Graduate academic research program:
MASTER OF PHYSICS – GEOPHYSICS

Plan and program for
2018/2019

Study group A: SEISMOLOGY AND PHYSICS OF SOLID EARTH

I YEAR		WINTER Semester		SUMMER Semester	
Compulsory courses	**ISVU code**	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Seismology III	45507	2+1+0	5		
Climatology I	45508	2+1+0	5		
Dynamic Meteorology 3	144772	2+2+0	6		
Numerical Methods in Physics 1	158571	2+2+0	6		
Seismology IV	45546			2+1+0	5
Engineering Seismology	45547			2+1+0	3
Gravity and Figure of the Earth	144888			2+1+0	4
Computation of Adjustments	53596			1+1+0	2
Numerical Methods in Physics 2	158573			2+2+0	6
Geology	45513			3+1+0	5
Field work 2 (10 hrs/year)	191775				1
TOTAL:		**14#**	**22#**	**19#**	**26#**

L = number of number of lessons per week, **E** = number of of training hours (practicum) per week, **S** = number of seminars per week.

Without timetable and credits of additional courses.

Optional courses TWO in winter semester and ONE in summer semester		WINTER Semester		SUMMER Semester	
Course title	**ISVU code**	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Selected Chapters in Seismology	45515	2+1+0	4		
Planetology	45517	2+1+0	4		
General and Inorganic Chemistry	45516	2+1+0	4		
Fundamentals of Atmospheric Modelling	66352	2+1+0	4		
Fundamentals of Geophysical Exploration I	45518			2+2+0	4
Statistical Physics	53595			2+1+0	4

II YEAR		WINTER Semester		SUMMER Semester	
Compulsory courses	**ISVU code**	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Geomagnetizam	144767	3+1+0	4		
Physics of the Interior of the Earth	45514	2+1+0	6		
Geophysical Practicum	45531	2+2+0	3		

Seminar in Seismology	45532, 45537	0+0+1	2	0+0+1	2
Geophysical Seminar	144886, 45539	0+0+1	1	0+0+1	1
Aeronomy	144777			2+1+0	4
Seismotectonics	45540			2+1+0	3
Field work 3 (10 hrs/year)	191776				1
Diploma Thesis	66715, 66716		10		15
TOTAL:		**13#**	**26#**	**26#**	**26#**

L = number of number of lessons per week, **E** = number of of training hours (practicum) per week, **S** = number of seminars per week.

Without timetable and credits of additional courses

Optional courses ONE in winter semester and ONE in summer semester		**WINTER Semester**		**SUMMER Semester**	
Course title	**ISVU code**	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Fundamentals of Geophysical Exploration II	45541	2+2+0	4		
Optional course from Faculty of Science		2+2+0	4	2+1+0	4

Study group B: METEOROLOGY AND PHYSICAL OCEANOGRAPHY

I YEAR		**WINTER Semester**		**SUMMER Semester**	
Compulsory courses	**ISVU code**	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Seismology III	45507	2+1+0	5		
Climatology I	45508	2+1+0	5		
Dynamic Meteorology 3	144772	2+2+0	6		
Numerical Methods in Physics 1	158571	2+2+0	6		
Climatology II	45521			2+1+0	4
Dynamic Meteorology 4	144773			3+2+0	6
Weather Analysis and Forecasting I	144887			2+1+0	4
Dynamics of Coastal Sea	45523			2+1+0	5
Numerical Methods in Physics 2	158573			2+2+0	6
Field work 2 (10 hrs/year)	191775				1
TOTAL:		**14#**	**22#**	**18#**	**26#**

L = number of number of lessons per week, **E** = number of of training hours (practicum) per week, **S** = number of seminars per week.

Without timetable and credits of additional courses

Optional courses TWO in winter semester and ONE in summer semester		WINTER Semester		SUMMER Semester	
Course title	**ISVU code**	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Selected Chapters in Seismology	45515	2+1+0	4		
Planetology	45517	2+1+0	4		
General and Inorganic Chemistry	45516	2+1+0	4		
Fundamentals of Atmospheric Modelling	66352	2+1+0	4		
Selected Chapters in Meteorology	63391			2+1+0	4
Introduction to limnology	158574			2+1+0	4
Statistical Physics	53595			2+1+0	4

II YEAR		WINTER Semester		SUMMER Semester	
Compulsory courses	**ISVU code**	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Geomagnetism	144767	3+1+0	4		
Weather Analysis and Forecasting I	45545	2+1+0	4		
Climatology III	45543	2+2+0	4		
Geophysical Seminars	144886, 45539	0+0+1	1	0+0+1	1
Aeronomy	144777			2+1+0	4
Meteorological Practicum	159287			1+2+0	3
Field work 3 (10 hrs/year)	191776				1
Diploma Thesis	66715, 66716		10		15
TOTAL:		**12#**	**23#**	**7#**	**24#**

L = number of number of lessons per week, **E** = number of of training hours (practicum) per week, **S** = number of seminars per week.

Without timetable and credits of additional courses

Optional courses ONE in winter semester and ONE in summer semester		WINTER Semester		SUMMER Semester	
Course title	**ISVU code**	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Seminar in Dynamic Meteorology	45562, 45566	0+0+1	3	0+0+1	2
Seminar in Climatology	45536, 45567	0+0+1	3	0+0+1	2
Seminar in Weather Analysis and Forecasting	45564, 45568	0+0+1	3	0+0+1	2
Seminar in Physical Oceanography	45565, 45569	0+0+1	3	0+0+1	2

Optional courses ONE in winter semester and ONE in summer semester		WINTER Semester		SUMMER Semester	
Course title	**ISVU code**	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Hydrology I	45570	2+1+0	4		
Physical Meteorology I	45571	2+1+0	4		
Selected Topics in Climatology	158575	2+1+0	4		
Hydrology II	45572			2+1+0	4
Physical Meteorology II	45573			2+1+0	4
Agrometeorology	158576			2+1+0	4
Micrometeorology	158577			2+1+0	4

Course program

COURSE: **Seismology III**		
YEAR OF STUDY: **I**		
SEMESTER: **1st**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Davorka Herak, PhD** **Asst Prof Iva Dasović, PhD**	**2**
Exercises	**Asst Prof Iva Dasović, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **5**		

COURSE OBJECTIVES:

Define, derive and analyze generation, propagation and basic characteristics of seismic surface waves in multilayered media. Derive and analyze dispersion of surface waves from seismograms and calculate group velocity in 3-layered model using e.g. Matlab. Describe the importance of introduction of lateral inhomogeneities in the theory of propagation of seismic waves.

COURSE CONTENT:

1. Introductory lecture.
2. Seismic surface waves.
3. Rayleigh equation.
4. Propagation and dispersion of seismic surface waves (Rayleigh waves) in vertical heterogeneous (multilayered) medium (the Thomson-Haskell method) – 1st part.
5. Propagation and dispersion of seismic surface waves (Rayleigh waves) in vertical heterogeneous (multilayered) medium (the Thomson-Haskell method) – 2nd part.
6. Propagation and dispersion of seismic surface waves (Rayleigh waves) in vertical heterogeneous (multilayered) medium (the Thomson-Haskell method) – 3rd part.
7. Propagation and dispersion of seismic surface waves (Love waves) in vertical heterogeneous (multilayered) medium (the Thomson-Haskell method).
8. Periodic equation – discussion.
9. Propagation and dispersion of seismic surface waves in vertical heterogeneous (multilayered) medium (the generalized matrix method). Periodic equation.
10. Determination of eigenvalues and eigenfunctions of surface waves in layered media.
11. Propagation of surface waves in laterally heterogeneous medium – 1st part.
12. Propagation of surface waves in laterally heterogeneous medium – 2nd part.
13. Propagation of surface waves in laterally heterogeneous medium – 3rd part.
14. Effect of irregular interfaces on propagation of seismic waves – 1st part.
15. Effect of irregular interfaces on propagation of seismic waves – 2nd part.

LEARNING OUTCOMES:

After completion the course Seismology III the student should be able to:

1. describe the generation and characteristics of seismic surface waves,
2. define the boundary conditions and derive the equation of propagation of seismic waves in vertically heterogeneous layered media (using two methods: the Thomson-Haskell and the matrix method),
3. analyze and compare the dispersion of seismic surface waves for different models,
4. distinguish the propagation of seismic waves in vertically and laterally heterogeneous medium,
5. define equations describing the propagation of seismic waves in laterally heterogeneous medium.

LEARNING MODE:

Lectures and exercises attendance, study of notes and literature. Equation derivation and example analysis.

TEACHING METHODS:

Lectures and discussion, derivation of equations. Independent solving of exercises concerning the surface wave dispersion.

METHODS OF MONITORING AND VERIFICATION:

Homework and oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Solved two homework assignments (students must write reports and present their work in front of their colleagues) and two problems

EXAMINATION METHODS:

Oral exam – the final mark is weighted average of marks from homework (30 %) and oral exam (70 %).

COMPULSORY LITERATURE:

Aki, K., P.G. Richards: Quantitative Seismology, 2nd Ed., University Science Books, Sansalito, California 2002.

Sato, H., M. C. Fehler: Seismic Wave Propagation and Scattering in the Heterogeneous Earth, Springer Verlag, Berlin 1997.

Stein, S. & Wysession: An introduction to Seismology, Earthquakes and Earth Structure, Blackwell Publ. 2003

COURSE: **Climatology I**		
YEAR OF STUDY: **I**		
SEMESTER: **1st**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Antun Marki, PhD**	**2**
Exercises	**Antun Marki, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **5**		

COURSE OBJECTIVES:

The students will be introduced into the basics of climatology and its elements. Physical understanding of long-term atmospheric and oceanic state changes. Introduction to basic climatological methods (statistical, analytical, numerical).

COURSE CONTENT:

Definitions of climate. Historical development of climatology. Climate system. Climate elements and factors. Solar radiation. Long-wave radiation of the Earth and the atmosphere. Radiation budget. Energy budget. Spatial and temporal changes of the air temperature. Measures of maritimity and continentality of climates. General atmospheric circulation. Air flows of synoptic and local scales. Hydrological cycle. Spatial and temporal changes of precipitation. Basics of bioclimatology. Climate classifications. Natural and anthropogenic climate changes. Climate models and parameterizations of physical processes.

LEARNING OUTCOMES:

After completion of the course the students will be able to:

1. explain the terms of climate, climate elements and factors which affect energy and radiation budget of the Earth and the atmosphere;
2. analyze real data to estimate maritimity and continentality;
3. explain spatial distribution of different climate elements;
4. define climate types and attribute climate type based on real data;
5. explain natural and anthropogenic climate changes;
6. explain climate models and used parameterizations.

LEARNING MODE:

1. listening lectures, studying notes and available literature,
2. case study,
3. solving problems through exercises.

TEACHING METHODS: 1. presentation with discussion, 2. independently solving of tasks with real data, 3. directing student on independent study of literature, 4. usage of Internet pages
METHODS OF MONITORING AND VERIFICATION: Homework, colloquiums, written and oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Accurate autonomous drafting of tasks (exercises) on computer.
EXAMINATION METHODS: Written (students which successfully pass the colloquiums are released from written exam) and oral exam.
COMPULSORY LITERATURE: Hartman, D.L.: Global Physical Climatology. Academic Press, N.Y., 1994. Hidore, J.J., J.E. Oliver: Climatology: An Atmospheric Science. Macmillan, 1993. Penzar, B., B. Makjanić: Uvod u opću klimatologiju, Sveučilište u Zagrebu, Zagreb, 1978.

COURSE: **Dynamic Meteorology 3**		
YEAR OF STUDY: **I**		
SEMESTER: **1st**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Branko Grisogono, PhD**	**2**
Exercises	**Asst Prof Željko Večenaj, PhD**	**2**
Seminars		**0**
ECTS CREDITS: **6**		

COURSE OBJECTIVES**:**

The main objective of the course is to familiarize students with the basics of the dynamics of the atmosphere of a large scale motions, the mesoscale and microscale dynamics and turbulence. One of the main goals of dynamic meteorology is to interpret the observed structures of atmospheric motions and the analysis and forecasting according to the basic laws of physics. For this purpose, in the course framework is needed to:

- Describe and analyze the quasi-geostrophic processes, define the basic system of quasi-geostrophic equations,
- Define the deviation from the quasi-geostrophic balance,
- Analyze the hydrodynamic and baroclinic instability of the atmosphere,
- Define the general circulation of the atmosphere and describe the law of conservation of the general circulation of the atmosphere,
- Define and describe the mesoscale processes,
- Analyze and modify the energy and momentum in the stratified fluid,
- Describe and analyze the dynamics of two-dimensional buoyancy mountain waves,
- Define the basic concepts of nonlinear wave dynamics and hydraulic flow,
- Define and describe the concepts related to the atmospheric deep convection,
- Define the atmospheric boundary layer, its structure and describe the microscale processes,
- To analyze the prognostic equation of the variance for the wind.

COURSE CONTENT:

Vertical structure of mid-latitude large-scale perturbations. Quasi-geostrophic theory. Barotropic and baroclinic models of the atmosphere. Hydrodynamic instability of atmospheric large-scale processes. Baroclinic instability. Conservation of general circulation. Energy conservation of mid-latitude atmospheric circulation. Introduction of mesoscale processes. Internal gravity waves. Convection. Atmospheric boundary layer.

Laminar and turbulent motions. Spectral analysis of turbulent motion. Turbulence kinetic energy. Hypotheses of Taylor and Kolmogorov. Turbulent fluxes. Similarity theory. Transport and diffusion in the atmosphere. Coastal and mountain circulations. Three-dimensional modeling of the atmospheric dynamics.
LEARNING OUTCOMES: It is expected that after the completion of this course, the students may: 1. be able to define the basic characteristics of large-scale processes, define the quasi-geostrophic system of equations and interpret individual members in these equations, 2. differ baroclinic from barotropic instability, can compare dispersion relations for the short and long waves in the stratified fluid, 3. define assumptions and derive equations for the simple mountain waves and discuss the differences between non-hydrostatic and hydrostatic flows, 4. apply default assumptions and derive basic system of equations for turbulent flow,-recognize introduced assumptions and be able to interpret the meaning of the individual members in the forecasting equation of the variance for the wind, 5. explain the basic processes at different scales of motion and explain the reasons for the introduction of the assumptions used.
LEARNING MODE: Critical discussions during lecturing, studying notes and references, derivation of equations and analysis of examples and problems, individual solving of problem tasks.
TEACHING METHODS: Lectures, exercises, referring students to independently study the literature, individual solving of problem tasks.
METHODS OF MONITORING AND VERIFICATION: Students are required to regularly attend classes, solve homework. Additionally, it is necessary to monitor and discus the current synoptic and local weather effects. The work of the students on the course is monitored and evaluated during the study (completion of homework assignments and additional assignments) and at the final written exam.
TERMS FOR RECEIVING THE SIGNATURE: The terms of course approval are: • Successfully solved all the homework during the semester, • Written course summary, 2-3 pages (basic questions & assumptions, relations and conclusions).
EXAMINATION METHODS: The written exam consists of questions that require a short answer and problem solving.
COMPULSORY LITERATURE: J. R. Holton: An Introduction to Dynamic Meteorology, Academic Press Inc., San Diego,

1992 (or 2004). R. B. Stull: An Introduction to Boundary Layer Meteorology, Kluwer, Dordrecht, 1988N. Šinik N and B. Grisogono: Dinamička meteorologija, Školska knjiga, Zagreb, 2008.
ADDITIONAL LITERATURE: J. Pedlosky: Geophysical Fluid Dynamics, Springer-Verlag, New York, 1987. F. Mesinger: Dinamička meteorologija, Građevinska knjiga, Beograd, 1976. Numerous web pages and ECMWF courses.

COURSE: **Numerical Methods in Physics 1**

YEAR OF STUDY: **I**

SEMESTER: **1st**

TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Tina Bosner, PhD**	**2**
Exercises	**Asst Prof Tina Bosner, PhD**	**2**
Seminars		**0**

ECTS CREDITS: **6**

COURSE OBJECTIVES**:**

To introduce students to modern methods in numerical analysis, in the area of ordinary differential equations (ODE), with an emphasis on their practical solution on computers.

COURSE CONTENT:

Initial value problem for ODE, existence and uniqueness of the solution. Euler-Cauchy method, single step methods, Taylor method, Runge-Kutta methods with fix and variable step size, variable-order method. Multistep methods, stiff equations. Boundary value problems for ODE, shooting method. Direct and iterative methods for solving linear systems of equations.

LEARNING OUTCOMES:

After the successful completion of the subject Numerical methods in physics, the student will be able to:

1. express the basic definition and theorems associated with the ordinary and partial differential equations, as well as with the approximation methods;
2. differentiate the methods for solving initial and boundary value problems for ordinary and partial differential equations;
3. choose and apply the correct approximation methods for the given problem;
4. derive an analogous approximation method with certain properties;
5. analyze a given approximation method;
6. write a simple computer program for solving a given problem.

LEARNING MODE:

Following lectures, study of notes and literature, analysis of examples and practicing, analysis of methods and practicing, analysis of computer programs and the results obtained by solving problems on the computer and practicing.

TEACHING METHODS:

Lectures; solving examples; analysis of the methods; presentation of the computer programs and their results.

METHODS OF MONITORING AND VERIFICATION:

Written exam through midterm exams; writing and presenting programming assignments; oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Regular attendance to the lectures, and achievement of minimal 17 points out of 56 on mid-term exams

EXAMINATION METHODS:

Grading components:
1. Two mid-term exams, 28 points each (together 56 points)
2. One programming assignment, 24 points
3. Final exam, 20 points

Mid-term exams

1. During the semester, students write two mid-term exams. Mid-term exams include also some theoretical questions.
2. Minimal condition for passing the exam is achievement of 17 points.
3. For students who were not able to achieve the minimal number of points, one makeup mid-term exam will be organized, which includes material of the whole semester. Maximum number of points on the makeup exam is 56. Minimal condition for passing this exam is achievement of 17 points. For students who approach the makeup mid-term exam, the points from the regular mid-term exams are reset.

Programming assignment

1. During the semester, one individual programing assignment is set, which must be solved within the time limit, which will be announced on the web page of the course. Each assignment, in principle, includes a solution implemented in F90/F95, and is explained to the lecturer.
2. Minimal condition for passing is achievement of 10 points.

Final exam

1. Final exam consists of an oral exam in front of the lecturer, which includes the material of the whole course, and may include some tasks and test of the practical knowledge on the computer.
2. The students who have passed the mid-term exams and the programming assignment may approach the final exam.

Final grade

Minimal number of points for passing grade is 45. The final grade is determined by the following table:

Points	Grade
45-59	2
60-74	3
75-89	4
>90	5

COMPULSORY LITERATURE:

Z. Drmač, M. Marušić, M. Rogina, S. Singer, Sanja Singer: Numerička analiza, script on web, 2003, https://web.math.pmf.unizg.hr/~rogina/2001096/num_anal.pdf
Trefethen, L. N.: Finite Difference and Spectral Methods for Ordinary and Partial Differential Equations, Cornell University, 1996.
Isaacson, E., H. B. Keller: Analysis of Numerical Methods, John Wiley and Sons, London 1966.
Buchanan, J. L., P. R. Turner: Numerical Methods and Analysis, McGraw-Hill, Inc., 1992.

COURSE: **Selected Chapters in Seismology** ***(optional)***		
YEAR OF STUDY: **I**		
SEMESTER: **1st**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Marijan Herak, PhD** **Asst Prof Iva Dasović, PhD**	**2**
Exercises	**Asst Prof Iva Dasović, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

Preparing students to extend their knowledge and skills in selected sub-disciplines of seismology. For instance, training students, using theory and practical skills, for determination and interpretation of fault-plane solutions.

COURSE CONTENT:

E.g.: Theoretical fundamentals – displacement caused by the force in infinite medium, dipoles, pairs of forces. Models of the seismic source. Types of faults. Stereographic projections. Practical determination of fault-plane solution.

LEARNING OUTCOMES:

After the course Selected chapters of seismology students are able to, e.g.:

1. Define and differentiate between force models used to describe ground motion in an infinite medium.
2. Defend the choice of the double-couple to describe earthquake faulting.
3. Derive and explain expressions describing radiation of the double-couple source in various coordinate systems.
4. Define and describe fault types.
5. Define and describe Wulff's and Schmidt's stereographic projections.
6. Describe faults as presented by their stereographic projection, as well as the tectonic stress field causing the faulting

LEARNING MODE:

Studying textbook and other literature (including lecture notes), attending lectures.

TEACHING METHODS:

Lectures, discussion.

METHODS OF MONITORING AND VERIFICATION: Regular attendance at lectures, solved problems. Oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Regular attendance to the lectures, successful completion of the exercises.
EXAMINATION METHODS: Oral exam.
COMPULSORY LITERATURE: Kasahara, K: Earthquake mechanics, Cambridge University Press, 1981. Aki, K., P. G. Richards: Quantitative Seismology, 2nd edition, University Science Books, Sausalito, California, 2002. Stein, S. and M. Wysession: An introduction to Seismology, Earthquakes and Earth structure, Blackwell Publ., 2003. Lay, T., T. C. Wallace: Modern Global Seismology, Academic Press, San Diego, 1995. Udias, A.: Principles of Seismology, Cambridge University Press, United Kingdom, 1999.

COURSE: **Planetology *(optional)***		
YEAR OF STUDY: **I**		
SEMESTER: **1st**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Giuliana Verbanac, PhD**	**2**
Exercises	**Asst Prof Giuliana Verbanac, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

Introduce students to the bodies of the Solar system, especially to the planets. To achieve the goals it is necessary to:
-define the body in the Solar system, their mutual positions and distances between them
-describe internal structure of planets, discuss similarities and differences
-describe planetary surfaces and explain relevant physical processes
-describe planetary atmospheres, their interaction with solar radiation
-discuss the evolution of extra-solar planets.

COURSE CONTENT:

Earth in the Universe, astronomical data about planets, satellites and small bodies in the Solar system. Methods for determination of distances. Description of the Earth's interior, mechanical properties of the Earth-Moon system, tides, change of the Earth's axis and length of the day. Milanković's cycles and glaciations. Moon structure and evolution. Internal structure of planets and representative elements. Surface features and geological processes. Termal regime in Solar system and proper source of energy. General features of planetary atmospheres and interaction with solar radiation. Planetary ionosheres and magnetosheres. Cosmology and extrasolar planets.

LEARNING OUTCOMES:

1. After completing the course and passing the exam students are able to:
2. describe basic characteristic of the Solar system-define characteristic of planetary interiors, planetary surfaces and atmospheres,
3. distinguish planets of the Earth's group from those of the Jovian group,
4. recognize the importance of studying the evolution of Solar system planets for detecting extrasolar planets,
5. independently analyze professional literature,

6. prepare and present seminars, discuss the presented topics.
LEARNING MODE: Attending lectures, study literature, preparation and discussion of seminars.
TEACHING METHODS: Lectures, individual and group discussions, consultations.
METHODS OF MONITORING AND VERIFICATION: Mid-term exams, written and oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Attending lectures 70%.
EXAMINATION METHODS: Writing (the students may not have to attend writing part of the exam if they successfully complete all mid-term exams) and oral examinations.
COMPULSORY LITERATURE: de Pater, I., Lissauer, J.J.: Planetary Sciences, Cambridge University Press, Cambridge 2001. Chamberlain, J.W.: Theory of Planetary Atmospheres, Academic Press, London 1978.

<table>
<tr><td colspan="3">COURSE: General and Inorganic Chemistry (optional)</td></tr>
<tr><td colspan="3">YEAR OF STUDY: I</td></tr>
<tr><td colspan="3">SEMESTER: 1st</td></tr>
<tr><td>TEACHING METHODS</td><td>LECTURER</td><td>CONTACT HRS PER WEEK</td></tr>
<tr><td>Lectures</td><td>Professor Mirta Rubčić, PhD</td><td>2</td></tr>
<tr><td>Exercises</td><td>Professor Mirta Rubčić, PhD
Asst Prof Jana Pisk, PhD</td><td>1</td></tr>
<tr><td>Seminars</td><td></td><td>0</td></tr>
<tr><td colspan="3">ECTS CREDITS: 4</td></tr>
<tr><td colspan="3">COURSE OBJECTIVES:
The main objective of the course is to familiarize students with the basic chemical principles. For this purpose, within the required courses:
-Define pure substances and mixtures and to compare their properties;
-Define and compare the physical and chemical changes;
-Describe the structure of atoms;
-Compare and analyze the reactivity of different elements;
-Describe and analyze the nature of chemical bonding and molecular structure of the substance;
-Describe the characteristics of a particular aggregation states and to describe and analyze the changes that occur in phase transitions;
-Describe the types of crystalline solids and compare their properties;
-Define and compare the types of intermolecular interactions;
-Define the composition of pure substances and mixtures;
-Classify chemical reactions and analyze the changes that occur during them.</td></tr>
<tr><td colspan="3">COURSE CONTENT:
Substances -mixtures (homogeneous mixtures, heterogeneous mixtures), pure substances (natural substances, compounds). Physical changes, separation of a mixture of ingredients. Chemical changes. The knowledge of the atomic structure of matter (Law of conservation of mass, law of constant weight ratio, Law multiple weight ratio, Dalton's atomistic theory). The discovery of the electron, the discovery of the atomic nucleus. The atomic theory today -an introduction to the structure of the atom. Symbols atoms, atomic number, mass number (nuclides, a chemical element, isotopes, isobars). Expression of the mass of atoms (relative atomic mass, relative atomic mass of the element). Plural, abundance. Periodic Table of Elements -historical overview. Build the periodic table -periods, groups (metals, semimetals, nonmetals).Electronic configuration -Bohr model of the atom, quantum mechanical model of the atom. Energy states of atoms</td></tr>
</table>

and atomic orbitals (quantum numbers and their relationship with the periodic table). The principle of construction of electron cloud.

Atom radius, ionization energy, electron affinity.

Chemical bond -ionic bond (Hess's law, the enthalpy of the crystal lattice), covalent bond (the term electronegativity), the properties of ionic and covalent compounds. Lewis structural formula (oxidation number, formal charge), molecular shape (VSEPR theory).

Metallic bond.

Formulas and nomenclature of covalent and ionic compounds, polyatomic ions. Molar quantities (molar mass, relative molecular mass, molar volume). The composition of the substance (ratios, shares). Determining the formula of unknown compound. Aggregation state (solid, liquid, gas) and phase changes. Changes at phase transitions (enthalpy of phase transitions), the balance at the phase transition. The phase diagram (pressure and temperature influence on the aggregation state).

Intermolecular interactions (ion-dipole, dipole-dipole, hydrogen bonding, and polarizability term induced dipole, dispersion forces). The properties of the liquid phase (surface tension, viscosity, capillarity).

Solid - amorphous and crystalline solid. Types and properties of crystalline solids (atomic, molecular, ionic, metallic, covalent solids). Crystal Systems. Cubic structures, hexagonal structure, the structure of the diamond. The structure of selected ionic solid (NaCl, CsCl).

Solutions - kind of solution. Liquid solutions -processes which take place in the melting solid into the liquid (dissolution enthalpy, melting as equilibrium process), the effect of temperature on the solubility of a solid in water. Dissolution of gases in water (influence of temperature and pressure). The composition of solutions (concentration molality).

Colligative properties of solutions (solvent vapor pressure, boiling point, melting point and osmotic pressure of the solution).

Types of chemical reactions. Reversible reactions. The stoichiometry of chemical reactions, the notion of excess and limiting reagenses.

Acids and bases. Neutralization reaction.

Oxidation and reduction reactions. Equating the redox reaction (ion-electron method, oxidation number). Electrochemical reactions (standard electrode potential). Galvanic cell, electrolytic cell (Faraday's laws of electrolysis).

LEARNING OUTCOMES:

After this course the student is expected to be able to:

1. Distinguish pure substances or mixtures of substances and their properties;
2. Distinguish the physical change of the chemical changes;
3. Compare the properties and reactivity of individual elements and connect them to their position in the periodic table;
4. Clarify the concept of ionic, covalent and metallic bonds;
5. Compare the properties of gaseous, liquid and solid phase and qualitatively and quantitatively analyze the changes that are happening at the phase transition;
6. Distinguish between types of intermolecular interactions and connect their influence with the aggregation state in which a substance exists (at given conditions) and the solubility of certain substances in a given solvent;
7. Distinguish between types of crystalline solids and connect the inner structure of

matter with its properties;
8. Calculate the composition of pure substances and mixtures of substances;
9. Distinguish between types of chemical reactions and qualitatively and quantitatively analyze the processes that occur during them.

LEARNING MODE:

Attending lectures, study literature, preparation and discussion of seminars.

TEACHING METHODS:

Lectures, seminars, independent assignments.

METHODS OF MONITORING AND VERIFICATION:

Attending of lectures, colloquiums and homework.

TERMS FOR RECEIVING THE SIGNATURE:

Homework, colloquiums, seminars.

EXAMINATION METHODS:

Two colloquiums -at each colloquium student must achieve a threshold of at least 50% in order to be released from written exam.
Seminar that student must submit before the oral exam. The success of the written and oral examination.

COMPULSORY LITERATURE:

S. Silberberg, Chemistry, 2. ed., McGraw-Hill, NewYork, 2000.
M. Sikirica, Stehiometrija, Školska knjiga, Zagreb, 1987.
P. W. Atkins and M. J. Clugston, Načela fizikalne kemije, Školska knjiga, Zagreb, 1989.
T. Cvitaš, I. Planinić and N. Kallay, Rješavanje računskih zadataka u kemiji, I.dio, HKD, Zagreb, 2008.
T. Cvitaš, I. Planinić and N. Kallay, Rješavanje računskih zadataka u kemiji, II.dio, HKD, Zagreb, 2008.

COURSE: **Fundamentals of Atmospheric Modelling *(optional)***		
YEAR OF STUDY: **I**		
SEMESTER: **1st**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Assoc Prof Maja Telišman Prtenjak, PhD**	**2**
Exercises	**Assoc Prof Maja Telišman Prtenjak, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

The course prepares students for (i) work with selected models, and (ii) for the development and understanding of the analysis and forecasts of atmospheric processes from the model output at different scales of varying complexity.

COURSE CONTENT:

Classification of atmospheric models. Types of atmospheric numerical models: global and climate models, meso-scale models, micro-scale models. Numerical schemes, initial and boundary conditions. Model initialization. Nesting. Parameterisations in atmospheric models: turbulence, surface layer, microphysics, convection, radiation, etc. Shallow-water model. Mesoscale model of high complexity. Air quality models: Gaussian, Euler, Lagrange. Coupling of atmospheric and oceanographic models.

LEARNING OUTCOMES:

Students will be able to:

1. explain the basic concepts about used numerical methods in the model;
2. set hypothesis about the origin and/or interaction of meteorological phenomena that is going to be modeled;
3. properly apply the model to the selected problem with the correct choice of model parameterization and othersimplifications/options during numerical computation;
4. identify and discuss the limitations on the use of numerical models in meteorology due to various types of numericalinstabilities during calculation;
5. formulate and generalize observed physical relationships among meteorological phenomena provided by the model results.

LEARNING MODE:

Listening to the lectures, making the homework, run the models, analysis of model results and writing reports.

TEACHING METHODS: Presentations, discussions, resolving equations and practical work with models.
METHODS OF MONITORING AND VERIFICATION: Written reports and theirs oral discussions. The final grade also includes the credits earned during the course.
TERMS FOR RECEIVING THE SIGNATURE: Attending lectures and exercises, homework, working on simulation models and writing reports.
EXAMINATION METHODS: A written report and its oral discussion linking with the acquired knowledge. The final score includes points acquired during class.
COMPULSORY LITERATURE: Beniston, M. (1998): From Turbulence to Climate. Springer, Berlin. Pielke, R. A. (2002): Mesoscale Meteorological Modeling. Academic Press, San Diego. Mesinger, F. (1976): Dinamička meteorologija. Građevinska knjiga, Beograd. Šinik, N. and B. Grisogono (2008): Dinamička meteorologija –uvod u opću cirkulaciju atmosfere. Školska knjiga, Zagreb.
ADDITIONAL LITERATURE: Durran, D. R. (1999): Numerical Methods for Wave Equations in Geophysical Fluid Dynamics. Springer, New York. Jacobson, M. Z. (1999): Fundamentals of Atmospheric Modeling. Cambridge University Press, New York. Lin, Y.-L. (2007): Mesoscale Dynamics. Cambridge University Press.

COURSE: **Seismology IV**

YEAR OF STUDY: **I**

SEMESTER: **2nd**

TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Davorka Herak, PhD** **Asst Prof Iva Dasović, PhD**	**2**
Exercises	**Asst Prof Iva Dasović, PhD**	**1**
Seminars		**0**

ECTS CREDITS: **6**

COURSE OBJECTIVES:

Define, derive and analyse the impact of lateral inhomogeneities and anisotropy on propagation and scattering of seismic waves and generation of coda waves. Analyse and discuss local coda waves. Describe generation and derive the equations of free oscillations of the Earth. Discussion of characteristics of free oscillations of the Earth.

COURSE CONTENT:

Fundamentals of theory of scattering of elastic waves in inhomogeneous media. Coda waves of local earthquakes. Quality factor (Qc) of coda waves, measurements and interpretation. Dependence of Qc on frequency and elapsed time. Seismic anisotropy. Tensor ofelasticity and fundamental properties of seismic plane waves in homogeneous anisotropic media. Equations of motion in 1-D and 2-D and in Earth as a uniform elastic sphere. Determination of eigen values and eigen functions of free oscillations. Spherical harmonics.

LEARNING OUTCOMES:

After completing the course Seismology IV (6 ECTS) the student should be able to:

1. Outline generation and characteristics of local coda waves.
2. Measure, calculate and interpret Qc of coda waves.
3. Analyse frequency and time dependence of the Qc factor.
4. Discriminate isotropic and anisotropic media.
5. Describe seismic anisotropy and its causes.
6. Define anisotropic structures in Earth's crust and mantle.
7. Define and describe basic systems of symmetry important for seismology.
8. Derive and discuss equations of free oscillations of Earth.

LEARNING MODE:

Attending of lectures, study notes and study literature.Derivation of the equations and analysis of examples.

TEACHING METHODS:

- Lectures, discussion.
- Derivation of the equations.
- Solving problems regarding determination of Qc quality factor of coda waves.
- Teleseismic shear wave splitting analysis

METHODS OF MONITORING AND VERIFICATION:

Homework. Oral exam

TERMS FOR RECEIVING THE SIGNATURE:

Solved 2 homework assignments, and 2 problems solved. Oral exam.

EXAMINATION METHODS:

Oral exam.

COMPULSORY LITERATURE:

Aki, K., P.G. Richards: Quantitative Seismology, 2nd Ed., University Science Books, Sansalito, California 2002.
Sato, H., M. C. Fehler: Seismic Wave Propagation and Scattering in the Heterogeneous Earth, Springer Verlag, Berlin 1997.
Stein, S. & Wysession: An introduction to Seismology, Earthquakes and Earth Structure, Blackwell Publ. 2003.

COURSE: **Engineering Seismology**		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Josip Stipčević, PhD**	**2**
Exercises	**Asst Prof Josip Stipčević, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **3**		

COURSE OBJECTIVES**:**

Acquiring basic notions of engineering seismology. Students are introduced to basic earthquake statistics and measuring of strong ground motion. They learn about the importance of knowing seismic hazard of an area, as well as the amplification properties of surface soil layers.

COURSE CONTENT:

Earthquake catalogues. Gutenberg-Richter relation, estimation of the catalogue completeness. Functions of attenuation of intensity, PGA, PGV, PGD. Dynamic factor of amplification (DAF), amplification spectra for vertically incident SH-waves. Seismic hazard and risk.

LEARNING OUTCOMES:

The course on Engineering seismologyenable students to:

1. Describe the typical contents of earthquake catalogues.
2. Define and discuss the Gutenberg-Richter relation, and to estimate its parameters, given an earthquake catalogue.
3. To estimate the catalogue completeness with respect to the smallestmagnitude and/or the time interval.
4. Define properties of the Poissonian process.
5. Describe main factors influencing recorded strong motion at some location.
6. Compute amplification spectra for given geotechnical models of soil layers.
7. Differentiate between properties of soil based on the corresponding amplification spectra.
8. Differentiate between the deterministic and probabilistic approach to hazard determination.
9. Argue for the properties of seismic hazard as described by a given hazard map.

LEARNING MODE:

Attending lectures, study notes and study literature, derivation of the equations

and analyses of examples.
TEACHING METHODS: Lectures, discussions, derivation of the equations, solving problems.
METHODS OF MONITORING AND VERIFICATION: Regular attendance to the lectures. Oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Successful completion of the exercises and homework assignments, attending lectures.
EXAMINATION METHODS: Oral exam.
PREVIOUS OBLIGATORY COURSES: Seismology III (completed)
COMPULSORY LITERATURE: Agarwal, P.N.: Engineering Seismology, Oxford & IBH Publishing, New Delhi 1991. McGuire, R. K: Seismic Hazard and Risk Analysis, EERI, Oakland CA, 2004. Reiter L.: Earthquake Hazard Analysis. Columbia University Press. New York 1991.

COURSE: **Gravity and Figure of the Earth**		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Assoc Prof Snježana Markušić, PhD**	**2**
Exercises	**Assoc Prof Snježana Markušić, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

The course prepares students to describe, define and determine the shape of the Earth and the forces on the Earth's surface.

COURSE CONTENT:

Forces acting on the Earth's surface. Gravity. General features of the gravitational field. Potential of the gravitational field. Poincare theorem. Potential and the gravitational field due to an ellipsoid of rotation. Clairaut theorem. Geoid. Stokes's formula. Boundary conditions on the geoid surface. Development of the theory of the figure of the Earth. Reduction of the gravity and anomalies. Fundamentals of the theory of isostasy and isostatic reduction of measurements.

LEARNING OUTCOMES:

Students will be able to:

1. state and discuss the elements of the theory of potential,
2. describe the forces on the Earth's surface and explain gravity,
3. explain, numerically demonstrate and discuss normal gravitational field,
4. explain the concept of the geoid,
5. specify the basic theory of isostasy and know how to apply isostatic reduction of measured values.

LEARNING MODE:

Listening sessions, study notes and literature, case study, derivation of equations.

TEACHING METHODS:

Presentation, discussion, task of equation derivation.

METHODS OF MONITORING AND VERIFICATION:

Homework, oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Regular attendance to the lectures (at least 70%), homework assignments.

EXAMINATION METHODS:

Oral exam.

COMPULSORY LITERATURE:

Kaufmann, A.A., R.O. Hansen: Principles of the gravitational method, Elsevier, Amsterdam 2008.

Lambeck, K.: Geophysical Geodesy, Clarendon Press, Oxford 1988.

Vaniček, P., E. Krakiwsky: Geodesy, The Concepts, Elsevier, Amsterdam 1986.

COURSE: **Computation of Adjustments**		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Assoc Prof Snježana Markušić, PhD**	**1**
Exercises	**Assoc Prof Snježana Markušić, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **2**		

COURSE OBJECTIVES**:**

The course prepares students for the application of adjustment calculus of measurements in geophysics.

COURSE CONTENT:

Types of errors. Basic theory of random errors. Gauss's law on probability of errors. Estimation of precision of direct observations (measurements). Error equations and normal equations. Errors of adjusted measurements.

LEARNING OUTCOMES:

Students will be able to:

1. expose the theory of random errors,
2. analyze and apply Gauss's law of probability of errors,
3. explain and discuss direct and indirect observations,
4. perform and solve normal equations and errors equations for a set of measurements (the direct and indirect).

LEARNING MODE:

Listening sessions, study notes and literature, case study, derivation of equations and problem solving.

TEACHING METHODS:

Presentation, discussion, task of equation derivation and solving numerical problems.

METHODS OF MONITORING AND VERIFICATION:

Homework, written exam.

TERMS FOR RECEIVING THE SIGNATURE:

Regular attendance to the lectures (at least 70%), homework.

EXAMINATION METHODS:

Written exam.

COMPULSORY LITERATURE:

Vaniček, P.: Introduction to Adjustment Calculus, Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton 1995.

Feil, L.: Teorija pogrešaka i račun izjednačenja, Geodetski fakultet, Zagreb 1989.

COURSE: **Numerical Methods in Physics 2**		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Tina Bosner, PhD**	**2**
Exercises	**Asst Prof Tina Bosner, PhD**	**2**
Seminars		**0**
ECTS CREDITS: **6**		

COURSE OBJECTIVES**:**

To introduce students to modern methods in numerical analysis, in the area of ordinary (ODE) and partial differential equations (PDE), with an emphasis on their practical solution on computers.

COURSE CONTENT:

Final difference method for boundary value problem for ODE. Partial differential equations, final difference method for Poisson equation, Liebmann method. Final element method (FEM) in one dimension and for elliptic (PDE) boundary value problems, variational formulation, Ritz-Galerkin method, basis functions and form functions, spaces of final elements. Approximation of domain, local coordinates and the nesting algorithm, the knot numeration problem. Methods for parabolic equations. Convergence of FEM. Classification of second order PDE in two dimensions. Hyperbolic equations of the first and second order, method of characteristics, propagation of discontinuities, Lax-Wendroff formulae and Courant-Friedrichs convergence condition.

LEARNING OUTCOMES:

After the successful completion of the subject Numerical methods in physics, the student will be able to:

1. express the basic definition and theorems associated with the ordinary and partial differential equations, as well as with the approximation methods;
2. differentiate the methods for solving initial and boundary value problems for ordinary and partial differential equations;
3. choose and apply the correct approximation methods for the given problem;
4. derive an analogous approximation method with certain properties;
5. analyze a given approximation method;
6. write a simple computer program for solving a given problem.

LEARNING MODE:

Following lectures, study of notes and literature, analysis of examples and

practicing, analysis of methods and practicing, analysis of computer programs and the results obtained by solving problems on the computer and practicing.
TEACHING METHODS: Lectures; solving examples; analysis of the methods; presentation of the computer programs and their results.
METHODS OF MONITORING AND VERIFICATION: Written exam through midterm exams; writing and presenting programming assignments; oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Regular attendance to the lectures, and achievement of minimal 17 points out of 56 on mid-term exams.
EXAMINATION METHODS: Grading components: 1. Two mid-term exams, 28 points each (together 56 points) 2. One programming assignment, 24 points 3. Final exam, 20 points Mid-term exams 1. During the semester, students write two mid-term exams. Mid-term exams include also some theoretical questions. 2. Minimal condition for passing the exam is achievement of 17 points. 3. For students who were not able to achieve the minimal number of points, one makeup mid-term exam will be organized, which includes material of the whole semester. Maximum number of points on the makeup exam is 56. Minimal condition for passing this exam is achievement of 17 points. For students who approach the makeup mid-term exam, the points from the regular mid-term exams are reset. Programming assignment 1. During the semester, one individual programing assignment is set, which must be solved within the time limit, which will be announced on the web page of the course. Each assignment, in principle, includes a solution implemented in F90/F95, and is explained to the lecturer. 2. Minimal condition for passing is achievement of 10 points. Final exam 1. Final exam consists of an oral exam in front of the lecturer, which includes the material of the whole course, and may include some tasks and test of the practical knowledge on the computer. 2. The students who have passed the mid-term exams and the programming assignment may approach the final exam. Final grade Minimal number of points for passing grade is 45. The final grade is determined by the

following table:

Points	Grade
45-59	2
60-74	3
75-89	4
>90	5

COMPULSORY LITERATURE:

Bellman, R.E., R.E. Kalaba: Quasilinearization and Nonlinear Boundary-Value Problems, Elsevier N.Y. 1965.
Strang, G., G. J. Fix: An Analysis of the FEM, Prentice-Hall, 1973.
Press, W. H., B.P. Flannery, S. A. Teukolsky, W. T. Vetterling: Numerical Recipes, Cambridge univ. press, 1987.
Smith, G.D.: Numerical Solution of PDE: Finite Difference Methods, Clarendon press, Oxford, 1978.

ADDITIONAL LITERATURE:

C. King, J. Billingham, S. R. Otto: Differential Equations, Linear, Nonlinear, Ordinary, Partial, Cambridge Univ. Press 2003.

G. Strang, G. J. Fix: An Analysis of the FEM, Prentice-Hall, 1973.

W. H. Press, B.P. Flannery, S. A. Teukolsky, W. T. Vetterling: Numerical Recipes, Cambridge univ. press, 1987.

G. D. Smith: Numerical Solution of PDE: Finite Difference Methods, Clarendon press,Oxford, 1978.

M. Metcalf, J. Reid: FORTRAN 90/95 Explained, Oxford Univ. Press, 1999.

T. M. R. Ellis, I. R. Philips, T. M. Lahey: Fortran 90 Programming, Addison-Wesley, 1996.

COURSE: **Geology**		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Đurđica Pezelj, PhD**	**3**
Exercises	**Asst Prof Đurđica Pezelj, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **5**		

COURSE OBJECTIVES**:**

Introduction to geology, acquainting with geological composition of the Earth, and processes in its interior and at the surface. Learning about tectonic processes and structures, Earth's inner dynamics, earthquakes and volcanism, karst and seas, their geological importance, evolution of life on the Earth and basic fossil types. Mastering basic methods of geological research.

COURSE CONTENT:

Evolution and composition of the Earth. Earth physics: isostasy, heat, magnetism. Plate tectonics (boundaries, causes, consequences). Earth dynamics: volcanism (causes, volcano types, types of eruptions and products), seismics (causes, detection methods, impact of substratum on earthquake damage). Tectonics: bed strike and dip, conformity and disconformity, folds, faults, overthrusts. Hydrological cycle, underground water. Weathering, transport and erosion, slope processes. Karst: genesis, hydrology, geomorphology, evolution. Sea: sea dynamics (tides, waves, currents), sea regions, sea-level changes. Geological time: dating methods (relative, radiometric). Environments, facies, fossilization and fossils. Presentation of geological data: geological maps, sections and columns. Geological compass.

LEARNING OUTCOMES:

Student will be able to:

1. Identify common rock-forming minerals and major rock types and describe the conditions under which each of them formed;
2. Recognize various types of geologic structures on geologic map, and use them to reconstruct and interpret the structural history of the area, and write a short report on the geology of the area;
3. Identify the common types of fossils and interpret their approximate age, the environments in which they lived and their evolution through geological time;
4. Describe the plate-tectonic history of the earth.

LEARNING MODE: Presentations, literature and notes, sample analysis and training, systematic observation/inference.
TEACHING METHODS: Lectures, exercises, independent assignments.
METHODS OF MONITORING AND VERIFICATION: Tests, written exam, oral exam.
TERMS FOR RECEIVING THE SIGNATURE: All exercises successfully completed and colloquiums passed.
EXAMINATION METHODS: Written and oral exam.
COMPULSORY LITERATURE: Nusset A. E. & Khan M. A. (2000): Looking into the Earth. An introduction to geological geophysics. Cambridge University press. Cambridge. Plummer, Ch. C., McGeary, D. & Carlson, D. (2001): Physical Geology, 8th Ed., Mc Graw Hill, Boston. Tarbuk, E.J. & Lutgens, F. K. (1988): Earth Science. 5th. Ed., Merrill Publ. Company, Columbus.

COURSE: **Climatology II**

YEAR OF STUDY: **I**

SEMESTER: **2nd**

TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Antun Marki, PhD**	**2**
Exercises	**Antun Marki, PhD**	**1**
Seminars		**0**

ECTS CREDITS: **5**

COURSE OBJECTIVES**:**

The students will be introduced into the basics of climatology and its elements. Physical understanding of long-term atmospheric and oceanic state changes. Introduction to basic climatological methods (statistical, analytical, numerical).

COURSE CONTENT:

Solar radiation components. Long-wave radiation of the Earth and the atmosphere. Radiation budget. Energy budget. Specifics of the general atmospheric circulation and air flows of different scales. Microclimatology. Hydrological cycle. Bioclimatology. Natural and anthropogenic climate changes. Parameterizations of physical processes in climate models. Integration of climate with other models.

LEARNING OUTCOMES:

After completion of the course the students will be able to:

1. Define solar and Earth radiation components and hydrological cycle,
2. Argue the relation between radiation budget and the energy balance of the Earth and the atmosphere,
3. Explain the specifics of the general atmospheric circulation of the atmosphere and air flows on different spatiotemporal scales,
4. To define natural and anthropogenic causes of climate changes,
5. Explain physical parameterizations used in climate models and
6. Compare climate and meteorological models.

LEARNING MODE:

Listening lectures, studying notes and available literature, case study and solving problems through exercises.

TEACHING METHODS:

Presentation with discussion, independently solving of tasks with real data, directing student on independent study of literature and usage of Internet pages

METHODS OF MONITORING AND VERIFICATION: Homework, colloquiums, written and oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Accurate autonomous drafting of tasks (exercises) on computer.
PREVIOUS OBLIGATORY COURSES: Climatology I (completed)
EXAMINATION METHODS: Written (students which successfully pass the colloquiums are released from written exam) and oral exam.
COMPULSORY LITERATURE: Hartman, D.L.: Global Physical Climatology. Academic Press, N.Y., 1994. Hidore, J.J., J.E. Oliver: Climatology: An Atmospheric Science. Macmillan, 1993. Penzar, B., B. Makjanić: Uvod u opću klimatologiju, Sveučilište u Zagrebu, Zagreb, 1978.

COURSE: **Dynamic Meteorology 4**		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Branko Grisogono, PhD**	**3**
Exercises	**Asst Prof Željko Večenaj, PhD**	**2**
Seminars		**0**
ECTS CREDITS: **6**		

COURSE OBJECTIVES**:**

The main objective of the course is to deepen the knowledge about midlatitude large-scale dynamics. Weather analysis and forecasting. Extending knowledge about mesoscale and microscale dynamics and turbulence. One of the main goals of dynamic meteorology is to interpret the observed structures of atmospheric motions and the analysis and forecasting according to the basic laws of physics. For this purpose, in the course framework is needed to:

- Describe, analyze and interpret the processes of quasi-geostrophic adjustment, define the basic system of quasi-geostrophic equation.
- Define the omega equation, Q-vector and explain the mechanisms of vertical motion in baroclinic waves.
- Explain the energy of the baroclinic waves and basic concepts related to it
- Refine the general circulation of the atmosphere, the circulating cells and describe the law of conservation of angular momentum.
- Define and describe the Lorenz energy cycle.
- Provide a basis of the semi-geostrophic theory and derive Eliassen-Sawyer equation.
- Describe and analyze the dynamics of buoyancy waves over bell-shaped mountain.
- Define and describe the concepts related to convective storms and the rotation of the super-cell.
- Define the spectral theory of turbulence.
- To analyze the prognostic equation of turbulent Reynolds stresses.

COURSE CONTENT: Structures of midlatitude large-scale perturbations. Quasi-geostrophic prognosis, semi-geostrophic theory. Barotropic and baroclinic dynamical models of atmospheres. Atmospheric instabilities of large-, meso-and micro-scale processes: baroclinic, isentropic-inertial and buoyant instability. Fronts. Conservation of atmospheric circulations. Mountain waves. Deep convection. Atmospheric boundary layers and turbulence. Turbulence kinetic energy prediction. Monin-Obukhov length. Reynolds stress tensor prediction. Modeling transport and diffusion in the atmosphere. Local circulations. Modeling of the atmospheric dynamics, parameterizations for micro-scale processes. Prandtl model for inclined boundary layers.
LEARNING OUTCOMES: It is expected that after the completion of this course, the students may: 1. Define the basics of geostrophic adjustment and interpret the physical meaning of individual members in the equation of Q-vector, 2. Distinguish the two models (for short and long wavelengths) for description of baroclinic instability in continuously stratified rotating fluid, 3. Define requirements and derive expression for dispersion relation of buoyancy waves over bell-shaped mountain and explain the concept of wave drag 4. Be able to list and compare the different types of linear waves, 5. Apply default assumptions and derive the basic system of equations for turbulent flows of momentum, heat, humidity and scalars, 6. Recognize introduced assumptions and be able to interpret the meaning of individual terms in the forecasting equation of the turbulent Reynolds stresses, 7. Explain the basic processes at different scales of motion and explain the reasonsfor the introduction of the assumptions used.
LEARNING MODE: Critical discussions during lecturing, studying notes and references, derivation of equations and analysis of examples and problems, individual solving of problem tasks.
TEACHING METHODS: Lectures, exercises, referring students to independently study the literature, individual solving of problem tasks.
METHODS OF MONITORING AND VERIFICATION: Students are required to regularly attend classes, solve homework. Additionally, it is necessary to monitor and discus the current synoptic and local weather effects. The work of the students on the course is monitored and evaluated during the study (completion of homework assignments and additional assignments) and at the final written exam.
TERMS FOR RECEIVING THE SIGNATURE: The terms of course approval are: • Successfully solved all the homework during the semester, • Written course summary, 2-3 pages (basic questions & assumptions, relations and conclusions).

EXAMINATION METHODS: The written exam consists of questions that require a short answer and problem solving.
PREVIOUS OBLIGATORY COURSES: Dynamic Meteorology 3 (completed)
COMPULSORY LITERATURE: J. R. Holton: An Introduction to Dynamic Meteorology, Academic Press Inc., San Diego, 1992 (or 2004). R. B. Stull: An Introduction to Boundary Layer Meteorology, Kluwer, Dordrecht, 1988N. Šinik N and B. Grisogono: Dinamička meteorologija, Školska knjiga, Zagreb, 2008.
ADDITIONAL LITERATURE: J. Pedlosky: Geophysical Fluid Dynamics, Springer-Verlag, New York, 1987. F. Mesinger: Dinamička meteorologija, Građevinska knjiga, Beograd, 1976. Numerous web pages and ECMWF courses.

COURSE: **Weather Analysis and Forecasting I**		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Željko Večenaj, PhD**	**2**
Exercises	**Asst Prof Željko Večenaj, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

The main goal is to teach students about traditional and modern methods for the weather analysis. Knowledge of such kind is necessary for all areas of theoretical and practical meteorology: deployment of measurements, data analysis as well as weather nowcasting and forecasting. In this purpose, it is necessary within this course to:

- Define and remove errors in the meteorological data
- Analyse analytical meteorological materials
- Objectively analyse spatially distributed data
- Analyse atmospheric pressure systems and associated physical processes
- Define and describe the horizontal wind field and vertical motions in the atmosphere
- Describe the link between the atmospheric systems and the general atmospheric circulation
- Describe and analyse the lee cyclogenesis
- Describe the influence of the orography to the weather.

COURSE CONTENT:

Global Observing System – World Weather Watch. Weather data control. Analytic materials, stressing weather map projections (conic, cylindrical and polar-stereographic). Objective analysis of the weather fields: fitting methods (polynomial and spectral), optimal (statistical) interpolation, successive correction method and variational approach. Isoplet construction technique. Atmospheric systems: air masses, atmospheric fronts (frontogenesis and frontolysis), jet stream including its genetic mechanism, bariccirculation systems (cyclone, anticyclone, trough and ridge) including cyclogenesis (cyclolysis), anticyclogenesis (anticyclolysis) and tendencies of constant pressure surface heights. Differential characteristics of wind field, streamlines and trajectories. Vertical atmospheric motion diagnosis. Baric systems within global atmospheric circulation. Lee cyclogenesis, especially on the southern side of the Alps.

Humidity field analysis and precipitation amount estimation. Atmospheric systems and the weather. Orographic influences on the weather. Coastal air circulation and the weather.

LEARNING OUTCOMES:

It is expected that after completion of this course, the students should know how to:

- Recognize random and systematic errors in meteorological data and deploy suitable methods to remove them,
- Explain what particular analytical meteorological material represents and what does it mean for the weather,
- Deploy a suitable objective analysis method to spatially inhomogeneous data,
- Recognize/distinguish atmospheric pressure systems and associated physical processes and explain how particular pressure system modulates the weather,
- Explain differential properties of the horizontal wind and its relationship with the vertical motions in the atmosphere,
- Explain the influence of orography to lee cyclogenesis.

LEARNING MODE:

Attending teaching of the theory and exercises, studying of the literature and notes, deriving equations and analysis of the examples, independently solving problems.

TEACHING METHODS:

Theory, exercises, encouraging students to explore the literature by themselves, solving the problems independently

METHODS OF MONITORING AND VERIFICATION:

The progress of students is monitored and evaluated during the course (homework, oral presentations and other assignments) and on the final oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Homework reports; attending the classes at least for 50 %.

EXAMINATION METHODS:

The oral exam consists of written preparation and its oral presentation/discussion. Here thelevel of formal adoption of course topics (especially their understanding) is evaluated, observing the professional terminology.

PREVIOUS OBLIGATORY COURSES:

Dynamic Meteorology 3, Climatology I (completed)

COMPULSORY LITERATURE:

Bluestein, H.B., 1992: Sinoptic-dynamic meteorology in midlatitudes, (Vol. I). Oxford University Press, New York. 431 pp.
Bluestein, H.B., 1993: Sinoptic-dynamic meteorology in midlatitudes, (Vol. II). Oxford University Press, New York. 431 pp.
Daley, R., 1991: Atmospheric data analysis.Cambridge University Press, Cambridge. 457 pp.
Pandžić, K., 2002: Analiza meteoroloških polja i sustava. HINUS, Zagreb. 314 pp

ADDITIONAL LITERATURE:

Atlas, D., 1990: Radar in meteorology. American Meteorological Society, Boston, 806 pp.

Blumen, 1990: Atmospheric processes over complex terrain. American Meteorological Society, Boston. 323 pp.

Carlson, T.N., 1994: Mid-latitude weather systems. American Meteorological Society, Boston. 507 pp.

Kurz, M., 1998: Synoptic meteorology. Deutscher Wetterdienst, Offenbach. 200 pp.

Palmen, E. and C.W. Newton, 1969: Atmospheric circulation systems –Their structure and physical interpretation. Academic Press, New York. 603 pp.

Petterssen, S., 1956: Weather analysis and forecasting (Vol. I and II). McGraw-Hill, New York, 428 (266) pp.

Radinović, Đ., 1969: Analiza vremena. Univerzitet u Beogradu, Beograd. 367 pp.

Saucier, W.J., 1955: Principles of meteorological analysis. The University of Chicago Press, Chicago. 438 pp.

Schott, J.R. 1997: Remote sensing –the image chain approach. Oxford University Press, Oxford. 394 pp.

Zverev, A.S., 1977: Sinoptičeskaja meteorologia. Gidrometeoizdat, Leningrad. 710 pp.

COURSE: **Dynamics of Coastal Sea**		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Mirko Orlić, PhD**	**2**
Exercises	**Mira Pasarić, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **5**		

COURSE OBJECTIVES**:**

The course prepares students to analyze barotropic processes that are generated by wind in inland seas.

COURSE CONTENT:

Wind-driven currents in the seas: models developed by Weenink, Felzenbaum and Welander. Comparison with the wind-driven currents in the oceans: models proposed by Sverdrup, Stommel and Munk. Seiches: analytical modeling of generation and decay, developmentof a simple one-dimensional numerical model, comparison with the observations. Topographic Rossby waves: analytic models for the straight coast and circular basin. Exercises include analyses of analytic solutions for various sets of parameters and one-dimensional numerical modeling of seiches.

LEARNING OUTCOMES:

Students will be able to:

1. identify wind-driven currents in the seas and oceans,
2. analyze seiches, on the basis of measurements, not only in time domain but also in frequency domain,
3. formulate a simple numerical model of the seiches,
4. identify topographic Rossby waves in inland seas.

LEARNING MODE:

Following the lectures as well as studying the lecture notes and literature, analyzing the data (time series of sea level), and performing one-dimensional numerical modeling.

TEACHING METHODS:

Presentation and discussion, posing the problems relying on data collected in the Adriatic, and formulation of one-dimensional numerical model.

METHODS OF MONITORING AND VERIFICATION:

Attending the lectures, homework assignments, written and oral examination.

TERMS FOR RECEIVING THE SIGNATURE: Regular attendance to the lectures, successful completion of the exercises.
EXAMINATION METHODS: Written and oral exam.
COMPULSORY LITERATURE: LeBlond P.H.and L. A. Mysak: Waves in the Ocean, Third Impression, Elsevier, Amsterdam, 1989. Pugh D. and P. Woodworth: Sea-Level Science, Cambridge University Press, Cambridge, 2014. Schwind J. J.: Geophysical Fluid Dynamics for Oceanographers, Prentice Hall, Englewood Cliffs, 1980. Simons T. J.: Circulation Models of Lakes and Inland Seas, Department of Fisheries and Oceans, Ottawa, 1980. Stocker T. and K. Hutter: Topographic Waves in Channels and Lakes on the f-Plane, Springer Verlag, New York, 1987.

COURSE: **Field work 2 (10 hrs/year)**		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Antun Marki, PhD**	
Exercises	**Antun Marki, PhD**	
Seminars		
ECTS CREDITS: **1**		

COURSE OBJECTIVES**:**

Students will be introduced with:
(i) ways of organizing work at meteorological stations,
(ii) measurements and observations of meteorological quantities using instruments and methods of observations
(iii) the observation of severe meteorological events by means of radars,
(iv) determining the cloudiness and type of cloud in terms of height, composition and shape of the cloud
(v) monitoring of observations and encryption of meteorological data.
2. Linking theoretical knowledge from previous meteorological courses with practical work at meteorological stations.
3. Students learn how to monitor meteorological phenomena, observe the states of the atmosphere, and how to associate their changes with weather changes.

COURSE CONTENT:

Properties of hydrological occurrences, hydrological data, basin, runoff factors. Hydrometry: measurements of water level, velocity, water and sediment discharge. Stage hydrograph, discharge curve, hydrograph and its component parts, frequency curves and water level and discharge curves, runoff coefficient and specific discharge from a basin. Probability and statistics in hydrology. Linear and nonlinear correlation, double mass amounts. High waters: distribution curves, unit hydrograph, triangle-shaped hydrograph, isochrone method. Rational formula and other empirical formulas. Low waters of various return periods, periods of low water and of hydrological drought. Sedimentation in watercourses. General equation of hydrological balance. Regional hydrological analysis.

LEARNING OUTCOMES: Getting experience with the organization of a meteorological measuring instruments. Surveying and Determining Clouds. Meteorological phenomena and atmospheric conditions recorded using symbols. Meteorological Diary. Observation of soil and agrometeorological magnitude. Use of radar in meteorology and application of radar equation.
LEARNING MODE: Lectures and practical exercises.
TEACHING METHODS: Field work.
METHODS OF MONITORING AND VERIFICATION: Meteorological field diary
TERMS FOR RECEIVING THE SIGNATURE: The students are obliged to attend all forms of teaching and are obliged to regularly keep the field diary, which at the end of the course is given to the course leader.
EXAMINATION METHODS: After the duties are duly completed, the students receive a signature without rating.
LITERATURE: DHMZ: Naputak za opažanja i mjerenja na glavnim meteorološkim postajama. Zagreb, 2008.

COURSE: **Fundamentals of Geophysical Exploration I *(optional)***		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Franjo Šumanovac, PhD**	**2**
Exercises	**Nataša Balaško, mag. ing. geol.**	**2**
Seminars		**0**
ECTS CREDITS: **4**		
COURSE OBJECTIVES**:** Introduction to the methods of geophysical research and their application in defining the geological structure and composition of terrain: in exploration of hydrocarbons and solid mineral resources, in geotechnical researches, groundwater and environmental studies.		
COURSE CONTENT: Lectures : Gravimetric researches - Theoretical basis. Gravimeter. Gravimetric effect of 3D structures. Instruments and equipment. Field measurements and data processing. Gravimetric correction. Transformation of gravimetric maps. Rock densities. Interpretation. Gravimetric ambiguity. Isostasy. Application of gravimetric surveys. Magnetic researches - Earth's magnetic field. Instruments and equipment. Measuring the total field. Theoretical foundations. Magnetic minerals and rocks. Elementary dipoles and monopoles. Induced and remanent magnetization. Field measurements. Use of the protone magnetometer. Data processing. Interpretation. Magnetometric ambiguity. Application of magnetic researches. Geoelectric researches - Electrical properties of rocks. Self - potential method. Electrical resistivity method. Electrical sounding and profiling: instruments and equipment. Measuring, data processing, interpretation. Electrical ambiguity. Application of geoelectrical researches. Induced polarization method. Exercises: Defining 3 exercises. Explanations related to preliminary exams and field work. Gravimetry – Introduction. Interpolation of values on Bouguer anomaly maps. Transformation of Bouguer anomaly maps using Griffin method. Calculation of residuals for different radiuses. Interpolation of calculated values on the map of gravimetric residuals for different radiuses. Magnetometry - Introduction. Defining the profile on the geomagnetic maps. Defining the cause of anomaly. Tangents methods - horizontal gradient Method of tangents – Peter´s method, tangent-intersection method.		

Calculating the depth of the anomaly cause. Geoelectric sounding – Introduction. Calculating the apparent resistivity for two layers Interpretation of depth distribution of resistivity for two layers using theoretical curves. Calculating the apparent resistivity for several layers. Interpretation of depth distribution of resistivity for multiple layers, using theoretical curves. Interpretation of depth distribution of resistivity for multiple layers, using theoretical curves. Field work - Geoelectrical sounding, geoelectrical profiling, Magnetometry.
LEARNING OUTCOMES: 1. To understand gravimetric regional and residual; 2. define the depth of the causes of magnetic anomalies with tangents methods; 3. to calculate and interpret the curve of geoelectric sounding; 4. to understand the operation of instruments for gravimetric, magnetic and electrical surveys.
TEACHING METHODS: Lectures, exercises, practical and field work.
METHODS OF MONITORING AND VERIFICATION: Regular attendance of lectures, practical work, preliminary exams, oral exams.
TERMS FOR RECEIVING THE SIGNATURE: Class attendance (lectures, exercises and field work), handed solved exercises, passed at least one preliminary exam.
EXAMINATION METHODS: Passed preliminary exams or oral exam (80%), solved exercises (20%).
LITERATURE: Šumanovac, F. (2012): Osnove geofizičkih istraživanja, Sveučilište u Zagrebu. Griffits, D.H. & King, R.F. (1981): Applied Geophysics for Engineers and Geologists, Pergamon Press, Oxford. Parasnis, D.S. (1986): Principles of Applied Geophysics, Chapman and Hall, New York.

<table>
<tr><td colspan="3">COURSE: Statistical Physics (optional)</td></tr>
<tr><td colspan="3">YEAR OF STUDY: I</td></tr>
<tr><td colspan="3">SEMESTER: 2nd</td></tr>
<tr><td>TEACHING METHODS</td><td>LECTURER</td><td>CONTACT HRS PER WEEK</td></tr>
<tr><td>Lectures</td><td>Professor Denis Sunko, PhD</td><td>2</td></tr>
<tr><td>Exercises</td><td>Asst Prof Marinko Jablan, PhD</td><td>1</td></tr>
<tr><td>Seminars</td><td></td><td>0</td></tr>
<tr><td colspan="3">ECTS CREDITS: 4</td></tr>
<tr><td colspan="3">COURSE OBJECTIVES:

Understanding the relationship between thermodynamics and statistical physics and the adoption of the fundamental concepts of statistical description of the thermodynamic limit: entropy, thermodynamic potentials, an ensemble, single distribution, fluctuation.</td></tr>
<tr><td colspan="3">COURSE CONTENT:

Thermodynamics as an autonomous discipline: Introduction. Basic concepts. The first law of thermodynamics. Machines. The second law of thermodynamics. The reversibility and entropy. Thermodynamic potentials. Practical accounts.
Introduction to statistical physics: Basic considerations. Ensemble: universal random model. The connection with thermodynamics.
Canonical and grand-canonical ensemble: The canonical ensemble. Grand-canonical ensemble. Sums by conditions such as generating functions. Classical ideal gas. Maxwell distribution and equiparticion energy.
Quantum statistical physics: Basic considerations. The ideal fermion gas. The ideal boson gas.
Examples and models: the barometric formula. Diatomic molecules. Heat capacity of the crystal. Van der Waals model of gas liquefaction.</td></tr>
<tr><td colspan="3">LEARNING OUTCOMES:

Upon successful completion of the course Statistical Physics student will be able to:
1. Demonstrate a thorough knowledge of abstract thermodynamics at an elementary level of the theory of functions of several variables;
2. Explain the difference of thermodynamics and theoretical mechanics, or thermalization as real physical process;
3. Describe the role of thermalization and Liouville theorem in the foundation of statistical physics;
4. Explain the physical construction of the thermodynamic potential, through the</td></tr>
</table>

interaction energy between the system and the outside world; 5. Demonstrate a thorough knowledge of statistical interpretation of thermodynamic potentials, especially entropy and Massieuovih function; 6. Explain the role of the chemical potential and the qualitative behavior of the classical and quantum border; 7. Qualitatively and quantitatively described four ideal gas (fermions, bosons, light, sound) in classical and quantum border; 8. Discuss basic properties of the phase transition of Van der Waals's gas liquefaction.
TEACHING METHODS: Lectures, exercises.
METHODS OF MONITORING AND VERIFICATION: Colloquiums, written and oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Students are required to pass two of three colloquiums that are held during semester.
EXAMINATION METHODS: Students can take the oral exam if they have passed the written exam. The written examination can be taken if they pass two of the three colloquia during the year with a passing grade. If all three are passed with grade 4 or 5, student receive a higher grade on the written exam.
COMPULSORY LITERATURE: C. Kittel, Elementary Statistical Physics, Dover 2004, ISBN 0486435148. R. Kubo et al., Statistical mechanics: an advanced course with problems and solutions, North-Holland, Amsterdam 1988, ISBN 0444871039. Skripta: http://www.phy.hr/dodip/notes/statisticka.html

COURSE: **Selected Chapters of Meteorology** ***(optional)***		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Assoc Prof Ivana Herceg Bulić, PhD**	**2**
Exercises	**Assoc Prof Ivana Herceg Bulić, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

The course offers insight into the most recent accomplishment in the field of meteorology and climatology. Also, the course aims to provide general knowledge and skills for analysis and comparison of atmospheric processes on different spatial and temporal scales. Under this course students achieve practical experience in work with meteorological and climatological data, their statistical analysis as well as basic experience in work with different software packages for data processing and visualization. The course cavers a large amount of work in computer lab to develop students' independence in learning, data processing and interpretation of results that are obtained in resolving specific problems.

COURSE CONTENT:

The course consists of several offered thematic modules. Each module contains the recent accomplishment in meteorology and links them to the existing students' knowledge and skills The course covers following areas: Earth climate system, main characteristics of the Earth system components and their interactions; statistical properties of atmospheric circulation; atmospheric disturbances; climate variability; climate forcing mechanisms and responses; feed-back processes; atmospheric teleconnection patterns - their identification and methods of examination; composite analysis; ensembles of climate simulations; climate signal, noise and potential predictability; El Niño Southern Oscillation (physical mechanisms, teleconnections, El Niño Modoki); equatorial waves and β-plane approximation; feed-back processes in the Tropics; Pacific Decadal Oscillation; North Atlantic Oscillation; climate change (natural and anthropogenic), global warming; climate change modelling and hierarchy of climate models; climate scenarios and climate projections. Practical aspects of the course include: basic statistical methods in meteorology and climatology; Grid Analysis and Display System (GrADS) usage and programming in GrADS; visualisation and statistical data analysis; atmospheric general circulation; atmospheric waves; meridional, zonal and vertical distribution of meteorological variables; seasonal and interannual variability; climate indices (calculation and visualization) and composite analysis; teleconnection patterns, correlation analysis and correlation maps.

LEARNING OUTCOMES:

Students will have the knowledge and skills to:

1. Understand, explain and describe atmospheric processes of different spatio-temporal scales.
2. Explain various feed-back processes in the atmosphere.
3. Explain climate variability, analysis its causes, discuss natural and anthropogenic climate change providing scientific methods for their examination.
4. Identify, visualize and explain atmospheric teleconnections and apply appropriate statistical methods.
5. Formulate and solve particular problem related to the specific thematic module.
6. Analyse, compare and discuss observed and modelled data.

LEARNING MODE:

Listening, sessions, independent study of notes and literature, case study analysis, derivation of equations and problem solving, exercises

TEACHING METHODS:

Lectures, exercises, practical work.

METHODS OF MONITORING AND VERIFICATION:

Homework, seminar (oral presentation), seminar essay, oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Regular attendance to the lectures (at least 70 %), homework, accomplished project.

EXAMINATION METHODS:

Oral exam.

LITERATURE:

Beniston, M.: From Turbulence to Climate. Springer, Berlin, 1998.
Marshall, J. i R. A. Plumb: Atmosphere, Ocean, and Climate Dynamics: An Introductory Text. Elsevier, Amsterdam, 2008.
Vallis, G. K.: Atmospheric and Oceanic Fluid Dynamics. Cambridge University Press, Cambridge, 2006.
Wilks, D.S.: Statistical Methods in the Atmospheric Sciences—An Introduction. International Geophysics Series, Vol. 59, Academic Press, 1995.

COURSE: **Introduction to limnology *(optional)***		
YEAR OF STUDY: **I**		
SEMESTER: **2nd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Zvjezdana Bencetić Klaić, PhD**	**2**
Exercises	**Professor Zvjezdana Bencetić Klaić, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

Acquiring the knowledge on formation, lake types, physical properties and physical processess occuring within lakes. Acquiring the knowledge on the influence of hydrologic and climatic processes, as well as, anthropogenic activities on limnological parameters.

COURSE CONTENT:

1) Introduction – what is limnology, basic terms, development of limnology.
2) Water characteristics (density, viscosity, specific heat, dielectric constant. Water resources, water pollution and its influence on lakes.
3) Hidrology and climate. The origin, types (glacial, tectonic, coastal, riverin, volcanic, man-made), and age of lakes.
4) Lake and catchment morphometry. Transport of materials, eutrophication, sedimens.
5) Radiation, radiation attenuation, temperature cycles, lake stratification, heat budget.
6) Water movements (laminar, turbulent, waves, seiches, currents, Langmuir cells).
7) Limnological investigations in Croatia, limnological investigations of Plitvice lakes system.

LEARNING OUTCOMES:

Students will have the knowledge and skills to:

1. Differentiation between the lake types based on their formation.
2. Understanding of mechanisms governing limnological parameters.
3. Understanding of the interplay of hydrologic-limnologic, climate-limnologic, and anthropogeic-limnologic processes.
4. Differentiation between the flow types, and understanding and explanation of phyisical processes responsible for particular flow types

LEARNING MODE:

Listening, sessions, independent study of notes and literature, derivation of equations

and problem solving, exercises.
TEACHING METHODS: Lectures, seminars, exercises, multimedia and the internet.
METHODS OF MONITORING AND VERIFICATION: Class attendance, seminar essay, oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Based on the insight in regularity of class attendance (at least 70%)
EXAMINATION METHODS: Oral exam and correctness of homework tasks.
COMPULSORY LITERATURE: Kalff, J., (2002): Limnology: inland water ecosystems. Prentice-Hall, Inc., Upper Saddle River, 592 pp. recent papers published within the field of limnology (one paper per student)
OPTIONAL LITERATURE: Hutter, K., Wang, Y., Chubarenko, I. P. (2011): Physics of Lakes. Volume 1: Foundation of the Matematical and Physical Background. Advances in Geophysical and Environmental Mechanics and Mathematics. Springer-Verlag, Heidelberg, 434 pp, DOI: 10.1007/978-3-642-15178-1. Hutter, K., Wang, Y., Chubarenko, I. P. (2011): Physics of Lakes. Volume 2: Lakes as Oscillators. Advances in Geophysical and Environmental Mechanics and Mathematics. Springer-Verlag, Heidelberg, 646 pp, DOI: 10.1007/978-3-642-19112-1. Hutter, K., Wang, Y., Chubarenko, I. P. (2014): Physics of Lakes. Volume 3: Methods of Understanding Lakes as Components of the Geophysical Environment. Advances in Geophysical and Environmental Mechanics and Mathematics. Springer-Verlag, Heidelberg, 605 pp, DOI: 10.1007/978-3-319-00473-0.

COURSE: **Geomagnetism**

YEAR OF STUDY: **II**

SEMESTER: **3rd**

TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Assoc Prof Giuliana Verbanac, PhD**	**3**
Exercises	**Igor Mandić, PhD**	**1**
Seminars		**0**

ECTS CREDITS: **4**

COURSE OBJECTIVES**:**

To introduce students with the properties of geomagnetic field, and the complex connection of the magnetic field with the highest layers of Earth's atmosphere. For this purpose, it is necessary to:
- handle physical processes that generate magnetic field,
- explain equations that connect electric and magnetic fields,
- elaborate and discuss the evolution of all the components of the geomagnetic field,
- describe the methods of measuring the geomagnetic field,
- define the particle distribution in all layers of the magnetosphere and their interaction with a magnetic field.

COURSE CONTENT:

Electromagnetic induction. Electrical conductivity. Maxwell equations. Magnetic properties of materials. Elements and basic properties of the geomagnetic field. Measurements of geomagnetic elements. Contributions to the measured magnetic field on the Earth's surface. Results of paleomagnetic research. Magnetic reversals. Temporal and spatial changes of the geomagnetic field. Evolution of the geomagnetic field. Modeling the geomagnetic field elements. The Solar Activity and physics of Sun-Earth space environment. Interplanetary magnetic field. Magnetospheric regions and related processes. Planetary magnetic fields.

LEARNING OUTCOMES:

After completing the course the student should be able to:
1. identify the characteristics of the Earth's magnetic field,
2. define and explain Maxwell's equations,
3. interpret the physical mechanisms responsible for the existence of the magnetic field and related changes,
4. describe changes in the geomagnetic field at various time scales,
5. classify various contributions to the measured magnetic field on the surface of the

Earth,
6. collect data from geomagnetic observatories,
7. analyze the geomagnetic measurements,
8. interpret the characteristics of ionized particles in various layers of magnetosphere,
9. prepare, present and discuss the presented topics.

LEARNING MODE:

Attending lectures, study literature, analyses of examples and practicing, discussion of homework assignments.

TEACHING METHODS:

Lectures, individual and group discussions, set individual tasks, using internet, discussion of examples.

METHODS OF MONITORING AND VERIFICATION:

Attending lectures. Written and oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Attendance in teaching 70%.

EXAMINATION METHODS:

Writing (the students may not have to attend writing part of the exam if they successfully complete all mid-term exams) and oral examinations.

COMPULSORY LITERATURE:

Campbell, W.H.: Introduction to Geomagnetic Fields, Cambridge Univ. Press, Cambridge 2003.
Vršnak, B.: Temelji fizike plazme, Školska knjiga, Zagreb, 1996.
Proelss, G.:Physics of the Earth's Space Environment, Springer-Verlag Berlin Heidelberg New York, 2004.
Parks,G.K.: Physics of space plasma,an introduction,Westview press, Boulder, 2004.

COURSE: **Physics of the Interior of the Earth**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Assoc Prof Snježana Markušić, PhD**	**2**
Exercises	**Assoc Prof Snježana Markušić, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **6**		

COURSE OBJECTIVES:

The course prepares students to describe and define the structure of the Earth's interior and to analyze the displacement field on the surface of the Earth based on the analysis of the seismic sources.

COURSE CONTENT:

Inverse problems (Lanczos's decomposition, Moore-Penrose matrix inverse, determination of seismic wave velocities using inverse method). Density, pressure and constants of elasticity in the Earth's interior (basics of density determination in the Earth's interior, Adams-Williamson equation for the variation of density in mantle). Physics of seismic sources (causes of earthquakes, elastic rebound theory, strain energy before an earthquake, Clapeyron's form of strain energy density, faulting sources, equivalent body forces, radiation pattern). Elastostatics (static displacement field due to a single force, a force couple and a double couple). Elastodynamics (near and far field displacements, far field radiation patterns, seismic moment tensor). Earthquake magnitude (energy of earthquake waves, energy per unit area of wave front in an emerging wave, energy of body and surface waves, earthquake magnitude).

LEARNING OUTCOMES:

After completing the course the student should be able to:

1. definirati i riješiti inverzne probleme u seizmologiji pomoću Lanczosove dekompozicije;
2. compute density distribution, pressure and constants of elasticity in the Earth's interior using the Adams- Williamson's law;
3. explain the basic concepts of physics of seismic sources;
4. explain the difference between elastostatics and elastodynamics;
5. explain the concept of magnitude, as well as compare different magnitudes.

LEARNING MODE:

Listening sessions, study notes and literature, case study, derivation of equations and

problem solving.
TEACHING METHODS: Presentation, discussion, task of equation derivation and solving numerical problems.
METHODS OF MONITORING AND VERIFICATION: Homework tasks, written and oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Regular attendance to the lectures (at least 70%), homework assignments.
EXAMINATION METHODS: Written and oral exam.
COMPULSORY LITERATURE: Aki, K., P.G. Richards: Quantitative Seismology, 2nd edition, University Science Books, Sausalito 2002. Ben Menahem, A., B.A. Singh: Seismic Waves and Sources, Springer-Verlag, New York 1981. Stein, S., M. Wysession: An Introduction to Seismology, Earthquakes and Earth Structure, Blackwell Publishing, Hoboken 2003. Tarantola, A.: Inverse Problem Theory, Methods for Data Fitting and Model Parameter Estimation, Elsevier Science Publishers, Amsterdam 1987. Lay, T., T.C. Wallace: Modern Global Seismology, Academic Press, San Diego 1995.

COURSE: **Geophysical Practicum**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Marijan Herak, PhD** **Assoc Prof Giuliana Verbanac, PhD**	**2**
Exercises	**Igor Mandić, PhD**	**2**
Seminars		**0**
ECTS CREDITS: **3**		

COURSE OBJECTIVES:

Introduce students to the measurements of geomagnetic elements. Implement knowledge about inverse problems to solve the problem of location of earthquake epicentre. Practice determination of fault-plane solution by the graphical method on the basis of first motion polarities.

COURSE CONTENT:

Basis of spherical astronomy. Determination of the horizontal component of the magnetic field and the declination. Lamont and Gauss's positions. Basics of inverse problems. Geiger's method for earthquake location. Graphical method for the fault-plane solution on Schmidt net.

LEARNING OUTCOMES:

Students will be able to:

1. define the geomagnetic elements,
2. describe methods of measuring the horizontal component of the magnetic field and the magnetic declination,
3. discuss geomagnetic field measurements data,
4. describe the method of least squares and conditions for its application to locate the hypocenter of the earthquake,
5. display the location of the focal point of the earthquake on the basis of seismic waves phase arrival time data at seismic stations,
6. graphically locate the parameters of seismogenic faults for each earthquake, and describe its properties,
7. debate which datasets will lead to reliable and unambiguous solutions, which to ambiguous results.

LEARNING MODE:

Studying literature, listening to presentations, solving homework, discussion of the results of homework tasks, practical work.

TEACHING METHODS: Presentations, homeworks, use of websites, discussions of homework.
METHODS OF MONITORING AND VERIFICATION: Oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Attending all practices, preparation of practices and homework assignments
EXAMINATION METHODS: Oral discussion of practices.
PREVIOUS OBLIGATORY COURSES: Seismology III, Seismology IV (completed)
COMPULSORY LITERATURE: Stein, S. and M. Wysession: An introduction to Seismology, Earthquakes and Earth structure, Blackwell Publ., 2003. Lay, T., T. C. Wallace: Modern Global Seismology, Academic Press, San Diego, 1995. Udias, A.: Principles of Seismology, Cambridge University Press, United Kingdom, 1999. Kasumović, M., Opća i primjenjena geofizika s osnovama sferne astronomije I dio – opća geofizika, PMF Sveučilište u Zagrebu, 1971. Kasumović, M., Opća i primijenjena geofizika s osnovama sferne astronomije III dio-opća geofizika, PMF Sveučilište u Zagrebu, 1971. Fanselau, G., Geomagnetismus und Aeronomie – Band II, VEB Deutscher Verlag der Wissenschaften, Berlin 1960.

COURSE: **Weather Analysis and Forecasting II**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Željko Večenaj, PhD**	**2**
Exercises	**Asst Prof Željko Večenaj, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

The main goal is to teach students about traditional and modern methods for the weather analysis. Knowledge of such kind is necessary for all areas of theoretical and practical meteorology: deployment of measurements, data analysis as well as weather nowcasting and forecasting. In this purpose, it is necessary within this course to:

- Define and describe subjective and objective methods of weather forecasting
- Describe the hydrodynamic equations in different coordinate systems
- Define and describe numerical methods for numerical solving of hydrodynamic equations
- Define and describe the operation principle of particular atmospheric numerical models
- Describe and define special weather forecasts
- Define and describe methods for verification of weather forecasts

COURSE CONTENT:

Subjective way of weather forecasting. Objective methods of weather forecasting: deterministic, stochastic and deterministic-stochastic approach. The governing equations of the atmosphere in different co-ordinate systems (generalised, spherical, tangential and map projections). Review of numerical methods for solving the governing equations: method of final differences and function expansion into series (spectral and final elements). Non-linear numerical nonstability and filtering (low-pass and bandpass filters). Initialisation of numerical models: equilibrium equations, normal modes, 4-dimensional variational analysis. Boundary conditions. Barotropic limited area model in conic map projection. Six-layer hemispheric forecasting model with primitive equations. Global spectral model of the European Centre for Medium Range Weather Forecasts (ECMWF). Introducing with the regional models ALADIN (Aire Limitee Adaptation et Development International) and HIRLAM (High Resolution Limited Area Modelling). Stochastic (regression) approach to the weather forecasting. Analogy method. Deterministic-stochastic approach: atmospheric predictability, ensemble forecasts.

Subjective interpretation of the prognostic model outputs. Regression way of interpretation (Method output Statistic, perfect Prognosis). Adaptive deterministic models (e.g. adaptation of air flow to the orography). Forecasts for special applications. Verification of the forecasts.

LEARNING OUTCOMES:

It is expected that after completion of this course, the students should know how to:

- Explain the meaning of individual terms in hydrodynamic equations with respect to coordinate systems
- Numerically solve the system of differential equations,
- Compare and contrast the meaning of the output of numerical models and the meaning of the analytical material,
- Make the subjective and the objective weather forecast,
- Distinguish between special and standard weather forecasts.

LEARNING MODE:

Attending teaching of the theory and exercises, studying of the literature and notes, deriving equations and analysis of the examples, independently solving problems.

TEACHING METHODS:

Theory, exercises, encouraging students to explore the literature by themselves, solving the problems independently.

METHODS OF MONITORING AND VERIFICATION:

The progress of students is monitored and evaluated during the course (homework, oral presentations and other assignments) and on the final oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Homework reports; attending the classes at least for 50 %.

EXAMINATION METHODS:

The oral exam consists of written preparation and its oral presentation/discussion. Here thelevel of formal adoption of course topics (especially their understanding) is evaluated, observing the professional terminology.

PREVIOUS OBLIGATORY COURSES:

Weather Analysis and Forecasting I (completed)

COMPULSORY LITERATURE:

Haltiner, G.J. and R.T. Williams, 1980: Numerical weather prediction. John Wiley & Sons, New York. 477 pp.

Kalney, E., 2003: Atmospheric modeling, data assimilation and predictability. Cambridge University Press, Cambridge. 341 pp.

Mesinger, F. and A. Arakawa, 1976: Numerical models in atmospheric models. Volume I. GARP Publication Series No. 17, WMO, Geneve. 135 pp.

Pielke R.A. and R.P. Pearce, 1994: Mesoscale modeling of the atmosphere. American Meteorological Society, Boston. 167 pp.

Radinović, Đ., 1979: Prognoza vremena. Univerzitet u Beogradu. Beograd. 266 str.

Zdunkowski, W. and A. Bott, 2003: Dynamics of the atmosphere – A course in theoretical meteorology. Cambridge University Press, Cambridge. 719 pp.
ADDITIONAL LITERATURE: Haltiner, G.J., 1971: Numerical weather prediction. John Wiley & Sons, New York, 317 pp. Houghton, D.D, 1985: Handbook of applied meteorology. John Wiley & Sons, New York, 1461 pp. Petterssen, S., 1956: Weather analysis and forecasting (Vol. I and II). McGraw- Hill, New York, 428 (266) pp. Richardson, L.F., 1922: Weather prediction by numerical process. Cambridge University Press, London, 236 pp. Riley, M.P., Hobson, M.P. and S.J. Bence, 1998: Mathematical methods for physics and enginering. Cambridge University Press, Cambridge, 1008 pp. Zverev, A.S., 1977: Sinoptičeskaja meteorologia. Gidrometeoizdat, Leningrad, 710 pp.

COURSE: **Climatology III**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Zoran Pasarić, PhD**	**2**
Exercises	**Professor Zoran Pasarić, PhD**	**2**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES:

To familiarize student with climatological data, to make him able to analyze climatological time series and interpret the results.

COURSE CONTENT:

Sources of climatological data. Climatological bulletins and atlases. Climatological data on Internet. Nature of climatological series: random and non-random part. Annual cycle, ways of computation and properties. Trend and long-term oscillations. Calculation of climatological normals for real data. Stationary stochastic processes, ergodicity, estimation of the autocorrelation function. Pseudo-random numbers. White noise, general linear process, AR(1), AR(2) processes, higher-order models. Fitting the model to measured data. Simulations of climatological time series.

Exercises comprise the processing and analysis of real time series. This includes writing programs (in Matlab) for analysis and simulation of time series, as well as interpreting the results.

LEARNING OUTCOMES:

It is expected that after completion of this course, the students be able to:

- list and describe the sources of climate data,
- to explain the nature of climatological time series and identify various time scales,
- calculate annual cycle and trend,
- define and explain the notion of stochastic process and stationarity,
- define white noise and general linear process,
- define models of autoregression and moving average and interpret their properties in climatological context,
- fit theoretical stochastic model to real time series and interpret the obtained results.

LEARNING MODE: Attending lectures, study of literature and lecture notes, programing, analysis of examples, solving of assigned problems by using computer, doing homework.
TEACHING METHODS: Presentation, discussion, problem solving by using computer.
METHODS OF MONITORING AND VERIFICATION: Project assignment (writing a computer program and analyzing real data), oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Regular attendance to lectures and exercises. Submitted homework.
EXAMINATION METHODS: Oral exam.
PREVIOUS OBLIGATORY COURSES: Climatology I, Climatology II (completed)
COMPULSORY LITERATURE: Wilks, D.S.: Statistical Methods in the Atmospheric Sciences, Academic Press, New York, 1995.
ADDITIONAL LITERATURE: Box G.E.P., G.M. Jenkins: Time Series Analysis: Forecasting and Control, Holden Day, San Francisco, 1970. Thompson, R.D., A. Perry: Applied Climatology, Routledge, London, 1997.

COURSE: **Seminar in Seismology**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd & 4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures		**0**
Exercises		**0**
Seminars	**Professor Marijan Herak, PhD**	**1**
ECTS CREDITS: **2+2**		

COURSE OBJECTIVES**:**

An overview of recent papers dealing with selected chapters of seismology is presented by students to their peers (one presentation per student per semester).

COURSE CONTENT:

An overview of recent papers dealing with selected chapters of seismology is presented by students to their peers (one presentation per student per semester).

LEARNING OUTCOMES:

After completing the course of the Seminar in Seismology students will:

- Better read and understand research papers;
- Improve their skills in presenting the research;
- Improve their discussion skills;
- Be able to defend and argue for the research conclusions.

LEARNING MODE:

Studying papers and other literature, presenting research, listening to presentations, participation in discussions.

TEACHING METHODS:

Students' presentations, discussion, moderation of discussions.

METHODS OF MONITORING AND VERIFICATION:

Regular attendance to the lectures.

TERMS FOR RECEIVING THE SIGNATURE:

Held presentation.

EXAMINATION METHODS:

Oral presentation.

PREVIOUS OBLIGATORY COURSES: Seismology III, IV (completed)
COMPULSORY LITERATURE: Recent seismological research papers, internet pages, etc. Numerous web pages.

COURSE: **Geophysical Seminar**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd & 4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures		**0**
Exercises		**0**
Seminars	**Assoc Prof Maja Telišman Prtenjak, PhD**	**1**
ECTS CREDITS: **2+1**		

COURSE OBJECTIVES**:**

The course prepares students for the preparation and presentation of research or scientific topics in the field of geophysics.

COURSE CONTENT:

Course provides an opportunity for students to learn about recent research in geophysics both in Croatia and in the world.

LEARNING OUTCOMES:

Students will be able to:

- learn how to prepare a presentation,
- show the results of measurements or models,
- organize public presentation.

LEARNING MODE:

Listening to presentations.

TEACHING METHODS:

Presentation, discussion.

METHODS OF MONITORING AND VERIFICATION:

Regular attendance to the lectures.

TERMS FOR RECEIVING THE SIGNATURE:

Regular attendance (at least 80%) to the lectures.

EXAMINATION METHODS:

There is no exam.

COURSE: **Aeronomy**		
YEAR OF STUDY: **II**		
SEMESTER: **4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Assoc Prof Giuliana Verbanac, PhD**	**2**
Exercises	**Assoc Prof Giuliana Verbanac, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

Introduce students with physical properties of plasma, plasma behavior within ionosphere and magnetosphere, and processes in the Sun and interplanetary space that lead to change of these properties. For this purpose, it is necessary to:
- describe the motion of charged particles in the gravitational, magnetic and electrical field,
- explain the collision processes in the ionospheric layers and other areas of the magnetosphere,
- define the magnetospheric currents,
- explain Solar-Terrestrial interaction
- explain Space Weather
- detailed the physical processes that generate planetary magnetic fields (planetary aeronomy).

COURSE CONTENT:

Physical characteristics of plasma. Motions of charged particles in gravitational, magnetic, and electrical field. Distribution of atmosphere and method of investigation. Formation of particular areas of high atmosphere. Formation of ionosphere. Atomic and molecular processes in individual ionosphere layers and in thermosphere; ionization and phodissociations. Propagation of radio waves. Colisonal processes in ionosphere and magnetosphere. Electrodynamics of ionosphere and thermosphere. Global changes in ionosphere and thermosphere. Airglow. Thermodynamics of ionosphere and thermosphere. Aeronomy of the planet.

LEARNING OUTCOMES:

After passing the exam, it is expected that the student will be able to:
1. explain the particle motion in the gravitational, magnetic and electric fields;
2. classify the collision processes in the ionosphere and the magnetosphere;
3. define and distinguish different currents within the magnetosphere;

4. characterize solar activity;
5. explain the interplanetary magnetic field,
6. identify the characteristics of the interplanetary magnetic field that lead to significant geomagnetic activity;
7. interpret the changes in the ionosphere and the magnetosphere caused by the physical characteristics of the interplanetary space;
8. apply the acquired knowledge for understanding the basis of the magnetic field other planets of the Solar System;
9. prepare and maintain professional presentations, and discuss the presented themes.

LEARNING MODE:

Presentations, individual and group discussions, assignment of independent and team tasks, use of web pages, example analysis.

TEACHING METHODS:

Lectures, individual and group tasks and discussions, discussion of examples, preparation of seminars.

METHODS OF MONITORING AND VERIFICATION:

Attending lectures. Written and oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Attendance in teaching 70%.

EXAMINATION METHODS:

Writing (the students may not have to attend writing part of the exam if they successfully complete all mid-term exams) and oral examinations.

COMPULSORY LITERATURE:

Proelss, G.:Physics of the Earth's Space Environment, Springer-Verlag Berlin Heidelberg New York, 2004.
Bertotti, B.,Farinela,P., Vokrouhlicky,D.:Physics of the Solar System, Kluwer Academic Publishers, Netherlands, 2003.
Banks, PM, Kocharts, G.: Aeronomy, Academic Press, London, 1980.
Vršnak, B.: Temelji fizike plazme, Školska knjiga, Zagreb, 1996.

COURSE: **Seismotectonics**		
YEAR OF STUDY: **II**		
SEMESTER: **4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Bruno Tomljenović, PhD**	**2**
Exercises	**Professor Bruno Tomljenović, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES:

To learn about recent tectonic activity, classification of structures and faults within seismo-tectonic activity. Use of knowledge in engineering (construction of large scale buildings, bridges, tunnels, hydro and power plants) and spatial planning.

COURSE CONTENT:

Research methods. Regional tectonic movements. Classification of structures and faults. Types of structures (examples). Relation between stress and deformation of structures. Seismogene structures. Underthrusting, reverse, normal, transform and transcurrent displacement. Seismotectonic active faults. Structural relations in space, marker horizons. Earthquakes and zones of occurrence. Tectonical causes of earthquakes. Energetic, spatial and temporal characteristics of earthquakes. Epicentral areas. Seismic sources. Effects of seismic forces at the surface. Non-seismic evolvement.

LEARNING OUTCOMES:

After successful completion of the course, student would be able:

1) To describe the basics of seismotectonics along the major plate boundaries, in active orogenic belts and in plate interior
2) To describe the basics of seismotectonics along the Adriatic plate boundary and in the Pannonian basin of Croatia
3) To conduct a seismotectonic analysis of selected area by synthesis of geophysical, geological and seismological data
4) To recognize potential seismogenic structures based on seismotectonic analysis of surface and subsurface, with definition of their arrangement, orientation and kinematic characteristics
5) To write a report on seismotectonic analysis of selected area.

LEARNING MODE:

Regular class attendance.

TEACHING METHODS: Lectures, exercises, practical work, oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Attending lectures 70%, correctly designed and submitted programs.
EXAMINATION METHODS: Oral exam.
COMPULSORY LITERATURE: Uyeda, S. (1979): The New View of the Earth. Freeman and Co. New York. Moores, M. E. & Twiss, J. T. (1999): Tectonics. Freeman and Co., New York. Balt, B. A. (1999): Earthquakes. Freeman and Co., New York. Keller, E. & R Pinter, N. (2002): Active Tectonics, Earthquakes, Uplifts and Landscape. Prentiuc Will New York. RGN university and Department of Geiphysics PMF (1990): Seismotectonic map of Croatia.

COURSE: **Meteorological Practicum**		
YEAR OF STUDY: **II**		
SEMESTER: **4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Nataša Strelec Mahović, PhD** **Professor Branko Grisogono, PhD**	**1**
Exercises	**Asst Prof Nataša Strelec Mahović, PhD**	**2**
Seminars		**0**
ECTS CREDITS: **3**		

COURSE OBJECTIVES:

Primary goal is to gain competencies in applying theoretical dynamic meteorology concepts in the analysis of the current state of the atmosphere and the forecast of the future processes. During lectures and practical exercises the students will be taught about different procedures of meteorological measurements and observations, visualization of the observations using meteorological symbols and practical use of different measurement and observation data in the analysis of the current state of the atmosphere. The students will be familiarized with numerical weather prediction models and taught how to use the model results in practical short and medium range forecasting.

COURSE CONTENT:

Meteorological symbols, measurements and observations. The use of remote sensing. Initial and boundary conditions for numerical prediction models; initialization. Some numerical model schemes and errors. Atmospheric predictability and prognostic models. Practical aspects of mountain, coastal and urban meteorology. Elements of short- and medium-range forecasting.

LEARNING OUTCOMES:

It is expected that after the completion of this course the students will be able to:

1. Describe the principles of meteorological measurements and observations,
2. Measure and observe basic meteorological parameters,
3. Read and draw meteorological symbols,
4. Analyze surface and upper-level measurement data,
5. Explain remote sensing methods and principles,
6. Interpret and practically apply different satellite data and products,
7. Explain and apply radar data,
8. Analyze the current state of the atmosphere using all available data types,
9. Describe the principles, limitations and possible errors of NWP models,

10. Demonstrate practical short and medium range weather forecast on real-time data and NWP model results.

LEARNING MODE:

Studying literature, listening to presentations, solving homework, discussion of the results of homework tasks, practical work.

TEACHING METHODS:

Lectures, exercises, referring students to independently study the literature, individual presentations, individual solving of problem tasks.

METHODS OF MONITORING AND VERIFICATION:

Students are required to regularly attend classes and do their homework. Additionally, it is necessary to monitor and discus the current synoptic situation.
The work of the students is monitored and evaluated during the course (completion of homework assignments and additional assignments) and at the final written exam.

TERMS FOR RECEIVING THE SIGNATURE:

Successfully solved all the homework during the semester, measurements and observations at meteorological station Horvatovac, presentation and interpretation of the data.

EXAMINATION METHODS:

The written exam consists of questions that require a short answer and problem solving.

COMPULSORY LITERATURE:

Stull, R., 2015: Practical Meteorology: An Algebra-based Survey of Atmospheric Science. Univ. of British Columbia. 938 pages. isbn 978-0-88865-176-1

poglavlja:
Atmospheric Stability :
https://www.eoas.ubc.ca/books/Practical_Meteorology/prmet/Ch05-Stab.pdf Satellites and Radar:
https://www.eoas.ubc.ca/books/Practical_Meteorology/prmet/Ch08-Satellite_Radar.pdf Weather reports and Map analysis:
https://www.eoas.ubc.ca/books/Practical_Meteorology/prmet/Ch09-WxMaps.pdf
Numerical Weather Prediction (NWP):
https://www.eoas.ubc.ca/books/Practical_Meteorology/prmet/Ch20-NWP.pdf
Daley, R., 1991: Atmospheric data analysis.Cambridge University Press, Cambridge, 457 pp. Haltiner, G.J. and R.T. Williams, 1980: Numerical weather prediction. John Wiley & Sons, New York, 477 pp.
Kurz, M., 1998: Synoptic meteorology. Deutscher Wetterdienst, Offenbach, 200 pp.
http://www.eumetrain.org – SATMANU, Synoptic Textbook...
https://www.meted.ucar.edu/

COURSE: **Seminar in Dynamic Meteorology**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd & 4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures		**0**
Exercises		**0**
Seminars	**Professor Branko Grisogono, PhD**	**1**
ECTS CREDITS: **3+2**		

COURSE OBJECTIVES:

Deepening knowledge of the midlatitude large scale dynamics. Expanding knowledge of mesoscale and microscale dynamics and turbulence. The focus is on the student's choice of the problem. The aim is to focus students on the selection of the high quality research topic in the field of dynamic meteorology. Students are prepared for the public presentation of scientific hypotheses, methods and results analysis.

COURSE CONTENT:

Structures of midlatitude large-scale perturbations. Mesoscale cyclones. Buoyancy waves. Atmospheric boundary layer. Turbulence kinetic energy prediction. Spectral description of turbulence. Transport and diffusion in the atmosphere.

LEARNING OUTCOMES:

It is expected that after the completion of this course, the students may:

- Critically analyze and compare methods and results of the scientific work done by scientists.

LEARNING MODE:

Attendance of seminars given by others, critical studying of the literature, participating in discussions.

TEACHING METHODS:

Referring students to independently study the literature, individual presentation (seminar), consultative sessions.

METHODS OF MONITORING AND VERIFICATION:

Regularly and actively participate in the seminar. Presentation of their own essay on a selected topic.

TERMS FOR RECEIVING THE SIGNATURE:

Individual presentation (seminar).
EXAMINATION METHODS: No exam.
PREVIOUS OBLIGATORY COURSES: Dynamic Meteorology III, Climatology I (completed)
COMPULSORY LITERATURE: Holton, J. R., 2004: An introduction to dynamic meteorology. Elsevier Academic Press, Amsterdam, 535 str. Stull, R.B.: An Introduction to Boundary Layer Meteorology, Kluwer, Dordrecht, 1988 Numerous web sites and ECMWF courses.

COURSE: **Seminar in Climatology**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd & 4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures		**0**
Exercises		**0**
Seminars	**Assoc Prof Ivana Herceg Bulić, PhD**	**1**
ECTS CREDITS: **3+2**		

COURSE OBJECTIVES:

The course prepares students for research in the field of climatology, for preparation and presentation of research results.

COURSE CONTENT:

Student is required to study on his/her own a given topic from climatology. Topics are taken from scientific papers as well as from monographs. One problem per semester should be analyzed and presented, giving the motivation, results and conclusions. During discussions with teacher and other participants the knowledge acquired previously is deepened.

LEARNING OUTCOMES:

Students will be able to:

1. autonomously design, conduct and evaluate a small original research project using appropriate scientific methods and analytical methodologies
2. organize and give a public presentation.

LEARNING MODE:

Listening sessions.

TEACHING METHODS:

Presentation, discussion.

METHODS OF MONITORING AND VERIFICATION:

Attending of lectures, writing reports and oral presentation of two seminars.

TERMS FOR RECEIVING THE SIGNATURE:

Regular attendance to the lectures (at least 80%), writing and oral presentation of two seminars.

EXAMINATION METHODS:

No exam.

PREVIOUS OBLIGATORY COURSES: Climatology I, Climatology II (completed)
COMPULSORY LITERATURE: Relevant scientific journals, monographs and sources from Internet.

COURSE: **Seminar in in Weather Analysis and Forecasting**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd & 4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures		**0**
Exercises		**0**
Seminars	**Asst Prof Željko Večenaj, PhD**	**1**
ECTS CREDITS: **3+2**		

COURSE OBJECTIVES:

Expanding the knowledge about the dynamics of the atmosphere on large scales in mid-latitude. The aim is to motivate the students to select an advanced research topic in the field of weather analysis and forecasting. Students prepare for the public presentation of scientific hypotheses, methods and results of the analysis.

COURSE CONTENT:

The teacher recommends to the students a topic for the seminar paper related to the weather analysis and provides appropriate literature. The topic should be related with operational meteorology as it is possible. The topics related with Croatian territory have some priorities (e.g. Mediterranean cyclones) or the topics devoted to special applications e.g. in aeronautical and marine meteorology.

LEARNING OUTCOMES:

It is expected that after completion of this course, the students should know how to:
- Critically analyze and compare methods and results of scientific work obtained by different authors.

LEARNING MODE:

Attending weekly seminars, critical studying of the literature, participate in the discussions.

TEACHING METHODS:

Independent exploration of the literature, consultations with the teacher.

METHODS OF MONITORING AND VERIFICATION:

Students are obligatory to attend weekly seminars.
Active engagement during the course. Oral presentation of the seminar work on selected topic.

TERMS FOR RECEIVING THE SIGNATURE:

Preparation and oral presentation of the seminar work on selected topic.
EXAMINATION METHODS: No exam.
PREVIOUS OBLIGATORY COURSES: Dynamic Meteorology III, Climatology II (completed)
COMPULSORY LITERATURE: Bluestein, H.B., 1992: Sinoptic-dynamic meteorology in midlatitudes, (Vol. I). Oxford University Press, New York, 431 pp. Bluestein, H.B., 1993: Sinoptic-dynamic meteorology in midlatitudes, (Vol. II). Oxford University Press, New York, 431 pp. Daley, R., 1991: Atmospheric data analysis.Cambridge University Press, Cambridge, 457 pp. Haltiner, G.J. and R.T. Williams, 1980: Numerical weather prediction. John Wiley & Sons, New York, 477 pp. Kalney, E., 2003: Atmospheric modeling, data assimilation and predictability. Cambridge University Press, Cambridge, 341 pp. Mesinger, F. and A. Arakawa, 1976: Numerical models in atmospheric models. Volume I. GARP Publication Series No. 17, WMO, Geneve, 135 pp. Pandžić, K., 2002: Analiza meteoroloških polja i sustava. HINUS, Zagreb, 314 pp. Pielke R.A. and R.P. Pearce, 1994: Mesoscale modeling of the atmosphere. American Meteorological Society, Boston, 167 pp. Radinović, Đ., 1979: Prognoza vremena. Univerzitet u Beogradu. Beograd, 266 str. Zdunkowski, W. and A. Bott, 2003: Dynamics of the atmosphere – A course in theoretical meteorology. Cambridge University Press, Cambridge, 719 pp. Atlas, D., 1990: Radar in meteorology. American Meteorological Society, Boston, 806 pp. Blumen, 1990: Atmospheric processes over complex terrain. American Meteorological Society, Boston, 323 pp. Carlson, T.N., 1994: Mid-latitude weather systems. American Meteorological Society, Boston, 507 pp. Kurz, M., 1998: Synoptic meteorology. Deutscher Wetterdienst, Offenbach, 200 pp. Palmen, E. and C.W. Newton, 1969: Atmospheric circulation systems – Their structure and physical interpretation. Academic Press, New York, 603 pp. Petterssen, S., 1956: Weather analysis and forecasting (Vol. I and II). McGraw-Hill, New York, 428 (266) pp. Radinović, Đ., 1969: Analiza vremena. Univerzitet u Beogradu, Beograd, 367 str. Richardson, L.F., 1922: Weather prediction by numerical process. Cambridge Unuversity Press, London, 236 pp. Saucier, W.J., 1955: Principles of meteorological analysis. The University of Chicago Press, Chicago, 438 pp. Schott, J.R. 1997: Remote sensing – the image chain approach. Oxford University Press, Oxford. 394 pp. Zverev, A.S., 1977: Sinoptičeskaja meteorologia. Gidrometeoizdat, Leningrad, 710 pp.

COURSE: **Seminar in Physical Oceanography**		
YEAR OF STUDY: **II**		
SEMESTER: **3rd & 4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures		**0**
Exercises		**0**
Seminars	**Professor Mirko Orlić, PhD**	**1**
ECTS CREDITS: **3+2**		

COURSE OBJECTIVES:

The course prepares students to follow the scientific literature, to present results of investigation in written form, and to present results of investigation in oral form.

COURSE CONTENT:

After an introductory lecture each student considers two physical oceanographic topics. The topics are selected from the papers recently published in scientific journals or from the monographs. Results of his/her study the student describes in writing and orally, paying attention to development of the problem, results of data analysis and/or mathematical modeling and main conclusions. Discussion with the teacher and other students enables the student to deepen the knowledge gained while attending the lectures and exercises during the previous years of study.

LEARNING OUTCOMES:

Students will be able to
1. identify scientific texts that are needed to perform the investigation,
2. analyze the selected scientific texts,
3. present results of scientific work in written form, and
4. present results of scientific work in oral form.

LEARNING MODE:

Study of the selected scientific texts, writing of seminar essays, and oral presentation of the essays.

TEACHING METHODS:

Presentation and discussion, commenting on the seminar essays, and discussion of the oral presentations.

METHODS OF MONITORING AND VERIFICATION:

Attending the seminars, writing and presenting two seminar essays.

TERMS FOR RECEIVING THE SIGNATURE: Preparation of two seminar papers and presentation of two seminar lectures.
EXAMINATION METHODS: No exam.
PREVIOUS OBLIGATORY COURSES: Dynamics of Coastal Sea (completed)
COMPULSORY LITERATURE: Papers recently published in scientific journals. Monographs.

COURSE: **Fundamentals of Geophysical Exploration II** ***(optional)***		
YEAR OF STUDY: **II**		
SEMESTER: **3rd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Professor Franjo Šumanovac, PhD**	**2**
Exercises	**Josipa Kapuralić, mag. ing. geol.**	**2**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

Introduction to the methods of geophysical research and their application in defining the geological structure and composition of terrain: in exploration of hydrocarbons and solid mineral resources, in geotechnical researches, groundwater and environmental studies.

COURSE CONTENT:

Lectures :
Seismic research – Introduction. Seismic wave spreading. Time-distance graph for a layered medium. Instruments and equipment: seismic sources, seismometers seismographs. Seismic Refraction: measuring and data processing, interpretation methods, difficulties in interpretation, application of refraction methods.
Seismic reflection: seismic velocity measuring, data processing, static, NMO, and residual corrections, velocity analysis. Interpretation of seismic profiles, migration Application of seismic reflection methods.
Geophysical research in boreholes – introduction to logging methods, electrical properties of rocks and formation factor. Distribution of liquids and resistivity in permeable layer. Self-potential (SP) logging. Resistivity logging: normal and lateral logs, focused current logs, microlog, induction log. Sonic logging, other logging methods: temperature logging, caliper logging, dipmeter logging.
Exercises:
Introduction. Defining 4 exercises. Explanations related to preliminary exams and field work.
Geoelectrical profiling - Introduction. Calculation of resistivity on profiles. Interpretation of lateral resistivity changes.
Seismic Refraction – Introduction. First arrivals on seismograms. Calculation of average 3 velocity for each layer, calculation of layers depths and inclination.v
Seismic reflection – Introduction. Estimating velocoties from first arrivals and selected reflexes. Diagram of seismic velocites. Calculation of NMO correction. Interpretation of

seismic reflection profile.
Resistivity logging - measuring normal and lateral logs in the borehole model. Working in teams. Measuring normal and lateral logs in the borehole model. Working in teams. Measuring normal and lateral logs in the borehole model. Working in teams. Measuring normal and lateral logs in the borehole model. Working in teams. Measuring normal and lateral logs in the borehole model. Working in teams. Calculating resistivity for borehole model. Interpretation of resistivity curve. Determination of layer boundaries and depths in model.
Field work – Measuring using seismic refraction and reflection methods. Geological and geophysical interpretation.

LEARNING OUTCOMES:

1. To understand creation and spreading of seismic waves, to interpret seismic profile using seismic refraction method,
2. to understand the application of static and NMO corrections,
3. to interpret seismic profile using seismic reflection method,
4. to understand the operation of a seismometer and seismograph,
5. to understand the logging methods in borehole geophysical explorations,
6. to interpret resistivity distribution diagram on the borehole model.

TEACHING METHODS:

Lectures, exercises, practical and field work.

METHODS OF MONITORING AND VERIFICATION:

Regular attendance of lectures, practical work, preliminary exams, oral exams.

TERMS FOR RECEIVING THE SIGNATURE:

Class attendance (lectures, exercises and field work), handed solved exercises, passed at least one preliminary exam.

EXAMINATION METHODS:

Passed preliminary exams or oral exam (80%), solved exercises (20%).

PREVIOUS OBLIGATORY COURSES:

Fundamentals of Geophysical Exploration I (completed)

LITERATURE:

Šumanovac, F. (2012): Osnove geofizičkih istraživanja, Sveučilište u Zagrebu.
Griffits, D.H. & King, R.F. (1981): Applied Geophysics for Engineers and Geologists, Pergamon Press, Oxford.
Parasnis, D.S. (1986): Principles of Applied Geophysics, Chapman and Hall, New York.

COURSE: **Selected Topics in Climatology** ***(optional)***

YEAR OF STUDY: **II**

SEMESTER: **3rd**

TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Assoc Prof Ivana Herceg Bulić, PhD**	**2**
Exercises	**Assoc Prof Ivana Herceg Bulić, PhD**	**1**
Seminars		**0**

ECTS CREDITS: **4**

COURSE OBJECTIVES**:**

Examination of selected topics in climatology. The course offers detailed discussion and insight into the concept of climate and climate-human interactions. The course also provides the fundamentals of climate modelling and enables gaining of the experience in running climate models, data visualization and explanation.

COURSE CONTENT:

The course consists of several offered thematic modules. Each module contains the recent accomplishment in climatology and climate modelling and links them to the existing knowledge and skills of students. The modules topics deal with following areas: statistical techniques used in climate studies (review of basic statistics, composite analysis, linear regression, time series analysis...);
dynamics, physical mechanisms, and impacts of natural climate variability phenomena; tropical forcing and teleconnections; the interaction between the atmosphere and slower components of the climate system; the physical and feedback mechanisms involved in global climate change; climate modelling and the hierarchy of climate models; natural climate variability and modelling; anthropogenic climate change, climate scenarios and climate projections; analysis and comparison of observed and simulated climate variables. The contents of modules are changeable following the newest achievements in the field.

LEARNING OUTCOMES:

Students will have the knowledge and skills to:

1. Understand and apply the principles of statistical techniques used in climate studies, apply statistical methods on large amount of data to extract and interpret climatological information.
2. Recognise, understand and explain primary physical mechanisms of the climate variability phenomena (oscillations, teleconnection patterns, patterns and indices of climate variability).

3. Understand and explain basics and the mechanisms of interaction between climate system components (land-ocean-atmosphere interactions) and feedback processes.
4. Identify observed global climate change signals (e.g. CO2, temperature trends, Arctic sea ice extent, etc.), explain certain physical mechanisms for global climate change, and articulate the uncertainties associated with global climate change forecasts and outcomes (e.g. observation errors and predicted future states of the atmosphere/ocean system).
5. Understand the fundamentals of climate modelling, acquiring experience in running climate models with a purpose of climate research.

LEARNING MODE:

Listening, sessions, independent study, case study, derivation of equations and problem solving, exercises.

TEACHING METHODS:

Lectures, exercises, practical work.

METHODS OF MONITORING AND VERIFICATION:

Homework, active participation in discussions during lectures and in particular during seminars, seminar (oral presentation by the student), seminar essay, oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Regular attendance to the lectures (at least 70 %), accomplished project, project essay and presentation.

EXAMINATION METHODS:

Oral exam.

LITERATURE:

Marshall, J., R. A. Plumb: Atmosphere, Ocean, and Climate Dynamics: An Introductory Text. Elsevier, Amsterdam, 2008.
Cook, K. H.: Climate dynamics, Princeton, Princeton University Press, 2013.
H. von Storch, A. Navarra: Analysis of climate variability: applications of statistical techniques, Springer, Berlin, Heidelberg, New York, 1999.
Stocker T.F., D. Qin, G.-K. Plattner, M. M.B. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, P. M. Midgley (eds.): Climate change 2013: the physical science basis, Cambridge University Press, Cambridge, 2014.
Lionello, P. (ed.): The climate of the Mediterranean region: from the past to the future, Elsevier, Amsterdam; Boston; Heidelberg, 2012.

COURSE: **Hydrology I** ***(optional)***		
YEAR OF STUDY: **II**		
SEMESTER: **3rd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Krešimir Pavlić, PhD**	**2**
Exercises	**Asst Prof Krešimir Pavlić, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

Students will become acquainted with basic hydrological and hydraulic characteristics of runoff from the basin. It is the aim of the course to train students to do hydrological calculations.

COURSE CONTENT:

Definition of hydrology and its connection with other sciences. Hydrological cycle. History, development, tasks and applicatin of hydrology. Estimated amounts of water on the Earth. Mean annual precipitation on a basin. PDF and IDF curves and their application in hydrology. Evaporation from water surface and evapotranspiration. Infiltration and humidity in the ground.
Hydraulics of open channels: application of Bernouly equation for ideal and real liquid, uniform flow, Chezy formula, Manning-Strickler formula, measuring equipment, spillways, ununiform flow. Filtration: Darcy's law, Dupuit's theory.

LEARNING OUTCOMES:

It is expected that after completion of the course students should know:

1. explain the historical development, application and significance of hydrology and its links with geophysics,
2. make a subjective and an objective analysis of the amount of water on Earth,
3. explain the terms evapotranspiration and infiltration,
4. know the basics of hydraulics of open streams, Darcy's law and Dupuit's assumption.

LEARNING MODE:

Attendance of lectures.

TEACHING METHODS:

Lectures, exercises.

METHODS OF MONITORING AND VERIFICATION: Colloquium, oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Regular attendance of lectures.
EXAMINATION METHODS: Oral exam.
LITERATURE: Žugaj, R.: HIDROLOGIJA textbook, Sveučilište u Zagrebu, Rudarsko-geološko-naftni fakultet, Zagreb, 2000.

COURSE: **Physical Meteorology I *(optional)***		
YEAR OF STUDY: **II**		
SEMESTER: **3rd**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Antun Marki, PhD**	**2**
Exercises	**Antun Marki, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		
COURSE OBJECTIVES**:** An introduction to processes of radiation, absorption, reflection and diffusion in the system Earth-atmosphere will be given.		
COURSE CONTENT: Sun and Earth radiation processes. Solar radiation extinction in the atmosphere. Measurement and estimation of direct, diffuse and global solar radiation. Radiation modelling.		
LEARNING OUTCOMES: After completion of the course the students will be able to: 1. Explain and derive the laws of radiation 2. Explain the processes of solar radiation attenuation in the atmosphere 3. Apply and compare methods for calculation and estimation of solar radiation components 4. Describe and apply deterministic and stochastic models of radiation.		
LEARNING MODE: Listening lectures, studying notes and available literature, case study and solving problems through exercises.		
TEACHING METHODS: Presentation with discussion, independently solving of tasks with real data, directing student on independent study of literature and seminar work presentation.		
METHODS OF MONITORING AND VERIFICATION: Colloquiums, written and oral exam.		
TERMS FOR RECEIVING THE SIGNATURE: Presented seminar.		

EXAMINATION METHODS: Written (students which successfully pass the colloquiums are released from written exam) and oral exam.
PREVIOUS OBLIGATORY COURSES: Climatology I (completed)
LITERATURE: Coulson, K.L.: Solar and Terrestrial Radiation, Academic Press, New York 1975. Selby M.L.: Fundamentals in Atmospheric Physics. Academic Press 1996.

COURSE: **Agrometeorology *(optional)***		
YEAR OF STUDY: **II**		
SEMESTER: **4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Assoc Prof Maja Telišman Prtenjak, PhD**	**2**
Exercises	**Assoc Prof Maja Telišman Prtenjak, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

The course prepares students (i) for understanding how atmosphere affects the biosphere, and (ii) for the development and understanding of the analysis and forecasts of agrometeorological processes at different scales of varying complexity.

COURSE CONTENT:

General impact of the atmosphere to the biosphere. Exchange of heat and energy in the biosphere. Relief and fitoclimate. Soil temperature. Temperature sums and heat stress. Dependency of plants' metabolism to the atmospheric conditions. Development phases of plants (phenology). Evapotranspiration and water balance components. Soil moisture. Drought indices. Vegetation fires and methods of their detection, prediction and warning. Numerical models in agrometeorology; analysis and forecast. Basics in agrometeorological modelling of crop yields. Climate change and plant life. Climate change and the potential hazard of vegetation fire.

LEARNING OUTCOMES:

Students will be able to:

1. explain the basic concepts in agrometeorology;
2. define main components of the atmosphere-biosphere interaction;
3. identify and discuss the limitations of methods and equations when calculating water balance components, drought indices, the index of vegetation fire, evapotranspiration, etc.;
4. properly apply the numerical model to the selected problem with the correct choice of model parameterization and other simplifications/options during numerical computation for the agrometeorological purpose;
5. explain the impact of climate change on plant life and the potential hazard of vegetation fire.

LEARNING MODE:

Attending classes.

TEACHING METHODS: Lectures, seminars, independent assignments.
METHODS OF MONITORING AND VERIFICATION: Finished project tasks and seminar papers, participation in teaching, written and oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Attending lectures and exercises, homework, seminars.
EXAMINATION METHODS: The final grade includes the points gained during the course through practical work and seminars and oral exam.
PREVIOUS OBLIGATORY COURSES: Dynamic Meteorology 3, 4 (completed)
LITERATURE: Penzar, I. & B. Penzar, 2000: Agrometeorologija, Školska knjiga, 222 str. Sivakumar, M.V.K., & J. Hansen, 2007:Climate Prediction and Agriculture, Advances and Challenges, Springer-Verlag Berlin Heidelberg, 306 str. Hudson I. L., Keatley,(ed.), 2010: Phenological Research: Methods for Environmental and Climate Change Analysis, Springer Dordrecht Heidelberg London New York, 518 str. Bertović, S., T. Dimitrov, I. Galović, V. Jurčec, D. Kiš. M. Knežević, A.-Ž.Lovrić, J. Martinović, I. Velić & J. Velić,1987: Osnove zaštite šuma od požara, Nakladno-novinska radna organizaija, Centar za informacije i publicitet, Zagreb, 340 str. Klečar, S., M. Kratohvil, R. Marotti, M. Paluh, N. Szabo, M. Vinković & M. Vučetić, 2010: Osnove gašenje požara raslinja, Mi Star d.o.o., Zagreb, 327 str. Bonan Gordon, 2016: Ecological climatology. Concepts and Applications. Third edition. Cambridge University Press, 692 str. Lalić Branislava, Eitzinger Josef, Dalla Marta Anna, Orlandini Simone, Firanj Sremec Ana, Pacher Bernhard, 2018: Agricultural Meteorology and Climatology. Firenze University Press. Firenze, Italy. 354 str.

COURSE: **Micrometeorology** ***(optional)***		
YEAR OF STUDY: **II**		
SEMESTER: **4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Željko Večenaj, PhD** **Professor Branko Grisogono**	**2**
Exercises	**Asst Prof Željko Večenaj, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

To enable students that, on the basis of familiarizing with the physical processes and, in particular, measurements of the bottom (surface) layer of the atmospheric boundary layer (ABL), they can define, calculate and explain the motion of the air and exchange of energy/matter in the ABL surface layer.

COURSE CONTENT:

On weekly basis:

(1) Introduction to micrometeorology.

(2) Vertical structure and diurnal cycles of the ABL. Characteristics of statically unstable, neutral and stable ABLs.

(3) Exchange of energy and matter in the surface layer of the ABL.

(4) Statistical description of turbulence.

(5) Equations for the turbulent motion.

(6) Forms of prognostic equations for turbulent kinetic energy, turbulent fluxes and concentration of the substance.

(7) Applications of Taylor's hypothesis on "frozen turbulence" and the similarity theory in the ABL surface layer.

(8) Prognostic equations and closure techniques.

(9) Basis of micrometeorological measurements: sampling rate, record length and data quality control.

(10) In situ measurement systems for turbulent flows: meteorological flux-tower and aircraft measurements.

(11) "Eddy covariance" method for measurement of turbulent fluxes.

(12) Measurements of turbulent flow over flat homogeneous terrain.

(13) Analysis of turbulence over flat homogeneous terrain.

(14) Measurements of turbulent flow over complex terrain.

(15) Analysis of turbulence over complex terrain.

LEARNING OUTCOMES: It is expected that students will be able to: (1) define physical processes relevant to the movement of air and/or exchange of energy/matter in the ABL surface layer, (2) mathematically formulate the above mentioned physical processes, (3) measure relevant variables/parameters that describe the current state and changes of physical processes, (4) calculate (quantify) physical processes and their changes based on measurements and mathematical formulations, (5) analyze spatial and temporal distributions of obtained values that describe the current state and changes of physical processes, and (6) explain what calculated and analyzed values mean for current and/or future physical state of the observed part of the ABL surface layer.
LEARNING MODE: Attending teaching of the theory and exercises, studying of the literature and notes, deriving equations and analysis of the examples, independently solving problems.
TEACHING METHODS: Theory, exercises, encouraging students to explore the literature by themselves, solving the problems independently.
METHODS OF MONITORING AND VERIFICATION: The progress of students is monitored and evaluated during the course (homework, oral presentations and other assignments) and on the final oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Homework reports; attending the classes at least for 50 %.
EXAMINATION METHODS: The final grade will be formed based on the following contributions: homework (30 %), written preparation of the final exam (30 %) and oral presentation/discussion of the final exam (40 %).
PREVIOUS OBLIGATORY COURSES: Dynamic Meteorology 4 (completed)
LITERATURE: Foken T (2008) Micro-meteorology. Springer-Verlag: Berlin Heidelberg. Kaimal JC, Finnigan JJ (1994) Atmospheric Boundary Layer Flows: Their Structure and Measurements. Oxford University Press: Oxford, UK. Arya SP (2001) Introduction to micrometeorology. Academic Press: San Diego. Bendat JS, Piersol AG (1986) Random Data: Analysis and Measurements Procedures. John Wiley & Sons: New York, NY. Stull RB (1988) An Introduction to Boundary Layer Meteorology. Kluwer Academic Publishers: Dordrecht, The Netherlands. Tennekes H, Lumley J (1972) A First Course in Turbulence. MIT Press: Cambridge, MA

COURSE: **Physical Meteorology II *(optional)***		
YEAR OF STUDY: **II**		
SEMESTER: **4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Antun Marki, PhD**	**2**
Exercises	**Antun Marki, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		
COURSE OBJECTIVES**:** An introduction in optical and acoustical atmospheric phenomena, the physics and modelling of cloud and precipitation formation and feasibilities of artificial influence on weather will be given.		
COURSE CONTENT: Optical and acoustic phenomena in the atmosphere. Physics of clouds and precipitation. Artificial weather modification. Radars and the radar equation. Cloud and precipitation formation modelling by numerical weather models.		
LEARNING OUTCOMES: After completion of the course the students will be able to: 1. Explain conditions and modes of genesis of optical and acoustic phenomena in the atmosphere; 2. Define processes of cloud and precipitation formation; 3. Explain the ways of artificial weather modification; 4. Describe radar and the radar equation and 5. Explain the principles of cloud and precipitation genesis in the numerical weather models.		
LEARNING MODE: Listening lectures and exercises, studying notes and available literature, deriving equations and solving problems through exercises.		
TEACHING METHODS: Presentation with discussion, independently solving of tasks with real data, directing student on independent study of literature and seminar work presentation.		
METHODS OF MONITORING AND VERIFICATION: Colloquiums, written and oral exam.		

TERMS FOR RECEIVING THE SIGNATURE: Presented seminar.
EXAMINATION METHODS: Written (students which successfully pass the colloquiums are released from written exam) and oral exam.
PREVIOUS OBLIGATORY COURSES: Dynamic Meteorology 3 (completed)
LITERATURE: Rogers R.R. & Yau, M.K.: A Short Course in Cloud Physics, Pergamon Press, 1989 (3rd ed.) Mason, B.J.: The Physics of Clouds. Clarendon Press, Oxford, 1971.

COURSE: **Hydrology II *(optional)***		
YEAR OF STUDY: **II**		
SEMESTER: **4th**		
TEACHING METHODS	LECTURER	CONTACT HRS PER WEEK
Lectures	**Asst Prof Krešimir Pavlić, PhD**	**2**
Exercises	**Asst Prof Krešimir Pavlić, PhD**	**1**
Seminars		**0**
ECTS CREDITS: **4**		

COURSE OBJECTIVES**:**

Students will become acquainted with basic hydrological properties of runoff from the basin. It is the aim of the course to train students to do hydrological calculations.

COURSE CONTENT:

Properties of hydrological occurrences, hydrological data, basin, runoff factors. Hydrometry: measurements of water level, velocity, water and sediment discharge. Stage hydrograph, discharge curve, hydrograph and its component parts, frequency curves and water level and discharge curves, runoff coefficient and specific discharge from a basin. Probability and statistics in hydrology. Linear and nonlinear correlation, double mass amounts. High waters: distribution curves, unit hydrograph, triangle-shaped hydrograph, isochrone method. Rational formula and other empirical formulas. Low waters of various return periods, periods of low water and of hydrological drought. Sedimentation in watercourses. General equation of hydrological balance. Regional hydrological analysis.

LEARNING OUTCOMES:

It is expected that after completion of the course students should know:

1. explain the features of hydrological phenomena,
2. be familiar with the most important aspects of hydrometry,
3. learn the application of probability and statistics in hydrology,
4. distinguish between large and small water and know their characteristics,
5. apply the regional hydrological analysis.

LEARNING MODE:

Attendance of lectures.

TEACHING METHODS:

Lectures, exercises, colloquium, oral exam.

METHODS OF MONITORING AND VERIFICATION: Regular attendance of lectures, colloquium, oral exam.
TERMS FOR RECEIVING THE SIGNATURE: Regular attendance of lectures.
EXAMINATION METHODS: Oral exam.
LITERATURE: Žugaj, R.: HIDROLOGIJA textbook, Sveučilište u Zagrebu, Rudarsko-geološko-naftni fakultet, Zagreb, 2000.

<table>
<tr><td colspan="3">COURSE: Field work 3 (10 hrs/year)</td></tr>
<tr><td colspan="3">YEAR OF STUDY: II</td></tr>
<tr><td colspan="3">SEMESTER: 4th</td></tr>
<tr><td>TEACHING METHODS</td><td>LECTURER</td><td>CONTACT HRS PER WEEK</td></tr>
<tr><td>Lectures</td><td>Antun Marki, PhD
Asst Prof Iva Dasović, PhD</td><td></td></tr>
<tr><td>Exercises</td><td>Antun Marki, PhD</td><td></td></tr>
<tr><td>Seminars</td><td></td><td></td></tr>
<tr><td colspan="3">ECTS CREDITS: 1</td></tr>
<tr><td colspan="3">COURSE OBJECTIVES:
1. Introduction to
a. problem of finding a suitable location for seismic station, installation and functioning of the station and instruments needed for quality operation,
b. problem of finding a suitable location for geomagnetic observatory, installation and functioning of the observatory and instruments needed for quality operation,
c. organisation of field work.
2. Association of previous curriculum in seismology and geomagnetism with practical fieldwork.
3. Adoption of knowledge and skills for successful application in future professional and/or scientific work.
4. Development of ability to choose and use relevant measuring methods and instruments for appropriate experiments or observations.</td></tr>
<tr><td colspan="3">COURSE CONTENT:
Seismology – seismic station
Getting to know the instruments at the seismic station location and local conditions. Identification of positive and negative impacts on the work of seismic stations. Getting acquainted with the characteristics of seismological observations and measurements.
Geomagnetism – geomagnetic observatory
Getting to know the instruments at the geomagnetic observatory location and local conditions. Identification of positive and negative impacts on the work of geomagnetic observatories. Getting acquainted with the characteristics of geomagnetic observations and measurements.</td></tr>
</table>

LEARNING OUTCOMES: After completion the course Field Work 3 the student should be able to: - understand theoretical knowledge adopted in previous courses in seismology and geomagnetism and apply it in practice, - describe and understand fundamentals of the instruments and measuring techniques at seismic stations and geomagnetic observatories, - be capable to prepare and organise field work as well as successfully implement it, - be independent in implementation of fieldwork, - to recognise the importance of teamwork.
LEARNING MODE: Practical exercises.
TEACHING METHODS: Field work.
METHODS OF MONITORING AND VERIFICATION: Fieldwork diary
TERMS FOR RECEIVING THE SIGNATURE: Students are obliged to attend all forms of teaching and to write fieldwork diary that they have to present to the teacher at the end of the course.
EXAMINATION METHODS: After the duties are duly completed, the students receive a signature without rating.
LITERATURE: Campbell, W.H.: Introduction to Geomagnetic Fields, Cambridge Univ. Press, Cambridge, 2003. Jankowski, J., Sucksdorff, C.: Guide for magnetic measurementss and observatory practice, International Association of Geomagnetism and Aeronomy, 1996. Bormann, P. (Ur.): New Manual of Seismological Observatory Practice (NMSOP-2), IASPEI, GFZ German Research Centre for Geosciences, Potsdam, 2012. DOI: 10.2312/GFZ.NMSOP-2. http://nmsop.gfz-potsdam.de Stein, S., Wysession, M.: An introduction to seismology, earthquakes, and earth structure. Oxford, Blackwell Publishing, 2003. Havskov, J., Ottemöller, L.: Routine Data Processing in Earthquake Seismology, Springer, 2010.