COURSE OUTLINE: GEOG 3311b MICROMETEOROLOGY

Instructor: James Voogt E-mail: javoogt@uwo.ca
Office: SSC 2401 Phone: 661-2111 x 85018

Lecture: Mondays 2:30 - 3:20 SSC-3006; Tuesdays 2:30 - 3:20 MC-6
Lab: Wednesdays: 3:30 – 5:30 SSC-3006 (or other rooms to be announced)
Office hours: Tues and Thurs 2 – 3 pm, or by appointment.
Course Website: There is a course WebCT site that will contain lecture and lab information.

Course Description and Objectives:

This course provides an introduction to the study of micrometeorology and microclimatology. It examines the processes that underly the behaviour of the atmosphere close to the surface; specifically the transfer of heat, mass and momentum and how these modify the microclimate. Presentations include theoretical and analytical examination of the processes that occur (i.e. we use equations and numbers in this course). Micrometeorology and microclimatology are generally restricted to that portion of the atmosphere known as the planetary boundary layer, so this course does not examine weather per se, but does deal with some local to mesoscale atmospheric effects such as seabreezes and atmospheric conditions important to air pollution. Assignments require use of a computer spreadsheet and hand calculation using calculators. An introduction to micrometeorological instrumentation is also provided that includes the use of instruments and construction of thermocouples.

Specific Course Objectives:

At the end of the course you should be able to:
• explain how the surface radiation and energy budget affects the surface climate
• describe important surface characteristics that affect surface energy budget and surface microclimates
• use numerical techniques to estimate surface energy budget terms
• explain how the principles of the surface energy budget have practical application to society

Course Prerequisite:

The official course prerequisite is GEOG 2310a/b. (A 1000-1099 level course in Applied Mathematics, Mathematics, or Physics is also recommended).

Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you will be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

Format:

Instruction is through two one hour lectures and one two-hour laboratory per week. Some lab sessions may be held in the instructor's lab or in a computer-equipped room.

Course Text: (Required):

Oke, T. R., 1987. *Boundary Layer Climates*, 2nd edition., Methuen, London.

See also: Oke, T.R. 1997. "Surface Climate Processes", Chapter 2 of Bailey, W.G., T.R. Oke and W.R. Rouse 1997. The Surface Climates of Canada, McGill-Queen's University Press, Montréal & Kingston 21-43.

Evaluation:

There will be a mid-term exam, final exam, and six marked assignments. In accordance with university policy, missed exams cannot be made up except on written medical grounds and notification prior to the exam date.

Assignments	40%[1]
Mid-term exam	20%
Final exam	40%
Total	100%[2]

Notes

1. Assignments handed in late will have marks deducted at a rate of 10% per day (including Saturdays and Sundays), except for medical or other extraordinary circumstances.
2. Marks as posted by the course instructor are considered provisional until approved by the Department Chair. Final marks are received from the Registrar; errors may be corrected through use of a Marks Revision Form.

Statement on Use of Electronic Devices:

No calculators will be required or permitted in the exams. Students who require electronic assistance with language translation must obtain prior approval from the instructor.

Penalties:

Exams: In accordance with university policy, missed exams cannot be made up except on written medical grounds and notification prior to exam date.
Labs: Late labs have a penalty of 10% per day. Labs submitted more than 1 week late will not be accepted. Exceptions can be made for documented medical and other significant reasons beyond your control (see subsequent sections).

Non-medical Absences:

Non-medical absence from the midterm requires prior approval of the instructor or approval by the Dean's office (appropriate documentation will be required by the Faculty Dean's Office for approval if it is not obtained prior to the midterm).

Medical Absences:

Students are referred to the Policy on Accommodation for Medical Illness https://studentservices.uwo.ca/secure/index.cfm. When medical illness affects work worth less than 10% of the total course grade (i.e. a lab assignment), medical documentation will be required for illnesses that affect completion of more than one laboratory assignment during the term. Appropriate documentation must be submitted by the student directly to the appropriate Faculty Dean's office and not to the instructor. It will be the Dean's office that will determine if accommodation is warranted.

Course Web Site:

Additional course information will be provided on the web. Use http://owl.uwo.ca and then click on WebCT (OWL) to log in using your uwo username and password. Your log in will require that you be officially enrolled in the course. This site will provide lecture and lab materials, and various other documents that may assist with course components.

Academic Honesty / Plagiarism:

"Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site: http://www.uwo.ca/univsec/handbook/appeals/scholastic_discipline_undergrad.pdf."

Support Services:

Registrarial Services: http://www4.registrar.uwo.ca
Student Development Services: http://www.sdc.uwo.ca/
The course website also provides some useful for information: see the "What do I do if?" document.

Fire Drills:

Students are required to evacuate the building when the fire alarm is activated.

Other Important Texts:

Arya, S.P. 2001. *Introduction to Micrometeorology*, 2nd Edition, Academic Press, San Diego.

Campbell, G.S. and J.M. Norman. 1998. *An Introduction to Environmental Biophysics*, Springer-Verlag, New York.

Bailey W.G., T.R. Oke and W.R. Rouse 1997. The Surface Climates of Canada, McGill-Queen's University Press, Montréal & Kingston, 44-67.

Foken, T. 2008 Micrometeorology. Springer-Verlag Berlin Heidelberg. On-line text! (link will require UWO connection or proxy connection)

Monteith, J.L. and M.H. Unsworth. 2008. *Principles of Environmental Physics*, 3rd ed., Elsevier: Amsterdam.

Other Useful Reference Texts:

Fritschen, L.J. and L.W. Gay. 1979. *Environmental Instrumentation*, Springer-Verlag, New York.

Garratt, J.R. 1992. *The Atmospheric Boundary Layer*, Cambridge Univ. Press, Cambridge.

Iqbal, M. 1983. *An Introduction to Solar Radiation*, Academic Press, Toronto.

Lowry, W.P. and P.P.II Lowry. 1989. *Fundamentals of Biometeorology*, Vol. 1, Peavine, Press, McMinnville.

Lyons, T.J. and W.D. Scott. 1990. *Principles of Air Pollution Meteorology*, Belhaven Press, London.

Rosenberg, N.J., B. Blad and S. Verma. 1983. *Microclimate: The Biological Environment*, Wiley-Interscience, New York.

Sellers, W.D. 1965. *Physical Climatology*, Univ. of Chicago Press, Chicago.

Steyn et al. 1997. Spatial Variability in Surface Climates. Chapter 3 of Bailey, W.G., T.R. Oke and W.R. Rouse 1997. The Surface Climates of Canada, McGill-Queen's University Press, Montréal & Kingston, 44-67.

Stull, R.B. 1988. *An Introduction to Boundary Layer Meteorology*, Kluwer Academic, Dordrecht.

Turner D.B. 1994. *Workbook of Atmospheric Dispersion Estimates: An Introduction to Dispersion Modeling* 2nd Edition. Boca Raton: Lewis Publishers.

Wark, K., C.F. Warner, W.T.Davis. 19988. Air Pollution: Its Origin and Control. 3rd Edition. Menlo Park CA: Addison-Wesley.

Williamson S.J. 1973. *Fundamentals of Air Pollution*. Reading, Mass: Addison-Wesley.

TOPICS COVERED

The following topics will be covered in the course, as time permits.

1. Introduction
    - Atmospheric Scales.
    - Atmospheric boundary layer and sublayers.
    - Diurnal evolution of the boundary layer.
    - Radiation, energy and water balance concepts.

2. Radiation
    - Definitions and radiation laws.
    - Short-wave radiation: modelling, measurement, transmission within systems, reflection.
    - Long-wave radiation: sky and surface emissions, emissivity, infrared surface temperature measurement.
    - Radiation budget, net radiation measurement.

3. Conduction (Subsurface climates)
    - Thermal and moisture properties of substrates.
    - Heat flow in soils: measurement and modelling.

4. Turbulence
    - Laminar and turbulent flow. Properties of turbulence.
    - Mean and fluctuating properties of fluids (Reynolds' decomposition).
    - Scales of atmospheric motion. Variances and fluxes.

5. Winds Near the Surface
    - The wind profile in neutral stability.
    - Surface roughness and zero-plane displacement effects.
    - Effects of stability on the wind profile

6. Convective Transfer: Sensible and Latent Heat Fluxes
    - Direct Measurement: Eddy correlation methodology.
    - Flux-profile relations: Aerodynamic and Bowen ratio approaches.
    - Stability Corrections, Richardson Number and Monin-Obukohov similarity theory.
    - Ohm's law (resistance) approach.

7. Air Pollution Meteorology
    - Stability, Diffusion and Transport
    - Gaussian Plume Models

8. Climates of Non-homogeneous Terrain
    - Flux divergence due to spatial variability.
    - Edge effects and oasis effects.

9. Applications of Micrometeorology and Micrometeorological Modelling
    - Road icing
    - Human heat stress
    - Urban climates
    - Numerical modeling of the surface energy budget

Lecture / Laboratory Timetable

The following topics will be covered in the course, as time permits.
Labs are due 1 week from the last lab period in which they are covered.

Week	Dates	Lecture Topic	Laboratory
1	Jan. 4,5	Course Introduction: What is micrometeorology and what are its applications? Defining the surface and near-surface layers. Radiation, energy and water balance concepts	Thermocouples
2	Jan. 11,12	Shortwave Radiation	Radiation Balance
3	Jan. 18,19	Longwave Radiation	Radiation Balance cont.
4	Jan. 25,26	Net Radiation	Infrared Temperature Measurement
5	Feb. 1,2	Conduction and storage of energy in the subsurface	Soil heat flux
6	Feb. 8	Atmospheric Flow and Turbulence	**Midterm (in class, 1 hour)**
7	*Feb. 15-19*	*Reading Week!*	*No labs.*
8	Feb. 22, 23	Momentum Transfer and Winds Near the Surface	
9	Mar. 1,2	Convective Transfer	Wind profile
10	Mar. 8, 9	Convective Transfer	Energy Balance
11	Mar. 15,16	Air Pollution Meteorology	Gaussian Plume Model
12	Mar. 22,23	Climates of Non-homogeneous terrain	
13	Mar. 29,30	Applications of Micrometeorology and Micrometeorological Modelling	
14	Apr. 5,6	Applications, Modelling cont. and Course Review	

Laboratories:

The lab assignments are comprised of practical exercises on the construction and use of microclimate sensors and numerical computations that includes algebraic manipulation of equations, some calculus (simple differentiation and integration - I will help you with this) and extensive use of computer spreadsheets to perform computational and graphical analysis. Labs are due 1 week following their completion in a formal lab period. Labs an supplemental information will be available from the course WebCT site.

Course Readings:

Students are expected to complete readings in the course text (Oke, 1987) and a selection from the other sources listed. (Some additional reading from selected journal articles is recommended; these are outlined in individual laboratories and are available in the Geography Map Library).

Codes: Letter - Author's Last Initial, Number - date of publication.
e.g. O87 - Oke (1987), MU90 - Monteith and Unsworth (1990)
Note: A88 – refers to Arya (1988) – the first edition of *Introduction to Micrometeorology*

1. Introduction **O87: ix-xxiv, 3-8, 20-36, 395-399** A88: 1-7; S88: 9-23 CN98: 1-8 **Planetary Boundary Layer** **O87: 40-42, 61-63, 71-76, 97-98, 310-313** A88: 57-63, 75-83, 214-218 S88: 441-456, 468-469, 473-477, 499-502, 520-522, 526-529, 534-536	**6. Convective Transfer** **O87: 59-71, Appendix A2** MU90: 234-242 A88: 54-57, 74-75, 117-119, 157-167, 169-176, 189-194 G92: 49-58 CN: 77-85, 93-99
2. Shortwave and Longwave Radiation **O87: 8-16, Appdx A1 + radiation aspects of Chps 3, 4** MU90: 28-35, 50-57, 79-97, 82-86, 93-97 A88: 21-33 RBV83: 71-83 CN98: 147-165, 167-183, 224-231	**7. Atmospheric Diffusion and Air Pollution** **O87: 310-318, 322-338** LS90: 83-128
3. Subsurface energy flow and storage **O87: 42-51, 259** A88: 37-46 MU90: 223-230 CN98: 23-26, 113-127	**8. Climate of Non-homogeneous Terrain** **O87: 34-36, Chp 5.** A88: 33-35, 223-235, 252-260 S88: 587-595, 601-609
4. The Neutral Boundary Layer **O87: 4-6, 37-39, 57-60, 375-383** A88: 90-91, 99-121 MU90: 101-106 S88: 2-5 CN: 64-65	9. **Applications of Micrometeorology and Micrometeorological Modelling**: A88: 1-7 Specific paper references to be given in the lecture.
5. Winds Near the Surface **O87: 54-58, 75-76, 83-84, 139-140, 363-365** A88: 75-83, 131-133, 141-151 LL89: 154-157 MU90: 112-117 CN: 63-74	