**Micrometeorology**

Prof. Giacomo Alessandro Gerosa

***COURSE AIMS AND INTENDED LEARNING OUTCOMES***

The aim of the course is the study of turbulence and physical processes involved in the exchange of energy and matter between the atmosphere and the Earth's surface. This knowledge is crucial to understanding the interactions between the atmosphere and biosphere, with particular regard to the fluxes of greenhouse gases, the removal of air pollutants from vegetation and the dynamics of the biogeochemical cycles. The course provides relevant knowledge for various applications of environmental physics, including: the management of air quality, the characterization and management of industrial air emissions, the risk assessment of pollutants for food security and preservation of natural ecosystems, the management of water resources in agriculture, the exploitation of renewable energy, the energetic certification of buildings and air conditioning, the urban and regional planning, the environmental modeling.

At the end of the course, students will know in depth the characteristics of PBL and turbulence, the processes of heat and matter exchange between atmosphere and terrestrial surfaces, the processes of evaporation and transpiration, and the main techniques for measuring the fluxes of matter and energy. Students will be able to set up measurement systems suitable for various applications, choosing the most appropriate measurement techniques and instruments. They will be able to process acquired data and interpret their meaning. They will also be able to mathematically describe the exchange processes and formulate diagnostic and prognostic models for computer simulation.

***COURSE CONTENT***

1. Purpose and scale of investigation. Variables and recalls of thermodynamics applied to the atmosphere.
2. Radiative energy balance at the Earth surface (soil, vegetation, water bodies). Short and long-wave radiation. Net radiation. Radiative divergence. Surface temperature and heat transfer in soils.
3. Thermal characteristics of PBL and ASL. Temperature and humidity profiles: stability, mixing layers, inversions. Wind profiles: effect of the surface friction on the balance of the forces.
4. Viscous flows: laminar and turbulent flows. Boundary layers. Navier-Stokes equation. Heat transfer in laminar layers. Turbulent flows. Turbulence generation and maintenance. Variances and turbulent fluxes. Eddies and scales of motion.
5. The mathematical description of turbulence. Continuity equation and Reynolds’ decomposition. Taylor hypothesis. TKE, Richardson’s number. Gradient-transport theories. Dimensional analysis and similarity theory of Monin-Obukhov.
6. Turbulence in the ASL. Surface roughness and resistances. Stability and similarity functions. Relationships for the momentum and heat transfer.
7. Evaporation from homogeneous surfaces. Wet bulb temperature and derivation of the Peman-Monteith equation. Evaporation from the leaves. Reference evaporation, equilibrium evaporation. Coupling between vegetation and atmosphere.
8. Micrometeorological methods for the determination of momentum, heat and evapotranspiration fluxes. Instruments for the measurement of the turbulent entities: ultrasonic anemometry and fast hygrometers. Eddy Covariance. Aerodynamical gradient. Bowen Ratio. Accumulation methods.

Measurement of fluxes of chemical compounds. EC data processing. Despiking, Mc Millen’s rotations, zero-offset. Spectral analysis and frequency loss corrections. Corrections for density fluctuations.

1. Micrometeorology of terrestrial ecosystems. Resistive analogy. Canopy resistance. Resistance of the sub-laminar layer. Canopy resistance. Evaporation from wet canopies. Evaporation from the understory. Fluxes of CO2: primary production and respiration. Fluxes of pollutants, stomatal and non-stomatal uptake. Intra-canopy transport. Flux footprint.
2. Modeling energy and matter exchanges. Energy balance methods. Big-leaf approach, single layer and multilayer approaches. Stomata and transpiration: Jarvis and Ball-Berry models. Stomatal and non-stomatal fluxes. Light interception by canopies. Examples and applications.

***READING LIST***

* Arya P., *Introduction to micrometeorology*, Academic Press, San Diego, California, 2001
* Foken T. *Micrometeorology*, Springer-Verlag, Berlin, 2008
* Monteith J. L.- Unsworth M. H. *Principle of Environmental Physics*, 3rd edition. Elsevier Science & Technology, 2014.

***Only for consultation***

* R. Stull R., *An introduction to boundary layer meteorology*, Kluwer, 1988.
* Ceccon P.- Borin M., *Elementi di Agrometeorologia* e *Agroclimatologia*, Ed. Imprimitur, 1995.
* Ventura F.- Rossi Pisa P., *Strumenti per l’agrometeorologia*, Aracne Editore

***And***

* Class slides
* Further material provided in class

***TEACHING METHOD***

Lectures, seminars, practical demonstrations, guided tours.

***ASSESSMENT METHOD AND CRITERIA***

The course examination consists in oral exam to ascertain the degree of assimilation of the concepts, results and procedures shown during the lessons, through the exposure and discussion of some points of the program, not excluding recall to the prerequisites or links between parts of the program.

The exam interview consists of two parts.

The first part involves the student's illustration and discussion of a scientific article of a micro-meteorological nature, published in a relevant ISI journal and agreed in advance with the lecturer.

The second part includes three in-depth questions asked by the lecturer on three of the course topics not covered by the article illustrated in the first part.

During the interview, students will be asked to produce or interpret outlines or maps relating to the phenomena illustrated in the course.

Evaluation will take into account accuracy of the explanation of the concepts, logical and methodological rigor, and effectiveness and fairness of the presentation, emphasising the assimilation of the concepts and personal elaboration by students.

There is a single final mark based 50% (15/30) on the article illustrated in the first part, and 50% on the answers to the three questions in the second part (5/30 for each correct answer). A distinction will be awarded according to the effectiveness and confidence of the student's presentation.

***NOTES AND PREREQUISITES***

The course is required for those who wish to carry out an Environmental Physics thesis. The taking of Atmospheric Physics and Ecology courses is a desirable requirement and is highly recommended.

The course provides for the acquisition of GEO ECTS, which are essential for those wishing to teach Mathematics and Sciences in first level secondary schools ("middle schools").

Further information can be found on the lecturer's webpage at http://docenti.unicatt.it/web/searchByName.do?language=ENG, or on the Faculty notice board.