Answer Key - Midterm Examination 2016

Part A: Multiple choice questions

1. *Which of the following atmospheric phenomena is micro-scale? [4]*

   ○ Thunderstorm ⊗ Dust devil ○ Land/sea-breeze circulation ○ Hurricane

   The only phenomena that is small enough to be considered micro-scale is a dust devil, as indicated on the graph in Lecture 1, slide 9. It has a diameter of a few to a few 10s of metres. Thunderstorms and land/sea-breeze circulations are both meso-scale phenomena, spanning >10 km. A hurricane is a macro-scale phenomena with a diameter in the order of 1000 km.

   → Lecture 1, slide 9.

2. *How is net short-wave radiation defined? [4]*

   ⊗ $(1-\alpha)K_\downarrow$ ○ $K_\uparrow/K_\downarrow$ ○ $K_\downarrow - K_\uparrow + L_\downarrow - L_\uparrow$ ○ σT^4

   Net short-wave radiation is $K^* = K_\downarrow - K_\uparrow$. $K_\uparrow$ can be rewritten as $\alpha K_\downarrow$, so $K^* = (1-\alpha K_\downarrow)$. $K_\uparrow/K_\downarrow$ is albedo. $K_\downarrow - K_\uparrow + L_\downarrow - L_\uparrow$ is net all-wave radiation. σT^4 is part of the Stefan-Boltzmann law.

   → Lecture 8, slide 8.

3. *In which of the following times is the Sun always at its highest point at noon (12:00) in Vancouver? [4]*

   ○ PST ⊗ LAT ○ UTC ○ LMST

   The correct answer is LAT = Local apparent time. This non-uniform is varying through the year according to the equation of time. It ensures that highest solar altitude is always observed at noon. PST is the time zone time (Pacific Standard Time), which ensures that on the 120°W meridian the sun is on average at its highest point at noon, but not in Vancouver (123°W). UTC is 'Universal Time Coordinated' and ensures that for the 0°W meridian the sun is on average at its highest point at noon. LMST is local mean solar time which ensures that on average, highest solar altitude is observed at noon (but not at each day throughout the year).

   → Lecture 4, slide 16.

4. *How are specific heat c and heat capacity C linked? [4]*

   ⊗ $C = \rho c$ ○ $C = \frac{1}{c}$ ○ $c = \frac{1}{C}$ ○ $c = \rho C$

   C is in $J\,\mathrm{m}^{-3}\,\mathrm{K}^{-1}$, c is in $J\,\mathrm{kg}^{-1}\,\mathrm{K}^{-1}$. ρ is the density of the material in $\mathrm{kg\,m}^{-3}$. To convert c to C you need to get rid of the kg^{-1} and replace it by m^{-3}. You achieve this by multiplying by ρ.

   → Lecture 10, slide 8.

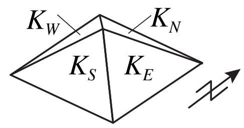
5. *What do we call the radiant flux density in $W\,m^{-2}$ emitted from a surface? [4]*

   ○ Emissivity ⊗ Emittance ○ Emission intensity ○ Emitter

   Emittance is the radiant flux density in $\mathrm{W\,m}^{-2}$ a surface releases by emission as prescribed by the Stefan Boltzmann Law. Emissivity is a property (dimensionless) described as the the ratio of the total emittance at a specified wavelength and temperature to that of a black body (emissivity = 1) under same conditions. 'Emission intensity' does not exist, and an 'Emitter' is a body or object that emits radiation (or pollutants).

   → Lecture 7, slide 6 and glossary.

6. *The following figure shows a pyramid, where K_N, K_E, K_S, and K_W are the slope-normal daily total short-wave irradiances on the North, East, South and West side, respectively. In absence of any atmospheric effects, which of the following equations is always correct for any day of the year and for any location on Earth? [4]*



○ $K_S > K_N$ ○ $K_N = K_S$ ○ $K_E < K_S$ ⊗ $K_W = K_E$

The only criteria that is fulfilled everywhere and on any day is $K_W = K_E$. $K_S > K_N$ is only valid for the northern Hemisphere when the Sun is not in the zenith, nor at the poles. Consequently, $K_N = K_S$ is only fulfilled when the Sun is in the zenith, and at the poles. $K_E < K_S$ is only fulfilled at the poles.

→ Lecture 14 and online applet.

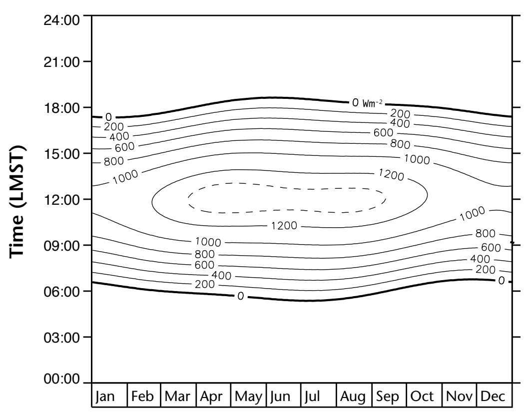
7. *What is a realistic value for the extraterrestrial irradiance K_{Ex} today, October 12, 2014, at noon? [4]*

○ $1366\,\mathrm{W\,m^{-2}}$ ○ $1366\,\mathrm{W\,m^{-2}\,sr^{-1}}$ ⊗ $720\,\mathrm{W\,m^{-2}}$ ○ $720\,\mathrm{W\,m^{-2}\,sr^{-1}}$

It must be $720\,\mathrm{W\,m^{-2}}$ not $1366\,\mathrm{W\,m^{-2}}$ as the latter is the solar constant, which is only equal to K_{Ex} if the Sun is in the zenith. The units are a flux density and not a radiance.

→ Lectures 4 and 5.

8. *The following graph shows the distribution of extraterrestrial irradiance K_{Ex} (in $\mathrm{W\,m^{-2}}$) for a given latitude over the course of the year (x-axis) and the course of a day (y-axis). Determine the latitude this graph is valid for? [4]*



○ Buenos Aires, Argentina (34°S)

⊗ Mumbai, India (19°N)

○ Yellowknife, Canada (62°N)

○ Manaus, Brazil (3°S)

The maximum of K_{Ex} if found between May and August. This tells us that it is a Northern hemisphere location, not Manaus, Brazil, and not Buenos Aires, Argentina.

Yellowknife has a latitude near Arctic circle. This means Yellowknife experiences very short nights in December and long days in June which is not the case.

The only remaining option is Mumbai, India (19°N).

→ Lecture 4, and http://ibis.geog.ubc.ca/courses/geob300/applets/latitude/

Part B: Short answer questions.

1. *Briefly explain the difference between* shortwave *and* longwave *radiation. [7]*

Both refer to electromagnetic radiation – but short-wave radiation is solar radiation. i.e. emitted by the Sun [2] and is in the waveband 0.15 μm [1] to 3 μm [1] (or 150 to 3000 nm)[1]. Long-wave radiation is mainly emitted from objects on Earth [2] (atmosphere, clouds, land, vegetation, ocean, etc.), and is in the waveband 3 μm to 100 μm [1].

→ See Lectures 3 and 6, and prerequisite courses.

2. *Briefly explain the difference between* Fourier's law *and* Beer's law *in a homogeneous medium [7]*

   Fourier's law describes how heat [2] is conducted [2] in a homogeneous medium (by relating a temperature gradient to the heat flux density). Beer's law describes how radiation [2] is transmitted [2] [1] through a homogeneous medium[3] such as snow, water etc.

   → Lecture 13, slide 9 and lecture 10, slide 18

3. *Briefly explain the difference between the* atmospheric boundary layer depth *and the* damping depth *in a soil. [7]*

   The atmospheric boundary layer depth is the height in the atmosphere [1] where there is no more a diurnal course of variables [3] (temperature, humidity, ect.)[4]. The damping depth in a soil is the depth at with the surface temperature [1] wave reaches 37%[5] [2] of the amplitude at the surface.

   → See Lecture 1 and Lecture 12, slides 20.

4. *Briefly explain the difference between* albedo *and* reflectance *of a surface. [7]*

   The albedo is the (relative) ratio [1] of reflected short-wave[6] radiation ($K_{\uparrow}$) [1] to short-wave radiation incident ($K_{\downarrow}$) [2] at a surface [7], while reflectance is just the absolute value of $K_{\uparrow}$ (or part of $L_{\uparrow}$), i.e. the flux density [1][8] of reflected radiation [2] from a surface.

   → See Lecture 6.

5. *A soil heat flux plate (SHFP) is made up of a material similar to soil with a well-known thermal conductivity that is put in-between two metal plates that are spaced 1 cm apart. A SHFP with a* $k = 0.5\,\mathrm{W\,m^{-1}\,K^{-1}}$ *is inserted into a soil. The upper metal plate of the SHFP measures* 20.0°C *while the lower plate measures* 18.0°C. *Determine the ground heat flux* Q_G *conducting heat through the plate. [7]*

   Marking: Provide [3] for choosing the correct equation (i.e. Fourier's law of heat conduction). [9].

   $$Q_G = -k\frac{\Delta T}{\Delta z}$$

   Provide [2] for correct gradient (only [1] if wrong sign).

   $$Q_G = -k\frac{\Delta T}{\Delta z} = -0.5\,\mathrm{W\,m^{-2}\,K^{-1}}\frac{18^\circ\mathrm{C} - 20^\circ\mathrm{C}}{0.01\mathrm{m}}$$

   Provide [1] for correct result and [1] for correct unit ($\mathrm{W\,m^{-2}}$).

   $$Q_G = 0.5\,\mathrm{W\,m^{-2}\,K^{-1}}\frac{-2\mathrm{K}}{0.01\mathrm{m}} = \frac{1}{0.01} = \underline{100\,\mathrm{W\,m^{-2}}}$$

   → See Lectures 10 and 11.

Part C: Problem questions

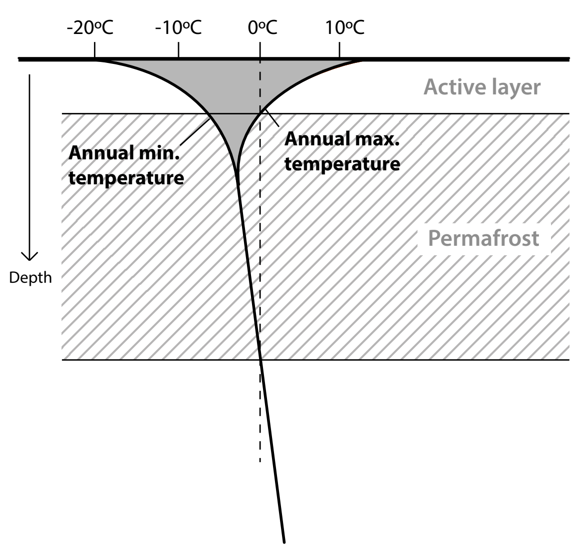
1. *Every year, about 6 million hectares of humid tropical forest are deforested and many logged regions are permanently transformed into rangeland for cattle (e.g. Brazil). This will change the regional climate and the surface radiation processes in addition to causing emissions of greenhouse gases.*

   In the table below, compare all four components and Q^* of the radiative budget over a landscape with humid tropical forest and a landscape of rangeland. Fill-in the boxes below with (=,<, or >). Briefly explain each postulated change (or explain why no change is expected). [10]

tropical forest landscape		rangeland landscape	brief explanation
$K\downarrow$	$\boxed{=}$ or <	$K\downarrow$	Incoming radiation is not affected by suface [1] *or* More incoming shortwave radiation over rangeland, because less clouds are formed [1] (less Q_E)
$K\uparrow$	$\boxed{<}$	$K\uparrow$	Higher albedo of rangeland [1] (low vegetation, more bare soil)
$L\downarrow$	$\boxed{=}$ or >	$L\downarrow$	Incoming radiation is not affected by suface [1] *or* Less incoming longwave over rangeland, because less clouds are formed [1] (less Q_E, clouds increas longwave incoming)
$L\uparrow$	$\boxed{<}$	$L\uparrow$	Higher surface temperature of rangeland [1] (lack of moisture, more bare soil).
Q^*	$\boxed{>}$	Q^*	More longwave and more shortwave loss over rangeland [1]. Note: Changes to incoming terms are minor.

[1 for each symbol]

2. *The curves below show the range of observed subsurface temperatures in the Canadian Arctic from the surface to a depth of approximately 500 m [10]*



(a) Label the depths, where you expect permafrost to occur? Where is the active layer? [4]

See labels on graph. [2] for correct depths of permafrost, [2] for active layer.

(b) If the thermal diffusivity of the subsurface would be significantly higher, how would that impact the occurrence of permafrost? [3]

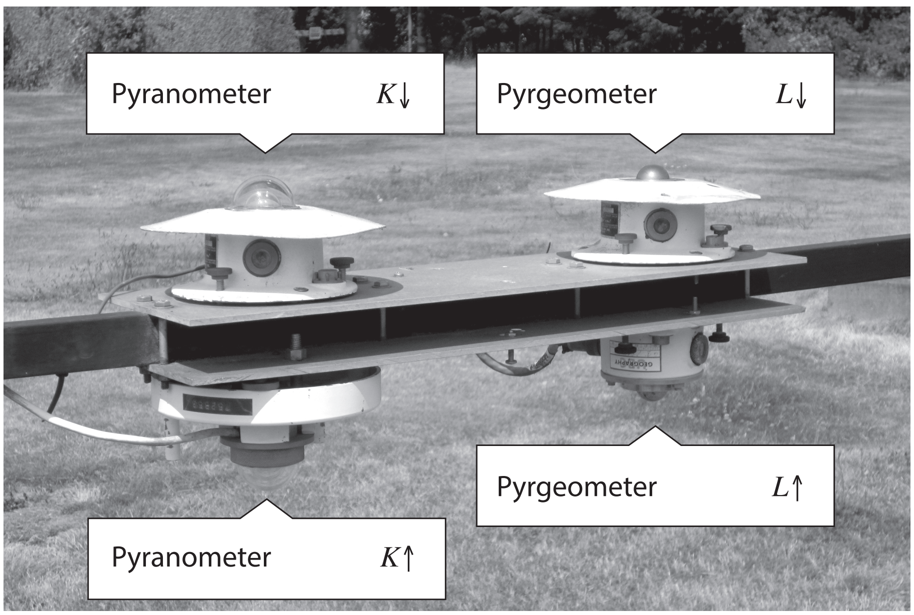
With a higher thermal diffusivity, the temperature wave would more easily penetrate to deeper depths [2]. Consequently it would thicken the active layer, and lower the onset of permafrost in the soil [1].

(c) Why is the temperature not constant as we move to deeper parts of the subsurface. [3]

This is because of the geothermal gradient [2], heat generated in the Earth's mantle is constantly conducted upwards, towards the surface [1].

→ Lecture 12, slide 10.

3. *You saw this instrumentation during your field visit to UBC's Totem Field. In each of the white boxes on the photo place the name of the meteorological instrument [4]. Also state which variable each instrument is recording [4]. Finally, explain which flux density can be measured by the combination of all four instruments? [2]*



You receive [1] for each correctly labelled variable (i.e. $K_\downarrow$[10], $K_\uparrow$[11], $L_\downarrow$[12], $L_\uparrow$[13]).

The flux density that can be measured by the combination of all four instruments is the net allwave radiation (Q^*) [2][14]

→ Lecture 9 (field visit) and corresponding reading package.

4. *In mid-latitude climates, farmers are often keen to retain a deep snow cover over their land during the winter and early spring. List two reasons why this could be an advantage from an agricultural perspective. [10]*

[Any of the statements below result in 5 marks each]

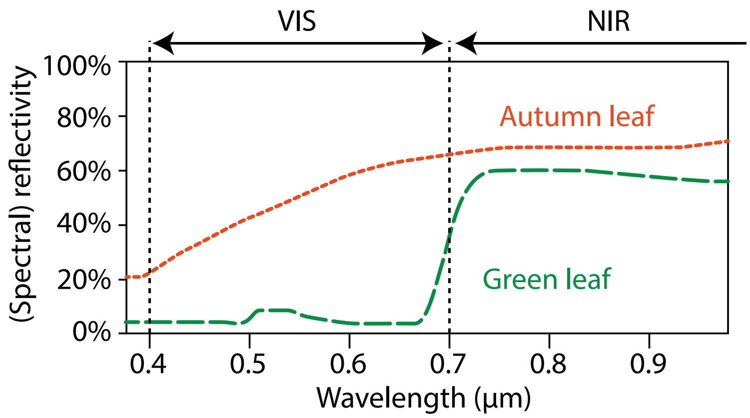
(i) Snow has a low thermal conductivity (k) (and/or low thermal diffusivity κ) which minimizes frost penetration. This in turn thus hastens spring warm-up ready for seed germination as no energy needs to be put into deep-soil warming.

(ii) Snow meltwater may be a significant source of soil moisture / water for the crop in the spring.

(iii) Snow cover may provide thermal protection for early seedlings. Plants within snow are in a conservative if cool environment, but if portions protrude above the surface they are open both to a wider range of temperature fluctuations, and to abrasion by blowing snow and ice pellets.

→ Lecture and reading package Lecture 14.

5. In class, we discussed the spectral reflectivity of leaves and how we can use this information in remote sensing applications. Below are two spectra, one is from a green leaf and one is from an autumn leaf.



(a) Label the y-axis of the graph [2]

Can say ‘Spectral reflectivity’ or just ’reflectivity’ or α_λ to get full marks.[15]

(b) Along the x-axis determine the relevant regions of the electromagnetic spectrum [2]

See graph. Per correctly identified region (VIS [1], NIR[1]).[16][17]

(c) Attribute the green and autumn leaf to the corresponding curves, and briefly justify your choice [4].

Get [2] for correct choice (see graph).

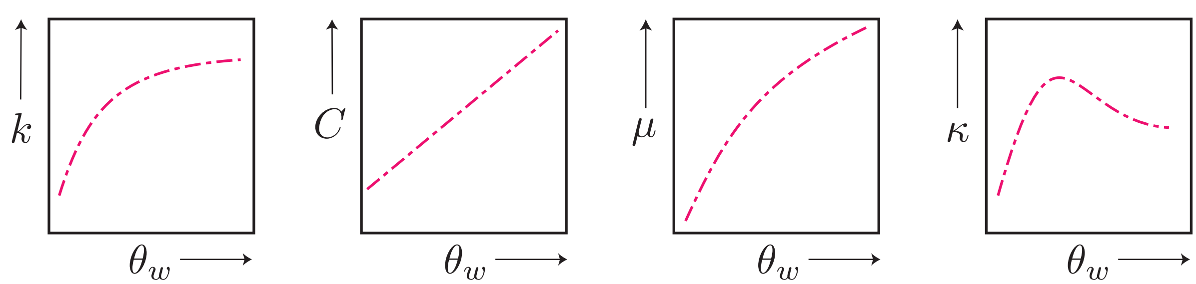
Justification: The green leaf has a slightly increased reflectivity at 0.5 μm (green, due to chloroplasts), and little reflectivity for blue and red (except at the boundary to NIR where we cannot see). The autumn leaf is reflecting much more, and also more in the red than the green and blue part [2].

(d) Briefly say how the difference in the curves may benefit the remote sensing of land surfaces [2].

We can measure reflectivity in the VIS and NIR and based on the difference determine whether vegetation is healthy (e.g. different values of NDVI) [2].

→ Lecture 6.

6. *To each of the blank graphs below, add a sketched line to show roughly the way each thermal property of soils varies with increasing soil water content θ_w (k - thermal conductivity, C - heat capacity, μ - thermal admittance, κ - thermal diffusivity). Briefly discuss the shape of each of the curves. [10]*



[1] if k increases with θ_w irrespective of shape. [1] if C increases with θ_w irrespective of shape. [4] for all curves as shown ([1] per curve). If you have everything correct, you should get [6] for the graphs.

(a) k is non-linear because of non-linear increase of contact area between soil grains as θ_w increases [1] (b) C is linear because of the linear increase of mass of water with increasing θ_w [1] (c) $\mu = \sqrt{kC}$ as the product of the two increases always (both get higher). Not linear, because k levels off. [1] (d) $\kappa = k/C$ increases first, when the increase in k with θ_w is faster than in C. Later, the increase in k with θ_w is slow, and C keeps increasing at the constant rate, so κ can decrease. [1]

→ Lecture 11, slide 26.

Notes

[1]Alternatively, instead of listing the ranges [3], you get just [1] mark if you state that short-wave has a smaller electromagnetic wavelength than long-wave

[2]or absorbed

[3]can also provide equation $I_z = I_0 e^{-k\,z}$ – but need to explain it.

[4]Can also say where frictional influences of the surface vanish.

[5]Can also say to e^{-1} or $1/e$

[6]or 'irradiance' or symbol $K_\downarrow$

[7]Alternatively, can write $\alpha = K_\uparrow / K_\downarrow$

[8]Can say 'absolute value' or 'flux' or 'flux density'

[9]No need to name law, equation is sufficient. Can write it in differential or discrete form.

[10]Instead of $K_\downarrow$ you can also write 'shortwave irradiance' or 'shortwave incoming' to get full marks.

[11]Instead of $K_\uparrow$ you can also write 'shortwave reflectance' or 'shortwave outgoing' to get full marks. But not 'Albedo' and not 'reflectivity'

[12]Instead of $L_\downarrow$ you can also write 'longwave irradiance' or 'longwave incoming' to get full marks.

[13]Instead of $L_\uparrow$ you can also write 'longwave emittance and reflectance' or 'longwave outgoing' to get full marks.

[14]You can either write 'net allwave radiation', 'net radiation' or Q^* to get full marks.

[15]'Albedo', 'Reflectance', and 'reflection coefficient' are incorrect and result in zero marks.

[16]Can also say 'visible' = 'PAR' and 'near infrared' to get full marks.

[17]No need to label 'UV' for wavelengths ¡ 0.4 μm, but UV starts there.