Space & Aeronautics Department

Earth Observation
Astrophysics
Satellite Technologies

V23.17 – February 6, 2017

(LC = Lecture Class ; TC = Tutorial Class ; LW = Lab Work)

SYLLABUS VALIDATED FOR THE NEW FRENCH ACCREDITATION
To start in September 2016

Master 1st year – 60 ECTS

Semester 1 (30 ECTS)

Core syllabus – Tronc commun (20 ECTS):

11.1 Human, Economic, Social and Juridical Sciences (5 ECTS)
Sciences sociales, cours de langues (5 ECTS)

11.2 Introduction to Astrophysics & Earth Observation (2 ECTS) – LC: 20h
Introduction à l'astrophysique et à l'observation de la Terre (2 ECTS)
Coordinators: Denis Puy (U. Montpellier) – Catherine Prigent (CNRS)
Teachers: *Pham Thi Tuyet Nhung (VNSC), Ngo Duc Thanh (USTH)*
General introduction to astrophysics and Earth observation.

11.3 Introduction to Satellite Technologies (3 ECTS) – LC: 30h
Introduction aux technologies des satellites (3 ECTS)
Coordinator: *Pham Anh Tuan (VNSC)*
Teachers: *Pham Anh Tuan (VNSC), Hoang The Huynh (VNSC), Le Xuan Huy (VNSC)*
History of space exploration, space environment, satellite mission, satellite orbit and constellation, satellite subsystems, introduction to rockets, ground station, AIT, space applications, system engineering, satellite project and activities, laboratory visit.

11.4 Optical, Infrared and Microwave Imaging Systems (4 ECTS) – LC: 20h ; TC: 20h ; LW: 8h
Systèmes d'imagerie optique, infrarouge et micro-onde. (4 ECTS)
Coordinator: Gérard Rousset (U. Paris Diderot)

Teachers: Gérard Rousset (U. Paris Diderot), Damien Gratadour(U. Paris Diderot), Guillaume Patanchon (U. Paris Diderot), Jean-Claude Souyris (CNES)

- *Radiometry, Planck's law and surface properties, theory of diffraction. Optical transfer and point spread functions of an optical system, image formation using an extended source. Image sampling and sensor scaling. Static and dynamic aberrations, image array sensors.*
- *Antennas. Active and passive microwave imaging systems (radar, interferometric synthetic aperture radar)*

11.5 Signal Analysis and Image Processing (3 ECTS) – LC+TC: 40h ; Project: 8h

Analyse du signal et traitement d'images (3 ECTS)

Coordinator: Damien Gratadour (U. Paris Diderot)

Teachers: Gérard Rousset (U. Paris Diderot), Guillaume Patanchon (U. Paris Diderot), Damien Gratadour (U. Paris Diderot)

Basics of statistics, Fourier transform, sampling, filters, impulse response, transfer function, convolution, random signals, correlation, power spectrum density, noise reduction. The objective of the mini-project is to explore several simple deconvolution strategies on astronomical images.

11.6 Algorithmics and Programming (3 ECTS) – LC: 15h – LW: 15h

Algorithmie et introduction à la programmation (3 ECTS)

Coordinator: Cyrille Rosset (CNRS)

Teacher: Cyrille Rosset (CNRS)

UNIX environment, standard commands, shell. Programming: interpreted vs compiled languages. Basics of programming in Python: loops, conditions, pointers and arrays, functions, input/output. Algorithms.

Satellite technologies – Ingénierie des satellites (10 ECTS)

11.7 Advanced Electronic Systems (4 ECTS) – LC+TC: 16h – LW: 24h

Systèmes avancés en électronique (4 ECTS)

Coordinator: Damien Prêle (CNRS)

Teacher: Damien Prêle (CNRS)

- ***Filters**: Filter parameters, Amplitude responses and Bode plot, polynomial filter synthesis using Sallen-Key cells. Tutorial and practical work: Active Butterworth and Chebyshev low-pass filters.*
- ***Power supply:** Linear vs switched-mode power supply, DC/DC buck, boost and flyback converters, feedback regulation - control. Tutorial and practical work: Pulse Width Modulator - PWM, DC/DC buck converter and regulation.*
- ***Phase Locked Loop:** Phase detector and voltage control oscillator - VCO. Tutorial and practical work: frequency shift keying - FSK demodulation and frequency synthesis.*
- ***Modulation:** Basic of transmitted signals. Amplitude modulation, modulation index, rectifying and product demodulation. Tutorial and practical work: Modulation with and without carrier transmission. Modulation index measurement. Envelope and product detection.*

11.8 Telecoms and Antennas (3 ECTS) – LC+TC: 28h – LW: 12h

Antennes et télécommunications (3 ECTS)

Coordinator: Alain Maestrini (UPMC)

Teachers: Alain Maestrini (UPMC), *Pham Ngoc Diep (VNSC), Nguyen Thi Phuong (VNSC)*

- ***Telecoms:** Basics of source and channel coding. Channel capacity. Basics of digital modulation and demodulation. Practical case of transmissions from space instruments*
- ***Antennas:** Basics of guided waves and antenna theory. Antenna pattern, gain, and impedance. Friis formula of radio link budget. Practical antennas and arrays for space instruments. Up and down conversion for signal transmission. Heterodyne detection. Receiver and system equivalent noise temperature.*

11.9 Radiation Thermometry (3 ECTS) – LC: 15h – TC: 15h

Thermométrie de radiation (3 ECTS)

Coordinator: Tristan Buey (Obs. de Paris)

Teacher: Tristan Buey (Obs. de Paris)

Space thermal environment, heat sources, thermal transfer processes (conduction, convection and radiation), heat equation, Fourier's law, black body radiation, Stefan-Boltzmann law, emissivity and absorptivity, Kirchhoff's law of thermal radiation, thermal design and control of satellites, forced convection, introduction to finite element methods.

Science from Space – Science depuis l'espace (10 ECTS)

11.10 Fundamental in Physics – I (4 ECTS) – LC: 20h ; TC: 20h

Fondements de la physique – I (4 ECTS)

Coordinator: Guillaume Patanchon (U. Paris Diderot)

Teachers: Guillaume Patanchon (U. Paris Diderot), Denis Puy (U. Montpellier), Cyrille Rosset (CNRS)

This includes three separate modules:

- *Statistical Physics: thermodynamics, microcanonical ensemble, canonical and grand-canonical ensembles, quantum gas. Goal is to define thermodynamical quantities such as entropy, temperature, chemical potential. Applications: ideal gas, crystals (Einstein model).*
- *Applied electromagnetism: Maxwell's equations, propagation of light in continuous media, continuity equations, Fresnel coefficients (to be coordinate with Bachelor program).*
- *Introduction to quantum mechanics.*

11.11 Earth and Planetary Sciences (3 ECTS) – LC: 20h ; TC:10h

Sciences de la Terre et des planètes (3 ECTS)

Coordinator: *Ngo Duc Thanh (USTH)*

Teachers: *Ngo Duc Thanh (USTH)*, Sonia Fornasier (U. Paris Diderot)

General introduction to Earth and planetary geophysics: solid Earth, atmosphere, ocean, continental surfaces. Climate studies and global change. Electromagnetic environment of the Earth.

11.12 Astrophysics (3 ECTS) – LC: 20h ; TC: 10h

Astrophysique (3 ECTS)

Coordinators: Denis Puy (U. Montpellier), *Pham Thi Tuyet Nhung (VNSC)*

Teachers: Denis Puy (U. Montpellier), *Pham Thi Tuyet Nhung (VNSC)*

Stellar physics, exo-planets, galactic physics, cosmology. Objects of astrophysics: stars, galaxies, Universe. Observations: coordinates, distance measurements.

Semester 2 : 30 ECTS

Core Syllabus – Tronc commun (13 ECTS):

12.1 Celestial Mechanics and Orbitography (2 ECTS) – LC:10h ; TC:10h

Mécanique céleste et orbitographie (2 ECTS)

Coordinator: Hubert Halloin (U. Paris Diderot)

Teacher: Hubert Halloin (U. Paris Diderot)

- *Celestial mechanics and spherical trigonometry*
- *Time and space reference frames*
- *Two-body problems, Keplerian orbits and osculating parameters*
- *Orbital perturbations and maneuvers*
- *Interplanetary trajectories*

12.2 Space Project Management (3 ECTS) – LC: 20h ; TC: 10h

Management des projets spatiaux (3 ECTS)

Coordinator: Emmanuel Hinglais (CNES)
Teachers: Emmanuel Hinglais (CNES), Rodolphe Clédassou (CNES)
Educational content:

- *Participating as part of a project throughout its life cycle.*
- *A 30-hour module is not sufficient to train an operational Project Manager. Course aims to show students how to work within a project early in their professional career how to work within a project, from start to finish. Only after several years of practice can these engineers acquire the necessary skills to manage a project throughout its life cycle*

12.3 Physics of Radiation and Particle Detectors (3 ECTS) – LC:10h ; TC: 10h ; LW: 10h
Physique des détecteurs de particules et des détecteurs de radiation (3 ECTS)
Coordinator: Eric Nuss (U. Montpellier)
Teachers: Eric Nuss (U. Montpellier), *Pham Thi Tuyet Nhung (VNSC), Nguyen Thi Thao (VNSC)*
Description of the radiation and particle interaction processes with matter.
General characteristics of sensors, detectors and measurement chains for astrophysics and space instrumentation

12.4 Numerical Methods (3 ECTS) – LC: 18h ; TC+LW: 18h
Méthodes numériques (3 ECTS)
Coordinator: Stéphane Jacquemoud (U. Paris Diderot)
Teacher: Stéphane Jacquemoud (U. Paris Diderot), *Nguyen Duc Manh (HNUE)*
Basic concepts (matrices, Taylor series, finite difference); numerical solution of ordinary differential equations; numerical integration techniques; roots of functions of a single variable; minimization of a multivariable function (linear least squares, gradient method, quasi-Newton method, simplex method)

12.5 Concept of Image Processing (2 ECTS) – LC: 20h – TC: 20h
Introduction au traitement d'images (2 ECTS)
Coordinator: Nicolas Delbart (U. Paris Diderot)
Teacher: *Le Huu Ton (USTH/ICT)*
Statistic extraction and image enhancement: histograms, univariate and multivariate statistics, convolution, Fourier 2D, filtering, edge detection. Segmentation: supervised and unsupervised classification, clustering. Inverse problem: multi-linear regression, neural network, bayesien estimation.

Satellite technologies – Ingénierie des satellites (10 ECTS)

12.6 Mechanics of Structures and Finite Element Method (3 ECTS) – LC: 20h ; TC: 20h
Mécanique des structures et méthode des éléments finis (3 ECTS)
Coordinators: Jean-Laurent Dournaux (CNRS), *Nguyen Manh Cuong (HUST)*
Teachers: *Nguyen Manh Cuong (HUST)*, Jean-Laurent Dournaux (CNRS)
Stress and deformations. Constitutive relations, Hooke's law. Choice of materials. Mechanics of continuous media, application to solving a beam subjected to tensile-compression or bending solicitations. Structural dynamics. Thermoelasticity. Buckling. Introduction to finite element modeling.

12.7 Workshop on Small Satellites Design (4 ECTS) – LC+TC: 40h
Atelier sur la conception des petits satellites (4 ECTS)
Coordinators: *Le Xuan Huy (VNSC)*, Linda Tomasini (CNES)
Teachers: *Le Xuan Huy (VNSC)*, Joël Michaud (CNES), Jean-Luc Le Gal (CNES)

- *Basic knowledge to design a spacecraft :*
  - *Choice of the orbit (through exercises on heliosynchronism, phasing, rentry)+ programmation (Matlab) of a propagator*
  - *Attitude control (through the programmation of a 3 axis controller on Matlab) and equipment choice on the internet*
  - *RF subsystem sizing (links budgets) and choice of equipments on the internet*
  - *Power subsystem sizing (solar flux, battery, solar array, energy balance exercice) and choice of equipments on the internet*
  - *Thermal subsystem (7 node thermal model on Excel to calculate spacecraft temperature)*

- *2nd part :*
  - *Structure design and analysis (study design requirements based on rocket environments, material selection, design, structure thermal model, EM, FM, vibration analysis, modal analysis, ...)*
  - *Attitude determination for attitude control (requirement analysis, attitude representations, attitude dynamics and kinematics, sensor modeling, attitude determination algorithms numerical simulation and testing, ...)*
  - *Command and Data Handling (requirement analysis, telemetry and command collecting, interface design, development plan, test plan, ...)*

12.8 ADCS: Attitude and Orbit Control Systems (3 ECTS) – LC+TC: 30h
SCAO : Système de commande d'attitude et d'orbite (3 ECTS)
Coordinator: *Le Xuan Huy* (VNSC)
Teachers: *Le Xuan Huy (VNSC)*
Actuators and sensors, dynamics of satellites, kinematic representations (quaternions, rotation matrices and Euler angles), internal and external perturbation torques, rigid and articulated structures, stabilisation techniques and associated performance, stability criteria

Science from Space – Science depuis l'espace (10 ECTS)

12.9 Fundamental in Physics - II (4 ECTS) – LC: 20h ; TC: 20h
Fondements de la physique - II (4 ECTS)
Coordinator: Isabelle Kleiner (CNRS)
Teachers: Isabelle Kleiner (CNRS), Ha Tran (CNRS), Eric Nuss (U. Montpellier)

- *Introduction to subatomic physics: relativistic kinematics, type of reactions, decay, cross-sections.*
- *Fundamental physics of remote sensing: radiation emission (Planck's law); intrinsic properties of matter (complex refractive index, dielectric constant, atomic and molecular spectroscoscopy); scattering (Rayleigh, Mie, non-selective); radiative transfer equation.*

12.10 Earth Observation: Methods and Applications (4 ECTS) – LC: 16h ; TC: 24h
Observation de la Terre : méthodes et applications (4 ECTS)
Coordinator: Catherine Prigent (CNRS)
Teachers: Catherine Prigent (CNRS), Stéphane Jacquemoud (U. Paris Diderot), Filipe Aires (CNRS)
Course provides basic knowledge of the various remote sensing sensor families, including optical, infrared and microwave radiometers, spectrometers, and active sensors such as LiDARS, radars, SAR, and altimeters. Selected applications (weather forecasting, hydrology, land use change, vegetation monitoring, oceanography, urban areas).

12.11 Image Processing applied to Remote Sensing (2 ECTS) – LC: 20h – TC: 20h
Traitement d'images appliqué à la télédétection (2 ECTS)
Coordinator: Nicolas Delbart (U. Paris Diderot)
Teachers: Nicolas Delbart (U. Paris Diderot), Dinh Ho Tong Minh (IRSTEA)
Statistic extraction and image enhancement: histograms, univariate and multivariate statistics, convolution, Fourier 2D, filtering, edge detection. Segmentation: supervised and unsupervised classification, clustering. Inverse problem: multi-linear regression, neural network, bayesien estimation...

12.12 Two-month internship (7 ECTS)
Stage de deux mois (7 ECTS)

Master 2nd year – 60 ECTS

Semester 1 (30 ECTS)

Core syllabus – Tronc commun (13 ECTS):

21.1 Human, Economic, Social and Juridical Sciences (5 ECTS)
Sciences sociales, cours de langues (5 ECTS)

21.2 Observational Techniques (3 ECTS) – LC+TC: 30h
Techniques observationnelles (3 ECTS)
Coordinator: Marcello Fulchignoni (U. Paris Diderot)
Teacher: Cédric Leyrat (CNAP)
Use and performances of different types of space instruments.

21.3 Space and Application Project (3 ECTS) – LC+TC: 20h ; project: 40h over 2-3 months
Projets spatiaux : phase 0 – phase A (3 ECTS)
Coordinator: Benoît Mosser (Obs. de Paris)
Teachers: Benoît Mosser (Obs. de Paris)
This module aims to train the students to the first phases of definition of a space project.

21.4 Merthodology for Astrophysics (2 ECTS) – LC: 10h ; LW: 10h
Méthodologie en astrophysique (2 ECTS)
Coordinators: Pierre Lesaffre (CNRS), *Pham Ngoc Diep (VNSC)*
Teachers: *Nguyen Thi Thao (VNSC)*, *Nguyen Anh Vinh (HNUE),* Pierre Lesaffre (CNRS), Daniel Rouan (CNRS)
This module will include mainly labworks, data analysis and related astrophysical lectures. See mail exchange, between Pierre Lesaffre and Pham Ngoc Diep, above.

- *Radio telescope: telescope operation, data taking and analysis, antennas, heterodyne detection, system sensitivity, calibration, pointing accuracy... Sun observation to measure the antenna's lobe, Milky Way observation to measure the galactic rotation curve and empty sky measurement to estimate the telescope's sensitivity.*
- *Optical telescope: CCD Imaging (offset, bias, flat-fielding, exposure time, signal / noise, aperture photometry, calibration). Standard star imaging. Slitless spectroimaging using the Alpy. Flatfielding for spectrometry, calibration, reduction of spectra. [in principle, this requires two observing nights, but CCD imaging with spectro could be done by day on Sun, sky or clouds].*

21.5 Seminars (0 ECTS)

Satellite technologies – Ingénierie des satellites (17 ECTS)

21.6 Engineering for Earth Observation Space Systems (2 ECTS) – LC+TC: 20h
Ingénierie Système des missions d'observation de la Terre (2 ECTS)
Coordinator: Linda Tomasini (CNES)
Teachers: Linda Tomasini (CNES)
Educational objectives are to understand the principles of earth observation space systems engineering in the early design phases:

- *To know the main types of earth observation missions*
- *To know how to capture and analyse user needs*
- *To know what an earth observation space system consists of*
- *To know how to identify the driving parameters of an earth observation mission*
- *To understand the iterative process between user needs definition and design*
- *To understand the interdependency between the different elements of an earth observation space system*

Teaching is based on Earth observation missions real case exercises and lectures on topics addressing the different steps of Earth observation engineering process as well as the remote sensing principles and techniques.

21.7 GNSS, Telecommunications (2 ECTS) – LC+TC: 20h

GNSS et télécommunications (2 ECTS)

Coordinator: *Phan Trong Trinh (VAST/IGS)*

Teacher: *Phan Trong Trinh (VAST/IGS), Ngo Van Liem (HUS)*

Introduction to GNSS: the case of GPS, geodesy and coordinate systems, from orbit to ECEF position, GPS: determining position, transmission and signal processing, other GNSS, AMS02: a case incorporating a GPS receiver in a spatial experimentation on ISS.

With the illustration of the GPS system, the basics of telemetry in space are presented, and more broadly the rules governing communication between the ground and space segments.

21.8 The Effect of Ionizing Radiation on the Components (2 ECTS) – LC+TC: 20h

L'effet des radiations ionisantes sur les composants électroniques (2 ECTS)

Coordinator: Frédéric Saigné (U. Montpellier)

Teachers: Frédéric Wrobel (U. Montpellier), Alain Michez (U. Montpellier)

Radiation-induced failures in microelectronics pose a growing concern in the aerospace and avionic communities. Incident radiation acting on these devices is mainly due to cosmic rays and their secondary particles produced in the Earth atmosphere. Energetic particles induce various device malfunctions via their interaction with materials in electronic devices. We will present the principles of Monte Carlo simulation tools, which are very useful to establish the transient current shapes and to evaluate the soft error rates.

→ needs introduction to solid state physics (cf. nano)

21.9 Spacecraft Architecture (3 ECTS) – TC+LC: 30h

Architecture des véhicules spatiaux (3 ECTS)

Coordinator: Rodolphe Clédassou (CNES)

Teachers: Rodolphe Clédassou (CNES), Emmanuel Hinglais (CNES)

- *To understand how the requirements and the constraints of a mission orient the design of a spacecraft.*
- *To design a satellite and its ground segment it is first necessary to express the mission needs and to challenge them against the requirements and the making constraints*
- *After a brief recall of the basic spatial mechanics notions, we will describe several types of missions and their typical constraints.*
- *Then, we will focus on the different types of equipment onboard satellites and learn what are its different functional chains.*
- *The course will end with two working sessions in small teams. These working sessions will permit the students to design themselves two space systems (one on an interplanetary mission and the other on a telecommunication system).*

21.10 Embedded engineering (2 ECTS) - LC: 8h, TC: 4h, LW: 8h

Ingénierie embarquée (2 ECTS)

Coordinator: Vincent Vigneron (U. Evry)

Teacher: Denis Perret (Obs. de Paris)

- *Lectures:*
  - *From interconnected logic devices to programmed logic devices.*
  - *Embedded system design methodology, focus on the abstraction levels.*
  - *System description: introduction to VHDL description language.*
  - *What about microcontrollers and microprocessors: the IP (intellectual property) revolution.*
- *Tutorial:*
  - *Design of a simple 16-bits processor by using VHDL description.*
- *Lab work:*
  - *Basic examples of VHDL implementation on an FPGA.*
  - *Altera NIOS processor (or another): an example of using IP bloc.*

Students should have some prerequisites about computer architecture, microcontroller concept and logic devices. Some lecture supports about these topics will be prepared and proposed before the start of this course.

21.11 Control Engineering (2 ECTS) – LC: 10h ; TC: 10h

Ingénierie de contrôle (2 ECTS)

Coordinator: Denis Perret (Obs. de Paris)

Teachers: Denis Perret (Obs. de Paris)

Linear systems, transfer functions ; Frequency-domain analysis of linear systems ; Analysis of linear feed back systems ; Analysis of discrete-time signals ; Stability and performance of discrete-time systems ; Discrete-time control systems ; State-space representation of continuous-time systems ; State-space representation of discrete-time systems ; State feedback control

21.12 PLMCC (2 ECTS) – TC+LC: 90h (over 3 semesters)

PLMCC (2 ECTS)

Coordinator: Jean-Louis Biaggi (USTH)

Teachers: Jean-Louis Biaggi (USTH), *Nguyen Ngoc Van Thanh (USTH)*

We propose dedicated training and course material on PLM concepts to prepare our customers for virtual product development. This course material covers 3D CAD, CAM, Simulation and virtual production processes in a collaborative way. All industrial areas are covered, including aeronautics, automotive, consumer goods and manufacturing.

21.13 Ground Segment (2 ECTS) – TC+LC: 20h

Segment sol (2 ECTS)

Coordinator: Anne-Thérèse Nguyen (CNES)

Teachers: Anne-Thérèse Nguyen (CNES), *Do Xuan Phong (VNSC)*

The module aims at presenting the Ground Segment in details. The following components will be presented: the Ground Stations, the Command and Control Center, the Mission and Operations Center, the Science Processing Centers. The course will focus on their respective roles and how they can interact/communicate together and with the satellite. The course will also explain the infrastructure needs to build these components and the challenging issues to overcome (ex: Big Data …). Different space projects in the domain of astronomy, earth observation will be used to illustrate the course.

Science from Space – Science depuis l'espace (17 ECTS)

21.14 Advanced Astrophysics and Planetology (5 ECTS) - Astrophysics LC: 30h + Planetology LC: 24h ; LW: 6h

Astrophysique et planétologie avancées (5 ECTS)

Coordinator: Daniel Rouan (CNRS)

Teachers: Daniel Rouan (CNRS), Davide Perna (CNAP), Yves Bénilan (UPEC)

Planetology, exoplanets, astrophysics – strongly coupled with 21.2 and 21.4

21.15 GIS: Geographical Information System (2 ECTS) – LC : 6h – TC : 14h

SIG : Système d'information géographique (2 ECTS)

Coordinator: Céline Clauzel (U. Paris Diderot)

Teachers: Maya Cohen (U. Paris Diderot), *Bui Quang Thanh (HUS-Geography)*

Types of geographical data (raster, vector), georeferencing systems. (suite 21.7)

21.16 Remote Sensing of Continental Surfaces (4 ECTS) – LC+TC: 40h

Télédétection des surfaces continentales (4 ECTS)

Coordinator: Nicolas Delbart (U. Paris Diderot)

Teachers: *Lam Dao Nguyen (VNSC),* Nicolas Delbart (U. Paris Diderot)*, Dinh Ho Tong Minh (IRSTEA),* Pham Duc Binh (USTH - Obs. de Paris)

- *Continental hydrology (flood, soil moisture)*
- *Agriculture and forest ecosystems*
- *Land use and land cover changes*
- *Geomorphology and geophysics*

au moins 50 heures

21.17 Remote Sensing of the Atmosphere (3 ECTS) – LC: 20h ; TC : 6h ; Project: 4h

Télédétection de l'atmosphère (3 ECTS)

Coordinator: Gilles Foret (UPEC)

Teachers: Gilles Foret (UPEC), *Ngo Duc Thanh (USTH)*

1. *Atmospheric composition (15h, Gilles Foret): Lectures (10h), tutorial class (5h)*
   Description: *This course provides an overview of the applications of remote sensing techniques about atmospheric composition aspects. This include the observation of*

pollutants associated to air quality and climate issues like ozone (O_3), particles, nitrogen oxydes (NO_2 …), carbon dioxide (CO_2), methane (CH_4). Besides theoretical lectures, tutorial class would confront students to real satellite data to develop their ability to analyze and understand these observations.

2. *Meteorological aspects (15h, Thanh Ngo-Duc): Lectures (9h), tutorial class (6h)*
   Description: *This course provides basic knowledge of the applications of remote sensing techniques in meteorological aspects: clouds classification, convective storms, quantitative precipitation estimation, water vapor imagery, synoptic scale meteorology such as fronts, cyclones. Besides theoretical lectures, tutorial class would help students be able to use satellite data to monitor and interpret various meteorological phenomena.*

21.18 Remote sensing of the Ocean and Coastal Zones (3 ECTS) - LC+TC: 30h

Télédétection des océans et des zones côtières (3 ECTS)

Coordinator: Catherine Prigent (CNRS)

Teachers: Hubert Loisel (ULCO), Fabrice Papa (IRD)

Ocean color, altimetry, surface temperature, ocean winds.

Semester 2 (30 ECTS)

22.1 Six-month internship (30 ECTS)

Stage de six mois (30 ECTS)