

Official Postgraduate Programs



Master in Geophysics and Meteorology

Faculty of Physics

Universidad Complutense de Madrid

Short English version

Master in Geophysics and Meteorology

Layout

Common Main Formation			
Compulsory Lectures (30 ECTS)		Research or Professional Work (30 ECTS)	
Geomagnetism: External field (7.5c) Physical oceanography (7.5c) Atmospheric thermodynamics (7.5c) Atmospheric radiation (7.5c)			
2 BRANCHES (60 ECTS)			
Geophysics		Meteorology	
Basic Blocks	Specialized Blocks	Basic Blocks	Specialized Blocks
Seismic waves (7.5c) Seismology (7.5c)	Physics of seismic sources and seismotectonics (7.5c) Seismicity and seismic risk (7.5c)	Atmospheric dynamics (7.5c) Advanced atmospheric dynamics (7.5c) Numerical weather forecast (7.5c)	North Atlantic Climate variability (6c) Global climate change and paleoclimates (6c) Modelization and reconstruction of climate variability (6c)
Geophysical prospecting Electromagnetic methods (7.5c) Geophysical prospecting Seismic and gravity methods (7.5c)	Lithospheric structure and dynamics (7.5c) Geophysical Exploration and Topo-Astronomic Orientation of Archaeological Sites (7.5c)	Atmospheric physics (7.5c) Clouds physics (7.5c) Atmospheric diffusion (7.5c)	Micrometeorology and atmospheric pollution (6c) Remote sensing in Atmosphere (6c) Middle atmosphere dynamics (6c)
Gravimetry (7.5c) Earth interior and Tectonophysics (7.5c)	Magnetic fields of the Earth (7.5c) Paleomagnetism and rocks magnetism (7.5c)	Physics of Climate (7.5c)	Atmospheric and climate models (6c)

Brief description of the Lectures

Code:	090	Lecture:	Geomagnetism: External Field	
Speciality/Module		ECTS Credits		Type
Compulsory Subject		7.5		Compulsory
Lecture Hours		Practical Hours		Personal Work
30		15		142.5
Contents				
<p>Characteristics of the Upper Atmosphere. Plasma Physics. Charged particle motion in plasmas. Van Allen radiations belts. Ionosphere: formation, structure and properties. Electromagnetic waves transmission. Ionospheric dynamo. Solar-terrestrial interaction. Magnetosphere. Regular and irregular variations of the External field.</p>				
Bibliography				
<p>* Campbell, W.H., 1997, <i>Introduction to Geomagnetic Fields</i>, Cambridge Univ. Press. * Hargreaves, J.K., 1992, <i>The Solar-Terrestrial Environment</i>, Cambridge Univ. Press. * Herraiz, M. y B. A, de La Morena (Editores), 2000, <i>Tendencias actuales en la investigación de la Ionosfera</i>, Física de la Tierra nº 12, Universidad Complutense, Madrid * Jacobs, J.A. (Editor), 1991, <i>Geomagnetism</i>, (Tomos 3 y 4), Academic Press, New York.</p>				

Code:	091	Lecture:	Physical Oceanography
Speciality/Module		ECTS Credits	Type
Compulsory Subject		7.5	Compulsory
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Physics properties of sea and the distribution in a synoptic point of view. Basic sea dynamics study. Interaction Ocean-Atmosphere.			
Bibliography			
KNAUSS: "Introduction to Physical Oceanography". Prentice Hall STEWART: Introduction to Physical Oceanography. Texas A & M University. (http://oceanworld.tamu.edu/ocean410/ocng410_text_book.html)			

Code:	092	Lecture:	Atmospheric Radiation
Speciality/Module		ECTS Credits	Type
Compulsory Subject		7.5	Compulsory
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Solar radiation, atmospheric transmission and solar warming rate, infrared radiative transfer, infrared warming rate, radiative balance and climate models.			
Bibliography			
<p>KONDRATYEV K. Ya., "Radiation in the Atmosphere", Academic Press, 1969. LIOU K., "An Introduction to Theoretical Radiation", Academic Press, 1980. WALLACE J.M y P.V. HOBBS, "Atmospheric Science. An introductory survey", Academic Press, 1977. HOUGHTON J.T., "Física de Atmósferas Planetarias", Instituto Nacional de Meteorología, 1992. PEIXOTO J.P. y A.H. OORT, "Physics of Climate", American Institute of Physics, 1992.</p>			

Code:	093	Lecture:	Atmospheric Thermodynamics
Speciality/Module		ECTS Credits	Type
Compulsory Subject		7.5	Compulsory
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Stability criteria. Saturation and condensation processes in the atmosphere. Conditional Instability. Thermodynamic diagrams.			
Bibliography			
<ul style="list-style-type: none"> • Iribarne, J.V. and W.L. Godson: <i>Atmospheric Thermodynamics</i>. Reidel Publ. Co., Dordrecht , 259 pp. (1981) • Bohren, C. and B. Albrecht : <i>Atmospheric Thermodynamics</i>. Oxford University Press, 402 pp. (1998). • Curry, J.A. and P.J. Webster: <i>Thermodynamics of Atmospheres & Oceans</i>. Academic Press, 471 pp. (1999) • Morán, F.: <i>Apuntes de Termodinámica de la Atmósfera</i>. Inst. Nac. Meteorología, Madrid, 345 pp. (1984). • Wallace, J.M. and P.V. Hobbs : <i>Atmospheric Science : An Introductory Survey</i>. Academic Press, 483 pp. (2006) 			

Code:	094	Lecture:	Seismic Waves
Speciality/Module		ECTS Credits	Type
Geophysics		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Elastic medium: stress, strain and displacement. Navier equation: P and S body waves Refraction and reflection of body waves. Energy partition. Ray theory. Ray propagation in heterogenous médium in flat Earth. Generalization for Spheric Earth. Surfaces waves generation: Rayleigh and Love. Wave dispersion			
Bibliography			
T. Lay y T. Wallace. "Modern global seismology". Academic Press. 1995 A. Udias. "Principles of seismology". Cambridge University Press. 1999 K. Aki y P.G. Richards. "Quantitative seismology". W.H. Freeman 1980 K.E. Bullen y B.A. Bolt. "An introduction to the theory of seismology". Cambridge University Press. 1985			

Code:	095	Lecture:	Seismology
Speciality/Module		ECTS Credits	Type
Geophysics		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Travel times and structure of the Earth. Waves dispersion. Phase and group velocities. Focal parameters of earthquakes. Seismicity, seismotectonic and seismic risk. Seismic prevention and prediction. Instrumentation: seismograms and acelerograms			
Bibliography			
K.E. Bullen y B.A. Bolt. An introduction to the theory of Seismology. Cambridge University Press, 1985 T. Lay y T. Wallace. Modern global seismology. Academic Press, 1995 A. Udías. Principles of Seismology. Cambridge University Press, 1999			

Code:	096	Lecture:	Geophysical prospecting: Electromagnetic methods	
Speciality/Module		ECTS Credits		Type
Geophysics		7.5		Optional
Lecture Hours		Practical Hours		Personal Work
30		15		142.5
Contents				
Geophysical exploration: Electromagnetic methods. Electromagnetic theory. Electrical properties of rocks and minerals. Resistivity methods. Induced polarization. Methods employing natural electrical sources. Electromagnetics methods. Ground penetrating radar. Simple data processing techniques. Reports.				
Bibliography				
Orellana, E. Prospección geoelectrica en corriente continua. Paraninfo, 1982. Orellana, E. Prospección Eléctrica por campos variables. Paraninfo, 1974. Telford, W.M., Geldart, L.P., Sheriff, R.E., Applied Geophysics. Cambridge University Press, 1990. Revistas especializadas: Geophysics, Gophysical Prospecting,..				

Code:	097	Lecture:	Geophysical prospecting: Gravity and seismic methods		
Speciality/Module		ECTS Credits		Type	
Geophysics		7.5		Optional	
Lecture Hours		Practical Hours		Personal Work	
30		15		142.5	
Contents					
<p>Geophysical exploration: Gravity and seismic methods. Potential methods. Principles and elementary theory. Properties of rocks and minerals. Field operations. Anomalies. Regionals and residuals. Interpretation. Seismic methods. Seismic theory. Geometry of seismic wave paths. Characteristics of seismic events. Reflexion and refraction methods. Seismic velocity. Attenuation of noise. Data processing. Seismic interpretation. Report</p>					
Bibliography					
<p>Sheriff, R.E., Enciclopedia de exploración geofísica, SEG, 1984. Telford, W.M., Geldart, L.P., Sheriff, R.E., Applied Geophysics. Cambridge University Press, 1990. Revistas especializadas: Geophysics, Geophysical Prospecting,...</p>					

Code:	098	Lecture:	Gravimetry
Speciality/Module		ECTS Credits	Type
Geophysics		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Theory of Gravity Field. Absolute and relative gravity measurements. Gravity corrections. Surface gravity anomalies. Gravimetric methods. Isostasy. Fundamental of the Earth rotation. The Earth's tides. Tidal deformation of the Earth Crust.			
Bibliography			
<ul style="list-style-type: none"> - Heiskanen, W. y Moritz, H. Geodesia Física. Instituto Geográfico Nacional. 1985. - Torge, W. Gravimetry. Walter de Gruyter. Berlin, 1989. - Watts, A.B. Isostasy and flexure of the Lithosphere. Cambridge Univ. Press. Cambridge, 2001. 			

Code:	099	Lecture:	Internal Geophysics and Tectonophysics.	
Speciality/Module		ECTS Credits		Type
Geophysics		7.5		Optional
Lecture Hours		Practical Hours		Personal Work
30		15		142.5
Contents				
<p>Mechanical principles of continuous methods. Earth structure. Geochronology. Plate tectonics basic concepts. Plates kinematic. Finite rotations. Seismotectonic. Paleomagnetism and magnetic anomaly. Stress and strain in geophysics. Lithospheric flexion and elasticity. Geothermic flux. Rheology. Planetology compared.</p>				
Bibliography				
<ul style="list-style-type: none"> - Cox, A. y Hart, R.B. 1986. Plate Tectonics: How it works. Blackwell Scientific Publications. - Fowler, C.M.R. 1990. The Solid Earth. An introduction to Global Geophysics. Cambridge University Press. - Lowrie, W. Fundamentals of Geophysics. 1997. Cambridge University Press. - Turcotte, D.L. y Schubert, G. Geodynamics. 1982. John Wiley & Sons, Inc. New York. - Udías, A. y Mézcua, J. 1997. Fundamentos de Geofísica. Alianza Universidad Textos. 				

Code:	100	Lecture:	Atmospheric Dynamics
Speciality/Module		ECTS Credits	Type
Meteorology		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Basic forces in the atmosphere, motion equations, continuity and energy, basic flows, ageostrophic wind , thermal wind and advection, vorticity, and quasigeostrophic approach.			
Bibliography			
<p>HALTINER, G.J. y F.L.MARTIN: “Meteorología dinámica y física”, Ed. Instituto Nacional de Meteorología, 1990.</p> <p>HOLTON J.R. “Introducción a la meteorología dinámica”, Ed. Instituto Nacional de Meteorología, 1990.</p> <p>HOUGHTON J.T., “Física de las atmósferas planetarias, Ed. Instituto Nacional de Meteorología, 1992.</p> <p>WALLACE J.M y P.V. HOBBS, “Atmospheric Science. An introductory survey”, Academic Press, 1977.</p>			

Code:	101	Lecture:	Advanced Atmospheric Dynamics
Speciality/Module		ECTS Credits	Type
Meteorology		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Movements equations in atmosphere and energy. Perturbation theory. Waves in atmosphere. Baroclinic instability. Atmospheric General Circulation.			
Bibliography			
<p>Holton J (2002). An introduction to Dynamic Meteorology. AP New York</p> <p>Haltiner G.J. and Williams R.T.(1999) Numerical Prediction and Dynamic Meteorology</p> <p>Durrant D. R.(1999).Numerical Methods for Wave Equations in Geophysical Fluid Dynamics .Springer</p> <p>Lindzen S. R. Dynamics in Atmospheric Physics (1999) Cambridge .New York</p>			

Code:	102	Lecture:	Numerical Prediction
Speciality/Module		ECTS Credits	Type
Meteorology		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
<p>Movement equations in atmosphere and energy. Coordinate physical system. Prediction models: Barotropic and baroclinic, primitives equations. Integration numerical models. Different levels models in atmosphere. Initial conditions. Hydrostatic and not hydrostatic methods. Prediction reach limit.</p>			
Bibliography			
<p>Holton J (2002). An introduction to Dynamic Meteorology. AP New York Haltiner G.J. and Williams R.T.(1999) Numerical Prediction and Dynamic Meteorology Durrant D. R.(1999). Numerical Methods for Wave Equations in Geophysical Fluid Dynamics .Springer</p>			

Code:	103	Lecture:	Atmospheric Physics	
Speciality/Module		ECTS Credits		Type
Meteorology		7.5		Optional
Lecture Hours		Practical Hours		Personal Work
30		15		142.5
Contents				
<p><u>Atmospheric electricity</u>: diferents electricals magnitudes in atmosphere and their relation with meteorology problems, clime and boundary layer.</p> <p><u>Atmospheric turbulence</u>: atmospheric movements near the ground, orography and warming and difusive dynamic determination.</p> <p><u>Stratification</u>: Management forms of atmospheric dynamic exposed to diferents thermic situations in lower atmosphere.</p>				
Bibliography				
<p>CHALMERS, J. A. (1967): "Atmospheric Electricity". Pergamon Press. London</p> <p>HALTINER, W. G. J. (1957): <i>Dynamical and Physical Meteorology</i>. Mc Graw Hill. New York.</p> <p>PANOFSKY, H. A. and DUTTON, J. A. (1984): <i>Atmospheric turbulence</i>. J. Wiley and Sons. New York.</p> <p>ISRAEL, H. (1973): <i>Atmospheric Electricity</i>. Mac Graw Hill. New York.</p>				

Code:	104	Lecture:	Cloud Physics
Speciality/Module		ECTS Credits	Type
Meteorology		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Classical theory of nucleation. Growth models of cloudy particles. Precipitation theory. Cloud Dynamic.			
Bibliography			
<u>R.R. Rogers</u> : Física de las Nubes. Ed. Reverté (1977) <u>K.C. Young</u> : Microphysical Processes in Clouds. Oxford Univ. Press (1993) <u>R.A. Houze</u> : Cloud Dynamics. Academic Press (1993)			

Code:	105	Lecture:	Atmospheric Diffusion
Speciality/Module		ECTS Credits	Type
Meteorology		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Diffusion equations viscous (or molecular) and turbulents. Movement, continuity and energy equations. Heat transport, humidity and contamination problems, specially air pollution.			
Bibliography			
HANNA, S.. (1982): <i>Handbook on Atmospheric Difusión</i> . Tech. Infor. Centre. US Dept Commerce. Springfield, Va. SEINFELD J. H. (1986): <i>Atmospheric Chemistry and Physics of Air Pollution</i> . J. Wiley and Sons. New York			

Code:	106	Lecture:	Physics of Climate
Speciality/Module		ECTS Credits	Type
Meteorology		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Climate system. Radiative balance. Dynamic balance. Climate models.			
Bibliography			
<p>Hartmann, D.L. (1994) : <i>Global Physical Climatology</i>. Academic Press Inc.</p> <p>Peixoto, J.P. y A.H. Oort (1992). <i>Physics of Climate</i>. American Institute of Physics. New York.</p> <p>Holton, J.R. (1992). <i>An Introduction to Dynamic Meteorology</i>. Academic Press Inc.</p> <p>Trenberth, K.E. editor (1992). <i>Climate System Modelling</i>. Cambridge University Press.</p> <p>McGuffie, K. Y A. Henderson-Sellers (1997). <i>A Climate Modelling Primer</i>. J. Wiley & Sons.</p>			

Code:	107	Lecture:	Physics of the seismic sources and seismotectonics	
Speciality/Module		ECTS Credits		Type
Geophysics		7.5		Optional
Lecture Hours		Practical Hours		Personal Work
30		15		142.5
Contents				
Kinematic and dynamics models. Equivalent forces and dislocations. Seismic moment tensor. Point source. Methods for the determination of the focal mechanism. Source dimensions. Directivity. Nucleation, propagation and arrest of the rupture. Dynamics models. Stress pattern and geological faults. Seismotectonic interpretation.				
Bibliography				
K. Aki y P. G. Richards. Quantitative Seismology. 2ª edición. University Sciences Book. Sausalito, Cal. 2002. B.V. Kostrov y S. Das. Principles of Earthquake Source Mechanics. Cambridge University Press, 1988. A. Udías. Principles of Seismology. Cambridge University Press, 1999				

Code:	108	Lecture:	Seismicity and Seismic Risk
Speciality/Module		ECTS Credits	Type
Geophysics		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
Seismicity. Localization and size parameters: Evaluation methods. Crustal seismic anisotropy. Seismic hazard and risk. Strong motion characterization. Civil engineering applications. Seismic codes.			
Bibliography			
<p>*T. Lay y T. Wallace. "Modern global seismology". Academic Press. 1995</p> <p>*A. Udías. "Principles of seismology". Cambridge University Press. 1999</p> <p>*K. Aki y P.G. Richards. "Quantitative seismology". W.H. Freeman 1980</p> <p>*Babuska y Cara: "Seismic anisotropy in the Earth".</p> <p>*Física de la Tierra, Vol 11 Ingeniería sísmica, ed: Benito, B y Muñoz, D, Editorial Complutense.</p> <p>*"Assessing and Managing Earthquake Risk : Geo-Scientific and Engineering Knowledge for Earthquake Risk Mitigation Developments, Tools, Techniques"</p> <p>Editores: Carlos Sousa Oliveira, Xavier Goula, Antoni Roca</p> <p>* Artículos de Revistas Científicas</p>			

Code:	109	Lecture:	Lithosphere Structure and Dynamics	
Speciality/Module		ECTS Credits		Type
Geophysics		7.5		Optional
Lecture Hours		Practical Hours		Personal Work
30		15		142.5
Contents				
Methods for the determination of the lithosphere structure. Thermo-mechanic behaviour and lithosphere rheology: Elastic, visco-elastic and elasto-plastic plate models. Application to extensional and compressional processes and lithosphere recycling				
Bibliography				
<ul style="list-style-type: none"> - <i>Geodynamics</i>. D. Turcotte and G. Schubert. 2nd edition, Cambridge University Press, 2002. - <i>Geodynamics of the Lithosphere</i>. Kurt Stüwe. Springer, New York. 2002. - <i>Rheology of the Earth</i>. G. Ranalli. 2nd ed. Chapman & Hall. London <i>The Solid Earth</i>. CMR Fowler, Cambridge University Press, 1990. 				

Code:	110	Lecture:	Geophysical Exploration and Topo-Astronomic Orientation of Archaeological Sites
Speciality/Module		ECTS Credits	Type
Geophysics		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
<p>The archaeology like interdisciplinary subject. Geophysical prospection methods. Numerical processing, graphic representation and interpretation of anomalies maps. Astronomical reference systems. Celestials bodies movements and fundamental plane. Field work in geophysical prospection and orientations calculus.</p>			
Bibliography			
<p>CARDINI, A. (1997) Historia de la Tierra. Manual de excavación arqueológica. Crítica. Barcelona.</p> <p>FERNÁNDEZ, V. (2000): Teoría y método de la Arqueología. Síntesis. Madrid (2ª ed.)</p> <p>ROSKAMS, S. (2002): Teoría y práctica de la excavación. Crítica. Arqueología.</p> <p>CONYERS, L., GOODMAN, D. (1997). Ground-penetrating radar. An introduction for Archaeologists. Altamira Press. London.</p> <p>GRIFFITHS, D. H., KING, R. F. (1981) Applied Geophysics for Geologists and Engineers. Pergamon press 2ª ed.</p> <p>ARCHEOLOGICAL PROSPECTION. John Willey-Sons, Ltd.</p> <p>ARCHEOASTRONOMY. Supplement to journal for the History of Astronomy. Publicación cuatrimestral del Center for Archaeoastronomy.</p> <p>BAQUEDANO, I., MARTINEZ ESCORZA, C. (1998): Alineaciones astronómicas en la necrópolis de La osera. Complutum, 9. Madrid.</p> <p>BELMONTE, J. A. (coord) (2000): Arqueoastronomía hispana. Equipo Sirius. Madrid.</p> <p>IVANISZESKI, S. (ed.) (1992): Reading in Archaeoastronomy. International Conference: Current Problems and Future of Archaeoastronomy. Museum and Department of Historical Anthropology. Warsaw.</p> <p>WALKER, C. (ed) (1996): Astronomy before the telescope. The British Museum Press. London.</p>			

Code:	111	Lecture:	Constituents Fields of Earth Magnetism	
Speciality/Module		ECTS Credits		Type
Geophysics		7.5		Optional
Lecture Hours		Practical Hours		Personal Work
30		15		142.5
Contents				
The Earth's Magnetic Field: real data and theoretical models. Harmonic Analysis and separation of field sources. Fields of internal origin: Main field and local field. Fields of external origin: diurnal and irregular variations. Space Weather. Induced fields. Ocean tidal effects.				
Bibliography				
<p>* Campbell, W.H., 1997, <i>Introduction to Geomagnetic Fields</i>, Cambridge Univ. Press.</p> <p>* Jacobs, J.A. (Editor), 1991, <i>Geomagnetism</i>, Academic Press, New York.</p> <p>* Merrill, R.T, M. McElhinny y P. McFadden, 1996, <i>The Magnetic Field of the Earth</i>, Academic Press, Boston.</p> <p>* Parkinson, W.D., 1983, <i>Introduction to Geomagnetism</i>, Elsevier, Amsterdam.</p>				

Code:	112	Lecture:	Paleomagnetism and Rocks Magnetism
Speciality/Module		ECTS Credits	Type
Geophysics		7.5	Optional
Lecture Hours		Practical Hours	Personal Work
30		15	142.5
Contents			
<p>Characteristics of the geomagnetic field. Magnetic properties of natural minerals. Acquisition of natural remanent magnetisation. Methods of palaeomagnetic analysis. Determination of alaeodirections and palaeo-poles. Statistical analysis. Applications: Geomagnetic field studies, plate tectonics and magnetostratigraphy, cyclostratigraphy, palaeomagnetic and archaeomagnetic dating, secondary magnetisations and hydrocarbon migration, environmental change, pollution.</p>			
Bibliography			
<ul style="list-style-type: none"> - Butler, R.F. 1992. Paleomagnetism. Blackwell Scientific Publications. - Dunlop, D.J. and Özdemir, O. 1997 Rock Magnetism.. Cambridge Univ. Press - Evans, M.E. and F. Heller 2003. Environmental Magntism. Academic Press. Elsevier Science. - Tauxe, L. 1998. Palaeomagnetic Principles and Practice. Kuwler Acad. Pub. 			

Code:	113	Lecture:	North Atlantic Climate variability
Speciality/Module		ECTS Credits	Type
Meteorology		6	Optional
Lecture Hours		Practical Hours	Personal Work
20		10	120
Contents			
<p>General circulation of the atmosphere and ocean. Statistical techniques used in climate variability studies. Classification of the most relevant North Atlantic atmospheric and oceanic variability patterns. Troposphere-Stratosphere links in the Atlantic. Air-sea interaction mechanisms in the North Atlantic.</p> <p>Teleconnection dynamics.</p>			
Bibliography			
<ul style="list-style-type: none"> ▪ Hartmann. D. L. 1994: <i>Global Physical Climatology</i>.. Academic Press. 411 pp. ▪ Holton , J. R, 1992:.. <i>An introduction to dynamic meteorology</i>.. Academic Press, New York, 319 pp. ▪ Hurrell, J.W., Y. Kushnir, G. Ottersen, and M. Visbeck, 2003: <i>The North Atlantic Oscillation: Climate Significance and Environmental Impact</i>. Eds. Geophysical Monograph Series, 134, 279pp ▪ Peixoto, J.P and A. H. Oort, 1992: <i>Physics of Climate</i>. American Institute of Physics. New York, 520 pp ▪ Preisendorfer, R. W., 1988: <i>Principal Component Analysis in Meteorology and Oceanography</i>. Elsevier. 425 pp.^o ▪ von Storch H., and F.W. Zwiers, 1999: <i>Statistical Analysis in Climate Research</i>., Cambridge University Press, ISBN 0 521 45071 3, 494 pp. 			

Code:	114	Lecture:	Global Change and Paleoclimatic Techniques.
Speciality/Module		ECTS Credits	Type
Meteorology		6	Optional
Lecture Hours		Practical Hours	Personal Work
20		10	120
Contents			
Climatic change, variability at different timescales. Paleoclimatic techniques: Ice cores, tree.rings, corals and documentary sources.			
Bibliography			
<p>K. Alverson, R. Bradley y T. Pedersen (eds). Paleoclimate, Global Change and the Future. Springer. 2003.</p> <p>R. Bradley. Paleoclimatology. Harcourt Academic Press.1999</p> <p>http://www.pages.unibe.ch/</p> <p>http://www.ngdc.noaa.gov/</p>			

Code:	115	Lecture:	Modeling and Reconstruction of Climate Variability	
Speciality/Module		ECTS Credits		Type
Meteorology		6		Optional
Lecture Hours		Practical Hours		Personal Work
20		10		120
Contents				
Mechanisms of climate variability at different time scales. Instrumental period, last millennia and Late Quaternary. Paleoclimate modeling. Paleoclimatic reconstructions. Climatic forcings. Paleoclimatic key periods. Abrupt climate change.				
Bibliography				
Bradley, R. S. Paleoclimatology. Reconstructing Climates of the Quaternary. 2 nd Edition. Harcourt Academic Press, 1999. Broecker, W. The Glacial World according to Wally. Palisades, NY, Eldigo Press, 2002. Ruddiman, W. F.: Earth's climate, Past, and Future, Freeman, 2000. Storch, H. v. and F. W. Zwiers. Statistical Analysis in Climate Research. Cambridge University Press, 1999. Washington, W. M. and C. L. Parkinson. Introduction to three dimensional climate modeling. 2 nd Edition. University Science Books, 2005.				

Code:	116	Lecture:	Micrometeorology and Atmospheric Pollution	
Speciality/Module		ECTS Credits		Type
Meteorology		6		Optional
Lecture Hours		Practical Hours		Personal Work
20		10		120
Contents				
Lower atmosphere structure: stability influence. Closure problem in basic equations. Monin-Obukhov similarity theory: Applications. Atmospheric boundary layer modelling. Numerical modelling of air quality.				
Bibliography				
<ol style="list-style-type: none"> 1. ARYA, S.P.S (2001): <i>Introduction to Micrometeorology</i>, 2nd edition International Geophysics Series, Academic Press. 2. STULL, R.B. (1988): <i>An Introduction to Boundary Layer Meteorology</i>, Kluwer Academic Publishers. 3. GARRATT, J.R. (1992): <i>The Atmospheric Boundary Layer</i>, Cambridge University Press. 4. SORBJAN, Z. (1989): <i>Structure of the Atmospheric Boundary Layer</i>, Prentice Hall. 5. JACOB, D. J. (1999). <i>Introduction to Atmospheric Chemistry</i>. Princeton University Press 6. JACOBSON, M.Z (2002): <i>Atmospheric Pollution</i>. Cambridge University Press. 7. JACOBSON, M.Z (1999): <i>Fundamentals of Atmospheric Modelling</i>. Cambridge University Press. 8. ZANNETTI, P. (1991): <i>Air Pollution Modelling</i>. Computational Mechanics Publications. 9. Dirección electrónica: www.epa.gov 				

Code:	117	Lecture:	Remote Sensing in Atmosphere
Speciality/Module		ECTS Credits	Type
Meteorology		6	Optional
Lecture Hours		Practical Hours	Personal Work
20		10	120
Contents			
Geostationary and polar satellites. Radiometers and atmospheric band of radiation. Imagery. Radiation budget measurements. Remote Sounding of temperature principles. Meteosat Second Generation System. Others systems of remote observation.			
Bibliography			
Houghton J.T. Taylor F.W. Rodgers C.D. (1986) 'Remote sounding of atmospheres'. Cambridge Univ. Press. Szekiela K. (1988) 'Satellite Monitoring of the Earth' Wiley- Interscience pub.			

Code:	118	Lecture:	Middle Atmosphere Dynamics
Speciality/Module		ECTS Credits	Type
Meteorology		6	Optional
Lecture Hours		Practical Hours	Personal Work
20		10	120
Contents			
Structure of the middle atmosphere. Temperature and zonal wind distributions. Wave lineal theory. Wave propagation from troposphere to middle atmosphere: Propagation criteria. Wave-mean flow interactions. Eliassen-Palm flux. Mean Meridional circulation. Equatorials circulations: Quasi-Biennial Oscillation (QBO). Semi-Annual Oscillation (SAO). Ozone Depletion. Middle Atmosphere General Circulation Models.			
Bibliography			
<p>Andrews, Holton y Leovy, 1987. Middle Atmosphere Dynamics. International Geophysical Series. Volume 40. Academic Press. 489 pp.</p> <p>Brasseur, G., and Solomon, S., 2005. Aeronomy of the Middle Atmosphere. Chemistry and Physics of the Middle Atmosphere. Springer. 644 pp. Chapter 3: Dynamics and Transport.</p> <p>García, R., Hess, P., Smith, A., 1999. Atmospheric Dynamics and Transport. Chapter 2 in Atmospheric Chemistry and Climate Change. Editors: Brasseur, G., Orlando, J., Tyndall, G. Oxford University Press. 654pp.</p> <p>Labitzke y van Loon, 1999. The Stratosphere. Phenomena, History and Relevance. Springer-Verlag. Berlin.</p>			

Code:	119	Lecture:	Models in Meteorology, Atmospheric Physics and Climate
Speciality/Module		ECTS Credits	Type
Meteorology		6	Optional
Lecture Hours		Practical Hours	Personal Work
20		10	120
Contents			
<p>Numerical Prediction models. Tilted Models. Linear Balanced Model. Primitive Equation Models Initialization. Baroclinic spectral Models. Predictability. Ensemble-based atmospheric data assimilation. Economic Value of prediction. Economics of climate change.</p>			
Bibliography			
<p>Radall D.A. (2000) General Circulation Model Development AP. Elsevier Rayner J.N. (2001) Dynamic Climatology .Oxford Davis T. and Hunt J.C. R (2005) New Development in Numerical Weather Prediction. Oxford University Press. Haltiner G.J. And Williams R.T. (1990). Numerical Prediction and Dynamic Meteorology. J: Wiley & Sons Durrant D. R. (1999) Numerical Methods for Wave Equations Fluid Dynamics .Springer Stern Review on the economics of climate change Cambridge University Press London 2006.</p>			

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