**Atmospheric Physics**

Prof. Giacomo Alessandro Gerosa

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

Understanding structure and composition of Earth's atmosphere and the processes which are occurring in it. Know the main investigation methods and tools used by the meteorological research. Provide relevant atmospheric knowledge for various applications of environmental physics, including: the air quality management, ecological investigations, environmental impact studies of plant and infrastructures, evaluation of renewable energy resources and assistance to the operation of the related production plants, water resources management, planning of tourist activities, civil protection, assessment of the possible effects of local decisions on global climate change.

At the end of the course, students will know the structure and composition of the atmosphere, including from an evolutionary point of view, as well as its dynamics, atmospheric thermodynamics and circulatory phenomena.

Students will be able to explain the main atmospheric and meteorological phenomena. They will be able to read pressure maps, vertical surveys and model outputs and, based on these, make predictions. They will be able to identify the presence of air pollution and give indications for its mitigation. They will also be able to explain the global distribution of climates and their relationship with the presence of certain terrestrial and marine ecosystems.

***COURSE CONTENT***

1. Characteristics of the atmosphere

Introduction. Mass of the atmosphere, density, pressure, temperature. Space-time scales of atmospheric phenomena.

Composition of the Earth's atmosphere. Main components and features. Minor elements and trace gases. Climate-changing gases. Aerosols.

Origin of the Earth's atmosphere. Primary and secondary atmosphere. Transition to an oxidising atmosphere.

Global warming. Climate of the Holocene and future scenarios.

Vertical structure of the earth's atmosphere. Characteristics of troposphere, stratosphere, mesosphere, thermosphere, exosphere with ionosphere and magnetosphere.

2. Thermodynamics of the atmosphere

Equation of state for dry and humid air. Virtual temperature. Hydrostatic equation. Geopotential. Hypsometric equation. First principle of thermodynamics applied to the atmosphere, specific heats, enthalpy. Adiabatic processes in the atmosphere: *dry adiabatic lapse rate*, Poisson's equation and potential temperature. Pseudoadiabatic charts.

Humid air thermodynamics. Measurement of water vapour and hygrometric quantities. Evaporation, condensation and saturated vapour tension. Dew temperature and lifting condensation level (LCL). Latent heat, saturated adiabatic *lapse rate* . Foehn wind.

Stability. Acceleration of *buoyancy* and *gravity waves*. Thermodynamic diagrams, interpretation and applications. Conditional and convective instability. Inversions. Mixing height and PBL. Second law of thermodynamics applied to the atmosphere, entropy. Clausius-Clapeyron equation, phase diagram. Cloud formation and classification, precipitation.

3. Radioactive transfer

Electromagnetic spectrum. Physical laws of radiation: Planck, Stefan-Boltzmann, Wien, Kirchhoff.

Solar constant. Emission temperature of a planet. Global radiative balance. Incident solar radiation and orbital parameters. Solar declination and total radiative flux. Albedo. Terrestrial radiation. Net radiation. Radiative forcing and transport of energy towards the poles.

Radiative transfer into the atmosphere. Diffusion: Rayleigh and Mie *scattering*, non-selective *scattering* . Absorption: rotational, vibrational, electronic transitions and translational energy of molecules.

Radiative transfer equations. Lambert-Beer equation. Absorption rate and radiative heating rate. Schwarzschild equation.

Models of radiative equilibrium and greenhouse effect. Radiative-convective equilibrium and vertical thermal gradient. Role of clouds.

4. Atmospheric dynamics

Definitions and references, Eulerian and Lagrangian approaches. Kinematics of horizontal flow: properties, vorticity and divergence, deformation.

Real forces: pressure gradient force, revised gravity, friction. Non-inertial reference systems and apparent forces: Coriolis force, centrifugal force. Equations of motion and scale analysis.

Dynamics of horizontal flow. Geostrophic balance: geostrophic and ageostrophic winds, effect of friction and cyclonic and anticyclonic circulation. Gradient and cyclostrophic winds. Barotropic and baroclinic atmosphere, thermal wind.

Dynamics of vertical flow. Pressure as a vertical coordinate. Continuity equation as an equation of vertical motion. Vertical ground speed and Margules' equation. Hydrostatic balance.

Conservation equation of thermodynamic energy.

The set of primitive equations. Numerical simulation strategies and deterministic predictivity of atmospheric models.

5. Global circulation

Three-cell circulation model. Baroclinical instability. Trade winds and intertropical convergence zone (ITCZ). Monsoons. Palmen model. Climatic bands.

Extratropical cyclogenesis and frontal systems. Warm fronts and cold fronts. Tropical cyclones. Local circulation. Breezes. Interpretation of meteorological charts.

Deep extratropical convection: single cell, multicell, supercell thunderstorms. Tornado. Deep intertropical convection: hurricanes.

6. Instrumentation for atmospheric investigations

Keynotes on meteorological sensors, rapid sensors, balloons. Instruments for remote sensing of meteorological parameters: *SODAR*, *LIDAR*, *DOASS*, meteorological satellites.

***READING LIST***

* Wallace J.M. & Hobbs P.V., *Atmospheric Science*, Academic Press, New York, 2006
* Holton J.R., *An Introduction to Dynamic Meteorology*, Third Edition, Academic Press, San Diego, 1992.
* Class slides
* Further material provided in class

***TEACHING METHOD***

Lectures, seminars.

***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.

Students will be asked to start with the presentation and discussion of a topic of their choice. Three questions will follow on topics that have not been covered in the chosen presentation.

During the interview, students may be asked to interpret diagrams or maps related to the phenomena discussed in the course. The evaluation of the oral examination will take into account accuracy of the explanation of concepts, logical and methodological rigor, and the effectiveness and fairness of the presentation, emphasising assimilation of the concepts and personal elaboration.

In the formulation of the final mark, 40% will be assigned to the presentation and discussion of the chosen topic (up to 12/30). The subsequent three questions will each be assigned 20% of the mark (up to 6/30 per question). A distinction will be awarded according to the effectiveness and confidence of the student's presentation.

***NOTES AND PREREQUISITES***

There are no prerequisites for attending the course.

The course is preparatory (albeit not in a binding way) to the subsequent courses in the field of environmental physics, in particular the Micrometeorology exam.

*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.*