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GeoPlaNet-EMJM

Master programme guide

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History of the project

The Erasmus Mundus Joint Master (EMJM) is based on **3 existing long-lived national master programmes** (see table 1) in **Nantes Université**, France (**NU**), **University Gabriele d'Annunzio, Chieti/Pescara,** Italy (**UdA**) and **University of Coimbra, Portugal (UC)**. Each partner HEI master degree is fully recognized and accredited by national accreditation agencies, according to national procedures. The EMJM has been designed to ensure academic continuity and complementarity with first cycle programmes and to ensure access to PhD opportunities throughout the consortium, within the European Higher Education Area and worldwide. All partners offer a range of first cycle degrees in related studies.

These 3 Master programmes are already well inter-connected through the implementation of joint activities developed within the GeoPlaNet Strategic Partnership project since 2020 (Erasmus + Action 2). This EMJM programme is anchored on the numerous international collaborations developed within the Consortium, through research projects and space exploration programmes.

HEI	Existing Master programmes	Integration within EMJM
UC	Master degree in Astrophysics and Instrumentation for Space - MAIS	S1 (PT) - 30 ECTS
UdA	Master: Percorso in Planetary Sciences - PPS	S2 (IT) - 30 ECTS
NU	Earth and Planetary Sciences - EPS	S3 (FR) - 30 ECTS S4 (FR) - 30 ECTS

Table 1: integration of the EMJM within the degree catalogues of the partnership.

Each semester will benefit from the strong and complementary expertise of each Partner.

Institution	Semester	Objective
UC (PT)	**S1** **30 ECTS**	Provide a strong background in planetary science and in acquisition, processing and analysis of space data.
UdA (IT)	**S2** **30 ECTS**	Training in planetary geology, mineralogy and field work on planetary analogues. + Field trip activity on analogue studies in Spain + Field trip in the Dolomites (IT) on a voluntary basis.
NU (FR)	**S3** **30 ECTS**	Focus on planetary surface imaging and planetary interiors modelling. + International workshop organized at ESTEC (European Space Reasearch and Technology Center), alternatively on site and remotely.
GeoPlaNet Consortium of 19 Worldwide Institutes/Agencies	**S4** **30 ECTS**	Employability, Research & lab experience, Networking, PhD and job opportunities.

Table 2: Objectives of each semester of the EMJM supported by the complementary and multidisciplinarity expertise of the partnership.

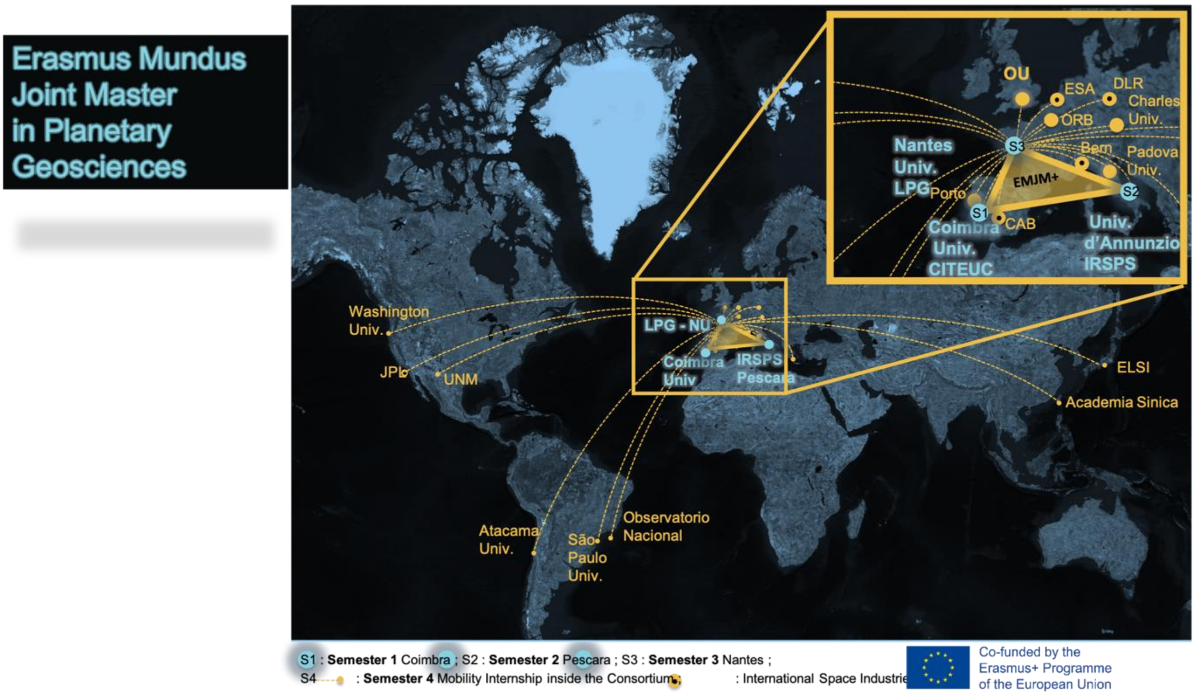

Fig 1: internship of the EMJM within the associated partners.

ACADEMIA SINICA	Taiwan
ACTIVE SPACE TECHNOLOGIES	Portugal
AGRICULTURAL UNIVERSITY OF ATHENS	Greece
DLR	Germany
ESA	Netherlands
EUROPLANET	Belgium
CENTRO DE ASTROBIOLOGIA (CAB)	Spain
PEDRO NUNES ASSOCIACAO PARA A INOVACAO E DESENVOLVIMENTO EM CIENCIA E TECNOLOGIA	Portugal
INTERNATIONAL RESEARCH SCHOOL OF PLANETARY SCIENCES (IRSPS)	Italy
JPL - CALTECH (NASA)	USA
OBSERVATÓRIO NACIONAL	Brasil
EARTH-LIFE SCIENCE INSTITUTE (ELSI)	Japan
OPEN UNIVERSITY	UK
ORB- ONINKLIJKE STERRENWACHT VAN BELGIE	Belgium
UNIVERSIDAD REY JUAN CARLOS	Spain
UNIVERSITA DEGLI STUDI DI PADOVA	Italy
UNIVERSITAET BERN	Switzerland
UNIVERSITY OF NEW MEXICO	USA
UNIVERSITY OF PORTO	Portugal
UNIVERZITA KARLOVA	Czech Republic
VR2PLANETS	France

Table 3: List of the associated partners welcoming internship

	Module name	ECTS	Semester
Coimbra, Portugal	Planetary sciences	6	1
	Image processing and analysis	6	1
	Applied remote sensing	6	1
	Computational methods applied to geophysics	6	1
	Tools for planetary sciences (options)	6	1
UdA, Italy	Planetary geology	6	2
	Planetary analogues field work	6	2
	Planetary materials	6	2
	Mapping and data processing	6	2
	Comparative Sedimentology	6	2
Nantes Université, France	Earth and planetary surface processes	5	3
	Earth and planetary interiors	5	3
	Lab analyses and field geophysics	4	3
	Space exploration programmes	3	3
	Earth and planetary remote sensing	3	3
	Geographic information systems 2	2	3
	Data analysis	2	3
	Fluid dynamics	5	3
	Science and Research communication	1	3
Worldwide	Internship	30	4

Table 4 : Course programme

Student support

Student services

Each host organisation will provide support, upon arrival in EU for **administrative procedures** (ie. opening an EU bank account in France), registration processes, accommodation, health requirements, specific immigration requirements (residence permits etc.). They will also provide students with **information concerning campus and department facilities and services** (local transport, libraries, access to labs, university restaurants, internet access, cultural activities, sports etc.). **Activities for social integration** in collaboration with student association (ie. local association or ESN) will be organized.

Upon arrival and throughout the stay at host universities, **Portuguese, Italian and French initiation language courses will be offered to EMJM students.** Language support will also be offered via the Erasmus+ Online Language Support (OLS) platform, which will allow students to assess, practice and improve their knowledge of languages.

Inclusiveness

Selection and participation to the Program

The Erasmus Programme seeks to promote equal opportunities and access, inclusion, diversity and fairness. Participants (students, staff and guest scholars) will be recruited following the principles of **equal access opportunity and a specific attention will be paid** from application stage to Gender Balance and individual needs and requirements. Indeed, applicants will be requested to indicate if they have special needs (and to describe their needs so hosting HEIs can provide them with the most adapted support).

Inclusion support during activities and mobility

All partners comply with the European applicable standards regarding disabilities and inclusion needs.
Provision will be provided for participants with special needs (health issues), including those related to physical and learning disabilities (e.g., dyslexia) and to teaching and learning activities. Any student may be assessed for additional support needs and a Personal Learning and Support Plan will be developed with the student to promote full engagement and access to the EMJM activities. Inclusion support will include:

- General admin support, especially for mobility preparation (ex: finding an adapted accommodation),
- Support for learning and teaching: availability of lecture material, reinforced individual academic monitoring and support for exam /in class assessment, coursework, assignment

and presentation support, library provision, additional needs associated with field trips, practical sessions and laboratory work.

- Cooperation with adequate university services to ensure students receive information (university presentation, campus, programme, courses etc.) in relevant formats and get the adequate support during their mobility periods (carer, tutoring etc.)
- IT equipment that enables participation (e.g. voice recognition, screen magnification), adaptation of furniture and rooms layout.

Skills

The Master programme will enable students to widen their mind to different cultures and languages and will enable them to experience new learning and working methods through an immersion in up to 4 different countries. On completion of the programme, **students will have achieved a wide range of soft and transversal skills and competencies which will ensure they meet the needs of the current employment market. The identified skills are as followed:**

General and transversal skills

- **Analyse and model scientific or technical problems** in Earth, Planetary and Environmental Sciences,
- Apply **the scientific approach**, develop innovative ideas and manage projects,
- **Work in team environments** and maintain lasting interpersonal relationships.
- **Develop research skills** at a top-level international environment in order to conduct and perform original research projects,
- **Develop learning and self-study methods** in a variety of socio-cultural and multidisciplinary environments, which will sustain life-long learning and professional development,
- **Develop innovative skills** through cutting-edge numerical tools,
- **Lead a project** from the description of its specifications to its fulfilment,
- **Communicate orally and write the results** of a methodological or technical study in a synthetic and pedagogical way,
- **Present materials coherently in written form**, with clear use of language, professional referencing and use of tables, diagrams and graphics where appropriate;
- **Construct, formalize and express rigorously** (using written, oral, graphic or mathematical language) questions, hypotheses, reasoning, models, observations, protocols, results, interpretations and conclusions,
- **Develop team projects** to answer scientific questions.
- **Linguistic skills** (Capacity for language learning, basic knowledge of 3 European languages)
- **Communication skills and networking competences** (ability to communicate effectively with different audiences at different levels, and present materials orally in a clear manner, using audio-visual aids where appropriate);
- **Capacity for independent learning and maturity**
- **Capacity to work flexibly and constructively in teams**, including the ability to answer questions on their work and to give and receive constructive criticism;
- **Knowledge and critical understanding** of a number of disciplines connected to PG

Specific skills

- Acquire **state-of-the-art knowledge** and understanding of the formation, structure and evolution of planetary bodies in order to critically analyse and interpret space mission data.
- **Plan, carry out, describe, analyse and interpret field observations, laboratory experiments and numerical or analogical modelling** to answer scientific or technical questions, qualitatively and quantitatively (sampling, measurement, statistics).
- **Combine qualitative and quantitative information**, derived from the observation of natural systems, experimentation, modelling and consultation of the scientific and technical literature, to ask and answer new questions in Planetary Geosciences with a multidisciplinary approach
- Include the notions of spatial variation, temporal evolution and interaction in natural systems using methods of data analysis and spatialization of information (Cartography, Geographic Information Systems),
- **Capacity to frame and to test hypotheses**; to deploy a range of research techniques and methodologies appropriate to their field of study at different scale and to define and develop creative responses to new research problems
- **IT competencies** (using a range of IT resources, including cutting-edge tools such as planetary data processing and integration and VR);
- **Understanding process of scientific communication** and the publishing process.

Degree recognition

- Successful graduates will receive a **Joint Master Degree from the 3 Partner Universities** in line with national legislation.
- In addition to these degree certificates, graduates will receive a **diploma supplement**. This document outlines the nature of the course, curriculum and marking scheme and should help employers and universities understand the skills and achievements obtained as part of the study on the EMJM GeoPlaNet.
- To **ensure transparency and the conversion of marks between institutions**, the EMJM GeoPlaNet uses the European Credit Transfer System (ECTS). Upon successful completion of the course **you will gain a total of 120 ECTS**.

Career opportunities

The mastery of advanced knowledge, techniques and digital tools will offer you various opportunities to pursue a career in academic or private entities related to geosciences and space exploration, such as:

- Engineer in field geology/geophysics
- Remote sensing/geomatics Engineer
- Engineer in instrumentation for geosciences and space exploration
- Consultant/Project manager (PhD level) in study office related to Geosciences and Space exploration
- Science Officer in research organisations/companies
- Earth and Planetary data scientist (PhD Level)
- Research engineer (PhD level) in Earth and Planetary data acquisition, processing, experimentation, instrumentation, numerical modelling
- Researcher and professor in Earth and Planetary Sciences (PhD level)

Semester 1 - Universidade de Coimbra, Portugal

Course unit title
PLANETARY SCIENCES
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T:30;TP:15;OT:15
ECTS
6
Level
M1
Language(s) of instruction
English
Learning outcomes
General culture in Planetary Sciences. Know the most important properties of the various classes of bodies in the Solar System. Understanding the relevant physical phenomena in planetary sciences. Ability to solve problems. Developing the capacity to estimate results based on general arguments. Ability to search and use specialized scientific publications. Being Planetary Sciences a very bonded area to instrumentation for space it is intended to further develop the capacity to identify and conceptualize: (i) the instrumentation for measuring observable parameters and (ii) the modeling necessary to forecast observable quantities.
Syllabus
1- The Solar System: 1.1 Inventory of the Solar System; 1.2- Properties of bodies in the Solar System; 1.3- the solar system study methods; 1.4- solar system formation models. 2. Dynamics of the Solar System: 2.1 two-body problem of Review; 2.2 The three-body problem, Lagrange points and resonance; 3- The Terrestrial Planets: 3.1- Internal structure of the terrestrial planets; 3.2 Surface Processes of the terrestrial planets; 3.3- atmospheres of the terrestrial planets. 4- The Planets Giants: 4.1- Structure of the giant planets; 4.2- atmospheres of the giant planets; 4.3- The satellites and rings of giant planets systems. 5- The Small Bodies of the Solar System 6- The Extra-Solar Planets (Exoplanets): 6.1- detection of extrasolar planets; 6.2- properties of extrasolar planetary systems.

7. Understanding of Astrobiology
Demonstration of the syllabus coherence with the curricular unit's objectives
This syllabus addresses a wide range of topics in the area of the course, using extensive reference literature. The knowledge is put in context in an area that has been witnessing a rapid evolution, especially in exoplanet detection techniques and planetary knowledge using space probes.
Teaching methods
The teaching will be based on exposing the matters in the classic sense, using specifically cases as part of the learning method focused on the student, solving of classic problems, discussion of research problems will be carried out in the tutorials.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The teaching methods provide the student with the theoretical knowledge and relevant skills, being similar to those commonly used in similar courses in reference schools.
Assessment method (total =100%)
Exam: 60 % **Project:** 40 %
Bibliography
Solar System Dynamics. C.D. Murray and S.F. Dermott (1999). Cambridge Univ. Press Planetary Sciences. Imke de Pater and Jack J. Lissauer (2001). Cambridge Univ. Press An Introduction to the Solar System. Eds. Neil McBride and Iain Gilmour (2003). Cambridge Univ. Press Introduction to Planetary Science: the geological perspective. Gunter Faure and Teresa M. Mensing (2007). Springer. An Introduction to Astrobiology. Eds Iain Gilmour and Mark A. Sephton (2003). Cambridge Univ. Press Le système solaire. T. Encrenaz, J.-P. Bibring, M. Blanc, M. A. Barucci, F. Roques et Ph. Zarka (2003) EDP Sciences / CNRS Editions.

Course unit title
APPLIED REMOTE SENSING
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T-15; TP-15; PL-30; OT-15
ECTS
6
Level
M1
Language(s) of instruction
English

Learning outcomes

The aim of the curricular unit is to give the students knowledge on how to aply the Remote Sensing Techniques in the extraction of Geographic Information (GI) from images captured by mutispectral optical sensors located in spatial platforms. The basic knowledge to the extraction of GI from grorreferenced data captured by active sensors (LiDAR and RADAR) is also studied. From the applications point of view, the students are expected to perform laboratory work in the following areas: i) satellite image pre-processing; ii) production and update of thematic and topographic cartografy of rural and urban areas and iii) management of natural resources and environmental monitoring.

Syllabus

- Fundamentals of Remote Sensing
  - Electromagnetic radiation principles
  - Sources and characteristics of optical remote sensing data
  - Principal optical remote sensing sensors and platforms
- Pré-processing of multispectral satellite images
  - Image quality assessment and statistical evaluation
  - Radiometric correction
  - Geometric correction
  - Image enhancements
  - Multispectral transformations
- Image classification methodologies
  - Supervised classification
  - Unsupervised classification
  - Contextual classification
  - Fuzzy classification
  - Thematic map accuracy assessment
- Basic principles of active remote sensing
  - LiDAR
  - RADAR
- Case studies
  - Data fusion and geometric correction of satelite images of high and medium spatial resolution
  - Urban and rural imperviousness from remote sensing data
  - Land-cover/Land-use change detection

Demonstration of the syllabus coherence with the curricular unit's objectives

In order to acquire the necessary knowledge and to master the techniques for extracting geographic information from multi-spectral images it is necessary to address the basic principles of Remote Sensing (chap. 1) and to know how to do the necessary pré-processing of these images before GI extraction (chap. 2). In order for students use these images for updating and production of topographic and thematic maps it is necessary that they dominate the main methods of image classification using both commercial and open source software (Chapter 3). Because the active remote sensors (LiDAR and RADAR) have been used efficaciously in natural resources management and environmental monitoring, they will be studied in chapter 4. To help students appreciate that their knowledge and skills can be effectively applied in multiple contexts chapter 5 will covering some published remote sensing case studies.

Teaching methods

The fundamental concepts are taught on the theoretical-practical classes, along with the resolution of exercises and tutorials to clarify the subjects. The laboratorial-practical classes include the resolution of exercises and labs using remote sensing software. The evaluation includes a practical component and an exam. The practical component consist on the execution of labs, initiated in the laboratorial-practical classes and concluded by the students outside the classes, which are accompanied by the elaboration of reports describing the theoretical context and all the work performed.

Demonstration of the coherence between the teaching methodologies and the learning outcomes
The more theoretical components of the course will be taught in the theoretical-practical classes and will be evaluated using midterm exams and/or a final exam. In the laboratorial-practical classes exercises and practical work are executed, that allow the students to apply the concepts learned in the theoretical-practical classes. The evaluation of the skills the students gained to implement the taught methodologies will be done with labs, that require the choice of the appropriate methodologies, their implementation and the elaboration of a report with the description of the all developed work. The execution of the labs involves the capabilities of synthesis and analysis, communication, problem solving, critic reflection, autonomous learning and practical application of theoretical knowledge. The evaluation using a practical component and an exam enables the full evaluation of the several aspects of the student learning.
Assessment method (total =100%)
Exam: 60 % **Fieldwork or laboratory work:** 40 %
Bibliography
John R. Jensen. Introductory Digital Image Processing: A Remote Sensing Perspective. 3rd Edition. Prentice Hall, 2005. 526 pags. Richards, J., Jia, X. **Remote Sensing Digital Image Analysis: an introduction**. 2006. 4th Edition. Berlin: Springer. 439 pags. Fonseca, A. e Fernandes, J. Detecção Remota. 2004. Lisboa, Lidel, 224 pags. Gonçalves, G, (2013). Cadernos de Detecção Remota. FCTUC

Course unit title
COMPUTATIONAL METHODS APPLIED TO GEOPHYSICS
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T: 28 hours; TP: 21 hours
ECTS
6
Level
M1
Language(s) of instruction
English
Learning outcomes
Upon completion of this course, students will be able to: - Understand the basic physical principles of geophysical methods. - Understand the numerical methods applicable to geophysical methods. - Analyse time series. - Numerically solve partial differential equations using finite-differences. - Formulate and implement modelling and inversion methods for the solution of geophysical problems. - Write clear and efficient Python scripts in serial or parallel computing architectures. - Use open source Python modules for geophysical applications. Secondary skills: - Physics and computational skills to solve problems.

- Autonomy to learn and articulate concepts. - Ability to search and use specialized bibliography.
Syllabus
1. Python for Geophysics - Introduction to Python - Visualization tools for geophysical data - The SciPy ecosystem - Fast array processing - Parallel computing - Python modules for Geosciences 2. Time series analysis - Practical estimation of spectra - Processing of time sequences - Time series analysis with Pandas 3. Finite-differences solution of partial differential equations - Finite-differences discretization - Application to heat flow - Application to wave propagation 4. Inversion methods - Linear parameter estimation - Nonlinear inverse problems 5. Modelling and inversion with open source Python modules 6. Gravimetric modelling and inversion - Modelling of gravimetric anomalies - Gravimetric inversion 7. Geoelectric modelling and inversion - 2D Modelling of electrical resistivity sounding - 2D electrical resistivity tomographic inversion 8. Seismic modelling and inversion - 1D Modelling, synthetic seismograms - Reflection and refraction seismology
Demonstration of the syllabus coherence with the curricular unit's objectives
The programm contents cover both the essential and the most important computational methods in Geophysics. In addition to the qualitative and quantitative description of the various computational methods covered, special emphasis is given to the presentation of examples of their practical application.
Teaching methods
Learning contents are presented and discussed in lecture classes (2 hours/week). In supervised computer laboratory classes (1.5 hours/week), students are expected to formulate the solutions of proposed problems and implement them in the form of Python scripts. Weekly problem sets and computer exercises will be provided.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The teaching methodologies adopted in the lecture and computer laboratory classes are complementary and aim to reinforce learning by combining the oral exposure of the contents and application examples with the supervision of the implementation of Python scripts in solving proposed problems. Since the training is multifaceted with components of formal reasoning in understanding the methods and in the elaboration of solutions to the proposed problems, and practical reasoning in the implementation of Python scripts, the encouragement of active participation of students during classes is crucial for an active and effective learning of taught subjects.
Assessment method (total =100%)
Project: 60 %

Problem resolving report: 40 %
Bibliography
1. Fundamentals of Geophysics, W. Lowrie, Cambridge University Press, 2007. 2. Field Geophysics, J. Milsom, Wiley, 2011. 3. Introduction to Seismology, P. Shearer, Cambridge University Press, 2009. 4. An Introduction to Seismology, Earthquakes, and Earth Structure, S. Stein and M. Wysession, Wiley-Blackwell, 2002. 5. Geophysical Data Analysis: Discrete Inverse Theory, W. Menke, Academic Press, 2018. 6. Univariate Time Series in Geosciences, Theory and Examples, H, Gilgen, Springer-Verlag, 2006. 7. Introduction to Numerical Geodynamic Modelling, T. V. Gerya, Cambridge University Press, 2010. 8. Pythonic Geodynamics, Implementations for Fast Computing (Lecture Notes in Earth System Sciences), Gabriele Morra, Springer, 2018. 9. Computational Methods for Geodynamics, A. Ismail-Zadeh and P. Tackley, Cambridge University Press, 2010. 10. Parameter Estimation and Inverse Problems, 3rd edition, Richard C. Aster, Brian Borchers and Clifford H. Thurber, Elsevier, 2018.

Course unit title
IMAGE PROCESSING AND ANALYSIS
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
ECTS
6
Level
M1
Language(s) of instruction
English
Learning outcomes
This course is planned so as to enable the students to: 1) understand the theoretical foundations of digital image processing, including their context in the acquisition and analysis of biomedical images, and learn some of the main techniques 2) develop skills allowing them to put in practice what they've learned, mastering the appropriate image processing tools and, in particular, a specialised programming language
Syllabus
Introduction. Fundamentals of digital image: image formation, acquisition and digitalisation. Binary representation, storage and visualisation of digital images. Image characterisation. Spatial domain processing: histograms, equalisation, image improvement. Spatial filtering. Spectral domain processing: Fourier transforms. Filters. FFT. Convolution and correlation theorem. Image recovery: degradation/recovery process model. Noise models. Deconvolution. Colour processing: colour models. Shape processing and segmentation: dilation, erosion. Detection/extraction of characteristics. Hough transform. Domain growth. Image reconstruction: data organization. Radon transform. Analytical and iterative methods. Reconstruction.

Other techniques: alignment and fusion. PCA. "Machine Learning".
Practical classes syllabus: use of programming languages for image processing and visualisation.

Demonstration of the syllabus coherence with the curricular unit's objectives

Objectives pertaining to knowledge acquisition are reached through the oral presentation of the content of the syllabus.
Objectives related to practical applications are attained with the programming problems and the exploring of several image processing techniques.

Teaching methods

Oral presentation using audiovisual means
- Examples that explore additional sources such as the internet and latest research results
- Group discussion of practical problems
- Solving programming problems

Frequent practical tests.
- Writing of an essay (either a programming project's report or an essay on a given theme).

Demonstration of the coherence between the teaching methodologies and the learning outcomes

Given that teaching methods will mainly be centred on the discussion and solution of practical problems, the main objectives of this course will be automatically fulfilled.

Assessment method (total =100%)

Midterm exam: 70 %
Test: 20 %
Project: 10 %
Other:
The student can obtain approval by continuous assessment with the marks of mid-term exam, mini-tests and project (a computing project including a report or a synthesis work) or with the marks obtained in the exam and the project, i.e. the marks obtained in the mid-term exam and the mini-tests can be replaced by that of the exam.

Bibliography

Main book:
R. C. Gonzalez and R. E. Woods, Digital Image Processing, Prentice Hall, 2nd ed., 2001
Other books:
Rangaraj M R, Biomedical Image Analysis, CRC Press, 2005
R. C. Gonzalez, R. E. Woods, S. L. Eddins, Digital Image Processing using Matlab, Prentice Hall, 2004
Anil J. Kain, Fundamentals of Digital Image Processing, Prentice Hall, 1989

Tools for Planetary Sciences

Unit Option (6 ECTS) to choose between different courses given in Coimbra during the first semester to personalize the student profile.

Semester 2 – Università Gabriele d'Annunzio di Chieti-Pescara, Italy

Course unit title
PLANETARY GEOLOGY
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
60 hours per semester (theoretical and practical teaching)
ECTS
6 ECTS
Level
M1
Language(s) of instruction
English
Learning outcomes
Students will become familiar with major research results obtained in the field of planetary geology of the Solar System. They will also learn that advances in such researches will also help us understand the Earth system.
Syllabus
Geological sciences do not limit their field of interest to the study of Earth. Any planet, characterized by a solid surface, can be studied using the principles and fundamentals of geology, to understand its processes and history. The course offers a comprehensive introduction of planetary geology studies developed over the last 60 years. The planetary bodies to be covered include Mercury, Venus, Moon, Mars, icy moons, asteroids, comets, Kuiper-belt objects, and extrasolar planets. The range of disciplines to be covered include geomorphology, sedimentology, volcanology, tectonics and mass wasting. Many of the geological processes referred in the course are discussed together with ample examples of terrestrial analogs.
Demonstration of the syllabus coherence with the curricular unit's objectives
This is an introductory course intended to give an overview of planetary geology as we know of today and the course will provide passage to research of individual planetary body or geological processes. Each planetary body is discussed for different types of geological processes to have operated or to be operating today. Examples of terrestrial analogs illustrated during the course are fundamental in connecting the principles of geology we know from the Earth and applicable to planetary landscapes. This in turn help students understand the importance of the Earth system.
Teaching methods
Frontal lectures, discussion and reading assignment. The lectures overview important geological processes and planetary bodies in the Solar System. The course encourages discussion between the lecturer and students, and among students. Some selected bibliography will be introduced as the reading assignment.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The teaching method of the course is an effective way to deliver a large amount of information necessary to be covered for becoming familiar with the field of planetary geology. The encouraged discussion is essential

training for fostering critical thinking. The reading assignment provides opportunity for learning directly from scientific publications.
Assessment method (total =100%)
Exam: 100 % The final exam will be conducted as oral presentation of a topic selected by the student and it should be related to planetary geology. The final exam will judge the student in terms of the progress in learning of the course's subjects, and of the capacity to select a proper topic, add original interpretation and prepare and give a professional-level presentation. Other elements of consideration include attendance and participation during the course.
Bibliography
Scientific articles introduced during the lectures

Course unit title
MAPPING AND DATA PROCESSING
Face to face teaching
60 hours per semester (theoretical and practical teaching)
ECTS
6 ECTS
Level
M1
Language(s) of instruction
English
Learning outcomes
Learn the tool to find, understand and process the data necessary to realize a planetary geological map. Learn the technical as well as the scientific skills to realize a planetary geological map.
Syllabus
PDS Geosciences Node Orbital Data Explorer (ODE): footprint and data search. Other tools. Accompanying Material. Data processing: ISIS (Integrated Software for Imagers and Spectrometers). Installation and basic commands; examples of data processing with different missions. Cartography. Nomenclature. Coordinate systems and projections. DEM production: NASA AMES Stereo Pipeline. Installation and basic commands; data selection for stereo processing; examples of data processing with different missions. GIS Integration. Planetary cartography protocols. Planetary Geological Mapping: data different resolution; geological mapping vs geomorphological mapping. Scale of work. Definition of a stratotype. Stratigraphic relations and their meaning. Definition of the mapping attributes. Crater counting Realization of a geological map. Realization of the accessory Information: Legend; Geological sections; Stratigraphic schemes.

Demonstration of the syllabus coherence with the curricular unit's objectives
The first part of the syllabus is devoted to the acquisition of the technic skills that will lead to the preparation of a GIS-based project with different datasets. The students will learn how and where to look for data, the nature and meaning of these data and how to treat them in order to have the GIS-ready data needed for science purposes. In order to test these skills, the students will develop their work project by selecting a study area, identifying, downloading, and processing the available datasets. The second part of the syllabus is devoted to the realization of the geological/geomorphological map. Data will be integrated in a GIS system. The USGS existing mapping protocols will be evaluated in order to identity the eventual consistency with the project. The student will define the units, linear and polygonal, to be mapped by characterizing a stratotype for each of them and for their stratigraphic relations, which will be the base to write the mapping attributes.
Teaching methods
Classroom-taught lecture for the basic principles. Practical exercises with the realization of a cartographic project from the data selection phase up to the geological map preparation.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
Through the materials produced by the students during the technic (GIS-ready dataset) and the geological (geological map and accessory information) parts of the course.
Assessment method (total =100%)
Exam: 100 % **Midterm exam:** 10 % **Problem resolving report**: 10 % **Research work**: 30 % **Synthesis work**: 10 % **Fieldwork or laboratory work**: 40 % **Other:** The assessment will occur according to the following steps. Realization of a geological mapping project through the following steps: - Choice of the study area - Realization of the geographical and geological contexts - Data processing - Geological Map preparation - Geological section preparation - Stratigraphic schemes preparation
Bibliography
Scientific articles introduced during the lectures.

Course unit title
PLANETARY MATERIALS
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T- 60
ECTS
6

Level
M1
Language(s) of instruction
English
Learning outcomes
Develop a broad understanding of meteorites in terms of their chemistry, isotope geochemistry and mineralogy. Understand the environments, processes of formation and differentiation during the formation of meteorites, planetesimals, asteroids and planets. Knowledge of the principle methods used in the study of planetary materials.
Syllabus
Big bang. The Sun. First 100 Ma. Stellar Disk and Telluric eras. Accretion and differentiation - core formation, early atmospheres. Isotopes. Radiogenesis. Decay modes. Isotopic fractionation. Heavy elements. Nucleosynthesis. Solar Nebular Disk Model. 3-D Accretion. Mass spectrometry and its applications. Short-lived radioisotopes. Falls/Finds. Statistics. Classification. C chondrites - classes. Early studies - Prior, Urey-Craig, Anders. CI, CM, CR, CO, CV, CK, CH petrographic indices, petrologic grades. SEM and TEM. Chondrule mineralogy. Nucleation and growth. Mossbauer spectroscopy. Crystal field theory. CAI, REE, L chondrites. Shock. Noble gases. Diffusion. H and E chondrites. Cosmic ray exposure. R and K chondrites. Achondrites, Vesta and HED. Ureilites, aubrites, brachinites. Lunar and martian meteorites, SNC. Pallasites, mesosiderites, iron groups. Core formation models, the asteroid belt and types, H2O on Earth.
Demonstration of the syllabus coherence with the curricular unit's objectives
A rigorous parameterisation of meteorite groups based on chemical, mineralogical, and isotopic characteristics is the basis of the course. With this knowledge the student is able to rationalise possible origin and history of meteoritic material, including accretion and differentiation of parent bodies, their thermal and chemical environments and the processes that may have occurred such as shock events, alteration and metamorphism. The course also includes introduction to several analytical and experimental methods common to the study of meteorites
Teaching methods
Frontal teaching (powerpoint)
Demonstration of the coherence between the teaching methodologies and the learning outcomes
Frontal teaching is necessary in order to provide the student with an abundance of information both in graphical and photographical form. The rarity of meteorite samples, particulary of those outside of the chondritic groups prevents any effective "hands on" teaching methods.
Assessment method (total =100%)
Exam: oral exam 67% **Project:** oral presentation 33%
Bibliography
Planetary Materials (1998), Reviews in Mineralogy vol. 36, Mineralogical Society of America, ISBN 0-939950-46-4

Course unit title
PLANETARY ANALOGUES FIELD WORK
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
60

ECTS
6
Level
M2
Language(s) of instruction
English
Learning outcomes
Provide to the student knowledge and experience on: i) working with planetary data (from orbiter, lander and rover) on Mars; ii) interpreting rocks and sedimentary environments from remote sensing data; iii) reconstructing the geological evolution of sedimentary environments and sequences. This will give to the student a great background on the analysis of mission data (both in orbit and in situ), on the definition of scientific objectives in the Solar System exploration at large and on the analysis of landing sites in different planetary bodies
Syllabus
The course is highly practical consisting in 7 – 10 days of field work on Martian analogue environments in Spain (fluvial deposits). During the field work the student will describe fluvial deposits, the sedimentary structures, the internal and external geometries of the sedimentary bodies, the stratigraphic relationships , sedimentary surfaces, subsurface and related processes. Then, the student will identify the possible similarities and differences with sedimentary bodies on Mars.
Demonstration of the syllabus coherence with the curricular unit's objectives
The student will be able to investigate the surface of planetary bodies with exogenic processes and with the formation of the sedimentary environments. This will be based on the comparative analysis of the different processes on Mars and Titan, starting from the Earth that will be used as reference model.
Teaching methods
The course will consist of a mix of theoretical classes and practical training. The former mode will deal with the explanation of concepts and methods involved in the analysis of sedimentary environments, their processes and this variability in the Solar Systems. The latter mode will consists of a practical approach where the students will be able to learn through experiencing the work on real cases both in lab and the field.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The course will allow the student to link the remote sensing observations with surface exploration. They will understood the value of their work performed on orbital data, as well as will learn how to interprete orbital data and matching them with geological models. The "analogue experience" is extremely useful to students in order to understand the process of collecting and interpreting data from planetary exploration that is basically from orbital data and surface landers/rovers.This method is linked with a number of teaching activities involving data collection and rendering of them in maps and other visual systems, in interpretation of geological data and comparative planetology.
Assessment method (total =100%)
Test: 20%, tests on parts of the programme **Problem resolving report**: 70%, the student will have to provide an assessement of a particular aspect of the sedimentation on Planets **Fieldwork or laboratory work:** 10%, field notes of field work
Bibliography
Readings H.G.,1996, Sedimentary Environments, 668 pp. Blackwell James N.P. and Dalrymple R.W., Facies Models 4, 453 pp., Geological Association of Canada

Several papers provided during the teaching

Course unit title
COMPARATIVE SEDIMENTOLOGY
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
60h
ECTS
6
Level
M1
Language(s) of instruction
English
Learning outcomes
The course will provide the capability of observing, describing and interpreting the different sedimentary environments in the Satellites and Planets where the presence of an atmosphere allows surface exogenic processes. The Solar System exhibits a huge variability in terms external processes and the student will be able to understand the variables controlling the sedimentation patterns. The acquired knowledge will provide the student with scientific capabilities, but will contribute to play a role in the planning of planetary surface missions and in controlling surface operations.
Syllabus
The course will deal with the following items: Processes of sedimentation: clastic, chemical, biochemical on Earth, Mars and Titan. Process of sedimentation in other planetary bodies Sedimentary environments on Earth, Mars and Titan with special attention to continental (alluvial, lacustrine), coastal and deltaic settings. Sedimentary rocks and the rock record in different planetary bodies: the realms of subsidence, basins and the source to sink approach in absence of plate tectonics. The search for life and paleo-life on Mars.Landing sites of robotic missions. Human and robotic operation on Mars and Moon. Mechanical sedimentary processes, sedimentary environments: aeolian, fluvial, glacial, coastal, deltaic. Biological-induced sedimentation.
Demonstration of the syllabus coherence with the curricular unit's objectives
The student will be able to investigate the surface of planetary bodies with exogenic processes and with the formation of the sedimentary environments. This will be based on the comparative analysis of the different processes on Mars and Titan, starting from the Earth that will be used as reference model.
Teaching methods
The course will consist of a mix of theoretical classes and practical training. The former mode will deal with the explanation of concepts and methods involved in the analysis of sedimentary environments, their processes and this variability in the Solar Systems. The latter mode will consists of a practical approach where the students will be able to learn through experiencing the work on real cases both in lab and the field.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
Geological sciences do not limit their field of interest to the study of Earth. Any planet, characterized by a solid surface, can be studied using the principles and fundamentals of geology, to understand its processes and history. The course offers a comprehensive introduction of the sedimentology of planetary bodies with a exogenic dynamic sustained by atmospheres and surface mobility of materials. Many of the geological processes referred in the course are discussed together with ample examples of terrestrial analogs.

Assessment method (total =100%)
Test: 20%, tests on parts of the programme **Problem resolving report:** 70%, the student will have to provide an assessement of a particular aspect of the sedimentation on Planets **Fieldwork or laboratory work:** 10%, field notes of field work

Bibliography
Readings H.G.,1996, Sedimentary Environments, 668 pp. Blackwell James N.P. and Dalrymple R.W., Facies Models 4, 453 pp., Geological Association of Canada Several papers provided during the teaching

Semester 3 – Nantes Université, France

Course unit title
DATA ANALYSIS
Presential time T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S-Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T:4, TP:16; O:4.
ECTS
2
Level
M2
Language(s) of instruction
English
Learning outcomes
Analyze, interpret and model data associated with different space and time scales. Identify the appropriate analysis technique according to the nature and the type of data. Learn the limits of the different data processing techniques. Master the statistical tool in data characterization. Master a programming language and use data processing software.
Syllabus
Fourier Analysis Time-frequency and time-scale representations Correlation analysis Dynamic Linear Models
Demonstration of the syllabus coherence with the curricular unit's objectives
This course provides an overview of the numerical tools needed to analyze, model and interpret time series and spatial data for disciplines ranging from ecology and paleoenvironments, to planetary geosciences. The analysis of time series will be based on the application of different methods such as Fourier transforms, time-frequency representations, wavelets, Dynamic Linear Models and correlation detection techniques. Signal processing methods such as the use of filters and outlier detection will also be discussed.
Teaching methods
The teaching is based on lectures and practicals, focusing on different methods to characterize time series from different disciplinary fields.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The teaching methods provide the student with both the theoretical knowledge and the associated data analysis skills.
Assessment method (total =100%)
Test: 100 %
Bibliography
- Méthodes et techniques de traitement du signal - 5ème édition, Jacques Max, Jean Louis Lacoume, Sciences Sup, Dunod, 2004. - Une exploration des signaux en ondelettes, S. Mallat, Les Editions de l'Ecole Polytechnique, 2000. Analyse continue par ondelettes, B. Torresani, Savoirs actuels -Interéditions/CNRS éditions, 1995.

Application de la théorie des ondelettes, V. Perrier, Enseignement UNESCO Traitement du signal et des images numériques, Tunis, ENIT, 14-18 mars 2005. - Linear algebra, signal processing, and wavelets. A unified approach. Python version, Øyvind Ryan, 2015. - Ondelettes continues en Sciences de la Terre - méthodes et applications, P. Gaillot, Université Paul Sabatier - Toulouse III, 2000.

Course unit title
EARTH AND PLANETARY REMOTE SENSING
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T - 8h; TP - 16h; O - 8h (Project)
ECTS
3
Level
M2
Language(s) of instruction
English
Learning outcomes
At the end of the course, students will be able to : - understand what physico-chemical information can be extracted from imaging spectrometer data acquired over Earth and other planets and moons of the solar system - correct hyperspectral images from atmospheric effects using empirical and physical approaches - extract quantitative information from hyperspectral images - use hyperspectral images to map surface compositions - understand how light propagates into the ocean - understand how above-water reflectance can be used to quantitatively retrieve biogeophysical information on the main seawater colored constituents
Syllabus
Physical principles of hyperspectral remote sensing (imaging spectroscopy) Image quality - Image calibration Atmospheric correction methods Extraction of physico-chemical parameters - Surface composition, grain size, moisture content, etc. Application to Earth and Planetary surfaces First concepts in marine optics: inherent and apparent optical properties Main seawater colored constituents Introduction to ocean color remote sensing: chlorophyll algorithms in case 1 waters Ocean color remote sensing in coastal waters Particular case of turbid waters: turbidity and chlorophyll algorithms Application of Ocean color remote sensing to bivalve aquaculture
Demonstration of the syllabus coherence with the curricular unit's objectives
This course covers the fundamentals of imaging spectroscopy in the Visible-, Near- and Shortwave Infrared (VNIR-SWIR) spectral range required to be able to extract relevant information from hyperspectral images. Imaging spectroscopy is one of the standard tools used to explore and understand planetary surfaces. A good understanding of image radiometric and spectral calibration, atmospheric correction procedures and image processing tools is necessary in order to extract and map physico-chemical properties of planetary surfaces. All these aspects are covered based on hands-on ? experience by the students using images from the various missions available at the time.

Teaching methods
Lectures are dedicated to the theory (physics) and some examples of applications from the literature. Practicals allow students to familiarize themselves with hyperspectral image processing through different applications (understanding and using spectral signatures, quantitative mapping, classification, spectral indices, etc.). Students then select a project among the proposed ones (Environmental Geology on Earth, mineral mapping on Earth, Mars, the Moon, Ice on Mars, etc.) and work by themselves, in small groups. Results are presented orally and in a report.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
Theory and practice (face-to-face, possibly E-learning), as well as on-hand experience for the students through the final project.
Assessment method (total =100%)
Project: 100 **%**
Bibliography
Bishop, J., Bell III, J., & Moersch, J. (Eds.). (2019). Remote Compositional Analysis: Techniques for Understanding Spectroscopy, Mineralogy, and Geochemistry of Planetary Surfaces (Cambridge Planetary Science). Cambridge: Cambridge University Press. doi:10.1017/9781316888872. R. N. Clark, Spectroscopy of Rocks and Minerals, and Principles of Spectroscopy, in Manual of Remote Sensing, vol. 3, 3rd Edition, ISBN: 978-0-471-29405-4, March 1999, 728 Pages, John Wiley and Sons, Inc., A. Rencz, Editor, New York. Surveys in Geophysics, Volume 40, issue 3, May 2019, Special Issue: Exploring the Earth System with Imaging Spectroscopy, Saskia Foerster, Luis Guanter, Teodolina Lopez, José Moreno, Michael Rast, Michael E. Schaepman Eds. Mobley, C., 1994. Light and Water. Academic Press. - Kirk, J.T.O., 1994, Light and Photosynthesis in Aquatic Ecosystems, Second Edition. Cambridge University Press.

Course unit title
EARTH AND PLANETARY INTERIORS
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T:36; O:4
ECTS
5
Level
M2
Language(s) of instruction
English
Learning outcomes
- Translate geophysical and geochemical observables in terms of thermal structure, composition and mechanical properties. Integrate the physico-chemical mechanisms governing the dynamics of planetary interiors and their thermal evolution. Understand the physico-chemical couplings between the main constituent domains of planetary interiors. Relate the diversity of planetary evolutions with their internal structure. To appropriate the state of the art in studies on the structure and evolution of planetary interiors.

Acquire a critical mind on the subject. - Know how to synthesize one's own knowledge in English, both written and oral.
Syllabus
The course will quantitatively address the following major topics: The descriptive parameters of planetary internal structures The knowledge and the interrogations brought by terrestrial observations and space missions (orbital probes and landers) Contributions and feasibility of different geophysical methods in planetology Comparative structures and evolutions of the solid bodies of the solar system Extrapolation to exoplanets
Demonstration of the syllabus coherence with the curricular unit's objectives
The course is organized to provide a state of the art of the research on the structure and physico-chemical evolution of planetary interiors, including the Earth, with particular examples selected according to space missions. The knowledge acquired in previous years is used to characterise the physico-chemical structure of planetary bodies and to quantify the mechanisms that govern their evolution.
Teaching methods
The teaching will be based on exposing the matters in the classic sense, using in specific cases a learning method focused on the student, solving of classic problems, discussion of research problems in the tutorials. Students will also be asked to study key recent articles. Seminars will allow them to present their analysis and discuss those of their peers.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The teaching methods provide the student with the theoretical knowledge and relevant skills, being similar to those commonly used in similar courses in reference schools. The analysis, presentation and discussion of recent articles enable them to acquire the tools of a critical scientific approach.
Assessment method (total =100%)
Exam: 50 % **Synthesis work:** 50 %
Bibliography
The students will be provided a free access to the main journals of the discipline, e.g., Astronomy and Astrophysics, Icarus, Journal of Geophysical Research (Solid Earth, Planets), Geophysical Research Letters, Earth and Planetary Science Letters, Nature (Geoscience, Astronomy), Science, ...

Course unit title
FLUID DYNAMICS
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T:20; TP:16; PL:12; O:4
ECTS
5
Semester
Level
M2

Language(s) of instruction
English
Learning outcomes
Model a fluid dynamics problem applied to planetary surfaces or planetary interiors. Integrate a transport equation for temperature or concentration to solve problems of thermal/chemical couplings. Simplify the problem using the hypotheses of the problem and, if necessary, through a dimensional analysis. Write a detailed report on the experiments/modelling carried out in practical work in a synthetic document with adapted scientific tools (making a diagram, writing equations, etc.) in groups of two or three students. - Know how to synthesize one's own knowledge in English, both written and oral.
Syllabus
The course will quantitatively address the following major topics: The descriptive parameters of fluid mechanics (properties of fluids, kinematics of fluids, Bernoulli's equation, vorticity) Solution of fluid-flow problems that are modelled by differential equations (wave equation, diffusion equation, Laplace's equation) Application to Water waves and Boundary layers - Contributions of fluid dynamics in comparative planetology.
Demonstration of the syllabus coherence with the curricular unit's objectives
The knowledge acquired in fluid dynamics will be applied to cases encountered in planetology in order to move from experimental/numerical models to real geophysical flows, taking care to respect the scales of similarity necessary in comparative planetology
Teaching methods
The teaching will be based on lectures, tutorials to solve classical problems, practical work in project mode, distance learning. Specifically cases will be used as part of the learning method and discussion of research problems will be carried out in the tutorials. Students will also be asked to study key recent articles. Report will allow them to present their analysis.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The teaching methods provide the student with the theoretical knowledge and relevant skills, being similar to those commonly used in similar courses in reference thematic schools.
Assessment method (total =100%)
Exam: 70 % **Fieldwork or laboratory work:** 30 %
Bibliography
The students will be provided a free access to the main journals of the discipline (fluid mechanics, heat and fluid flows and planetology).

Course unit title
GEOGRAPHICAL INFORMATION SYSTEMS 2
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T - 4 h; TP - 16 h; O - 4 h

ECTS

2

Level

M2

Language(s) of instruction

English

Learning outcomes

After completing this teaching unit, the student will:
Be aware of the usefulness of Geographic Information Systems (GIS) and the possible applications to earth and environmental sciences
Understand and master the concepts of geographic and projected coordinate systems, the different data types and associated databases
Be able to use basic and advanced functions of a GIS (e.g., perform spatial data analysis, automatic data processing, produce a complex map)
• Be able to collect data required to implement a GIS in the domain of earth, planetary, and environmental sciences.

Syllabus

1 - Fundamental GIS concepts

- Definitions and generalities
- Geodesy : concepts of geographic and projected coordinate systems
- Spatial data types
- Metadata
- Map layout
- The GIS softwares on the market
- The data producers
- The online GIS
- Advanced spatial data analyses
- Project properties and its coordinate reference system (CRS)
- Addition of spatial data
- Digitization – creation of vector layers
- Field calculations
- Georeferencing
- Attribute and spatial queries
- Joints
- Layout – the print composer

- Geodatabases and data processing automation

3.1- Geodatabases

– Generalities
- SQL notions
– SpatiaLite

- Automation of data processing

- Batch processing
- The graphical modeler (model builder/ArcGIS)
3.2.3 - Python scripting

Demonstration of the syllabus coherence with the curricular unit's objectives
This teaching unit builds upon concepts introduced in GIS 1 and provides a thorough overview of GIS functions required to perform combined analyses of spatial datasets in earth and environmental sciences. Fundamental GIS concepts are presented in the form of lectures. Technical skills are developed by hands-on training using concrete examples applied to earth, planetary, and environmental sciences. Fundamental GIS concepts: Geographic and projected coordinate systems; Different types of data (vector, raster, attributes) and metadata ; Databases; Data suppliers; Web Feature and Map Services; GIS softwares; and online GIS. Advanced spatial data analyses: Creating, editing, and managing vector data; Operations with vector data (field calculations and geometry operations) ; Operations with raster data (classifications, data extraction); Georeferencing raster data; Joins and relates; Spatial statistics. Automation of data processing: batch processing, models, Python and SQL scripting. Produce a complex map using proper semiology and mandatory information.
Teaching methods
This module is taught by introducing and explaining the fundamental and advanced notions in the theoretical courses, and then applying these notions in problem solving practical sessions using a GIS. At the end of the module the students will need to present a project where they apply their acquired knowledge in a new situation.
Assessment method (total =100%)
Midterm exam: 40 % **Problem resolving report:** 60 %

Course unit title
LAB ANALYSES AND FIELD GEOPHYSICS
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
PL : 35
ECTS
4
Level
M2
Language(s) of instruction
English
Learning outcomes
Synthesize in a report chemical, mineralogical and crystallochemical data obtained from laboratory rock analyzes. Be able to quantitatively describe the behavior of natural systems and the principles of geophysical measurement using mathematical models based on physics. Perform analyzes by applying a specific protocol and geophysical processing through numerical software. Interpret analyzes by comparing the data obtained with those from the literature. Use of software ((EVA, RUFF) to interpret the results by comparison with chemical and mineralogical databases. Calculate structural chemical formulas of minerals and report them in ternary diagrams in order to identify them.

Syllabus
Raman spectroscopy Mineralogy Chemistry Field geophysics
Demonstration of the syllabus coherence with the curricular unit's objectives
This UE combines theoretical and applied methods of analysis in the field and laboratory. In the field, this is an education provided by Université Gustave Eiffel in which geophysical measurements of sub-surface are performed in the field and interpreted. In the laboratory, the methods used are complementary techniques allowing to characterize petrology, mineralogy, crystallochemistry as well as rock / mineral chemistry natural or synthetic. These are scanning microscopy, X-ray diffraction, infrared and raman spectroscopy and finally ICPMS.
Teaching methods
The teaching are based on lectures and practicals. The practicals involve the use of laboratory equipments to characterize materials.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The teaching methods provide the student with both the theoretical knowledge and the associated data analysis skills.
Assessment method (total =100%)
Project : 100 %

Course unit title
EARTH AND PLANETARY SURFACE PROCESSES
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
T:36, O : 4
ECTS
Level
M2
Language(s) of instruction
English
Learning outcomes
Apply geological concepts, theories and methods to the study of planetary surfaces: Recognise, analyse and interpret planetary surface landsystems and mineral assemblages, with reference to geological models. Assess the relevance of observational data, experimental data and models for the interpretation of surface processes on the Earth and other bodies of the Solar System. Determine planetary surface ages. Produce mineralogical, morphological and geological maps of planetary surfaces. Review and criticise scientific papers. Write critical scientific reviews. - Give oral scientific presentations.

Syllabus
The main processes that drive the evolution of icy and rocky surfaces on the Earth, Planets and other Bodies of the Solar System: deformation processes and landforms, volcanic processes and landforms, impact cratering processes and landforms, erosion, transport and sedimentation processes and landforms, weathering processes and minerals, dating planetary surfaces, - mineralogical, morphological and geological mapping of planetary surfaces.
Teaching methods
Lectures, literature reviews, critical reading of scientific papers, written and oral presentations, lab work
Assessment method (total =100%)
Other : 100 %
Bibliography
H. Jay Melosh (2011) Planetary Surface Processes, Cambridge University Press, doi: 10.1017/CBO9780511977848

Course unit title
SCIENCE AND RESEARCH COMMUNICATION
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
TP - 12 horas; O - 4 horas de ensino distancial
ECTS
1
Level
M2
Language(s) of instruction
English
Learning outcomes
After completing this module the student will be capable of: Analyze any type of scientific publication Be capable of organizing a literature review Be capable of summarizing any type of scientific publication Be capable of presenting a research topic in a condensed and clear way Be capable of searching for research positions and applying for them Understanding the process of scientific communication and the publishing process.
Syllabus
1 – What are science, scientific hypothesis and the scientific method 2 - The world of scientific journals 3 – The peer review system and the scientific impact metrics 4 – Authorship criteria 5 – Writing scientific papers 6 – Oral and poster presentations

7 – Looking for research positions 8 – Managing the research process and coping with the research environmental conditions.
Demonstration of the syllabus coherence with the curricular unit's objectives
The module introduces the different activities of a researcher; from looking for funding and planning research projects to writing and publishing the results. The main focus of the module is on the principles of scientific analysis and writing but all associated aspects are discussed, e.g., types of journals, scientific quality, authorship, the publishing industry, impact factor and citation metrics, grant proposals, and oral presentations.
Teaching methods
The main method is transmitting the information and then interacting with the students by stimulating group discussions around the presented topics. There are also several demonstrations on how to improve scientific communication and how to simplify written language.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The presentation of the different topics and the systematic presentation of good vs bad examples supply the students with a framework to build their referential of what is good (scientific) communication. This is an interactive process where the students collaboratively work on finding the right solutions. Once the bases are set up we ask the students to write their own examples in order to consolidate the taught concepts.
Assessment method (total =100%)
Project: 50 % **Other:** 50 %

Course unit title
SPACE EXPLORATION PROGRAMMES
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
S: 24
ECTS
3
Level
M2
Language(s) of instruction
English
Learning outcomes
Knowledge of current space exploration programs and scientific challenges. Identify the many facilities associated to the preparation, design, implementation and management of space exploration programs.
Syllabus
History of the solar system. Structure and dynamics of planets and moons highlighted by space missions. Understanding of the operating modes of international space science projects. Project designed by student groups.

Demonstration of the syllabus coherence with the curricular unit's objectives
The aim of this module is to illustrate a particular aspect of the scientific approach which is the development of international space exploration programs involving large budgets and based on the collaboration of many scientists. The example of space missions is used to present the objectives and challenges of these major international projects, as well as the results and scientific advances they have achieved. Particular emphasis will be placed on the missions or projects that are dedicated to the study of rocky planets and satellites and /or to the study of the origins of our solar system.
Teaching methods
Conferences + on-site or virtual visits of the ESTEC center + project by group around the conception of a space mission related to space actuality.
Demonstration of the coherence between the teaching methodologies and the learning outcomes
The teaching methods provide to the student the most recent news in space exploration programs. The on-site or virtual visit of the ESTEC center will offer the student a unique opportunity to discover the many facilities associated with the preparation, design, implementation and management of space exploration programs.
Assessment method (total =100%)
Project: 100 %

Semester 4 – Internship, Worldwide

Semester 4 is dedicated to a research internship period, which can be carried out in one of GeoPlaNet consortium institutes, to specialise their training programme in relation to their career plans and objectives. The purpose of the internship is to introduce the student to professional life in academic research, industry, or administration. It can be carried out in any establishment of the GeoPlaNet Consortium or the Network of associated Partners. The work carried out during the internship is presented in a report and defended. All internships will be supervised locally at the internship institution by a local referent and co-supervised by a teacher from NU.

Course unit title
INTERNSHIP
Student working time
770 h to 924 h (= 7 h/day x 22 working days/month x 5 to 6 months)
Face to face teaching T- Theoretical lessons; TP- Practical Task; PL – Lab. Practical; FTC- Field Camp Task; S- Seminar; I- Internship; OT- Orientation Tutorial; O - Other
I: 770 to 924 h
ECTS
30
Level
M2
Language(s) of instruction
English
Learning outcomes
- Acquire, process, analyze and interpret scientific and technical data - Define or be part of professional projects - Carry out and present projects in professional environments - Re-mobilize one's theoretical knowledge in complex professional contexts - Place one's work in a scientific, technical, industrial, economic or societal context - Make effective written and oral presentations in professional contexts - Work independently and as a team - Concretely apply job search techniques - Join professional networks
Syllabus
The purpose of the internship (5 to 6 months) is to introduce the student to professional life in academic research, industry, or administration. It can be carried out in any establishment (private or public) whose activity is linked to Earth and Planetary Sciences. The work carried out during the internship is presented in a report and defended. The internship is subject to an agreement between the University, the intern and the host organisation, in which are indicated the subject of the internship, the name of the professional supervisor and the of the university referent teacher. The professional supervisor manages the work of the intern. The referent teacher ensures the smooth running of the internship by guiding the student from the drafting of the internship agreement to the defence. Finding the internship is the responsibility of the student, and his internship project must be validated by the head of the Master program before signing the agreement.
Teaching methods
Internship, report, defence
Assessment method (total =100%)
Report + Oral + practical : 100 %