PHYSICAL SCIENCES

Programme Code: PHYS25

Programme Outcome:

- Gaining knowledge on areas in Earth Science & Geoscience
- Understanding climate system and its atmospheric, terrestrial, oceanic and cryospheric components
- Planetary exploration and related activities
- Basic knowledge on Mineralogy, Crystallography, Sedimentology, Stratigraphy, and Mineralogy
- Understanding Geophysics, Geochemistry, Hydrogeology and Geochronology
- Basic knowledge on Paleontology, Astrochemistry and Astrobiology, Evolution of planetary system,
- Exoplanets, Planetary atmosphere and space weather, Planetary Geochemistry and Geochronology

DETAILED COURSE STRUCUCTRE

ODD SEMESTER			
Sl. No.	**Course Code**	**Course Name**	**Credit**
1	EPSxxx	Theory-1*	4
2	EPSxxx	Theory-2*	4
4	EPS700	RM&RPE	4
Total Credit per semester			**12**

EVEN SEMESTER			
Sl. No.	**Course Code**	**Course Name**	**Credit**
1	EPSxxx	Theory-3*	4
3	EPS641	Practical Course/Field Work	2
4	EPS699	Mini Research Project	6
Total Credit per semester			**12**

*As recommended by the student's monitoring committee/standing academic committee from the list of approved (SEPS) theory courses

Note: ***L = Lecture, P = Practical, T = Tutorial.***

List of approved courses for SEPS PhD programme

Sl. No.	Course Code	Course Name	L-P-T	No of Lectures in hrs	Credits
1	EPS601	Introduction to Earth Sciences	45-0-15	60	4
2	EPS602	Introduction to Atmospheric and Oceanic Sciences	45-0-15	60	4
3	EPS603	Introduction to Planetary Sciences	45-0-15	60	4
4	EPS641	Practical Course/Field Work	-	-	-
5	EPS651	Mineralogy and Crystallography	40-0-20	60	4
6	EPS652	Igneous and Metamorphic Petrology	40-0-20	60	4
7	EPS653	Sedimentology and Stratigraphy	40-0-20	60	4
8	EPS654	Geochemistry and Geochronology	40-0-20	60	4
9	EPS655	Geophysics	40-0-20	60	4
10	EPS656	Remote Sensing and GIS	45-0-15	60	4
11	EPS657	Structural Geology	45-0-15	60	4
12	EPS658	Palaeontology	40-0-20	60	4
13	EPS659	Economic Geology	45-0-15	60	4
14	EPS660	Hydrogeology	45-0-15	60	4

15	EPS661	Physical Geology	40-0-20	60	4
16	EPS662	Uranium Geology	40-0-20	60	4
17	EPS666	Geophysical Fluid Dynamics	45-0-15	60	4
18	EPS667	Atmospheric Boundary Layer Meteorology and Air Pollution Modelling	45-0-15	60	4
19	EPS668	Tropical Meteorology	45-0-15	60	4
20	EPS669	Cloud Micro-Physics	45-0-15	60	4
21	EPS670	Atmospheric Thermodynamics and Convection	45-0-15	60	4
22	EPS671	Atmospheric Aerosols and Chemistry	45-0-15	60	4
23	EPS672	Climate and the Terrestrial Biosphere	45-0-15	60	4
24	EPS673	Ocean Biogeochemistry	45-0-15	60	4
25	EPS674	Atmospheric Radiative Transfer	45-0-15	60	4
26	EPS675	Physical Oceanography	45-0-15	60	4
27	EPS676	Paleoclimatology	45-0-15	60	4
28	EPS677	Numerical Prediction of the atmosphere and the ocean	45-0-15	60	4
29	EPS678	Techniques of Weather Prediction	45-0-15	60	4
30	EPS681	Astrochemistry and Astrobiology	45-0-15	60	4

31	EPS682	Formation and evolution of planetary system	45-0-15	60	4
32	EPS683	Exoplanets	40-0-20	60	4
33	EPS684	Planetary atmosphere and space weather	45-0-15	60	4
34	EPS685	Planetary surface processes	45-0-15	60	4
35	EPS686	Planetary Geophysics	40-0-20	60	4
36	EPS687	Planetary Geochemistry and Geochronology	45-0-15	60	4
37	EPS688	Seismology	45-0-15	60	4

COORDINATORS

Chief Coordinators:

Convener, Post-Graduate Committee of the School, Physical Sciences (Dr. Pratap Kumar Sahoo),

Chairperson of the School of Physical Sciences (Dr. Kartikeswar Senapati)

COURSES CO-ORDINATORS

Course	Coordinators	Email
Introduction to Earth Sciences	Dr. Pratap Kumar Sahoo and Dr. Kartikeswar Senapati	pratap.sahoo@niser.ac.in and kartik@niser.ac.in
Introduction to Atmospheric and Oceanic Sciences		
Introduction to Planetary Sciences		
Practical Course/Field Work		
Mineralogy and Crystallography		
Igneous and Metamorphic Petrology		
Sedimentology and Stratigraphy		
Geochemistry and Geochronology		
Geophysics		

Remote Sensing and GIS	Dr. Pratap Kumar Sahoo and Dr. Kartikeswar Senapati	pratap.sahoo@niser.ac.in and kartik@niser.ac.in
Structural Geology		
Palaeontology		
Economic Geology		
Hydrogeology		
Physical Geology		
Uranium Geology		
Geophysical Fluid Dynamics		
Atmospheric Boundary Layer Meteorology and Air Pollution Modelling		
Tropical Meteorology		
Cloud Micro-Physics		
Atmospheric Thermodynamics and Convection		
Atmospheric Aerosols and Chemistry		
Climate and the Terrestrial Biosphere		

Ocean Biogeochemistry	Dr. Pratap Kumar Sahoo and Dr. Kartikeswar Senapati	pratap.sahoo@niser.ac.in and kartik@niser.ac.in
Atmospheric Radiative Transfer		
Physical Oceanography		
Paleoclimatology		
Numerical Prediction of the atmosphere and the ocean		
Techniques of Weather Prediction		
Astrochemistry and Astrobiology		
Formation and evolution of planetary system		
Exoplanets		
Planetary atmosphere and space weather		
Planetary surface processes		
Planetary Geophysics		
Planetary Geochemistry and Geochronology		
Seismology		

CORE COURSES

EPS601 Earth Sciences (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Earth system science – a science system of lithosphere, hydrosphere, atmosphere, biosphere, and planetosphere/planetology
- Solar System and Earth – formation and evolution
- Mineralogy and crystallography
- Physical geology and the processes
- Petrology – Sedimentary, Igneous and Metamorphic
- Geochemistry and Geochronology of Earth
- Geophysics of Earth and mineral physics
- Structural geology and Engineering geology
- Geology and Stratigraphy of India in global context
- Economic geology – ore and mineral exploration
- Hydrogeology and Groundwater
- Paleontology – Fossils and markers in geosciences
- Environmental geology and natural hazards

Course Outcomes:

- Overview of Earth science. Introduction to the major areas and trends in Geoscience. Introduction to the basic tools needed for Geoscience and geoengineering, both class room practical and field work

References:

1. Frank Press and Raymond Siever, 1985. Earth. W.H. Freeman and Company.
2. Edward J. Tarbuck and Frederick K. Lutgens, 2015. Earth Science. Pearson Global Edition.
3. Thomas H. Jordan, John Grotzinger, 2014. Understanding Earth. W. H. Freeman and Company
4. Davies J.F. 2009. Dynamic Earth - Plates, Plumes and Mantle Convection. Cambridge University Press.
5. Brian J. Skinner, Stephen C. Porter and Jeffrey Park, 2003. The Dynamic Earth: An Introduction to Physical Geology. Wiley.
6. Lee R. Kump, James F. Kasting, Robert G. Crane, 2016. The Earth System 3e. Pearson Education India

EPS602 Atmospheric and Oceanic Sciences (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Uniqueness of the Earth System – The habitable zone, green-house gases, the ozone layer, the remarkable properties of water, the role of ocean and vegetation
- Primer on laws of radiation and application in the atmosphere, simple layered atmospheric models
- Scattering, extinction and atmospheric radiative heating profiles, Radiative properties and spectra of major greenhouse gases
- Surface energy balance, coupling with the atmosphere, atmospheric composition and hydrostatic balance, thermal vertical structure
- laws of thermodynamics, thermodynamics of dry and moist air, buoyancy and convection
- Radiative equilibrium and radiative-convective equilibrium temperature profiles of our atmosphere and the role of convection in deciding the atmospheric structure, mass momentum and energy transport
- Ocean temperature, salinity, mixed layer, thermocline, observed circulation
- The wind driven circulation: wind stress, Ekman layer and pumping
- The thermohaline circulation: air-sea interactions, meridional overturning circulation, air-sea heat fluxes and resulting surface temperature distributions
- Top of atmosphere energy balance, Equator to pole energy, momentum and mass transport in the current climate
- Natural and forced climate variability, coupled climate variability and present day climate, Climatologically important components of the Earth system
- Climate equilibrium, sensitivity and feedbacks, Transient versus equilibrium response

Course Outcomes:

- Course sets the ground for students to know and start asking questions related with the Earth's climate system which will help them choose specialized electives. Well-rounded introduction to the climate system and its atmospheric, terrestrial, oceanic and cryospheric components. Introduction to the basic tools needed for the understanding of this coupled system. Introduction to the major factors behind climate dynamics.

References:

1. Dennis L. Hartmann, Global Physical Climatology, Academic Press, 1994.
2. John Marshall and Allan R Plumb. Atmosphere, Ocean and Climate Dynamics, Academic Press, 2007.
3. John M. Wallace and Peter V. Hobbs. Atmospheric Science, An introductory survey. Elsevier, 2006.
4. James Holton. An Introduction to Dynamic Meteorology. Vol. 88, 4th Edition, Academic Press, 2004.
5. Ruddiman, W F. Earth's Climate: past and future. W.H. Freeman & Son, 2001.
6. Liou, Kuo-Nan. An Introduction to Atmospheric Radiation. 2nd ed. Burlington, MA: Academic Press, 2002.

EPS603 Planetary Sciences (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to Planetary Science in Solar System and Extra-Solar System – Planets, Moons, Dwarf planets and protoplanets, Asteroids, Comets, Kuiper Belt objects and other small bodies
- Formation and evolution of planetary system
- Planetary Astronomy and Planetary Astrophysics
- Astrochemistry and Astrobiology
- Planetary composition and mineralogy – rocky, icy, gaseous composition
- Planetary morphology and processes – impact cratering, volcanism, tectonism
- Planetary geochemistry – ground-/space-based study; in-situ and remote analysis of planetary samples and analogues of meteorites and lunar and asteroidal samples
- Planetary interior and geophysical processes
- Planetary geochronology – remote planetary surface dating and in-situ dating using meteorites and planetary samples
- Planetary atmosphere and space weather
- Exoplanetary science-detection techniques, atmospheres, bio-signatures and habitable conditions, feasibility of the search of Earth like planets
- Planetary exploration and future prospects (Indian and International contexts)- remote sensing, ground-based, space-based, robotic and in-situ experiments and instrumentations

Course Outcomes:

- Overview of planetary science in the solar system and extra-solar system. Overview of planetary exploration and activities. Exposure to the basic tools and methodologies in planetary science

References:

1. Planetary Sciences by lmke de Pater and Jack J. Lissauer, 2015
2. Exoplanets by Sara Seager, 2011
3. Exoplanetary Atmospheres: Theoretical Concepts and Foundations by Kevin Heng, 2017
4. Introduction to Astrochemistry: Chemical Evolution from Interstellar Clouds to Star and Planet Formation by Satoshi Yamamoto, 2017
5. The Physics and Chemistry of the Interstellar Medium by A. G. G. M. Tielens, 2010
6. An Introduction to Astrobiology, 3rd edition edited by David Rothery, Iain Gilmour and Mark Sephton, 2018
7. Cosmochemistry, by Harry McSween, Gary Huss. Cambridge University Press, 2010
8. Planetary Geoscience, by Harry McSween et al., Cambridge University Press, 2019

EPS651 Mineralogy and crystallography (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to mineralogy and crystallography
- Crystals – systematics and properties
- Minerals - physical and chemical properties, and the systematics
- Minerals identification - Optical and analytic techniques, Hand/Field specimen and characterization
- Minerals - applications and implications

Course Outcomes:

- This course provides the basic and advanced understanding of mineralogy and crystallography. Mineralogy and crystallography are considered as important basics for geosciences, especially for petrology, geochemistry and geochronology.

References:

1. William E. Ford, 2006, Dana`s Textbook of Mineralogy (With Extended Treatise on Crystallography and Physical Mineralogy). CBS Publishers & Distributors Pvt. Ltd.
2. Deer W.A., Howie R.A. and Zussman J., 2013. Introduction to the Rock-Forming Minerals by Mineralogical Society of America.
3. Dyar M. D., Gunter M. E., Tasa D., 2019. Mineralogy and Optical Mineralogy. Mineralogical, Society of America.
4. Perkins Dexter, 2012, Mineralogy. Pearson Education.
5. William Nesse, 2014. Introduction to Optical Mineralogy. Oxford University Press.
6. Berry, L.G., Mason, B. and Dietrich, R.V., 2004. Mineralogy. CBS Publishers.
7. Andrew Putins. 2012. An Introduction to Mineral Sciences. Cambridge University Press

EPS652 Igneous and Metamorphic petrology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to igneous and metamorphic petrology
- Igneous, magmatic and volcanic processes
- Igneous rocks - classification, and their physical and chemical properties, Phase equilibria in igneous system, Geochemical evolution of magma
- Metamorphic rocks - classification, and their physical and chemical properties, Field Gradients and Facies
- Chemical petrology, mineral reactions, Geothermometry and Geobarometry
- Igneous and metamorphic minerals and rocks - Optical and analytic techniques and identification
- Igneous and Metamorphic rocks- applications and implications

Course Outcomes:

- This course provides the basic and advanced understanding of igneous and metamorphic petrology. Igneous rocks are one of the very important major rock types that formed in the very initial stage of Earth and planetary formation. In due course of time, igneous rocks are subject to deform because of pressure and temperature and structural change because of various reasons.

References:

1. Sen, Gautam, 2013. Petrology. Springer.
2. Winter, J.D., 2010. An introduction to Igneous and Metamorphic Petrology. Prentice Hall.
3. Philpotts, A.R. 2009. Principles of Igneous and Metamorphic Petrology. Prentice Hall.
4. B. Ronald Frost and Carol D. Frost, 2013. Essentials of Igneous and Metamorphic Petrology. Cambridge University Press.
5. Best, Myron G., 2002. Igneous and Metamorphic Petrology. Blackwell Science.
6. Faure, G., 2001. Origin of Igneous Rocks – The Isotopic Evidence. Springer
7. Bucher, K. and Martin, F., 2010. Petrogenesis of Metamorphic Rocks. Springer – Verlag.
8. Rollinson, H.R., 1993. Using Geochemical Data: Evaluation, Presentation, Interpretation. Longman Geochemistry Series. Prentice Hall.

EPS653 Sedimentology and Stratigraphy (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to sediments and sedimentary rocks
- Introduction to stratigraphy - lithostratigraphy and biostratigraphy
- Sedimentary basins and sedimentology
- Sedimentary rocks - classification, and their physical and chemical properties and processes
- Sedimentary minerals and rocks - Optical and analytic techniques and identification
- Sedimentary rocks- applications and implications

Course Outcomes:

- This course provides the basic and advanced understanding of igneous and metamorphic petrology. Igneous rocks are one of the very important major rock types that formed in the very initial stage of Earth and planetary formation. In due course of time, igneous rocks are subject to deform because of pressure and temperature and structural change because of various reasons.

References:

1. Sengupta, S., 2018. Introduction to Sedimentology. Oxford-IBH.
2. Sam Boggs, Jr., 2011. Principles of sedimentology & stratigraphy. Prentice Hall.
3. Donald R. Prothero and Fred Schwab, 2013. Sedimentary Geology. W. H. Freeman.
4. Reading, H.G., 1996. Sedimentary Environments: Processes, Facies and Stratigraphy. Wiley-Blackwell.
5. Gary Nichols, 2009, Sedimentology and stratigraphy. Wiley-Blackwell.
6. Magnus Wangen, 2010. Physical Principles of Sedimentary Basin Analysis. Cambridge University Press.

EPS654 Geochemistry and Geochronology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to geochemistry and geochronology
- Physics and chemistry of isotope geochemistry - radiogenic, stable, noble gas, and major element evolution
- Analytic geochemistry - methods and analysis
- Analytic geochronology - methods and analysis
- Earth's Geochemistry and geochronology processes and events in time and space
- Experimental Petrology and Geochemical evolution – observation, model and experimental
- Geochemistry and geochronology- applications and implications

Course Outcomes:

- This course provides the basic and advanced understanding of geochemistry and geochronology. These are important to understand the formation processes of minerals and rocks in time and space. It can date the formation time of the minerals and rocks using the isotope chemical and physical properties. It has important implications to understand the formation and evolution of the minerals and rocks and of course applicable to Earth as a whole to build up its chronologic events.

References:

1. William M. White; 2013. Geochemistry. Wiley-Blackwell.
2. McSween Jr. H.Y., S.M. Richardson and M.E. Uhle, 2003. Geochemistry: Pathways and Processes. Columbia University Press,
3. Gunter Faure, 1998. Principles and applications of Geochemistry. Prentice Hall.
4. John V. Walther, 2010. Essentials of Geochemistry. Jones and Bartlett Publication.
5. Gunter Faure and Teresa M. Mensing, 2005. Isotopes: Principles and Applications. Wiley
6. Dickin, A.P., 2005. Radiogenic Isotope Geology. Cambridge University Press.
7. Jochen Hoefs, 2015. Stable Isotope Geochemistry. Springer International Publishing.
8. Mason, B. and Moore, C.B., 1991. Introduction to Geochemistry. Wiley Eastern.
9. Krauskopf, K. B., 1967. Introduction to Geochemistry. McGraw Hill.
10. Rollinson, H.R., 1993. Using Geochemical Data: Evaluation, Presentation, Interpretation. Longman Geochemistry Series. Prentice Hall.

EPS655 Geophysics (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to geophysics - Physical properties of Earth materials, physical laws and geophysical data
- Internal structure of Earth – from Crust to Core; Insights from Seismology to recent observation and understanding
- Solid earth geophysics- seismology, gravity, geomagnetism, origin of geomagnetic field& internal dynamo theory and geothermics
- Geophysics and geodynamics
- High Pressure Mineral physics – experiments, numerical model and observations
- Geophysical exploration applications

Course Outcomes:

- Geophysics is one of the key components in geosciences for understanding the geologic processes and its evolution, and this course provides the basic and advanced understanding of geophysics. Present and advanced study of geophysical observation, exploration including laboratory aspects are covered.

References:

1. Lowrie, W., 2007. Fundamental of Geophysics. Cambridge Univ. Press. London.
2. CMR Fowler, 2005. The Solid Earth: An Introduction to Global Geophysics. Cambridge University Press.
3. Robinson A., Clark D., 2017. Basic Geophysics. Society of Exploration Geophysicists.
4. Jaeger J., Cook N. G. and Zimmerman R., 2007. Fundamentals of Rocks Mechanics. Wiley-Blackwell.
5. Alan E. Mussett, M. Aftab Khan, 2000. Looking Into the Earth: An Introduction to Geological Geophysics. Cambridge University Press.
6. Henok Tesfamariam Tewelde. 2017. Introduction to Exploration Geophysics. CreateSpace Independent Publishing Platform.

EPS656 Remote Sensing and GIS (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Fundamentals of remote sensing and GIS
- Remote sensing - systematic observation and techniques
- Image processing, analysis and interpretation
- Cartography and global positioning system
- Remote Sensing observations and program - Indian and global context
- Remote Sensing and GIS- applications and implications

Course Outcomes:

- This course provides the basic and advanced understanding of remote sensing and GIS. Remote Sensing and GIS is rather a very broad term that has important implications not only in geoscience but also in many other fields of science. Various trends of applications and observations of remote sensing and GIS in geosciences are covered.

References:

1. Lillisand, T. M. and Keifer, R. W., 2015. Remote sensing and image interpretation. John Willey and Sons, USA
2. Joseph G., 2005. Fundamentals of remote sensing. Universities Press, Hyderabad.
3. Rees WG., 2012. Physical Principles of Remote Sensing. Cambridge University Press.
4. Chang, Kang-taung, 2016. Introduction to geographic information systems. Tata McGraw-Hill,USA.
5. William Emery Adriano Camps. 2017. Introduction to Satellite Remote Sensing: Atmosphere,Ocean, Land and Cryosphere Applications. Elsevier.
6. Shunlin Liang Xiaowen Li Jindi Wang, 2012. Advanced Remote Sensing - Terrestrial Information Extraction and Applications. Elsevier.
7. Gupta, R.P., 2018. Remote Sensing Geology. Springer Verlag.

EPS657 Structural geology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction of structural geology
- Brittle deformation and structure
- Ductile deformation and structure
- Rock failure and mechanics
- Tectonics and geodynamics
- Applied structural geology: Mining geology and engineering geology

Course Outcomes:

- This course expects to provide the basic and advanced understanding of structural geology. Structural geology has important implications towards understanding the overall structure and evolution and the Earth geologic processes. Structural geology has important implications to mining geology and engineering science.

References:

1. Ramsay, J.G., 1967. Folding and fracturing of rocks. McGraw Hill.
2. Ramsay, J.G. and Huber, M.I., 1983. Techniques of Modern Structural Geology. Vol. I. Strain Analysis. Academic Press.
3. Ramsay, J.G. and Huber, M.I., 1987. Techniques of Modern Structural Geology. Vol. II. Folds and Fractures. Academic Press.
4. Robert J. Twiss, Eldridge M. Moores, 2007. Structural Geology W. H. Freeman publisher.
5. Haakon Fossen, 2010. Structural Geology. Cambridge University Press
6. David D. Pollard, Stephen J. Martel, 2020. Structural Geology: A Quantitative Introduction. Cambridge University Press.
7. Douglas W. Burbank, Robert S. Anderson, 2011. Tectonic Geomorphology. Wiley.
8. Donald Turcotte, Davis Gerald Schubert, 2018. Geodynamics. Cambridge University Press.
9. Eldridge M. Moores, Robert J. Twiss, 2014. Tectonics. Waveland Press

EPS658 Paleontology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Basics of paleontology
- Fossil science – Nature and formation, Systematics and classification
- Microfossils and Micropaleontology
- Vertebrate and Invertebrate Paleontology
- Evolution – Morphology, Diversification & Extinction
- Applied paleontology: Paleoecology and Paleoenvironment, Litho- and Bio-stratigraphy, Paleobiogeography
- Paleontology in Indian and global context

Course Outcomes:

- This course expects to provide the basic and advanced understanding of paleontology. Paleontology has important implications towards understanding the evolution of life and its interconnectedness with geologic processes. Paleontology deals with the geological record of past macro and micro-fauna and flora to establish the history of life on Earth. It has important implications for dating, climate reconstruction and search for economically viable resources.

References:

1. Michael J. Benton, David A. T. Harper, 2020. Introduction to Paleobiology and the Fossil Record. Elsevier.
2. Kathal P.K., 2012. Applied geological micropalaeontology. Scientific publishers.
3. M. Foote and A. Miller, 2008. Principles of Paleontology, W.H. Freeman.
4. D. R. Prothero, 2004. Bringing Fossils to Life: An Introduction to Paleobiology, McGraw-Hill.
5. Shrock, N., 2005. Principles of Invertebrate Paleontology, CBS Publisher & distributor Private Ltd.
6. Jones, R.W. 2002. Applied Palaeontology, Natural History Museum, London.
7. Michael Benton, 2004. Vertebrate Palaeontology, Wiley-Blackwell.
8. Howard A. Armstrong, Martin D. Brasier, 2004. Microfossils, Blackwell Publishing Ltd.

EPS659 Economic Geology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to economic geology
- Economic minerals and ores – Nature and formation, Systematics and classification
- Energy sources and resources – Fuels and Flows
- Indian economic mineral and ore deposits – Occurrences and Formation
- Major energy sources - Hydrocarbon (Coal, Petroleum, and Natural Gas) and Nuclear and non-conventional
- Economic ore and mineral exploration – Techniques, Policies, and Environmental measures
- Economic minerals and Future aspects in Indian and global context

Course Outcomes:

- Economic geology is the study of valuable mineral, ore, and rocks that are of economic importance and implications to the society. This course will provide an overview of a wide range of mineral and ore deposits and their formation processes. The implications of such economic mineral and ore deposits and their associated rocks to the society and overall economy, and also issues and measures on environmental aspects, will be covered.

References:

1. Robb, L., 2005. Introduction to Ore-forming processes. Blackwell Publ., Oxford
2. Prasad U., 2019. Economic Geology: Economic Mineral Deposits. CBS Publishers & Distributors Pvt. Ltd., New Delhi.
3. Jensen M.L. and Bateman, A.M., 2013. Economic mineral deposits. Wiley& Sons.
4. Neukirchen, Florian, Ries, Gunnar, 2020. The World of Mineral Deposits. Springer.
5. Kirtikumar Randive, Sanjeevani Jawadand, 2020. Mineral Economics: An Indian Perspective. Nova Science Publishers.
6. Walter L. Pohl, 2011. Economic Geology Principles and Practice: Metals, Minerals, Coal and Hydrocarbons – Introduction to Formation and Sustainable Exploitation of Mineral Deposits. Elsevier.
7. S.M. Gandhi and B.C. Sarkar. 2016. Essentials of Mineral Exploration and Evaluation. Elsevier.
8. Robert D Nininger, 2013. Minerals for Atomic Energy. Literary Licensing, LLC.
9. R. Dhana Raju, 2019. Indian Uranium Deposits. Cambridge Scholars Publishing.

EPS660 Hydrogeology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to Hydrogeology
- Hydrosphere and Hydrologic cycle – Components and Processes
- Ground water – Principles and processes, Occurrences and Distribution
- Indian economic mineral and ore deposits – Occurrences and Formation
- Groundwater exploration techniques, Electrical resistivity tomography and well logging
- Hydrologic analysis and management and Environment: Flood, Drought, Drainage system, Land-Atmosphere effects
- Hydrologic resources and Water harvesting
- Groundwater and distributed contaminant sources for groundwater pollution, time-lapse leachate monitoring including ERT. Policy aspects in Indian and global context

Course Outcomes:

- This course provides an introduction to the hydrogeology and an advanced study of hydrologic cycle and its aspects in climate, geology and anthropogenic activities. Advanced knowledge of groundwater and its exploration and exploitation with its effects are covered. Topics on hydrologic analysis and management, hydrologic resources and future aspects are also covered. Upon successful completion of the course, the student is expected to get an overall and advanced aspect of this subject.

References:

1. Todd D.K., 2011. Groundwater Hydrology. John Wiley and Sons.
2. Raghunath, H.M. 2007. Groundwater. Wiley Eastern Ltd.
3. John H. Cushman, Daniel M. Tartakovsky, 2016. The Handbook of Groundwater Engineering. CRC Press.
4. C.W. Fetter Jr., 2000. Applied Hydrogeology. Pearson.
5. Paul L. Younger, 2006. Groundwater in the Environment: An Introduction. Wiley.
6. Joel R Gat. 2010. Isotope Hydrology A Study of the Water Cycle. Imperial College Press.

EPS661 Physical Geology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to Geomorphology
- Geomorphologic landforms – Fluvial, Glacial, Aeolian, Coastal, and their interaction with Climate
- Weathering and Erosion and Sedimentation, and the Rock cycle
- Geomorphological research methods and techniques and model
- Quaternary Geomorphology and Processes
- Tectonic and non-tectonic Geomorphology and Processes
- Physiography of India in global context

Course Outcomes:

- This course provides an introduction to the physical geology and geomorphology of various landforms on Earth. The various processes acting on the surface and their landforms signifies the subsurface and internal processes of earth. Advanced study and recent progresses in the field of geomorphology are also covered. Upon successful completion of the course, the student is expected to get an overall and advanced aspect of this subject.

References:

1. Paul R. B. and David R. M., 2020. Key Concepts in Geomorphology. Cambridge University Press.
2. Sharma, H.S. 1991. Indian Geomorphology. Concept Publishing Co. New Delhi
3. Allison R. J., 2001. Applied Geomorphology: Theory and Practice. Wiley.
4. Douglas, W. B and Anderson, R. S., 2016. Tectonic Geomorphology, Wiley-Blackwell.
5. Holmes' Principles of Physical Geology, 2016. edited by Peter MacLaren Donald Duff, Donald Duff.
6. Adrian Harvey, 2012. Introducing Geomorphology: A Guide to Landforms and Processes. Dunedin Academic Press.
7. Robert S. Anderson, Suzanne P. Anderson, 2012. Geomorphology- The Mechanics and Chemistry of Landscapes. Cambridge University Press.
8. Steven Earle. 2019. Physical Geology. Open Textbook Library.

EPS662 Uranium Geology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- **Introduction:**
  - Objectives and challenges - geological considerations, time and project value estimation, terrain, legal, political and local issues
  - Uranium in the crust: Distribution of uranium - crustal abundance
  - Time bound character
  - Uranium in different rocks and minerals with some examples
  - Exploration guides:
  - Controls of mineralization — stratigraphic, structural, lithological and other controls
  - Stratigraphic guides - Early Proterozoic basal Quartz-Pebble Conglomerate (QPC) type, Lower-Middle Proterozoic unconformity type, Mesozoic sandstone type
  - Lithological guides - quartz- pebble conglomerate, intrusive and reactivated granites, carbonaceous/graphitic metapelites, graphitic schists, black shales, porous and permeable carbonaceous matter rich Mesozoic sandstones, calcrete
  - Structural guides - fault, fracture, foliation and their intersections, fault-breccia systems
  - Geochemical guides - Indicator/pathfinder elements, weathering and alteration, diffusion aureole, leakage anomaly, dispersion and mobility patterns, K,O/ MgO, U, Ni, As, V, Mn and B abundances, geochemical association of uranium with other trace elements
  - Mineralogical guides - Polymetallic mineralisation- Pb, Cu, Ni, Co, Se, As, Au, Ag, Te and Zn and sulphide mineralisation

- **Exploration methodology:**
  - Uranium exploration through different stages—conceptual modelling, reconnaissance, follow up and detailed surveys, prospecting and exploratory mining
  - Literature survey and conceptual modelling - study of available maps, identification of favourable parameters and geological environments
  - Reconnaissance and detailed survey — geological mapping from exploration point of view by remote sensing and ground surveys, narrowing down the target area
  - Uranium mineralogy — primary and secondary uranium minerals, their field identification

- **Geochemical techniques:**
  - Stages of geochemical survey (Planning, Parameters for exploration, Orientation, Reconnaissance and Detailed

surveys)

- Hydrogeochemical techniques (Uranium and radium in surface and ground water, sampling)
- Radiometric techniques: (7 lectures + 3 tutorials/field)
- Ground radiometric survey, gross gamma and spectrometric measurements, Demonstration of field equipment,
- Traverse planning, background radiation and anomaly detection, evaluation of anomaly
- Isorad mapping, channel sampling, shielded probe logging and radiometric assay of grab samples
- Radon emanometry- isotopes of radon,migration, sampling techniques (CCT, SSNTD, ROC) and limitations;
- Helium survey - principle, diurnal variation, sampling system, uses

▪ **Prospecting for uranium**

- Sampling: point, grab, grid samples; channel sampling; sample volumes; sampling by drilling, stratigraphic, reconnoitary, exploratory and evaluation drilling;
- Planning of boreholes, choosing location and grid pattern
- Borehole plan, selection of type of drilling (non-core/core)
- Lithological and geophysical logging,
- Borehole surveying- drift/deviation
- Borehole correlation sections
- Preservation of core, core skeletonization, sampling of boreholes sludge/core, comparative study of physical and chemical assay results of boreholes
- Estimation of disequilibrium.
- Assaying rock density
- Averaging of assay values from one location — samples of equal length/unequal lengths
- Averaging of assay values from different locations — evenly spaced samples, unevenly spaced samples;
- Compensation for varying rock density; erratic assays
- Recent trends in uranium exploration
- Present status of uranium supply and demand, New discoveries of uranium deposits in the world and in India, Case studies using different exploration techniques with examples from India and world

Course Outcomes:

- Basic and introductory understanding of Uranium geology and its implications. Uranium exploration and techniques and prospecting. Recent advancements and progresses and future of Uranium exploration and its applications

References:

1. R. Dhana Raju, 2019. Indian Uranium Deposits. Cambridge Scholars Publishing.

2. Benedetto De, Vivo Felice, Ippolito'S. Capaldi, P. R. Simpson. 1984. Uranium geochemistry, mineralogy, geology, exploration and resources. Springer, Dordrecht.
3. Robert Lauf, 2016. Mineralogy of Uranium and Thorium. Schiffer
4. Michel Cuney and Kurt Kyser, 2015. The Geology and Geochemistry of Uranium and Thorium Deposits. Springer.
5. Peter C. Burns, and Robert J. Finch, De Gruyter, 1999. Uranium- Mineralogy, Geochemistry, and the Environment

EPS666 Geophysical Fluid Dynamics (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Fluid characteristics of atmosphere/ocean – Observations from tank experiments, thermal stratification and convection, boundary layers
- Modes of motion in fluids – concept of fluid parcel, body and shear stresses. Pressure gradient force, gravity, rotational effects.
- Concept of viscous forces and their relevance for atmosphere/ocean
- Tracer transport – diffusion, advection
- Modes of heat transport and thermodynamics of fluid flow
- Importance of conservation laws in prognosing fluid motion, Equations of motion for mass, momentum and energy. Potential vorticity and its conservation
- Concept and need of scale analysis in the atmosphere and the ocean, Non-dimensionalization and characteristic numbers to describe geophysical flows
- Hydrostatic balance and departures from it
- Geostrophicity and Rossby number – geostrophic flow and atmospheric and oceanic circulation, thermal wind, jet stream and the tropopause
- Importance of friction – The Ekman layer and ocean mixed layer, Sverdrup transport
- Ocean circulation, western boundary currents
- Stratification, Boussinesq approximation and regional convection
- dynamics in the ocean and the atmosphere

Course Outcomes:

- The aim here is to build in the student an intuition for geophysical flows related with the Earth's Atmosphere and Oceans by simplifying the traditional theoretical approach with a perspective of a physicist. A major skill students will learn throughout the course will be that of scale analysis and how it is utilized to simplify, visualize and understand rather complex phenomena in the Atmosphere and the Ocean. Intuition will be developed by showing the scale independence of such flows/phenomena once the equations have been non-dimensionalized. The course will set the stage for the students to relate dynamics to atmospheric and oceanic physics which together make the dynamic weather and climate system. Students will also learn the need for bio-physico-chemical parameterizations.

References:

1. Cushman-Roisin, Benoit, and Jean-Marie Beckers. Introduction to geophysical fluid dynamics: physical and numerical aspects. Vol. 101. Academic press, 2011.
2. Vallis, Geoffrey K. Atmospheric and oceanic fluid dynamics. Cambridge University Press,a 2017.

3. James Holton. An Introduction to Dynamic Meteorology. Vol. 88, 4th Edition, Academic Press, 2004.
4. Gill A. Atmosphere-Ocean dynamics, Academic Press, 1982
5. Joseph Pedlosky. Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics, Springer, 2003

EPS667 Atmospheric Boundary Layer Meteorology and Air Pollution (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Structure and formation of the atmospheric boundary layer
- Mass, momentum and energy equations of motion, boundary conditions for the ABL and their mathematical form.
- Turbulence, its scales, Reynolds decomposition, homogeneous isotropic turbulence
- Mathematical modeling of the ABL – the problem of turbulence closure, orders of closure approximations
- Experiments in the ABL – sensors and techniques, spatial statistics and spectral statistics
- Dimensional and similarity modeling of the ABL – neutral ABL flows, similarity theories for surface and outer layers
- Boundary conditions – the surface energy budget and stability in the ABL
- Neutral, convective and stable ABL
- Dispersion of pollutants in the atmosphere, types of pollutants, dispersion models and parametrizations
- -diffusion equation, numerical treatment of point, line and area sources of pollutants, gravitational removal and residence times
- Thermodynamic diagrams, cloud formation and entrainment
- Impacts of land cover heterogeneities on the ABL structure

Course Outcomes:

- This course will initiate the students in understanding how the Earth's surface interacts with the free atmosphere and how we represent that mathematically and numerically. The students will come to appreciate the need for fundamental experimentation and how it is applied to understand/model land-atmosphere interactions. Vegetation-, urban-, mountain- and water- atmosphere coupling will be discussed to give a perspective of how these cases are similar and different and how to handle a new coupling problem between a new type of landscape and the atmosphere. The treatment of parametrizations under different types of atmospheric conditions will give the student a perspective of how turbulence characteristics can evolve with the state of the fluid, while at the same time giving them the perspective of the universality of laws that govern the statistical nature of turbulence. Particular case of advection-dispersion of atmospheric pollutants will be discussed under the growing need for air pollution studies. Discussion of past lab experiments and atmospheric observations will help the student translate the theoretical knowledge to practical application and understanding.

References:

1. Stull, Roland B. An introduction to boundary layer meteorology. Vol. 13. Springer Science & Business Media, 2012.
2. Tennekes, Hendrik, John Leask Lumley, and J. L. Lumley. A first course in turbulence. MIT press, 1972.

3. Pope, Stephen B. Turbulent flows. IOP Science, 200

EPS668 Tropical Meteorology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Distinct features (overview)
- Radiative-convective Equilibrium
- The Hadley and Walker Circulations
- Tropical boundary layers
- Response of the tropical atmosphere to localized sea-surface temperature anomalies and weak temperature gradient approximation
- Monsoon (world monsoon, Asian monsoon: interannual and intraseasonal variability)
- Intra-seasonal and inter-annual tropical variability
- Equatorial wave theory
- Easterly Waves
- Tropical cyclones
- Tropical convection
- Inter-tropical convergence zone
- Interannual variability (QBO, ENSO, IOD)

Course Outcomes:

- This course introduces the student to the role played by the tropical atmosphere in the climate system and the weather phenomenon in this region. The student will learn how the various tropical circulations inter-connect and transport mass, momentum and energy to regions within the tropics, in the extra-tropics and also the vertical. An overview and theory of these circulations ranging from the planetary (Walker circulation) to the regional scale (like deep convection and tropical cyclones) will be provided. The crucially important role of the absence/minima of the impact of Earth's rotation in tropical latitudes on tropical dynamics will also be discussed to contrast the theory with which the tropical and the extra-tropical atmospheres are understood. Challenges in tropical weather observation and prediction will also be discussed.

References:

1. Krishnamurti, T.N., Stefanova, Lydia, Misra, Vasubandhu, Tropical Meterorology, An Introduction, Springer Atmospheric Science, 2013
2. Laing, Arlene and Evans J. L. Introduction to Tropical Meteorology, MetEd UCAR program, 2nd Edition, 2016

EPS669 Cloud Micro-Physics (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Types and structures of clouds, observations of microstructures of clouds
- Cloud nucleation, cloud condensation nuclei and the k-theory
- Growth of cloud droplets in warm clouds
- Microphysics of cold clouds – ice nuclei, concentration of ice particles
- Solid precipitation types
- Cloud and precipitation chemistry
- nucleation scavenging
- dissolution of gases in cloud droplets, aqueous phase chemical reactions
- precipitation scavenging
- chemical composition of rain

Course Outcomes:

- Clouds play a crucially important role in our climate and weather systems. The large uncertainty in the future changes in precipitation under climate change come largely from our low understanding of the radiative, thermodynamic and dynamic effects of clouds and convective processes. On the other hand on weather time scales cloud microphysics has been shown to control how convection could evolve in a positive feedback cycle. This course will introduce the students to how much we know about the microphysical properties of different types of clouds and how these properties in turn impact the radiative, thermodynamic and dynamic processes in the atmosphere. The course will cover physics of cloud nucleation and growth and its parameterization. Liquid and ice phase precipitation and their coupling with convective processes will also be discussed.

References:

1. Hans R. Pruppacher and James D. Klett. Microphysics of clouds and precipitation. Springer, 1996.
2. IPCC. Climate change 2007. Technical report, Intergovernmental Panel of Global Climate Change, 2007 and latest ones.
3. John M. Wallace and Peter V. Hobbs. Atmospheric Science, An introductory survey. Elsevier, 2006.
4. R. R. Rogers. A short course in cloud physics. Pergamon Press, 1976.

EPS670 Atmospheric Thermodynamics and Convection (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Thermodynamic state, state variables and functions
- Zeroth Law, thermal and thermodynamic equilibria – the atmospheric context
- Energetics of thermodynamic processes and reversibility
- Equation of state for gases and gaseous mixtures
- Internal energy, heat, enthalpy and the First law of thermodynamics
- Heat capacities
- Phase change and latent heat
- Adiabatic processes, conservation of thermal energy and conserved quantities
- Entropy and Second law of thermodynamics
- Thermodynamic potentials
- Water-air systems, Clausius Clapeyron equation, humidity variables, heat capacities of moist air
- , the parcel method
- Dry and moist adiabatic lifting and conditional instability
- Thermodynamic processes in the atmosphere
- Entrainment
- Radiative-thermodynamic coupling

Course Outcomes:

- Thermodynamics of dry gaseous elements through chemical reactions and phase change of water in the atmosphere are a major dynamical forcing for our atmosphere. The coupling of land and the atmosphere is also majorly through thermodynamics, especially that involving phase change of water. This course gives an overview of atmospheric energy sources and sinks. Students will be introduced to the basic laws of thermodynamics and theoretical development of major atmospheric thermodynamic processes. We will also cover cumulus convection, interactions between cumulus convection and large-scale atmospheric flows, cloud-convection-radiation interactions and their role in the climate system. Parameterizations of thermal processes that couple the land and atmosphere through the boundary layer will also be presented.

References:

1. Petty, Grant W: A First Course in Atmospheric Thermodynamics
2. Iribarne, Julio V., and Warren Lehman Godson, eds. Atmospheric thermodynamics. Vol. 6. Springer Science & Business Media, 2012.

EPS671 Atmospheric Aerosols and Chemistry (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Overview of links between trace gases/aerosols and climate
- Composition of tropospheric and stratospheric air; residence times and geographical distribution.
- Important trace gases and their sources, transport and sinks
- Important organic and inorganic aerosol species and their sources, transport and sinks; residence times and geographical distribution.
- Chemical kinetics
- Tropospheric chemistry – nitrogen and Sulphur cycles
- Photochemistry and stratospheric ozone, aerosols and trace pollutants
- Particulate matter chemistry
- Aqueous phase chemistry
- Multiphase chemistry of clouds
- Mathematical parameterizations
- Major natural events causing air pollution – fire, volcanic emissions and their instantaneous impact on climate
- Pollution monitoring – overview of techniques, instruments, emission inventories and major monitoring campaigns
- Major policy breakthroughs in controlling anthropogenic pollution – Kyoto Protocol. Status of relevant policy in India.

Course Outcomes:

- Trace gases and aerosols have substantial climatic and air quality impacts. Aerosols occur in a myriad form, large size ranges, spatial and temporal distributions. Trace gases also vary in concentration, spatial and temporal distribution. Both can also transform through physico-chemical processes in the atmosphere and hence can have diverse impacts. The challenge in understanding these impacts stems however from this very diversity. This course concentrates on aerosol and trace gas chemistry. The course treats in detail the sources and fates of atmospheric particles and trace gases. We will discuss how particles and trace gases are formed, chemical reactions they participate in, and the measurement of their chemical composition. Major international and national environmental policy to control these components will be discussed as well. Students will leave the course with the understanding of the present state of affairs with regards to anthropogenic pollution, its impacts and tools to find solutions.

References:

1. William C. Hinds, Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles, 2nd Edition, 1999.

2. John H. Seinfeld and Spyros Pandis, Atmospheric Chemistry and Physics: From Air pollution to Climate Change, 2nd Edition, 2006, Wiley.
3. Barbara J. Finlayson-Pitts and James N. Pitts, Jr., Chemistry of the Upper and Lower Atmosphere, 1999, Academic Press.
4. Pramod Kulkarni, Paul A. Baron, and Klaus Willeke. Aerosol Measurement: Principles, Techniques, and Applications, 3rd Edition, 2011, Wiley.

EPS672 Climate and the Terrestrial Biosphere (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Components of the Earth system – hydrosphere, atmosphere, ocean, geosphere, cryosphere, terrestrial biosphere, oceanic biosphere, anthroposphere
- Examples of coupling through hydrological and biogeochemical cycles
- Climate change history - role of and impacts on the biosphere
- Basics of hydrology – water and heat transport in soils, types of soils
- Biosphere-hydrology coupling – physical effects of vegetation on hydrology, infiltration, interception, runoff
- Surface energy balance – radiative and turbulent fluxes, climatic zones
- Leaf scale energy budget, leaf conductance
- Leaf photosynthesis and its control on biosphere fluxes – stomatal conductance, factors of photosynthetic limitation, examples from ecosystem experiments
- Photosynthesis modeling – meteorological and physiological schemes
- Plant canopy and atmosphere interactions, Boundary layer parameterizations and representation of plant canopies in numerical models
- Nutrient cycling – Carbon fluxes, Net Ecosystem Production, Gross and Net Primary Productivity, seasonality, impact of the changing climate
- Observational techniques to monitor biomes

Course Outcomes:

- Earth's climate is coupled to the terrestrial biosphere in more ways than obvious. In this course, we will explore the key mechanisms that link climate (e.g., cloudiness, rainfall, and temperature) with the terrestrial biosphere, and how these mechanisms are altered by humans. We will review the biophysical processes underlying land-atmosphere exchanges of energy, water and carbon dioxide. Students will learn how these processes are mathematically represented in numerical models and the features and limitations of the resulting formulations. We will then analyze the impacts of land-atmosphere hydrological coupling and the land carbon sink, with a focus on seasonality. Observed dynamics under a changing climate will also be discussed. The course will end with a detailed discussion of instrumentation to monitor energy, water and trace gas exchanges of vegetation with the atmosphere.

References:

1. Gordon Bonan. Ecological Climatology, Concepts and Applications, 3rd Edition, 2015, Cambridge University Press.
2. S Lawrence Dingman, Physical Hydrology, Prentice Hall, 2002
3. Relevant papers and IPCC reports.

EPS673 Ocean Biogeochemistry (60 Lecture Hrs)

Coordinators: -
-

Course Details:

- Chemical composition of seawater, major and minor components, elemental speciation, ionic interactions in seawater
- Oceans' role in the global biogeochemical cycling of select elements
- Biogeochemical cycles of macro and micro nutrients
- Trace elements and their isotopes as tracers for physical, biological and geological processes
- Physical Oceanography, coupling climate and ocean currents and biogeochemistry
- Trace elements toxicity for marine bioata
- Photochemical processes in seawater, interactions between metal and organic matter
- Sediments, suspended particulate interactions, element speciation, and biomineralization
- Equilibrium and kinetic perspectives of marine processes
- Coastal systems and geochemical processes (Fjords, estuarine and shallow near-shore waters)
- Climate changes and feedbacks from the marine biogeochemical cycles
- Ocean acidification and Carbon cycle
- De-oxygenation of ocean, suboxic, anoxic-sulfidic zones
- Limiting and controlling elements for biological production: interactions between biogeochemical cycles and marine ecosystems

Course Outcomes:

- What is the major source of oxygen in our atmosphere? If you answer 'trees' then you desperately need this course. Oceans and marine life play a substantial and critical role in the Earth's carbon cycle superseding terrestrial contributions. This course will introduce the student to the biogeochemical processes that influence the marine carbon and other nutrient cycles, including its role in the control of atmospheric CO2 concentrations and the influence of CO2 emissions in changing the 'climate' of the ocean for example by increasing its acidity. Interactions of seawater and marine life with pollutants, and radiation will be analyzed. Oceanic physical, chemical and biological feedbacks with the changing climate will also be studied.

References:

1. Micheal J. R. Fasham, Ocean Biogeochemistry - The Role of the Ocean Carbon Cycle in Global Change, A part of the Global Change – The IGBP Series, Springer, 2003
2. K. A. Sverdrup and E. V. Armbrust, An Introduction to the World's Oceans, Mc Graw Hill, 2009
3. Sarmiento, Jorge L., and Nicolas Gruber. Ocean biogeochemical dynamics. Princeton University Press, 2006.

EPS674 Atmospheric Radiative Transfer (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Radiative forcing of climate, observations of radiative impacts on the surface, oceans, the atmosphere and dynamics (2 lectures)
- Thermodynamic equilibrium, Planck's law, Wien's displacement law, Stefan-Boltzmann law
- Radiative properties of Black and Grey bodies, Kirchhoff's law
- Single and multi layer opaque and transparent atmosphere model
- Concept of extinction and emission of radiation. Optical depth, extinction, absorption, scattering coefficients. Radiative fluxes and intensity
- Scattering by spherical particles, Rayleigh scattering, Mie scattering
- Absorption and emission lines in planetary atmospheres
- Beer's law and Schwarzschild's equation
- Two stream approximation, Examples of simple numerical Radiative Transfer models
- Atmospheric radiative heating profiles
- Line shapes and broadening
- Water vapor continuum and importance for atmospheric thermo-dynamics
- Cloud droplet formation, Kohler theory
- Climate and radiation – radiative impacts of gases, clouds, aerosols
- Climatically important radiative forcings, climate sensitivity and feedbacks

Course Outcomes:

- Solar radiation is the major driving force for atmospheric, oceanic and climate dynamics. However, it usually is nontrivial to realize that radiation's interactions the various components of the atmosphere and the surface cause this dynamics. An atmosphere less Earth would not have such diversity in the atmospheric and oceanic phenomenon. This course provides a detailed treatment of how solar radiation interacts mostly with the atmosphere which acts as an almost transparent medium, but then interacts with the Earth and changes its form so that the atmosphere remains transparent no more and initiates all the myriad dynamics. The course introduces the underlying principles of radiation and their complex transformation when radiation interacts with matter. Ultimately the course material is tied to the importance of radiation on both weather and climate time scales.

References:

1. John M. Wallace and Peter V. Hobbs. Atmospheric Science, An introductory survey. Elsevier, 2006.
2. Goody, Richard M., and Yuk Ling Yung. Atmospheric radiation: theoretical basis. Oxford university press,

1995.
3. Liou, Kuo-Nan. An Introduction to Atmospheric Radiation. 2nd ed. Burlington, MA: Academic Press, 2002.

EPS675 Physical Oceanography (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Observations of the oceans – general ocean vertical structure, ocean currents, oceanic thermal structure
- Global budgets of heat, water and salt
- Properties of saline water, equation of state
- Equations of conservation of mass, salt; Continuity equation
- Equations of motion and thermodynamics on a rotating frame
- Geostrophic and hydrostatic balance, surface geostrophic flow, shallow water equations
- Wind driven circulation, eddy viscosity
- Planetary, relative and absolute vorticity, conservation of potential vorticity, Taylor-Proudman theorem
- The Ekman layer and Sverdrup circulation, western boundary currents, coastal upwelling
- Waves in the ocean, surface and internal gravity waves, Kelvin waves and Rossby waves, waves in the oceans surrounding India
- Ocean heat transport, thermo-haline circulation, meridional overturning circulation, fronts and vertical thermal structure in the oceans surrounding the Indian peninsula
- Theoretical forecasting of tides and storm surges

Course Outcomes:

- The course is designed to provide a detailed understanding of the major physical phenomenon in the oceans, the underlying physical principles and scale dependence of these motions. Wind driven and thermally driven large scale motions, their coupling and impact on tracers like nutrients, heat content, salinity etc will also be discussed. Oceanic phenomenon specific to Indian weather and climate will also be discussed.

References:

1. K. A. Sverdrup and E. V. Armbrust, An Introduction to the World's Oceans, Mc Graw Hill, 2009
2. Joseph Pedlosky. Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics, Springer
3. Gill A. Dynamics of Ocean and Atmosphere, Academic Press

EPS676 Paleoclimatology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Global energy balance and faint young sun
- CO2 weathering and climate regulation
- Snowball Earth
- Greenhouse Earth – Cretaceous Climate
- Late Paleocene Thermal Maximum
- Cenozoic Cooling and Glaciation
- Effects of closing of tropical seaways on climate – Isthmus of Panama and Indonesian seaway
- Milankovitch cycles – orbital parameters. Impacts on glaciation and monsoons
- Ice core records of atmospheric composition – Vostok Ice Core and climate history of the past 420,000 years
- Last glacial maximum – ice sheets, sea level, dust and dating techniques, Reconstructing ocean $\delta^{18}O$, Salinity and temperature, ocean circulation, CO2
- Rapid climate change – records from ice cores and land
- Holocene climate
- Climate records from corals – past ENSO variability
- Climate of the last 1000 years
- References:
- Ruddiman, W F. Earth's Climate: past and future. W.H. Freeman & Son, 2001
- Micheal L Bender. Paleoclimate, Princeton University Press, 2013

Course Outcomes:

- A key challenge facing climate change research is the careful attribution of recent climatic trends to natural versus anthropogenic factors. This is because the Earth's climate has never been stationary owing to its various coupled bio-physico-chemical components. Getting a perspective of natural climate variability on varying time-scales is essential to address the current climate change problem. This course will prepare the student to separate natural from anthropogenic climate variability by providing various observational and modeled examples from the past. Students will be introduced to the fascinating world of climate proxy data, its collection, usage and uncertainties. Examples from past periods of warming and glaciation will be used to impart perspective on climate change sensitivities and feedbacks. The course will also prepare students in doing paleoclimate observational and numerical studies.

EPS677 Numerical Prediction of the Atmosphere and the Ocean (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Dynamical equations, coordinate systems, boundary conditions and time evolution
- Hierarchy of numerical models in the atmosphere and ocean
- Turbulence scales, spectral gap and hierarchy of turbulence modeling
- Finite difference approximations for hyperbolic, parabolic and elliptic equations, their energetics and stability analysis
- Spectral methods, finite element and finite volume discretization
- Parameterizations of physical processes – boundary layer, radiation, land surface, microphysics, convective processes, parameterizations in the ocean
- Basics of inverse techniques, meteorological and oceanographic data assimilation
- Dynamic and normal mode initialization
- Techniques of verification, predictability and weather forecasting

Course Outcomes:

- This course prepares the students in numerical techniques in general and the specific methods with which they are applied for numerical integration of the dynamical equations pertaining to the atmosphere and the ocean. The course will prepare students to understand atmosphere and oceanic numerical models. Parameterizations of physical processes pertaining to the Earth system will also be discussed, developed and applied in a numerical setting. Overall the course will help the students in two ways – understand concepts in numerical techniques in general and apply them to modeling the atmosphere and ocean.

References:

1. Mark Z Jacobson. Fundamentals of Atmospheric Modeling, Cambridge University Press, 2005.
2. Randall, A., An Introduction to Numerical Modeling of the Atmosphere. Online material available at http://users.df.uba.ar/carlosv/randall/
3. Warner, T. T., Numerical Weather and Climate Prediction, Cambridge University Press, 2010.
4. Pope, Stephen B. Turbulent flows. IOP Science, 2001.
5. Kalnay, E. Atmospheric Modeling, Data Assimilation and Predictability. Cambridge University Press, 2003
6. Griffies, S., Fundamentals of Ocean Climate Models, Princeton University Press, 2004.

EPS678 Techniques of Weather Prediction (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Overview of operational forecasting systems, role of initial and boundary conditions, role of model physics and dynamics
- Overview of governing equations
- Major weather systems - air masses and fronts, jet streams, mesoscale systems, tropical and mid-latitude weather, seasonality in weather
- Deterministic versus statistical modeling, ensemble and super ensemble prediction systems
- Initialization and model spin-up - relevance of observations
- Model evaluation, correlation, skills, and bias correction
- Data assimilation through numerical inversion techniques, three-dimensional variational analysis, 3-D VAR and 4-D VAR
- Role of parametrizations schemes: cloud microphysics, boundary layer, land/sea atmosphere interactions, scale sensitive parametrization schemes for convection
- Meteorological instruments - sensors, radiosondes, satellite observations, ground based instruments
- Observational weather analysis techniques - Thermodynamic diagrams, weather charts, 850 hPa& 200 hP, ψ and χ fields, mass & wind fields, cyclone development, synoptic forecasting
- Challenges in weather forecasting, predictability theories, status of weather forecasting – nationally and internationally

Course Outcomes:

- This course will provide the student with the essential understanding and tools needed for weather prediction and analysis. Both numerical and observational aspects of studying and forecasting weather phenomenon will be covered. Inverse techniques for observational data assimilation will be overviewed. Major challenges and scopes of improvements in the current state of weather prediction will also be discussed.

References:

1. Coiffier, J., Fundamentals of Numerical Weather Prediction, Cambridge University press, 2012.
2. Warner, T. T., Numerical Weather and Climate Prediction, Cambridge University press, 2011.
3. Daley, Roger, Atmospheric Data Analysis, Cambridge Atmospheric and Space Series, 1999.
4. Kalnay, E., Atmospheric modeling, Data Assimilation and predictability, Cambridge University Press, 2003.
5. Peter Lynch, The emergence numerical weather prediction, Cambridge University Press, 2006.

EPS681 Astrochemistry & Astrobiology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to the cosmic environment-various phase of the interstellar medium (ISM), types of interstellar clouds with examples of physical conditions and time scales, cloud structures, star formation, Young Stellar Objects (YSOs) and protostellar disks
- Introduction to interstellar molecules and dust-gas and grain surface chemistry in the ISM, molecule formation mechanisms, physics of chemical reactions, interstellar grains, mantle formation and desorption, molecular survey: abundances by cloud type, observational techniques and examples
- Physical conditions and molecular abundances in diffuse clouds, dark clouds with example spectra and observational constraints on ionization, local UV and X-ray sources, shocks etc
- Introduction to star formation, formation of complex organic molecules (COMs) from pre-stellar cores to protostars and observational studies
- Physics and chemistry of Solar nebula
- The chemistry of Comets, Meteorites and interstellar dust particles
- Pre-biotic chemistry and origin of life

Course Outcomes:

- This course provides the journey of molecules through the Cosmos, from local diffuse interstellar clouds and PDRs to distant galaxies, and from cold dark clouds to hot star-forming cores, protoplanetary disks, planetesimals and exoplanets. Emphasis will be placed on identifying the physical conditions in various astronomical objects, time scales for physical and chemical change, various chemical processes, observational constraints, various models which attempt to describe the chemical state and history of astronomical objects in general and the early solar system in particular.

References:

1. Introduction to Astrochemistry: Chemical Evolution from Interstellar Clouds to Star and Planet Formation by Satoshi Yamamoto, 2017.
2. The Physics and Chemistry of the Interstellar Medium by A. G. G. M. Tielens, 2010.
3. Cosmochemistry Hardcover by McSween Jr, Harry Y., Gary R. Huss, 2010.
4. Physical Processes in the Interstellar Medium, Lyman Spitzer, Jr, New York: Wiley, 1978.
5. Interstellar chemistry, W.W. Duley, D. A. Williams London, Academic Press, 1984.
6. Interstellar Processes, edited by D. J. Hollenbach and H.A. Thronson, Dorcrecht, Reidel, 1987.
7. Meteorites and the Early Solar Sytem, edited by J. F. Kerridge and M.S. Matthews, Tucson, University of Arizona Press, 1988.
8. Physics and Chemistry of Comets, edited by W.F. Huebner, Berlin, Springer-Verlag, 1990.
9. IAU Symposium No. 178: Molecules in Astrophysics, edited by E. F. van Dishoeck, Dordrecht, Kluwer, 1997.

10. Protostars and Planets III, edited by E. Levy and J. Lunine, Tucson, University of Arizona Press, 1993.
11. Protostars and Planets IV, edited by V.G. Mannings, A. Boss, and S. Russell, Tucson, University of Arizona Press, 2000.

EPS682 Formation and evolution of planetary system (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to Solar System and Constraints
- Summary of stellar and primordial nucleosynthesis
- Introduction to radio, infrared and optical astronomy to study physical and chemical origin of planetary systems such as our own: spectral line fundamentals, astronomical spectroscopy: rotational, vibrational and electronic, radiative transfer methods, radio astronomy-single dish & interferometers, infrared Astronomy and optical Astronomy
- Star formation-molecular cloud cores, collapse of molecular cloud cores, observations of star formation, observations of circumstellar disks
- Evolution of the protoplanetary disk-infall stage, disk dynamical evolution
- Growth of solid bodies-timescale constraints, planetesimal formation, from planetesimals to planetary embryos
- Formation of Terrestrial Planets
- Formation of Giant Planets-disk instability hypothesis, core accretion
- Planetary migration
- Small bodies orbiting the Sun-Asteroid Belt and Comet Reservoirs
- Satellites of planets and minor planets

Course Outcomes:

- Stars and planets are formed deep inside molecular clouds, but how this happens is still being unraveled. In this course, various stages in the formation of stars, from the collapse of an interstellar cloud to the formation of a planetary system will be discussed. This course also discusses the fundamental aspects of atomic and molecular spectra that enable one to infer physical conditions in astronomical, planetary and terrestrial environments from the analysis of their electromagnetic radiation.

References:

1. Planetary Sciences by lmke de Pater and Jack J. Lissauer, 2015.
2. Astrophysics of Planet Formation, by Phil Armitag, 2020.
3. Principles of star formation by Peter Bodenheimer, 2011.
4. Introduction to Astrochemistry: Chemical Evolution from Interstellar Clouds to Star and Planet Formation by Satoshi Yamamoto, 2017.
5. The Physics and Chemistry of the Interstellar Medium by A. G. G. M. Tielens, 2010.
6. Cosmochemistry Hardcover by McSween Jr Jr, Harry Y., Gary R. Huss, 2010.
7. Tools of radio astronomy by T. L. Wilson, K. Rohlfs, S. Huttemeister, 2018.
8. Interferometry and synthesis in radio astronomy by A. Thompson, J. M. Moran, S. J. George W, 2017

EPS683 Exoplanets (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Detection of methods of exoplanets- radial velocity detections, astrometry, transit detections, microlensing
- Properties of observed extrasolar planets
- Sensitivity and future methods for detection of extrasolar planets-transit programs and direct optical detection
- The Brown Dwarf-Exoplanet connection: intrinsic properties of Brown Dwarfs, observational techniques for identifying low-mass companions, Brown Dwarf as companions
- Close-orbiting exoplanets: formation, migration mechanisms and properties
- Dynamics of multiple planet systems
- Searching for exoplanets in the stellar graveyard
- Formation, dynamical evolution and habitability of planets in binary star systems
- Biosignatures for habitability and life
- Moons of exoplanets: habitats for life?

Course Outcomes:

- This course provides the basic principles of planet atmospheres and interiors applied to the study of extrasolar planets. Focuses on fundamental physical processes related to observable extrasolar planet properties. Provides a quantitative overview of detection techniques. Introduction to the feasibility of the search for Earth-like planets, biosignatures and habitable conditions on extrasolar planets.

References:

1. Is there life out there? The search for habitable exoplanets by Sara Seager, 2010.
2. Exoplanets by Sara Seager, 2011.
3. Exoplanetary Atmospheres: Theoretical Concepts and Foundations by Kevin Heng, 2017.
4. Exoplanets: Detection, Formation, Properties, Habitability by John (Ed.) Mason, 2010.
5. Extrasolar Planets: Saas Fee Advanced Course 31, Cassen, Patrick, Guillot, Tristan, Quirrenbach, A., 2010.

EPS684 Planetary Atmosphere and Space Weather (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to planetary atmospheres-Mars, Venus, Titan
- Thermal structure
- Atmospheric composition-spectra, line profiles and observations
- Clouds
- Meteorology
- Photochemistry-Mars, Venus etc
- Molecular and eddy diffusion
- Atmospheric escape-thermal vs non-thermal
- History of secondary atmospheres
- Overview of space weather
- Solar sources of space weather
- Solar influence on planetary atmospheric processes

Course Outcomes:

- This course provides the basic understanding of the physics and chemistry of planetary atmospheres. Explores the formation and evolution of atmospheres, their structure and dynamics, and what is known about their chemical composition. Pays particular attention to their energy balance. This course also provides lectures in space weather which describes the solar sources of space weather disturbances (i.e. solar-flares, coronal mass ejections, solar energetic particles, and their effect on earth and planetary atmospheres.

References:

1. Atmospheric Evolution on Inhabited and Lifeless Worlds by D. C. Catling & J. F. Kasting,2017.
2. An Introduction to Planetary Atmospheres by A. Sanchez-Lavega, 2015.
3. Planetary Atmospheres by F. W. Taylor, 2010.
4. An introduction to space weather by M. Moldwin, 2008.
5. Space weather-physics and effects by V. Bothmer & L. A. Daglis, 2007

EPS685 Planetary surface processes (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to planetary surface processes
- Planetary surface composition – spectroscopy, spectrophotometry and imaging
- Planetary morphology and structure – Imaging and observation and mapping
- Planetary igneous and magmatic processes
- Planetary volcanism and tectonism)
- Comparative planetary surface processes, features and composition
- Planetary sample, Meteorites, and Terrestrial analogue
- Impact cratering and processes, and terrestrial analogues
- Exploration of Planetary surface processes – India's and global context

Course Outcomes:

- This course provides the basic and advanced understanding of planetary surface features, processes, and their composition covering the present and future perspective view of planetary explorations. Understanding the planetary surface processes are key to understanding the interior composition and geologic evolution of the planetary body. A comparative planetary surface processes of entire planetary bodies in the solar system and extra solar system is covered.

References:

1. Carle M. Pieters, Peter A. J. Englert., 1993. Remote Geochemical Analysis: Elemental and Mineralogical Composition. Cambridge University Press.
2. Roger G. Burns. 1993. Mineralogical Applications of Crystal Field Theory. Cambridge University Press.
3. Bruce Hapke, 1993. Theory of Reflectance and Emittance Spectroscopy. Cambridge University Press.
4. S. Ross Taylor, Scott McLennan, 2009. Planetary Crusts- Their Composition, Origin and Evolution. Cambridge University Press.
5. Hutchinson R., 1993. Meteorites: A Petrologic, Chemical and Isotopic Synthesis. Cambridge University Press.
6. Derek W. G. Sears. The Origin of Chondrules and Chondrites. 2004. Cambridge University Press.
7. H. Jay Melosh, 2011. Planetary Surface Processes. Cambridge University Press.
8. Ronald Greeley, Introduction to Planetary. 2013. Cambridge University Press.
9. H. Jay Melosh, 1996. Impact Cratering: A Geologic Process. Oxford University Press.
10. Thomas R. Watters, Richard A. Schultz, 2010. Planetary Tectonics. Cambridge University Press.
11. Tracy Gregg Rosaly Lopes Sarah Fagents. 2020. Planetary Volcanism across the Solar System, Volume 1.

EPS686 Planetary Geophysics (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to planetary geophysics and interior
- Planetary geophysical observation and techniques
- Physics of planetary interior and geodynamics - Seismology, Gravity, Magnetism and Dynamo; Spherical harmonic analysis and synthesis and their role
- Planetary interior model – numerical simulation and observation
- Comparative planetary geophysics and planetary interiors in Solar system and beyond
- Planetary geophysical exploration – Indian and global context

Course Outcomes:

- This course provides the basic and advanced understanding of planetary geophysics, covering the present and future perspective view of planetary explorations. Understanding planetary surface and subsurface geophysical processes are key to understanding the interior structure and the geologic processes. Comparative planetary geophysics of entire planetary bodies in the solar system and extra solar system is also covered.

References:

1. William B. Hubbard, 1984. Planetary interiors. Van Nostrand Reinhold.
2. G H A Cole, 1995. The physics of planetary interiors. Rep. Prog. Phys. 58 755.
3. T. Platz, P. K. Byrne, M. Massironi and H. Hiesinger, 2015. Volcanism and tectonism across the inner solar system: an overview. Geological Society, London, Special Publications.
4. Thomas R. Watters, Richard A. Schultz, 2010. Planetary Tectonics. Cambridge University Press.
5. Planetary Sciences by lmke de Pater and Jack J. Lissauer, 2015.

EPS687 Planetary Geochemistry and Geochronology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Introduction to planetary geochemistry and geochronology
- Geochemical evolution of planetary interior and processes
- Planetary Geochemistry and Geochronology - observation and techniques - in-situ, sample, analogue, and meteorites
- Remote planetary surface dating versus analytic planetary Geochronology
- Planetary geochemistry and processes – numerical simulation and observation and experiment
- Comparative planetary geochemistry in Solar system and beyond
- Planetary geochemical exploration – Indian and global context

Course Outcomes:

- This course provides the basic and advanced understanding of planetary geochemistry and geochronology, covering the present and future perspective view of planetary explorations. Understanding planetary geochemistry and geochronology, and their processes are key to understanding the geologic evolution. A comparative planetary geochemistry and geochronology of entire planetary bodies in the solar system and extra solar system is covered.

References:

1. William M. White; 2013. Geochemistry. Wiley-Blackwell.
2. McSween Jr. H.Y., S.M. Richardson and M.E. Uhle, 2003. Geochemistry: Pathways and Processes. Columbia University Press.
3. Hutchinson R., 1993. Meteorites: A Petrologic, Chemical and Isotopic Synthesis. Cambridge University Press.
4. Derek W. G. Sears. The Origin of Chondrules and Chondrites. 2004. Cambridge University Press.
5. James J. Papike, 1998. Planetary Materials. Mineralogical Society of America.
6. R.W. Carlson, 2005. The Mantle and Core, Elsevier.
7. Derek York Ronald M. Farquhar, 1972, The Earth's Age and Geochronology. Elsevier.

EPS688 Seismology (60 Lecture Hrs)

Coordinators: Dr. Pratap Kuma Sahoo and Dr Kartikeswar Senapati
pratap.sahoo@niser.ac.in and kartik@niser.ac.in

Course Details:

- Mathematical theory of elasticity – stress and strain tensors, Hooke's law in 3D
- Seismic wave equation (formulation and derivation), solutions to the wave equation in terms of potential and plane waves, particle motion of P and S-waves.
- Eikonal approximation and ray theory, travel times – forward and inverse calculations, ray tracing in layered and spherically symmetric media including Snell's law, Huygens's principle, Fermat's principle, ray parameter, slowness
- Ray theory: amplitude and phase, reflection and transmission coefficients, attenuation.
- Refraction and Reflection Seismology. Move-out, CMP stack, Migration.
- Surface waves and dispersion. Theory of Love and Rayleigh surface waves. Use of surface wave dispersion in deciphering Earth's structure. Crustal and Upper mantle anisotropy.
- Earthquake seismology – Earthquake sources, seismic moment and magnitude, earthquake scaling relations, earthquake cycle, estimation of earthquake hazard, microzonation
- Optional topics: Receiver functions (earthquake seismology application), environmental seismology. (If time permits)
- Text Books :
- Introduction to Seismology, Peter Shearer, Cambridge University Press, 3rd Edition.
- An Introduction to Seismology: Earthquakes and Earth Structure, Seth Stein and Michael Wysession, 1st Edition, Wiley-Blackwell.

Course Outcomes:

- This course introduces students to global, reflection, and earthquake seismology. Its content is divided into three portions – seismic waves and their properties, their propagation through media and reflection seismology. The academic emphasis will be on using the mathematical theory of elasticity as the basis to understand seismic wave propagation and generation, and the characterization of earthquake sources. Through hands-on exercises on real data, rudimentary uses of ray theory for imaging structures in both exploration and global context will also be introduced.
- The desired academic outcome of the course is to empower students with a theoretical understanding of seismology and practical experience of rudimentary numerical and observational techniques of relevance to seismological data.

References:

1. Theoretical Global Seismology, F. A. Dahlen and J. Tromp, Princeton University Press, 1st Edition.
2. Computational Seismology, A Practical Introduction, H. Igel, Oxford University Press, 1st Edition.
3. Quantitative Seismology, K. Aki and P. G. Richards, University Science Books, U.S.A., 2nd Edition.