# G470/G570 Micrometeorology Fall 2005

Class Numbers: 26315/26316

## *Biosphere-Atmosphere Exchange*

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| **Instructor:** | Dr. H.P. Schmid | **Office:** | 102 Student Building |
| **Phone:** | 855-6125 | **Office Hours:** | by appt. |
| **E-mail:** | hschmid | | |

**Lectures:** TR 9:30A-10:45A; Student Building 014

**Prerequisite:** MATH M211-M212, PHYSICS P201 or P221 (P221 recommended), GEOG G350, or G304 or consent of instructor

**Exercises:** Material covered in the lectures will be supplemented with several take-home exercises throughout the semester. For most exercises you will be expected to use Matlab.

**Project** A small research project will be conducted to investigate a micrometeorological process. The study may involve data analysis, a computer model, literature review, or theoretical work.

Each student choses a topic, submits a formal proposal to discussion in class and writes and presents a final report. You need to identify a topic and get it approved by me before October 15.

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| **Grading:** (guideline only) | **Exercises** | | **60%** |
| | **Project** | **(report and presentation)** | **40%** |

**Graduate Students:** Graduate students will work also with research literature and present it to the class.

**Rationale:** The exchange between the atmosphere and terrestrial vegetation is probably the component with the greatest temporal and spatial variability in the biogeochemical cycles of water, heat, carbon and other bio-climatically relevant substances. One consequence of this variability is that we know very little about the dynamics of these exchanges, despite the direct dependence of the atmospheric content of $CO_2$, water vapor, heat, and many trace gases on this exchange.

The objective of micrometeorology is to understand the exchange processes of energy, mass and momentum between Earth's surface and the atmosphere. Its subject is the interaction between the biosphere and the atmosphere. Vegetation is both dependent on the state of the atmosphere and exerts an active control on weather and climate processes, in particular through evapotranspiration and carbon assimilation. Biosphere-atmosphere exchange is heavily dependent on the type of the vegetation (or the lack thereof), its geometry and its extent. These surface conditions can vary at very small scales and thus bring about micro-scale patterns or interrelationships of atmospheric variables and particular surface types. It is these microclimates that determine whether a location is suitable to grow grapes for wine, or to build a bird's nest. Micrometeorology and microclimates are everywhere and together they determine the weather and climates of all scales.

The emphasis of the course is on the theoretical underpinnings of the physics and mathematical description of transport processes of energy and mass in the soil-vegetation-atmosphere aggregate.

**Class web-page:** http://www.indiana.edu/~climate/g470 (this will be updated as we progress in the class)

**Policies:** The standard University rules and policies of conduct in and outside of class apply. Class participation and completion of all parts of the course are required.

**Readings:**

**Main Text:**

- Campbell, G.S., and J.M. Norman: 1998, *An Introduction to Environmental Biophysics*, 2nd Edition, Springer-Verlag, New York, 286 pp, (QH505.C34). (abbreviated **CN**)

  This text (2nd Ed.) is available in the bookstore, and is on hold in the Geography and Map Library, 015 Student Building.

**Supplementary:**

On reserve in the Geography and Map Library, SB015. Other selected material will be deposited at the reserve desk in the Geography and Map Library, 015 Student Building.

- Monteith J.L. and M.H. Unsworth: 1990, *Principles of environmental physics*. 2nd ed. Edward Arnold, London ; New York 1990. 291 pp. (QC911 .M774)
- Brutsaert, W: 1984, *Evaporation into the atmosphere : theory, history, and application,* Kluwer Boston. 299 pp. (QC915.6 .B78)
- Oke, T.R.: 1987, *Boundary Layer Climates*, 2nd Edition, Methuen, New York, 435 pp, (QC981.7.M5034). (abbreviated: **O**)

  Although not required, it is highly recommended to purchase this text.
- Arya, S.P.S: 2001,*Introduction to Micrometeorology*, 2nd Ed., Academic. Press, San Diego, 307 pp, (QC883.8.A79). (abbreviated: **A**)
- Bailey, W.G., T.R. Oke, and W.R. Rouse (Eds): 1997, *The Surface Climates of Canada*, McGill-Queens University Press, Montreal & Kingston, 369 pp, (GB447.S87). (abbreviated: **SCC**)
- Jones, H.G.: 1983, Plants and Microclimate – a quantitative approach to environmental plant physiology, Cambridge U.P., 428 pp., (QK754.J66). (abbreviated: **J**)

## Course Outline:

*The topics listed in this course outline are an intended program. Special needs or interests of the class or any other event may warrant spending more or less time on a particular subject, or the introduction of subjects not listed in this outline.*

*The references to book chapters are not all required reading, but rather are indications where supportive material may be found. Required reading assignments will be announced in class.*

| | **Topic** | **Text References*** |
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| 1 | Introduction to Matlab. Variations of temperature and humidity, using data from MMSF (Indiana) and UMBS (Michigan). Water vapor in the atmosphere. Gas relationships. | CN: 1, 2, 3 |
| 2 | The scope of micrometeorology, emphasis on biosphere-atmosphere exchange, vertical structure of the soil-vegetation-boundary layer system, models, heterogeneity and scale.<br>Review of basic concepts: radiation, energy, and mass balances.<br>Atmospheric motion: wind and turbulence. | CN: 1, 2, 3, 5<br>A: 1, 2-3, 5<br>O: 1.1-1.2, 1.3-1.4, 2.1<br>J: 1, 2 (i-iii)<br>SCC: 2 |
| 3 | Heat, Mass and Momentum Transport:<br>- different approaches to model/measure a flux: diffusion/ gradient equations; bulk transport formulations, Ohm's law analogy (resistances, conductances), exchange coefficients | CN: 6<br>A: 4<br>O: 2.2<br>J: 3 |
| 4 | Heat transport in soils:<br>- thermal response and thermal characteristics of soils<br>- Fourier's I and II laws and applications | CN: 8<br>A: 4<br>O: 2.2 |
| 5 | Turbulence and Turbulent Transport<br>- molecular (laminar) vs. turbulent transport | CN: 7 |
| 6 | - boundary layers and turbulence<br>- movie "Turbulence" by R. Stewart | CN: 5<br>A: 7<br>O: 2.1c<br>J: 3 |
| 7 | - turbulent transport, conservation equations, mixing length hypothesis and the adiabatic flux-profile relations | CN: 5<br>A: 8-10<br>O: 2.3a-b |

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| 8 | - turbulence kinetic energy and dynamic stability<br>- Obukhov length and Monin-Obukhov Similarity Theory | CN: 7<br>A: 11<br>O: 2.3a |
| 9 | - diabatic flux-profile relations, differential and integrated forms | CN: 7<br>A: 11-12<br>O: A2.4b |
| 10 | Energy and mass balance of vegetated surfaces<br>- Light penetration and leaf area index (LAI)<br>- scale interactions from leaf to canopy to boundary layer | CN: 14, 15<br>A: 11-12, 15<br>O: 4<br>SCC: 11 |
| 11 | Evaporation and Transpiration<br>- response of plants to vapor deficit and heat loading<br>- energy and aerodynamic forcing: the Penman-Monteith combination equation | CN: 14<br>A: 12<br>O: 4<br>SCC: 2 |