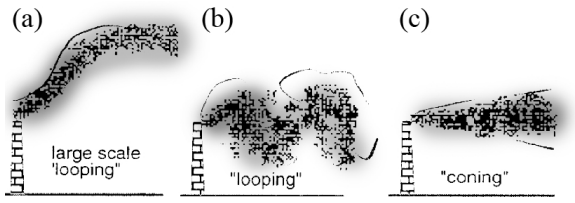


3. The sketch below shows a 'puff' of diameter D that contains air pollutants (grey). The originally spherical 'puff' is deformed by atmospheric turbulence, under different situations - the right hand side shows the consequence of turbulence acting upon the 'puff'.

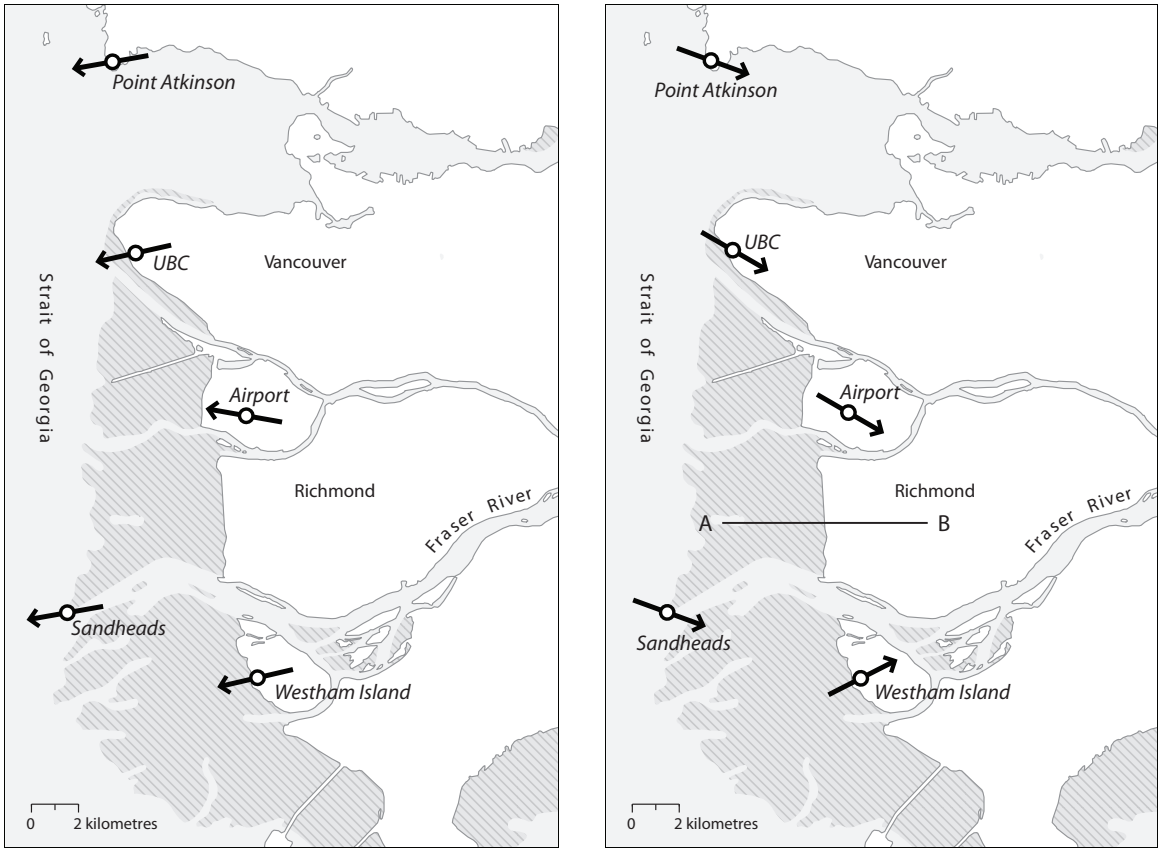


(a) For each case, indicate how the integral length scale ℓ of the turbulence compares to D. Explain under which atmospheric / weather situations you would expect each of the cases 1-3 to occur. [6]

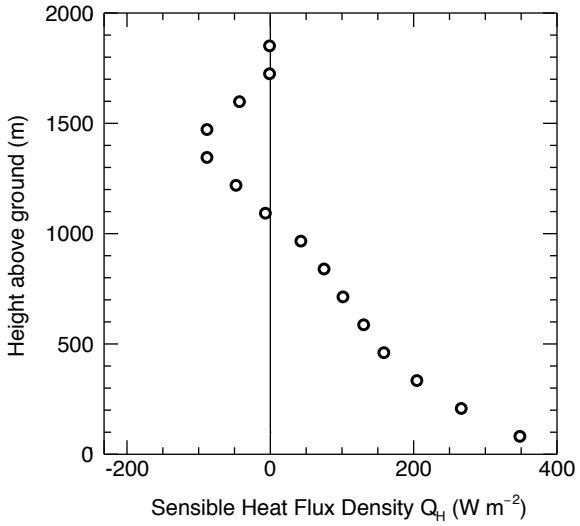
(b) Indicate which of the following three plume shapes you would expect to see during each of the above three conditions, (i.e., match 1-3 to a-c). Wind is from left to right. [4]

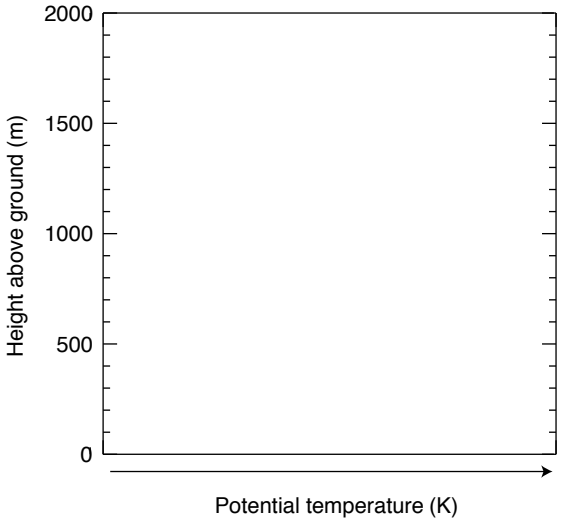


4. The two maps below show measurements of wind direction (indicated by arrows) recorded by climate stations along the coast in the Lower Fraser Valley. Both maps are from August 3, 2008 a day characterized by clear-skies and little synoptic wind. One map is from midnight (00:00 local time) and one from mid-afternoon (16:00 local time). (a) Attribute the correct times to each of the maps [2]. (b) What is the name of the winds recorded [2] (c) In graph on the right there is a profile indicated from the Ocean A (Strait of Georgia) to the land B (City of Richmond). Sketch how would you expect Q_E and Q_H at the surface to change across the profile from A to B in the right case. [6]



5. The graph on the left shows the measured sensible heat flux density Q_H (x-axis) through the daytime convective boundary layer as a function of height above ground (y-axis). In the graph, indicate where you expect the *mixed layer*, the *surface layer*, and the *free atmosphere* [3]. (b) Explain why we observe a negative Q_H in the layer between 1'200 and 1'600 m above ground [4]. (c) Sketch into the empty graph to the right a corresponding profile of potential temperature θ [3].





6. You have used the instrument shown in the photo below during the first field visit. (a) Provide the name of the instrument [3], (b) briefly outline the measurement principle [4], and (c) explain why there is need for buttons labelled ε on the back of the instrument [3].

[End of Exam - 12 pages]