

Applied Geosciences

Curriculum

SEMESTER 1

Subject Code:	Name	L-T-P	Credit
ESA6001	Dynamics of Fluid in Earth System	4-0-0	4
ESA6002	Analytical & Measurement Techniques	3-1-0	4
ESA60XX	Elective - I	3-0-0	3
ESA60XX	Elective - II	3-0-0	3
ESA60XX	Elective - III	3-0-0	3
ESA60XX	Elective - IV	3-0-0	3
ESA6101	Advance Instrumentation Laboratory	0-0-3	2
ESA6401	Seminar - I	0-0-3	2
Total		19-1-6	24

SEMESTER 2

Subject Code:	Name	L-T-P	Credit
ESS6001	Science of Climate & Climate Change	4-0-0	4
ESS6002	Remote Sensing and GIS Applications	3-1-0	4
ESS60XX	Elective - V	3-0-0	3
ESS60XX	Elective - VI	3-0-0	3
ESS60XX	Elective - VII	3-0-0	3
ESS6101	Remote Sensing and GIS Laboratory	0-0-3	2
ESS6102	Modeling and Visualization Laboratory	0-0-3	2
ESS6401	Seminar - II	0-0-3	2
ESS6201	Comprehensive viva-voce		3
Total		16-1-9	26

SEMESTER 3

Subject Code:	Name	L-T-P	Credit
ESA6301	Thesis Part - I		20
Total			20

SEMESTER 4

Subject Code:	Name	L-T-P	Credit
ESS6301	Thesis Part - II		20
Total			20

Total Credit:

90

List of Subjects as Elective (I to IV)

Subject Code:	Name	L-T-P	Credit
ESA6004	Geothermal Energy	3-0-0	3
ESA6005	Applied Rock Mechanics	3-0-0	3
ESA6006	Environmental Geosciences	3-0-0	3
ESA6007	Mathematical & Statistical Methods in Geosciences	3-0-0	3
ESA6008	Hydrogeological Exploration & Modeling	3-0-0	3
ESA6009	Gas hydrates	3-0-0	3
ESA6010	Carbon Capture & Sequestration	3-0-0	3
ESA6011	Seismic Stratigraphy	3-0-0	3
ESA6012	Applied Coal Petrography & Coal Bed Methane	3-0-0	3
ESA6013	Marine Geology & Geophysics	3-0-0	3
MAA60XX	Mathematical Methods -I	3-0-0	3

List of Subjects as Elective (V to VII)

Subject Code:	Name	L-T-P	Credit
ESS6003	Mass & Heat Transfer in Solid Earth	3-0-0	3
ESS6004	Borehole Geophysics	3-0-0	3
ESS6005	Earthquake Seismology	3-0-0	3
ESS6006	Electromagnetic Exploration	3-0-0	3
ESS6007	Magnetotelluric Method	3-0-0	3
ESS6008	Glaciology	3-0-0	3
ESS6009	Geophysical Inverse Problem	3-0-0	3
ESS6010	Seismic Interpretation	3-0-0	3
ESS6011	Deep water imaging	3-0-0	3
ESS6012	Geodynamics	3-0-0	3
ESS6013	Hydrocarbon Basin Modeling	3-0-0	3
ESS6014	Exploration Seismology	3-0-0	3
ESS6015	Pre-stack Imaging	3-0-0	3
ESS6016	Geophysical Tomography	3-0-0	3
ESS6017	Transport Phenomena in Earth Systems	3-0-0	3
ESS6018	Aqueous Environmental Geochemistry	3-0-0	3
ESS6019	Ocean Resources & Technology	3-0-0	3
ESS6020	Polar Science	3-0-0	3
ESS6021	Carbon Cycle & Global Climate Change	3-0-0	3
ESS6022	Groundwater Modeling & Simulation	3-0-0	3
MAS60XX	Mathematical Methods -II	3-0-0	3

Syllabus

Core Subjects:

Subject Code: ESA6001	Name: Dynamics of Fluids in Earth System	L-T-P: 4-0-0	Credit: 4
<p>Fundamental concepts of continuum hypothesis, systems and control volumes, kinematics of fluids, integral and differential forms of the equations of motion, boundary conditions, dimensional analysis, scaling and stability; special limits and features of flows occurring in geological situations such as boundary layers, potential flow, vorticity, lubrication theory, turbulence and waves; Coverage of the fundamentals of fluid dynamics; Formulation of the equations of fluid flow such as Navier Stokes, Euler, Bernoulli, etc. and their applications; Examples of ideal and viscous fluid flow in open and closed conduits; Multiphase fluid flow in porous / fractured media; Introduction to Computational Fluid Dynamics - Numerical methods of simulation of reactive flow transport of fluids in porous/fractured rocks; Geological applications: (i) modeling and simulation of hydrocarbon maturation and migration in sedimentary basins; (ii) Thermal structure of the Mantle and mantle convection models, thermal perturbation in subduction zones, pipe and channel flow; (iii) reactive flow modeling and simulation of mineralization in hydrothermal systems; (iv) modeling and simulation of folding of multilayer rocks.</p>			
Subject Code: ESA6002	Name: Analytical & Measurement Techniques	L-T-P : 3-1-0	Credit: 4
<p>Concepts in analytical chemistry; Classical and rapid methods of analyses; Atomic absorption spectrometry; Inductively coupled plasma-atomic absorption spectrometry; X-ray fluorescence analysis; Energy dispersive X-ray spectrometry; X-ray diffraction analysis; micro beam and surface analysis techniques; neutron activation analysis, mass-spectrometry. General measurement system, principles, measurement of meteorological parameters, wind speed, temperature and humidity, pressure etc, in-situ and remote measurements, SODAR, LIDAR, RADAR techniques, aerosol measurement techniques, optical depth, size distribution, chemical composition, trace gas measurement techniques.</p>			
Subject Code: ESS6001	Name: Science of Climate & Climate Change	L-T-P: 4-0-0	Credit: 4
<p>Description of the climate system, natural greenhouse effect and the effect of trace gases and aerosols, feedbacks in the climate system, climate change in the past, ice ages, proxy records, abrupt climate change, Instrumental record of climate, climate variability on various time-scales, simple models of climate, General Circulation Models, natural and anthropogenic climate change: detection and attribution, impacts and mitigation of climate change</p>			

Subject Code: ESS6002	Name: Remote Sensing & GIS Applications	L-T-P: 3-1-0	Credit: 4
<p>Concepts of remote sensing; electromagnetic energy and its interactions in the atmosphere and with terrain features; elements of photographic systems, aerial photo-interpretation and geological applications, Fundamentals of photogrammetry, satellite remote sensing, multi-spectral scanners, thermal scanners, microwave remote sensing, fundamentals of image interpretation and geological applications, Digital image processing. Geographic Information System, spatial data models and data structures, visualization and query of spatial data, overlay analysis, geological applications of GIS.</p>			

Electives Subjects: (I, II, III, IV):

Subject Code: ESA6003	Name: Tectonics and Crustal Evolution	L-T-P: 3-0-0	Credit: 3
<p>Composition of crust, mantle and core; plate tectonics; tectonic setting; deformation pattern and magma association, Precambrian tectonics. Phanerozoic plate tectonics. Evolution of the Himalayas and Indian Ocean. Evolution of Indian subcontinent, Ur to Rodinia to Gondwanaland.</p>			
Subject Code: ESA6004	Name: Geothermal Energy	L-T-P: 3-0-0	Credit: 3
<p>Heat transfer: conduction, convection, radiation, heat flow measurements, structural influence on the heat flow distribution, effect of radioactivity, role of groundwater circulation and changes of state of groundwater. Natural hydrothermal systems chemical nature of hydrothermal systems, hydrothermal solutions, chemical and isotopic geothermometers, origin and age of geothermal resources, rock alteration related to water geochemistry, data collection and processing. Utilization of geothermal energy. Economics and management of geothermal energy,</p>			
Subject Code: ESA6005	Name: Applied Rock Mechanics	L-T-P: 3-0-0	Credit: 3
<p>Rock Mechanics, its applications, rock rheology, basic concepts of rock excavation and its utility. Open excavations: dams, reservoirs, canals, outfalls, trenching, cutting, ripping, highways.</p> <p>Underground excavation: Tunnels, Caverns, Bunkers. Engineering rock properties and its applications and determination, in-situ stress measurement techniques, flat jack, hydro-fracturing, drilling and blasting practices, water-rock interaction - effect on physical properties, stress-distribution in and around openings, stabilization and strengthening of structures.</p> <p>Soil/rock transportation and erosion, fluid migration through porous media and its effects on time dependent behaviour of rock, rock dynamics, rock mechanics aspects of reservoir performance, fracture mechanics, damage mechanics and naturally fractured reservoirs,</p>			

numerical and physical modeling for rock excavations, earth pressure theories, settlement analysis, liquefaction, rock mass rating for design and construction, health monitoring of various type of structures, rock engineering system.

Subject Code: ESA6006	Name: Environmental Geosciences	L-T-P: 3-0-0	Credit: 3
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Introduction to Natural hazards – earthquakes, tsunamis, volcanoes, landslides, avalanches, floods, cyclones, mine fire and blow out; Causes, risk and mitigation of natural hazards; Mechanics of recent and historical earthquakes, seismic risk and hazard, earthquake prediction, types of volcanism, styles of eruption, forecasting and mitigation of volcano hazard, Tsunami – causes and prediction, prediction and prevention of landslides, landslide zonation and risk assessment, Flood hazard and mitigation, geological hazards - vulnerability and risk assessment using GIS, Environmental hazards – Nuclear waste, ground water pollution, Important case studies of natural hazards

Subject Code: ESA6007	Name: Mathematical & Statistical Methods in Geosciences	L-T-P: 3-0-0	Credit: 3
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Concept of a frequency distribution: Moments, skewness and kurtosis Probability: Various approaches of probability classical, frequency (statistical), subjective and axiomatic. Theorems on probability, conditional probability, Independence, Bayes Theorem. Random variable: discrete and continuous. Distribution function and their properties, probability mass and density functions, Mathematical expectation, Moment generating function and its properties. Probability distributions: Bernoulli, binomial, negative binomial, Poisson and normal distributions. Theory of least squares and curve fitting. Correlation Simple, multiple and partial, Regression lines and regression coefficients, Multiple and partial regression. Test of Significance: Normal test, t-test, Chisquare and F-test, Principal component analysis

Subject Code: ESA6008	Name: Hydrogeological Exploration & Modeling	L-T-P: 3-0-0	Credit: 3
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Hydrology and basin characteristics, run-off and stream flow, aquifer characteristics, geology of groundwater occurrence, trans-boundary aquifers, groundwater quality, saline water intrusion, groundwater contamination, groundwater exploration: geological, geophysical and remote sensing methods, artificial recharge, groundwater modeling, groundwater law, watershed management Hydrocarbon Basin Modeling,

Subject Code: ESA6009	Name: Gas hydrates	L-T-P: 3-0-0	Credit: 3
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Introduction to gas hydrates; Importance of gas hydrates; Various hydrate structures Hydrate formation conditions; Gas hydrates and oil and Petroleum Industries; Gas hydrates in drilling operations; Gas hydrates in oil and gas production and transportation; Experimental techniques in determining the hydrate stability zone; Sample preparation; Predictive techniques; case histories.

Subject Code: ESA6010	Name: Carbon Capture & Sequestration	L-T-P: 3-0-0	Credit: 3
Carbon sources; Capture processes- Flue Gas Separation, Oxy-Fuel Combustion, Pre-Combustion Capture; CO2 storage- Geologic Storage, Ocean Storage; Economics; Alternate approaches.			
Subject Code: ESA6011	Name: Seismic Stratigraphy	L-T-P: 3-0-0	Credit: 3
Theory and geometry of seismic wave propagation, Seismic wave velocities in rocks, Review of marine and land seismic data acquisition techniques; Fundamentals of time series analysis, auto and cross correlation, convolution, sampling theorem and aliasing, filtering, deconvolution; Data enhancement techniques - Noise reduction, travel time correction, stacking, wavelet processing, frequency filtering, velocity analysis, amplitude correction, migration techniques, Seismic interpretation - typical trap types and their seismic definition, velocity, structural and timing effects; Basic concepts, definitions and objectives of seismic stratigraphy, Stratigraphic patterns in seismic data, Seismic attribute analysis, Seismic sequence analysis - interpretation of depositional environment and lithology, eustatic sea level changes, Seismic Facies analysis- seismic reflection characteristics, simple and complex reflection configuration, Seismic reflection character analysis- amplitude and continuity.			
Subject Code: ESA6012	Name: Applied Coal Petrography & Coal Bed Methane	L-T-P: 3-0-0	Credit: 3
Coal depositional environments; Controls on coal quality; Coal occurrence; Maceral (kerogen) types; Liquid- vs. gas-prone kerogen; Effects of maceral type on gas sorption and diffusion; Coal bed gas origin; thermal maturity of coal; Coal bed gas composition and heating value; Coal bed permeability; estimation of coal tonnage and gas volume; Coal bed exploration models; Case studies.			
Subject Code: ESA6013	Name: Marine Geology & Geophysics	L-T-P: 3-0-0	Credit: 3
Morphology of Ocean basins; Origin of ocean margins; Composition of marine sediments; Waves and currents; Sea level processes and sea level change; Imprint of climate zonation on marine sediments; Paleogeography-Deep sea record; marine mineral resources; Plate tectonic theory; Concepts of Imaging and Arrays; Seafloor Imaging Systems; Marine Magnetism; Marine Gravity and Satellite Altimetry; Seafloor Heat flow; Seafloor Seismicity; Refraction Seismology; Reflection Seismology			

Electives (V, VI, VII):

Subject Code: ESS6003	Name: Mass & Heat Transfer in Solid Earth	L-T-P: 3-0-0	Credit: 3
Basic concepts of heat transfer by conduction, convection and thermal radiation and their relevance to metallurgical processes; Heat conduction equation; convection and heat transfer calculations; thermal resistance; heat transfer coefficient; selected dimensionless			

groups; Fluid flow and viscosity; mass transfer in Earth's interior; Applications of mass transfer to magma generation and transport; Case studies-ocean ridges, trenches, continental rift systems; mantle plumes.

Subject Code: ESS6004

Name: Borehole Geophysics

L-T-P: 3-0-0

Credit: 3

Principles methods and applications; Subsurface Formation evaluation, Oil well technology; Drilling fluids; Logging techniques including neutron techniques; Image scanning methods; Data acquisition and interpretation; M-N plots; Estimation of physical parameters of rock formations; case studies.

Subject Code: ESS6005

Name: Earthquake Seismology

L-T-P: 3-0-0

Credit: 3

Introduction to seismology, Elasticity, Stress-strain relationships, Equations of motion, seismic wave equations, Body waves and ray theory, Partitioning of energy, Attenuation, anisotropy and anelasticity, Travel times in layered media, Surface waves dispersion and free oscillations, Seismometry and Principles of Digital seismographs, Seismic observatory practices, Seismogram interpretation - Nomenclature of seismic phases, Body wave travel times in earth, Internal structure and composition of the earth, Earthquakes - Seismic sources, Directivity, Scaling laws, Magnitude scales, Location, Focal mechanisms, Moment tensors, Stress drop, Earthquake characteristics, effects and distribution, Seismotectonics, Earthquake prediction, Seismic hazard and risk, Waveform modeling and Inverse problems.

Subject Code: ESS6006

Name: Electromagnetic Exploration

L-T-P: 3-0-0

Credit: 3

Principle of electromagnetic induction; VLF and AFMAG methods, TURAM method. Analysis of response function; Maxwell's equations; Hertz vector, Lorentz condition, boundary conditions, Electromagnetic scale modeling;; Basic principles of transient electromagnetic methods, transient emf and magnetic field behavior; concepts of toroidal and poloidal induction; geometric sounding, Airborne EM.

Subject Code: ESS6007

Name: Magnetotelluric Method

L-T-P: 3-0-0

Credit: 3

Sources of MT signal, interaction with the earth uniform earth, horizontal layers, anisotropy, inhomogeneity, impedance tensor and tipper, topographic and regional effects, static shift. Theory of electromagnetic wave propagation in horizontally layered earth and response over multi layered earth, skin depth for homogeneous and layered earth. Data processing and analysis: auto and cross spectra, solution to the impedance and tipper equations, local and remote references, errors and noise. Robust and hybrid processing. Interpretation: interpretation of MT data over a two layered earth, strike, rotation swift strike. Case studies.

Subject Code: ESS6008	Name: Glaciology	L-T-P: 3-0-0	Credit: 3
<p>Glaciers-formation, occurrence movement; glacier mass balance; Ice core analyses; glacier dynamics; glacier hydrology; temperature conditions in glaciers; remote sensing techniques in glaciology; Review of past changes in Earth's climate system with emphasis on the climate during the Quaternary period. Climate change causes, techniques used to reconstruct paleoclimate records from ice cores.</p>			
Subject Code: ESS6009	Name: Geophysical Inverse Problem	L-T-P: 3-0-0	Credit: 3
<p>Foundation of Inverse theory: Hilbert space; Norm and dimension; Common matrices in inverse problems, rank of a matrix, matrix partitioning; eigen values and eigen vectors, inverse of a matrix, Classification of inverse problems: linear, quasi linear and non-linear inverse problems, examples. Structure of an inverse problem: Gauss Newton, Levenberg Marquardt approaches, model and data covariance; Monte Carlo, simulated annealing, genetic algorithm, tabu search, neural networks and hybrid methods, 1D and 2D structures: gravity and magnetic anomalies, resistivity, IP and MT data, travel time and velocity inversion, full waveform inversion, cross hole tomography.</p>			
Subject Code: ESS6010	Name: Seismic Interpretation	L-T-P: 3-0-0	Credit: 3
<p>Travel time relation for direct, reflected and head waves over multi layered earth. Land and marine energy sources, electromagnetic pulse and Accelerated Weight Drop. Basic theory and working principle of seismic transducers, MEMS technology (Digital Sensor) and marine transient EM. Concept of seismic channel. Seismic recording instruments. Non distributed and distributed systems. Telemetry; refraction/transmission shooting techniques: reduction of refraction data, Seismic attenuation, reflection and transmission; Methodology for 2D reflection Survey: Common depth point shooting and its advantages. 3D survey designing: Different 3D geometries, swath, MESA, GEOLAND, GXIII, 3D survey Offshore survey: Single, streamer and multiple streamer surveys, feathering, Q Tech, OBS surveys. Various navigation and positioning systems used for reflection/refraction survey. Computation of navigational data, geodesy, Elements of map projection. Introduction to shear wave prospecting.</p>			
Subject Code: ESS6011	Name: Deep water imaging	L-T-P: 3-0-0	Credit: 3
<p>Introduction: Deep water: Indian and World Scenario, Deepwater Depositional System, Deepwater Challenges and Strategy, Problems associated with Seismic in Deep Water Imaging; Marine Controlled Source Electromagnetic (MCSEM): Physics of MCSEM, EM Boundary Condition and Attenuation, Numerical Studies and Case Studies Principles of Marine Magnetotelluric and Case Studies</p>			

Subject Code: ESS6012	Name: Geodynamics	L-T-P: 3-0-0	Credit: 3
<p>Geodynamic models and plate tectonics: Oceanic magnetic anomalies and their interpretations, magneto stratigraphic time scale, paleomagnetic evidences from continental drift, APWP for different continents and their main results, seismological evidences for lithospheric deformation, concept of sea floor spreading and plate tectonics, plate margins and processes at plate margins, triple junction, Characteristic movement of Indian plate and formation of the Himalayas.</p>			
Subject Code: ESS6013	Name: Hydrocarbon Basin Modeling	L-T-P: 3-0-0	Credit: 3
<p>Chemical composition and physical properties of petroleum crude, origin of petroleum, migration of oil and gas. Reservoir rocks classification and petrophysical properties. Hydrocarbon traps - definition and classification, structural, stratigraphic and combination traps. Plate tectonics and global distribution of hydrocarbon reserves. Petroliferous basins of India: classification and tectonic setup</p>			
Subject Code: ESS6014	Name: Exploration Seismology	L-T-P: 3-0-0	Credit: 3
<p>Introduction to seismic data processing. Processing sequences, preparation of processing geometry, quality checks, true amplitude recovery, deconvolution, filtering, velocity analysis, statics, noise elimination through multichannel filtering, parameter optimization for generation final stacked section. DMO and migration, AVO and attribute analysis. Anisotropy processing: HTI, VTI .Mode .Converted Wave Processing.3D Processing techniques, generation of time slice and stacked sections. Concepts of SRME, Radon. PSTM, Imaging, PSDM. Seismic modeling: Introduction to wave equations & wave equation modeling. Overview of Seismic Stratigraphy. Wavelet processing for seismic stratigraphic interpretation. Seismic sequence analysis and seismic facies analysis. Interpretation: Study of seismic section and other geological aspects of prospecting, structural interpretation, construction of isochron and isopach maps, thin bed resolution and pitfalls, prospect evaluation, new development such as work station environment in seismic interpretation using standard packages.</p>			
Subject Code: ESS6015	Name: Pre-stack Imaging	L-T-P: 3-0-0	Credit: 3
<p>Review of post stack imaging techniques. Mathematical background of wave equation migration techniques. The exploding reflector concept, its advantages and limitations. Kirchoff's Migration, Kirchoff's Integral, Time versus Depth and post stack versus pre-stack migration, time migration, depth conversion of time migration, post stack migration, pre-stack migration. Migration velocity analysis, frequency domain migration, time versus frequency domain, geometrical overview of migration, phase shift migration. Finite Difference migration</p>			

Subject Code: ESS6016	Name: Geophysical Tomography	L-T-P: 3-0-0	Credit: 3
<p>Theory and geometry of seismic waves, seismic velocity of rocks, characteristics of seismic events, seismic sources and equipment. Seismic reflection and refraction field methods, CDP technique, seismic noise, velocity measurements, marine seismic surveys, data processing - convolution, correlation, filtering, velocity analysis, stacking and migration, synthetic seismograms, seismic interpretation. Fundamental concepts of inverse theory with application to Geophysics, Probability, Inverses with discrete and continuous models, inverse methods based on length, generalized matrix inverses and maximum likelihood methods, non-uniqueness, applications of vector spaces, resolving kernels, use of prior information, singular value decomposition, non-linear inverse problems, continuous inverse theory and tomography, Backus-Gilbert inverse problem, Applications of inverse theory to geophysics.</p>			
Subject Code: ESS6017	Name: Transport Phenomena in Earth Systems	L-T-P: 3-0-0	Credit: 3
<p>General property balances; Convective and diffusive flux; Conservation equation for thermal energy; Fourier's Law; Steady-state unidirectional conduction; Conservation equation for chemical species. Fick's Law; Mass transfer boundary conditions; Steady-state unidirectional diffusion; Steady-state unidirectional diffusion; Transient and diffusion and conduction.</p> <p>Conservation equation for momentum; Momentum diffusion and viscous stress; Navier-Stokes equations; Steady-state duct flows; Low Reynolds hydrodynamics; Potential and boundary layer flows, Convective heat and mass transfer.</p>			
Subject Code: ESS6018	Name: Aqueous Environmental Geochemistry	L-T-P: 3-0-0	Credit: 3
<p>Shallow earth interactions in emphasizing: groundwater geochemistry; elemental cycles linked to biological activity in the oceans; geochemistry and global climate cycles; geo-bioremediation; and applied analytical techniques.</p>			
Subject Code: ESS6019	Name: Ocean Resources & Technology	L-T-P: 3-0-0	Credit: 3
<p>Ocean boundaries; fundamentals of marine geological principles; Geomorphology and structure of the Ocean floor, continental slope and shelf.</p> <p>Marine sediments: their formation; types; distribution and classification.</p> <p>Distribution of marine minerals along the Indian Coasts; Marine geo-physical technology; prospecting for oil-bearing strata; natural gas and oil traps.</p>			

Marine mineral resources: Placer deposits hydrocarbon deposits and polymetallic nodules; Exploration and exploitation of natural minerals off the coast.

Energy from oceans - Tides, Waves, Currents, Salinity and thermal gradients with special reference to Indian coast - Energy converters for extraction of ocean energy - Design principles of wave power, tidal power and OTEC systems -Cost-benefit analysis autonomous underwater vehicle (AUV); ocean bottom features by swath bathymetry.

Subject Code: ESS6020

Name: Polar Science

L-T-P: 3-0-0

Credit: 3

Overview of Polar Geography and Climate; History of Indian Antarctic programme; Physical characteristics; weather and climate, ice coring in Antarctica for Paleo-environment studies, logistics of Antarctic Science, opportunities, Antarctic governance and protection of Antarctic environment, International linkages.

Ice characteristics and physical oceanography of polar seas; Sea ice: types, physical and mechanical properties, heat flux, temporal and spatial distribution, melting and freezing processes, forecasting models, and remote sensing of ice/snow covered surfaces. Physical oceanography of currents and water masses, deep and bottom water formation, fronts and eddies, polynya processes, and underwater acoustics.

Operational aspects of Arctic and Antarctic meteorology, including polar lows, boundary layer and marginal ice zone influences.

Polar oceanography: Sea ice amount, seasonal distribution, melting and freezing processes, physical and mechanical properties, drift and predictions. Physical oceanography of currents and water masses, deep and bottom water formation, fronts and eddies.

Subject Code: ESS6021

Name: Carbon Cycle & Global Climate Change

L-T-P: 3-0-0

Credit: 3

Introduction: Climate in the Spotlight; the Spectrum of Scientific Opinion.

The Earth's Natural Greenhouse Effect -General Overview, the radiative balance, greenhouse gases - An Overview, The Role of Carbon Dioxide, The Role of Methane, -Major Uncertainties, Polar regions as an indicator of climate change, CO₂ Emissions, Human Emissions of CO₂.

Carbon Cycling: Some Examples, the Physical Carbon Pump, the Biological Carbon Pump, the Marine Carbon Cycle, and the Terrestrial Carbon Cycle. Climate and Weather, Definitions, -The Earth's Climate Machine, Clouds, Storms and Climate -Cloud Formation and Climate, tropical cyclones and Global Warming.

Global Ocean Circulation: Introduction and Overview; El Niño and the Southern Oscillation; El Niño and its Effects; Upwelling and Climate.

Outlook for the Future: IPCC projections; Introduction to Climate Change; Advances in Computer Modeling.

Subject Code: ESS6022	Name: Groundwater Modeling & Simulation	L-T-P: 3-1-0	Credit: 4
<p>Fundamentals of Groundwater: Occurrence, physical properties- porosity, effective porosity and permeability, Darcy's Law and its validity, Dupuit-Forchheimer assumptions. Types of Aquifers: Confined, unconfined and leaky aquifers, aquifer hydraulics. Surface and sub-surface investigations of groundwater. Aquifer Tests and Parameter Estimation: Necessity of aquifer tests, steady and transient methods for determining aquifer parameters from pumping test data, recovery test, analysis of step-drawdown test data. Artificial recharge techniques. Groundwater Contamination: Sources and causes of groundwater contamination, water-quality parameters and standards, groundwater quality monitoring, attenuation of groundwater contamination. Seawater Intrusion: Occurrence, freshwater-saline water interface and transition zone, upconing of saline water intrusion, origin and movement of contaminant, control of seawater intrusion, case studies. Groundwater Flow Modelling and Simulation Techniques: Terminology, model types, steps in model development, simulation of two-dimensional and three-dimensional groundwater systems, application of models in hydrogeology, numerical modelling, modelling protocol, development of finite-difference and finite element models, inverse modelling technique, familiarity with some groundwater flow and transport software packages- MODFLOW and its use, case studies.</p>			