COURSE OUTLINE: GEOG 3311A MICROMETEOROLOGY

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Days, Location and Hours

Lectures: Mondays 2:30 - 3:20, Tuesdays 3:30 – 4:20 SH 3355

Lab: Wednesdays 9:30-11:20 STVH 1155 (or other rooms as announced)

Office hours: Tuesdays 2:00 – 3:00 or by appointment (best to setup an appointment via email).

Course Website: There is a course OWL 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 sea breezes 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
- understand and use basic instrumentation related to micrometeorology
- explain how the principles of the surface energy budget have practical application to society

Course Prerequisite:

The official course prerequisite is:
One of Geography 2310A/B, 2320A/B or 2330A/B, or at least 3rd year standing in an Environmental Science or Earth Sciences program. (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 may 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", Chap 2 of Bailey, WG, TR Oke and WR 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. With permission of the instructor, students may elect to undertake a project. The project may take several forms: it may involve field work including the setup of meteorological instrumentation, use of dataloggers, collection of data and interpretation of the data, or use of data already collected from a project, or use of numerical models to answer a micrometeorological question, or it may consist of a review paper on some aspect of micrometeorology. The project will be done under the supervision of the course instructor. Work may be done as an individual or small group (2 or 3 students maximum), but an individual project report must be submitted by the end of the examination period. A decision on proceeding with a project may need to be made early due to the expectation that weather conditions will become less suitable as term proceeds. A limited number of projects may be available, depending on resources.

Assignments[1,2]	40%	40%
Mid-term exam	25%	10%
Final exam	35%	15%
Project		35%
Total[3]	100%	100%

In accordance with university policy, missed exams cannot be made up except on written medical grounds and notification prior to the exam date (see relevant sections of this outline).

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. All assignment marks will be totaled to arrive at a final assignment grade (i.e. each individual mark is worth the same on each assignment)
3. 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).

Lab Fee:
A small lab fee may be charged this year to cover the cost of materials and equipment used in the labs. More information will be available through the term. I expect the cost will be between $5 and $20.

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). Non-medical absences from laboratory sessions require approval of the instructor.

Medical Absences:
Students seeking academic accommodation on medical grounds for any missed tests, exams, participation components and/or assignments worth **10% or more** of their final grade must apply to the Academic Counselling office of their home Faculty and provide documentation. Academic accommodation cannot be granted by the instructor or department.

For UWO Policy on Accommodation for Medical Illness and a downloadable SMC see:
http://www.uwo.ca/univsec/handbook/appeals/accommodation_medical.pdf
Downloadable Student Medical Certificate (SMC): https://studentservices.uwo.ca under the Medical Documentation heading
When medical illness affects work worth **less than 10%** of the total course grade (i.e. a lab assignment), please contact the course instructor for academic accommodation (documentation not required).

Course Web Site:
Additional course information will be provided on the web. Use http://owl.uwo.ca and then log in to Sakai 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 Offences:
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/scholoff.pdf.

Western's Commitment to Accessibility:
The University of Western Ontario is committed to achieving barrier free accessibility for persons studying, visiting and working at Western.

Please contact the course instructor if you require material in an alternate format or if you require any other arrangements to make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 x 82147 for any specific question regarding an accommodation.

Support Services:
Registrarial Services: http://www3.registrar.uwo.ca/index.cfm
Student Development Services: http://www.sdc.uwo.ca/
Emotional/Mental Health: Students who are in emotional/mental distress should refer to Mental Health@Western http://www.uwo.ca/uwocom/mentalhealth/ for a complete list of options about how to obtain help.

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.

Shuttleworth, W.J. 2012. *Terrestrial Hydrometeorology*, Wiley-Blackwell, Oxford.

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.

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.

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.

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 and the concept of radiative source areas.

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 and the turbulent source area.
    - Flux-profile relations: Aerodynamic and Bowen ratio approaches.
    - Ohm's law (resistance) approach.
    - Stability Corrections, Richardson Number and Monin-Obukohov similarity theory.

7. Air Pollution Meteorology
    - Dynamic Stability, Plume Shapes, 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
    - Urban climates
    - Intentional modifications: green roofs, white roofs
    - Road icing
    - Human heat stress
    - 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 Assignment
1	Sep. 9,10	Course Introduction: The near-surface atmosphere.	Thermocouples
2	Sep. 16,17	Radiation, energy and water balance concepts Radiation Budget: Shortwave Radiation	Radiation Budget: Part 1
3	Sep. 23,24	Radiation Budget: Shortwave Radiation	Radiation Budget: Part 2
4	Sep. 30, Oct. 1	Radiation Budget: Longwave and Net Radiation Conduction and storage of energy in the subsurface	Infrared Temperature Measurement: Part 1
5	Oct. 7, 8	The Conductive Heat Flux	Infrared Temperature Measurement: Part 2
6 M	*Oct. 14*	*Thanksgiving Monday (no lecture)*	
6	Oct. 15	Heat Storage	Soil heat flux
7	Oct. 21,22	Winds Near the Surface	Midterm
8	Oct. 28,29	Atmospheric Turbulence, Dynamic Stability	*Fall study break Oct 31- Nov 3*
9	Nov. 4,5	Turbulent Source Areas, Surface Atmosphere Exchange Basics	Wind profile
10	Nov. 11,12	Aerodynamic Method	Energy Balance
11	Nov. 18,19	The Atmospheric Boundary Layer, Air Pollution Meteorology and the Gaussian Plume Model	Gaussian Plume Model
12	Nov. 25,26	Climates of Non-homogeneous terrain	
13	Dec. 2,3	Select applications of micrometeorology; 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 and supplemental information will be available from the course OWL 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 will usually be available via OWL)

Codes: Letter - Author's Last Initial, Number - date of publication.
e.g. O87 - Oke (1987), MU90 - Monteith and Unsworth (1990; 2nd edition of text)
Note: A88 – refers to Arya (1988) – the first edition of *Introduction to Micrometeorology*

Week 1. Introduction **O87: ix-xxiv, 3-8, 20-36, 395-399** A88: 1-7; S88: 9-23 CN98: 1-8	**Week 9-10. Convective Transfer** **O87: 59-71, Appendix A2** MU90: 232-252 A88: 54-57, 74-75, 117-119, 157-167, 169-176, 189-194; Chp 11, 12 G92: 49-58 CN: 77-85, 93-99
Weeks 2-4 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	**Week 11** **Atmospheric (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
Weeks 5-6 Subsurface energy flow and storage **O87: 42-51, 259** A88: 37-46 MU90: 223-230 CN98: 23-26, 113-127 F08: 15-18, 212-217.	**Week 11 Air Pollution and Gaussian Plume Model** **O87: 310-318, 322-338**
Week 7 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	**Week 12. Climate of Non-homogeneous Terrain** **O87: 34-36, Chp 5.** A88: 33-35, 223-235, 252-260 S88: 587-595, 601-609
Week 8 Atmospheric Turbulence & Dynamic Stability **A88: Chp 8**	**Week 12 Applications of Micrometeorology and Micrometeorological Modelling**: A88: 1-7 Specific paper references to be given in the lecture.