



CIRCULAR

The Academic Council & Executive Council of the University has approved Ordinance OA-35A relating to PG Programmes offered at the University campus and its affiliated Colleges based on UGC 'Curriculum and Credit Framework for Postgraduate Programmes'. Accordingly, the University has proposed introduction of Ordinance OA-35A from the Academic year 2026-2027 onwards for the **Master of Science in Atmospheric Science** Programme.

The Programme structure and syllabus for Semester I and II of the **Master of Science in Atmospheric Science** Programme approved by the Academic Council in its meeting held on 24th April, 12th & 13th May 2026 is attached.

The Dean & Vice-Dean (Academic) of the School of Earth, Ocean and Atmospheric Sciences are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,

1. The Dean, School of Earth, Ocean and Atmospheric Sciences, Goa University.
2. The Vice-Dean (Academic), School of Earth, Ocean and Atmospheric Sciences, Goa University.

Copy to:

3. Chairperson, BoS in Atmospheric Science, Goa University.
4. Programme Director, M.Sc. Atmospheric Science, Goa University.
5. Controller of Examinations, Goa University.
6. Assistant Registrar Examinations (PG), Goa University.
7. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

GOA UNIVERSITY
MASTER OF SCIENCE IN ATMOSPHERIC SCIENCE
(Effective from Academic Year 2026-2027)

ABOUT THE PROGRAMME

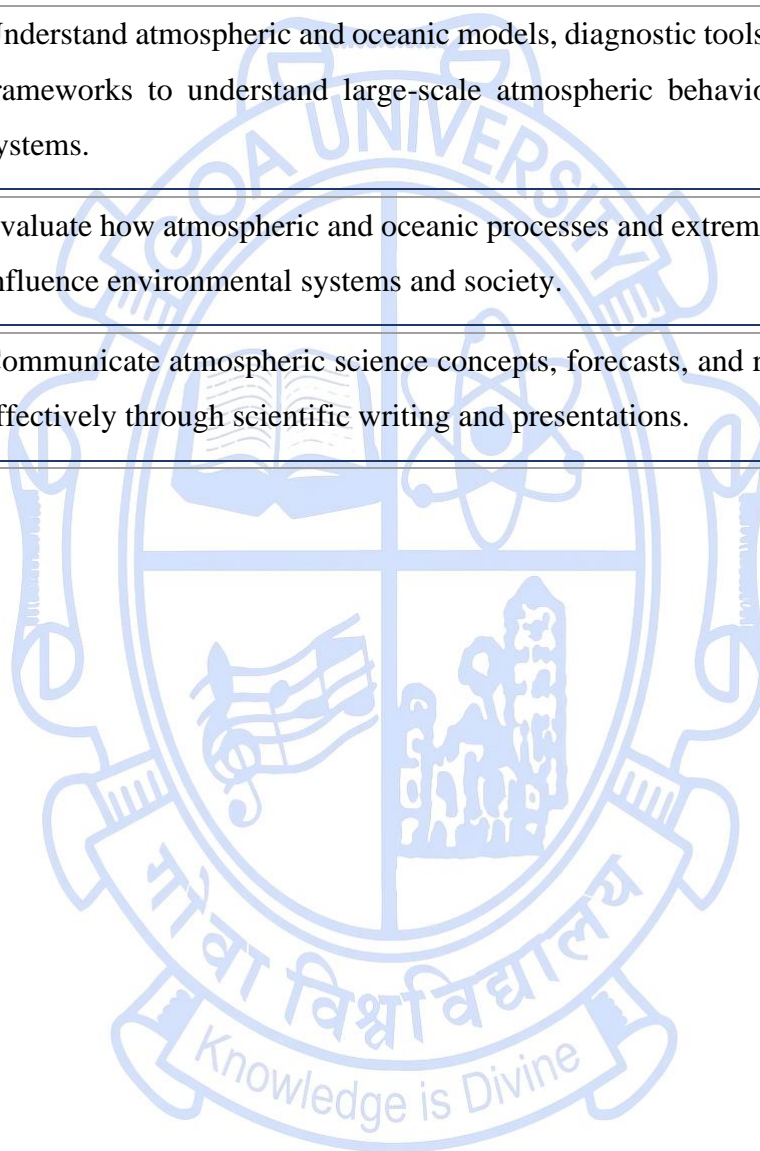
Established in 2019, the School of Earth, Ocean and Atmospheric Sciences (SEOAS) at Goa University was founded to promote a comprehensive, systems-based approach to understanding the Earth as an integrated and dynamic system. Moving beyond the traditional compartmentalisation of the lithosphere, atmosphere, hydrosphere, and cryosphere, the School emphasises an interdisciplinary perspective that underpins modern Earth System Science. SEOAS seeks to train emerging scientists, including oceanographers, atmospheric researchers, Earth scientists, and specialists in geographic information systems, with the conceptual and analytical skills necessary to address complex challenges such as climate change, environmental degradation, and sustainable development. Within this academic vision, the M.Sc. Atmospheric Science programme forms a central pillar of SEOAS's commitment to advancing the understanding of atmospheric processes and their coupling with other components of the Earth system. The programme blends theoretical foundations with practical, research-driven applications to investigate the physical, chemical, and dynamical behaviour of the atmosphere from local to global scales. It encompasses the study of weather systems, climate variability, air-sea interactions, boundary-layer processes, radiative transfer, cloud microphysics, aerosols, and climate change, integrating the principles of physics, chemistry, mathematics, and environmental science. Students receive rigorous training in both observational and computational techniques. The curriculum provides hands-on exposure to modern atmospheric instrumentation, including automatic weather stations, aerosol samplers, sun photometers, and radiometers, as well as to advanced numerical methods in weather prediction, data assimilation, and climate modelling. Emphasis is placed on developing data-driven analytical skills through the use of reanalysis datasets, satellite observations, and numerical simulations. In alignment with the School's interdisciplinary ethos, the programme encourages students to explore the linkages between the atmosphere, ocean, and land systems, as well as to understand the societal and policy implications of atmospheric research. Project-based learning, field observations, and research dissertations

enable students to engage directly with real-world environmental problems, cultivating scientific rigour, critical thinking, and technical proficiency. Graduates of the M.Sc. Atmospheric Science programmes are well prepared to pursue research, forecasting, and applied roles in meteorology, climatology, atmospheric chemistry, and environmental modelling. Through this integrated and contemporary training, the programme contributes to the national and global efforts toward climate resilience, environmental sustainability, and Earth system understanding.

OBJECTIVES OF THE PROGRAMME

The **Atmospheric Science** programme at SEOAS aims to equip students with a comprehensive understanding of atmospheric processes and their interactions within the Earth system. It integrates theoretical knowledge with hands-on training in numerical modelling, climate dynamics, Indian monsoon studies, atmospheric chemistry, and climate change impacts to address real-world environmental challenges. Emphasising both scientific rigour and technical proficiency, the programme prepares students for research and professional careers in academia, industry, and public policy, while promoting ethical and sustainable approaches to atmospheric and climate studies.

PROGRAMME SPECIFIC OUTCOMES (PSO)	
PSO 1.	Demonstrate comprehensive knowledge of the physical principles, governing equations, and dynamical processes of the atmosphere and ocean.
PSO 2.	Interpret mathematical, statistical, and computational methods to understand and analyse atmospheric and oceanic data.
PSO 3.	Understand atmospheric and oceanic models, diagnostic tools, and conceptual frameworks to understand large-scale atmospheric behaviour and weather systems.
PSO 4.	Evaluate how atmospheric and oceanic processes and extreme weather events influence environmental systems and society.
PSO 5.	Communicate atmospheric science concepts, forecasts, and research findings effectively through scientific writing and presentations.



PROGRAMME STRUCTURE
Master of Science in Atmospheric Science
Effective from Academic Year 2026-27

Semester I				
Discipline Specific Core (DSC) Courses (16 credits)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	ATM-5000	Physics of the Atmosphere	3T	400
2	ATM-5001	General Circulation of the Atmosphere	3T	400
3	ATM-5002	Geophysical Fluid Dynamics	3T	400
4	ATM-5003	Data Analysis Methods for Atmosphere and Ocean	4P	400
5	ATM-5004	Numerical and Statistical Methods	3T	400
Total Credits for DSC Courses in Semester I			16	
Discipline Specific Elective (DSE) Course (4 credits)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	ATM-5201	Physical Oceanography	2T	400
2	ATM-5202	Fundamentals of Earth System Science	2T	400
3	ATM-5203	Satellite Meteorology and Atmospheric Sensing <i>(Interdisciplinary Course)</i>	2T	400
4	ATM-5204	Satellite Meteorology and Atmospheric Sensing Practical <i>(Interdisciplinary Course)</i>	2P	400
5	ATM-5205	Climate Science and Services	4T	400
Total Credits for DSE Courses in Semester I			4	
Total Credits in Semester I			20	

Semester II				
Discipline Specific Core (DSC) Courses				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	ATM-5005	Ocean Dynamics	3T	500
2	ATM-5006	Atmospheric Chemistry and Air Pollution	3T	500
3	ATM-5007	Atmospheric Chemistry and Air Pollution Practical	1P	500
4	ATM-5008	Dynamic Meteorology	3T	500
5	ATM-5009	Meteorological Instruments and Observational Techniques	4P	500
6	ATM-5010	Extreme Weather and Natural Hazards	2T	500
Total Credits for DSC Courses in Semester II			16	
Discipline Specific Elective (DSE) Courses (4 credits)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	ATM-5206	Aerosol and Climate	4T	400
2	ATM-5207	Modelling of the Atmosphere and Ocean	4T	400
3	ATM-5208	Hydrometeorology	4T	400
Total Credits for DSE Courses in Semester II			4	
Total Credits in Semester II			20	

SEMESTER I

Discipline Specific Core (DSC) Courses

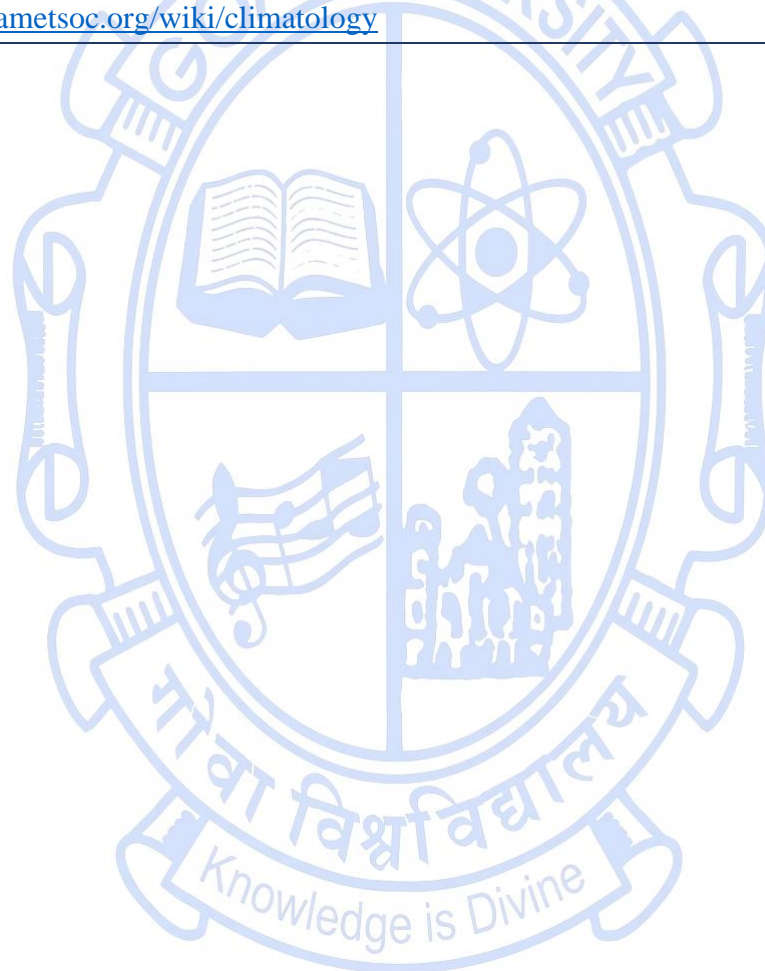
Title of the Course	Physics of the Atmosphere
Course Code	ATM-5000
Number of Credits	3
Theory/Practical	Theory
Level	400
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value-added Course	No
Course for advanced learners	No
Pre-requisites for the Course:	Nil
Course Objectives:	To provide students with a foundational understanding of the physical principles governing the Earth's atmosphere, including its thermodynamic structure, radiative processes, moisture and cloud physics, and the energy-mass-momentum balances that control weather and climate, while building the ability to interpret atmospheric observations and apply basic quantitative methods in atmospheric analysis.

Course Outcomes:	Students will be able to,	Mapped to PSO		
	CO 1. Explain the Sun-Earth geometrical controls on insolation, the vertical thermal structure of the atmosphere, and the role of atmospheric composition (dry air, water vapour, aerosols) in governing key atmospheric properties.	PSO 1		
	CO 2. Apply radiation laws and conceptual radiative transfer principles to interpret atmospheric optical phenomena and to describe how absorption, scattering, and reflection determine observed visibility, sky colour, and surface-atmosphere radiative fluxes.	PSO 1, PSO 2		
	CO 3. Analyse the terrestrial radiation budget and the mean Earth-atmosphere heat balance by evaluating the roles of greenhouse gases, clouds, and aerosols, and by relating radiative processes to diurnal temperature variability and large-scale energy transport.	PSO 1, PSO 4		
	CO 4. Diagnose thermodynamic state and stability using moist thermodynamics, hydrostatic relationships, and thermodynamic diagrams, and evaluate convective potential using parcel theory and stability indices	PSO 1, PSO 2, PSO 3		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Sun-Earth Geometry, Atmospheric Composition, Vertical Structure, and Stratification.	Sun-Earth relationship; Earth's motions and seasons (solstices, equinoxes); latitudinal and seasonal control of insolation; vertical thermal structure of the atmosphere (troposphere to thermosphere: key lapse-rate features and transitions); composition of the atmosphere (dry air, variable constituents); water vapour distribution and significance; aerosols (sources, types, spatio-temporal variability, role as radiative and microphysical agents); basic atmospheric stratification concepts relevant to thermodynamics and radiation.	10	CO 1, CO 2	K1, K2
Module 2: Atmospheric Optics and Radiative Processes (Solar and Basic Radiative Transfer)	Visibility and attenuation (turbidity, extinction concept); scattering fundamentals in the atmosphere (qualitative: Rayleigh/Mie and particle-size dependence); blue colour of the sky; sunrise/sunset colours; atmospheric refraction and mirages; optical phenomena (rainbows, haloes, corona, glory); radiation basics and blackbody laws (Planck concept, Stefan-Boltzmann, Wien displacement, Kirchhoff); introduction to radiative transfer	15	CO 2, CO 3	K1, K2, K3

	(absorption, scattering, reflection; optical depth: conceptual); solar radiation through the atmosphere (absorption, scattering, reflection; mean disposition of solar radiation).			
Module 3: Terrestrial Radiation, Energy Balance, Radiative Forcing Agents, and Atmospheric Thermodynamics & Stability	Terrestrial (longwave) radiation; absorption in the atmosphere; atmospheric window; radiative heat exchange; radiative cooling of the atmosphere; influence of clouds on radiation fluxes; influence of aerosols on scattering and partitioning of direct vs diffuse radiation; linkages to diurnal cycle (diurnal maximum/minimum temperature); mean heat balance of the Earth-atmosphere system; atmospheric greenhouse effect; poleward transport of energy; fundamental linkage between energy balance and general circulation. Equation of state for dry and moist air; humidity measures and virtual temperature; first and second laws of thermodynamics; specific heats and adiabatic processes; potential temperature and entropy (conceptual); water vapour thermodynamics (latent heat; Clausius-Clapeyron equation); dry adiabatic lapse rate and moist adiabatic lapse rate (unsaturated vs saturated ascent; pseudo-adiabatic concept; equivalent potential temperature); hydrostatic balance (geopotential, hydrostatic equation), standard atmosphere and altimetry; thermodynamic diagrams (Skew T-log P / tephigram: requirements and core interpretation), height estimation from soundings; parcel stability framework (Brunt-Väisälä frequency concept; LCL/CCL), CAPE and CINE; stability indices and essentials of cumulus growth and entrainment.	20	CO 3, CO 4	K1, K2, K3, K4, K5
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments			
Texts:	<ol style="list-style-type: none"> 1. Salby, M. L. (1996). <i>Fundamentals of atmospheric physics</i> (Vol. 61). Elsevier. ISBN-10: 0126151601 2. Stull, R. B. (2012). <i>An introduction to boundary layer meteorology</i> (Vol. 13). Springer Science & Business Media. ISBN-13: 978-94-009-3027-8 3. Wallace, J. M., & Hobbs, P. V. (2006). <i>Atmospheric science: an introductory survey</i> (Vol. 92). Elsevier. ISBN-10: 012732951X 			
References/ Readings:	<ol style="list-style-type: none"> 1. Bolton, D. (1980). The computation of equivalent potential temperature. <i>Monthly Weather Review</i>, 108(7), 1046-1053. DOI:10.1175/1520-0493(1980)108%3C1046:tcoep%3E2.0.co;2 2. Romps, D. M. (2017). Exact expression for the lifting condensation level. <i>Journal of the Atmospheric Sciences</i>, 74(12), 3891-3900. DOI:10.1175/jas-d-17-0102.1 			

	<p>3. Stephens, G., Li, J., Wild, M. et al. An update on Earth's energy balance in light of the latest global observations. <i>Nature Geoscience</i>, 5, 691-696 (2012). DOI:10.1038/ngeo1580</p> <p>4. Trenberth, K. E., Fasullo, J. T., & Kiehl, J. (2009). Earth's global energy budget. <i>Bulletin of the American Meteorological Society</i>, 90(3), 311-324. DOI:10.1175/2008bams2634.1</p>
Web Resources:	American Meteorological Society, 2020: Climatology. Glossary of Meteorology, http://glossary.ametsoc.org/wiki/climatology

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Title of the Course	General Circulation of the Atmosphere
Course Code	ATM-5001
Number of Credits	3
Theory/Practical	Theory
Level	400
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To introduce the large-scale dynamical processes that govern the Earth's atmospheric circulation, including the global energy and momentum balances, major circulation cells, jet streams, storm tracks, and climate variability, and to develop the ability to interpret circulation patterns using conceptual models and observational/reanalysis datasets.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Describe the observed global distributions of winds, geopotential height, temperature, moisture, precipitation, and zonal-mean circulation features (including ITCZ and mean meridional circulation) using standard diagnostic frameworks (including isentropic coordinates).	PSO 1
	CO 2. Analyse the dynamical controls of the general circulation through angular momentum and eddy-mean flow interactions, including the formation/maintenance of jets, planetary waves, and dominant circulation regimes such as zonal and blocking patterns.	PSO 1, PSO 3

	CO 3. Analyse the atmospheric energy cycle using the Lorenz framework by relating APE generation, conversions, and kinetic energy budgets to observed stationary/transient eddies and midlatitude variability.		PSO 1, PSO 3, PSO 4
	CO 4. Apply the modelling hierarchy to interpret how parameterisations and coupling choices shape simulated circulation and climate, including sources of drift and spin-up/cold-start behaviour.		PSO 2, PSO 3
Content:		No of hours	Mapped to CO Cognitive Level
Module 1: Observed Global Circulation and Zonally Averaged Diagnostics	Atmospheric mass, geopotential height, zonal/meridional wind, vertical velocity; zonal-mean framework; mean meridional circulation (Hadley/Ferrel/Polar cells: diagnostic view); angular momentum and its relevance to large-scale flow; global temperature structure and ITCZ; isentropic (potential temperature) circulation view; global water vapour distribution, precipitation, and surface turbulent fluxes; role of large-scale eddies in shaping zonal-mean climate.	10	CO 1, CO 2 K1, K2
Module 2: Jets, Planetary Waves, Blocking, and Low-Frequency Variability	Nature of the general circulation problem; zonally averaged circulation and angular momentum budget; longitudinally varying time-mean flow; jet streams and zonal index; planetary (Rossby) waves and eddy-mean flow interaction (conceptual + diagnostic); zonal vs blocking flow regimes; blocking mechanisms and persistence; low-frequency variability and intraseasonal oscillations (overview); laboratory analogues for large-scale circulation and climate characteristics.	15	CO 2, CO 3 K1, K2, K3, K4
Module 3: Atmospheric Energy Cycle, Eddy Dynamics, and Climate Modelling Hierarchy	Lorenz energy cycle: APE and kinetic energy reservoirs; generation of APE (static stability, meridional temperature gradients, surface pressure structure) and conversion to kinetic energy; interpret forms of eddy and zonal kinetic energy budgets; diagnostics and observed structure of stationary vs transient midlatitude eddies. Modelling hierarchy: EBMs (0D/1D) and parameterised heat transport; radiative-convective (1D) models, purpose and limitations; overview of GCM components (radiation, boundary layer, clouds, convection, large-scale precipitation, land surface, gravity-wave drag); essentials of coupled modelling (atmosphere-ocean coupling concept, drift/cold-start issues: brief).	20	CO 3, CO 4 K1, K2, K3, K4, K5
Pedagogy:	Use of Conventional, Online and ICT Methods.		

Texts:	<ol style="list-style-type: none"> 1. Donner, L., Schubert, W., & Somerville, R. (Eds.). (2011). <i>The development of atmospheric general circulation models: Complexity, synthesis and computation</i>. Cambridge University Press. ISBN-13: 978-0521190060 2. Vallis, G. K. (2017). <i>Atmospheric and oceanic fluid dynamics</i>. Cambridge University Press. ISBN-13: 978-1107065505 3. Wallace, J. M., Battisti, D. S., Thompson, D. W., & Hartmann, D. L. (2023). <i>The atmospheric general circulation</i>. Cambridge University Press. ISBN-13: 978-1108474245
References/ Readings:	<ol style="list-style-type: none"> 1. Arakawa, A. (1975). General circulation of the atmosphere. <i>Reviews of Geophysics</i>, 13(3), 668-680. DOI:10.1029/RG013i003p00668 2. Federer, M. (2025). A synoptic perspective on available potential energy (Doctoral dissertation, ETH Zurich). DOI:10.3929/ethz-b-000745047 3. Ghil, M. (1981). Energy-balance models: An introduction. In <i>Climatic Variations and Variability: Facts and Theories: NATO Advanced Study Institute First Course of the International School of Climatology, Ettore Majorana Center for Scientific Culture, Erice, Italy, March 9–21, 1980</i> (pp. 461-480). Dordrecht: Springer Netherlands. DOI:10.1007/978-94-009-8514-8_27 4. Green, J. S. A. (1970). Transfer properties of the large-scale eddies and the general circulation of the atmosphere. <i>Quarterly Journal of the Royal Meteorological Society</i>, 96(408), 157-185. DOI:10.1002/qj.49709640802 5. Held, I. M., & Hou, A. Y. (1980). Nonlinear axially symmetric circulations in a nearly inviscid atmosphere. <i>Journal of the Atmospheric Sciences</i>, 37(3), 515-533. DOI:10.1175/1520-0469(1980)037%3C0515:nascia%3E2.0.co;2 6. Lin, H. (2022). The Madden-Julian Oscillation. <i>Atmosphere-Ocean</i>, 60(3-4), 338-359. DOI:10.1080/07055900.2022.2072267 7. Lorenz, Edward N. (1955). Available potential energy and the maintenance of the general circulation. <i>Tellus</i> 7.2: 157-167. DOI:10.3402/tellusa.v7i2.8796 8. Wiin-Nielsen, A. (1968). On the intensity of the general circulation of the atmosphere. <i>Reviews of Geophysics</i>, 6(4), 559-579. DOI:10.1029/RG006i004p00559
Web Resources:	<ol style="list-style-type: none"> 1. COMET MedEd: https://www.meted.ucar.edu/

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Title of the Course	Geophysical Fluid Dynamics
Course Code	ATM-5002
Number of Credits	3
Theory/Practical	Theory
Level	400
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To introduce the fundamental principles governing fluid motion on a rotating Earth, emphasising the dynamical balances and wave-vortex processes that control atmospheric and oceanic flows, and to develop the ability to apply these concepts to interpret large-scale circulation features and their variability using simplified theoretical models and diagnostic analysis.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Explain foundational fluid concepts and fluid statics, including pressure/ force balances, hydrostatic equilibrium, and their application to compressible and incompressible geophysical fluids	PSO 1
	CO 2. Apply kinematic descriptions (Eulerian/Lagrangian), streamfunction concepts, and derivative operators (local/material) to represent and interpret idealised geophysical flow fields using divergence and vorticity diagnostics.	PSO 1, PSO 2

	CO 3. Analyse viscous-flow dynamics using the Navier-Stokes framework, canonical laminar solutions, and Reynolds-number-based similarity arguments to distinguish low- and high-Re regimes relevant to geophysical systems.		PSO 1, PSO 2	
	CO 4. Analyse inviscid rotating-frame dynamics through scaling (Rossby number), coordinate formulations (spherical/isobaric/sigma), and balanced-flow theory (geostrophic/gradient/thermal wind) to interpret large-scale atmospheric motion.		PSO 1, PSO 2, PSO 4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Fluid Statics, Kinematics, and Flow Description	Continuum hypothesis; basic fluid properties; ideal vs real (viscous) fluids; flow classifications. Fluid statics: pressure; surface and body forces; hydrostatic balance for compressible and incompressible fluids; perfect gas equation (application to atmosphere); hydrostatic equation in the vertical. Kinematics: Lagrangian vs Eulerian descriptions; pathlines/streamlines/streaklines; steady vs unsteady flow; local flow decomposition (rotation, divergence, strain); stream function (2D); divergence and vorticity (key coordinate forms); material derivative and kinematic relations used in geophysical analysis.	10	CO 1, CO 2	K1, K2
Module 2: Viscous Flow, Governing Equations, and Dynamic Similarity	Newtonian viscosity; coefficient of viscosity; Navier-Stokes equations (interpretation and term scaling); canonical laminar solutions (Poiseuille, Couette: concept and relevance); Reynolds number and dynamic similarity; physical meaning of low vs high Reynolds regimes; relevance to geophysical flows (boundary layers vs interior “nearly inviscid” flow idealisations).	15	CO 2, CO 3	K1, K2, K3
Module 3: Rotating-Frame Dynamics, Scale Analysis, and Balanced Flow	Continuity equation (applications to incompressible/compressible limits); Euler equations (inviscid form: interpretive). Inertial vs rotating frames; Coriolis force and geophysical interpretation; Rossby number and regime diagnosis; scale analysis of the equations of motion. Balanced horizontal motion: geostrophic and gradient-wind concepts (diagnostic use, not extended synoptic repetition); thermal wind (compact statement and interpretation); barotropic vs baroclinic distinction (brief); implications for vertical shear in large-scale flow.	20	CO 3, CO 4	K1, K2, K3, K4, K5
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments			

<p>Texts:</p>	<ol style="list-style-type: none"> 1. Cushman-Roisin, B., & Beckers, J. M. (2011). <i>Introduction to geophysical fluid dynamics: physical and numerical aspects</i> (Vol. 101). Academic Press. ISBN-13: 978-0120887590 2. Gill, A. E. (2016). <i>Atmosphere-ocean dynamics</i>. Elsevier. ISBN-13: 978-0122835223 3. Holton, J. R., & Hakim, G. J. (2013). <i>An introduction to dynamic meteorology</i> (Vol. 88). Academic Press. ISBN-13: 978-0123848666. 4. McWilliams, J. C. (2006). <i>Fundamentals of geophysical fluid dynamics</i>. Cambridge University Press. ISBN-13: 978-0521856379 5. Pedlosky, J. (2013). <i>Geophysical fluid dynamics</i>. Springer Science & Business Media. ISBN: 978-1-4612-4650-3
<p>References/ Readings:</p>	<ol style="list-style-type: none"> 1. Fang, C. (2018). Fundamental concepts. In <i>An Introduction to Fluid Mechanics</i> (pp. 31-57). Cham: Springer International Publishing. DOI:10.1007/978-3-319-91821-1_2 2. Holm, D. D., & Luesink, E. (2021). Stochastic wave-current interaction in thermal shallow water dynamics. <i>Journal of Nonlinear Science</i>, 31(2), 29. DOI:10.1007/s00332-021-09682-9 3. Jänicke, H., & Scheuermann, G. (2010, September). Measuring complexity in Lagrangian and Eulerian flow descriptions. In <i>Computer Graphics Forum</i> (Vol. 29, No. 6, pp. 1783-1794). Oxford, UK: Blackwell Publishing Ltd. DOI:10.1111/j.1467-8659.2010.01648.x 4. Kalashnik, M. V., & Chkhetiani, O. (2017). Generation of gravity waves by singular potential vorticity disturbances in shear flows. <i>Journal of the Atmospheric Sciences</i>, 74(1), 293-308. DOI:10.1175/JAS-D-16-0134.1 5. McVittie, G. C. (1948). The equations governing the motion of a perfect-gas atmosphere. <i>The Quarterly Journal of Mechanics and Applied Mathematics</i>, 1(1), 174-195. DOI:10.1093/qjmam/1.1.174 6. Tambyah, T. A., Lee, D., & Badia, S. (2025). Energy and entropy conserving compatible finite elements with upwinding for the thermal shallow water equations. <i>Journal of Computational Physics</i>, 531, 113937. DOI:10.1016/j.jcp.2025.113937 7. Vallis, G. K. (2016). Geophysical fluid dynamics: whence, whither and why?. <i>Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences</i>, 472(2192), 20160140. DOI:10.1098/rspa.2016.0140 8. Walters, K., & Jones, W. M. (2003). Measurement of viscosity. In <i>Instrumentation reference book</i> (pp. 45-52). Butterworth-Heinemann. DOI:10.1016/B978-075067123-1/50006-5

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Title of the Course	Data Analysis Methods for Atmosphere and Ocean
Course Code	ATM-5003
Number of Credits	4
Theory/Practical	Practical
Level	400
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To develop practical competence in acquiring, managing, analysing, and visualising atmospheric and oceanographic datasets using modern computational tools, with emphasis on statistical reasoning, reproducible workflows, and physically informed interpretation of spatio-temporal variability for research and applications.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Acquire, read, quality-control, and manage atmospheric/ocean datasets in standard formats (NetCDF/CSV; gridded and in situ).	PSO 1, PSO 2
	CO 2. Perform exploratory analysis, statistical summarisation, and robust visualisation (time series, profiles, maps, Hovmöller).	PSO 1, PSO 2
	CO 3. Apply core analysis methods (anomalies, filtering, trends, EOF/PCA, correlations/lags, spectral tools) with an awareness of uncertainty.	PSO 1, PSO 2, PSO 3
	CO 4. Build reproducible analysis workflows and produce publishable figures, as well as a	PSO 2, PSO 3, PSO

concise technical report.		5		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Python Fundamentals for Met-Ocean Data	Introduction; Python interpreter (interactive vs script); argument passing (basics); data types-numbers, strings, Unicode strings, lists; basic operations; flow control-if statements, for statements, range function, pass/break/continue; loops. Basic data reading, unit conversions, summary statistics (min/max/mean), missing-value handling, simple time-series summaries (temperature, wind, rainfall, SST).	20	CO 1, CO 2	K3, K4
Module 2: Functions for Analysis Pipelines	Functions-default argument values, keyword arguments, arbitrary argument lists (*args/**kwargs), unpacking argument lists, lambda forms, documentation strings (docstrings). Functions for (i) moving averages/smoothing, (ii) anomaly computation, (iii) wind component conversions, (iv) threshold-based event detection; basic plotting for interpretation (time series and scatter); a small script that reads data, computes derived variables, and exports outputs.	30	CO 2, CO 3	K3, K5
Module 3: Data Structures for Environmental Datasets	Python data structures; using lists as stacks and queues; del statement; tuples and sequences; sets; dictionaries; comparing sequences and other types. Station/buoy metadata and observations using dictionaries; querying/filtering records; set-based identification of event days (e.g., rain days, high-wind days, SST threshold exceedance); building daily summary products; simple intercomparison (bias/RMSE) between two datasets using structured containers.	30	CO 3, CO 4	K2, K3, K4
Module 4: Modules, Packages, I/O, and Error Handling for Robust Workflows	Data modules-executing modules as scripts, module search path, compiled Python files (conceptual), standard modules, dir(); packages (importing from packages, intra-package references, packages in multiple directories). Python input/output-formatted output, reading/writing files, file object methods, pickle. Errors and exceptions, handling, raising, user-defined exceptions, and clean-up actions (predefined and custom). Create a small modular toolbox (I/O, QC, statistics, plotting); robust file ingestion with exception handling; save intermediate results using pickle; end-to-end mini-project: ingest dataset, QC, compute derived variables, generate plots and summary tables, export results. finite-difference differentiation and numerical integration (trapezoidal/Simpson); interpolation and gridding (nearest, bilinear, objective analysis/Cressman, IDW; optional kriging);	40	CO 3, CO 4	K2, K3, K4, K5

	time-series filtering and spectral analysis (detrending, anomalies, low-pass filters, FFT-based spectra, cross-correlation); regression and least-squares fitting (with uncertainty); matrix methods for variability analysis (SVD-based EOF/PCA).			
Pedagogy:	Use of Conventional, Online and ICT Methods. Hands-on Practicals			
Texts:	<ol style="list-style-type: none"> 1. Boyce, W. E., DiPrima, R. C., & Meade, D. B. (2021). <i>Elementary differential equations and boundary value problems</i>. John Wiley & Sons. ISBN-13: 978-1119777694 2. Döös, K., Lundberg, P., & Campino, A. A. (2022). <i>Basic Numerical Methods in Meteorology and Oceanography</i>. Stockholm University Press. ISBN: 978-91-7635-172-7 3. Dumka, P., Dumka, R., & Mishra, D. R. (2022). <i>Numerical methods using Python (for scientists and engineers)</i>. Blue Rose Publishers. ISBN-13: 978-9357046688 4. Mesinger, F., & Arakawa, A. (1976). <i>Numerical methods used in atmospheric models</i>. ISBN-13: 978-92-63-10444-1 5. Powers, D. L. (2009). <i>Boundary value problems: and partial differential equations</i>. Academic Press. ISBN-13: 978-0-12-374719-8 6. Press, W. H. (2007). <i>Numerical recipes 3rd edition: The art of scientific computing</i>. Cambridge University Press. ISBN-13: 978-0-521-88068-8 7. Zill, D. G. (2020). <i>Advanced engineering mathematics</i>. Jones & Bartlett Learning. ISBN 9781284206241 			
References/ Readings:	<ol style="list-style-type: none"> 1. Debella-Gilo, M., & Rizzi, J. (2021). Computing remote sensing big data using local hardware and open-source software packages. <i>Kart og Plan</i>, (3-4), 254-273. DOI:10.18261/issn.2535-6003-2021-03-04-09 2. Hunter, J. D. (2007). Matplotlib: A 2D graphics environment. <i>Computing in science & engineering</i>, 9(03), 90-95. DOI:10.1109/MCSE.2007.55 3. Jellen, C. D. (2024). ndbc-api: Accelerating oceanography and climate science research with Python. <i>Journal of Open Source Software</i>, 9(104), 7406. DOI:10.21105/joss.07406 4. Millman, K. J., & Aivazis, M. (2011). Python for scientists and engineers. <i>Computing in science & engineering</i>, 13(2), 9-12. DOI:10.1109/MCSE.2011.36 5. Oliphant, T. E. (2007). Python for scientific computing. <i>Computing in science & engineering</i>, 9(3), 10-20. DOI:10.1109/MCSE.2007.58 			

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Title of the Course	Numerical and Statistical Methods
Course Code	ATM-5004
Number of Credits	3
Theory/Practical	Theory
Level	400
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To introduce the fundamental principles governing fluid motion on a rotating Earth, emphasising the dynamical balances and wave-vortex processes that control atmospheric and oceanic flows, and to develop the ability to apply these concepts to interpret large-scale circulation features and their variability using simplified theoretical models and diagnostic analysis.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Learn the basics of Numerical Weather Prediction, and various numerical techniques and equation-solving methods used in NWP.	PSO 1
	CO 2. Finite difference form of the standard heat and wave equations, including Finite difference form of standard heat and wave equations.	PSO 1, PSO 2
	CO 3. Convergence and stability of different numerical schemes.	PSO 1, PSO 2

	CO 4. Learn statistical hypothesis testing, probability and basic statistical measures.		PSO 1, PSO 2, PSO 4
Content:		No of hours	Mapped to CO Cognitive Level
Module 1: Numerical Methods in PDE	Historical Background, Finite Difference Schemes for Space and Time, Truncation Error, Linear and Non-linear Computational Instabilities, Staggered Grid, Aliasing, Arakawa Jacobian. Numerical solution of partial difference equations such as the heat equation, the wave equation, the Laplace equation and the Poisson equation.	15	CO 1, CO 2 K1, K2
Module 2: Descriptive and Inferential Statistics	Basic concepts and definition of statistics: Concepts of statistical measures of central tendency, mean, weighted mean, median, mode, moments, skewness, etc. Measures of variation, range, standard deviation, variance, and coefficient of variation. Least square principle, Root Mean Square, etc. Scatter diagram, correlation, partial correlation, etc. Pie diagram, bar graph, etc. Different distributions, such as the Normal distribution. Statistical tests such as Student's t-test, linear and nonlinear regression models	20	CO 2, CO 3 K1, K2, K3, K4
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments		
Texts:	<ol style="list-style-type: none"> 1. Box, G. E., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015). Time series analysis: forecasting and control. John Wiley & Sons. 2. Haltiner, G. J., & Williams, R. T. (1980). Numerical prediction and dynamic meteorology. 3. Holton, J. R., & Hakim, G. J. (2013). An introduction to dynamic meteorology (Vol. 88). Academic Press. 4. Mesinger, F., & Arakawa, A. (1976). Numerical methods used in atmospheric models. 5. Thompson, P. D. (1952). Notes on the theory of large-scale disturbances in atmospheric flow with applications to numerical weather prediction (No. GRP16). 6. Wilks, D. S. (2011). Statistical methods in the atmospheric sciences (Vol. 100). Academic Press. 		
References/ Readings:	<ol style="list-style-type: none"> 1. Palmer, T. N., Shutts, G. J., Hagedorn, R., Doblus-Reyes, F. J., Jung, T., & Leutbecher, M. (2005). Representing model uncertainty in weather and climate prediction. Annu. Rev. Earth Planet. Sci., 33(1), 163-193. 		

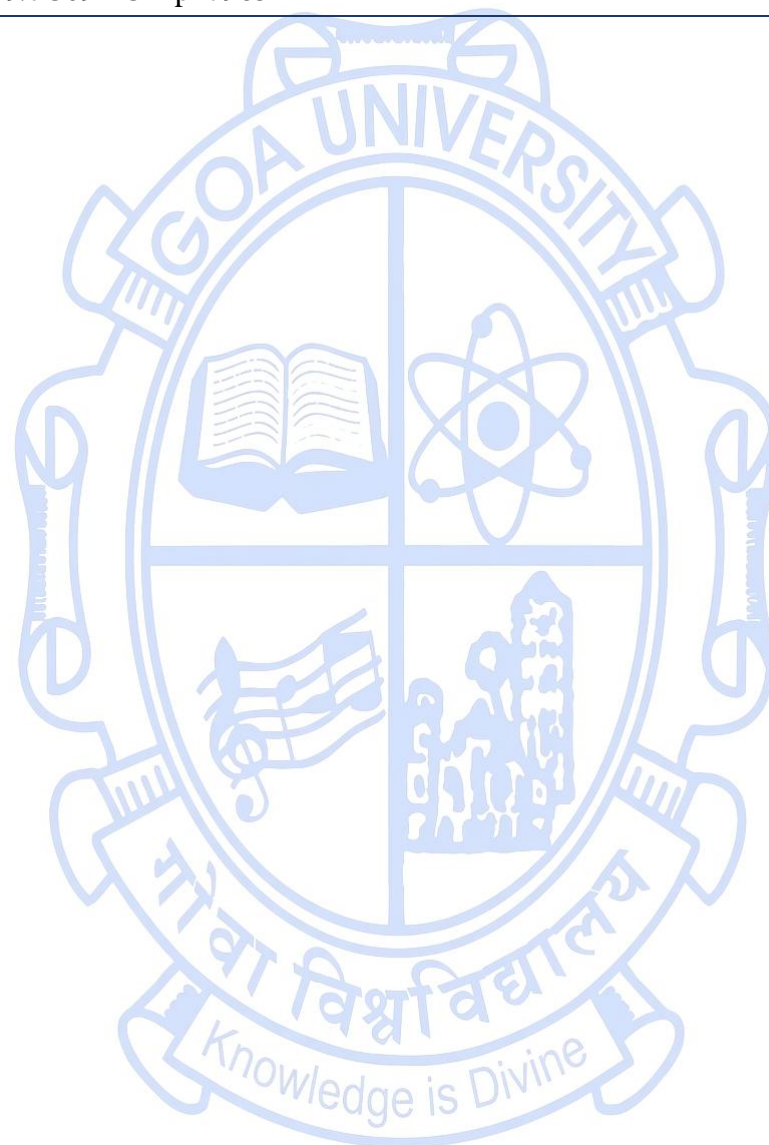
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Discipline Specific Elective (DSE) Courses

Title of the Course	Physical Oceanography	
Course Code	ATM-5201	
Number of Credits	2	
Theory/Practical	Theory	
Level	400	
Effective from AY	2026-2027	
New Course:	Yes	
Bridge Course/ Value-added Course:	No	
Course for advanced learners:	Yes	
Pre-requisites for the Course:	Nil	
Course Objectives:	To provide a foundational understanding of the physical processes governing the ocean, including its water-mass structure, circulation and mixing, air-sea interaction, and variability across temporal and spatial scales, and to develop the ability to interpret observational and gridded datasets to explain key oceanographic phenomena relevant to weather, climate, and coastal environments.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Explain seawater properties, their spatio-temporal variability, and the formation/diagnosis of water masses using T/θ-S concepts.	PSO 1, PSO 2
	CO 2. Apply heat budget components and air-sea flux concepts to interpret the seasonal/interannual variability of ocean heat storage and transport.	PSO 1, PSO 2

	CO 3. Apply wave and tide concepts to explain coastal processes, tidal regimes, and estuarine responses.		PSO 2, PSO 3, PSO 4
	CO 4. Analyse wind-driven and thermohaline circulation, with emphasis on Indian Ocean monsoon dynamics and major ocean-climate processes		PSO 1, PSO 2, PSO 4
Content:		No of hours	Mapped to CO
Module 1: Seawater Structure, Water Masses, and Observations	Ocean basins and observing systems: CTD and profiling floats. Seawater properties and vertical structure: temperature, salinity, density, pressure, oxygen, typical vertical profiles and basin-scale patterns; T/θ-S diagrams. Water masses: formation (surface forcing, mixing, convection), identification, and mixing; major water masses of the World Ocean. Expert overview of the Arabian Sea and Bay of Bengal.	10	CO 1 K1, K2
Module 2: Air-Sea Interaction, Upper-Ocean Dynamics, and Indian Ocean Processes	Air-Sea Fluxes and Ocean Heat Budget (Upper Ocean Focus): Insolation and shortwave penetration; longwave radiation; cloud influence. Sensible and latent heat fluxes; Bowen ratio; freshwater flux (P-E) and buoyancy relevance. Mixed-layer concept, ocean heat storage, and seasonal cycle of the mixed layer. Regional/seasonal variability of heat budget terms (seasonal and interannual interpretation). Waves, Tides, and Coastal/Estuarine Relevance (Applied Level). Surface gravity waves: key parameters, energy, dispersion (conceptual). Nearshore transformations: shoaling, refraction, breaking; coastal currents (longshore, cross-shore); rip currents. Tides: generating forces; diurnal/semi-diurnal; spring-neap; tidal currents and estuarine flushing (basic response). Indian Ocean Circulation and Coupled Regional Processes (Process-based Applied). Wind-driven circulation: Ekman transport (concept and application); upwelling/downwelling and Ekman pumping (conceptual). Monsoon-driven seasonality: NE/SW monsoon forcing; Arabian Sea vs Bay of Bengal contrasts. Key current systems: Somali Current, equatorial currents/undercurrents, Indonesian Throughflow, Agulhas exchange (overview). Variability and climate links: mesoscale eddies, winter cooling/convection, tropical cyclone upper-ocean response, IOD, ENSO, Southern Annual Mode (SAM), North Atlantic Oscillation (NAO) teleconnections (overview). Regional feature focus: Indo-Pacific Warm Pool, Seychelles-Chagos	20	CO 2, CO 3, CO 4 K1, K2, K3, K4, K5

	Thermocline Ridge.			
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments			
Texts:	<ol style="list-style-type: none"> 1. Apel, J. R. (2013). <i>Principles of ocean physics</i> (Vol. 38). Elsevier. ISBN-10: 012058865X 2. Knauss, J. A., & Garfield, N. (2016). <i>Introduction to physical oceanography</i>. Waveland Press. ISBN-13: 978-1478632504 3. Stewart, R. H. (2008). <i>Introduction to physical oceanography</i>. ISBN-13: 978-1616100452 4. Talley, L. D. (2011). <i>Descriptive physical oceanography: an introduction</i>. Academic press. ISBN-13: 978-0750645522 5. Tomczak, M., & Godfrey, J. S. (2003). <i>Regional oceanography: an introduction</i>. Daya books. ISBN-13: 978-8170353063 6. Vallis, G. K. (2011). <i>Climate and the Oceans</i>. Princeton University Press. ISBN-13: 978-0691147158 7. Wang, B. (2006). <i>The asian monsoon</i>. Springer Science & Business Media. ISBN: 978-3-540-37722-1 			
References/ Readings:	<ol style="list-style-type: none"> 1. Dhame, S., Taschetto, A. S., Santoso, A., & Meissner, K. J. (2020). Indian Ocean warming modulates global atmospheric circulation trends. <i>Climate Dynamics</i>, 55(7), 2053-2073. DOI:10.1007/s00382-020-05369-1 2. Fofonoff, N. P. (1985). Physical properties of seawater: A new salinity scale and equation of state for seawater. <i>Journal of Geophysical Research: Oceans</i>, 90(C2), 3332-3342. DOI:10.1029/JC090iC02p03332 3. Greatbatch, R. J., Zhai, X., Eden, C., & Olbers, D. (2007). The possible role in the ocean heat budget of eddy-induced mixing due to air-sea interaction. <i>Geophysical Research Letters</i>, 34(7). DOI:10.1029/2007GL029533 4. McWilliams, J. C., & Restrepo, J. M. (1999). The wave-driven ocean circulation. <i>Journal of Physical Oceanography</i>, 29(10), 2523-2540. DOI:10.1175/1520-0485(1999)029%3C2523:TWDOC%3E2.0.CO;2 5. Rogers, D. P. (1995). Air-sea interaction: Connecting the ocean and atmosphere. <i>Reviews of Geophysics</i>, 33(S2), 1377-1383. DOI:10.1029/95RG00255 6. Schott, F. A., Xie, S. P., & McCreary Jr, J. P. (2009). Indian Ocean circulation and climate variability. <i>Reviews of Geophysics</i>, 47(1). DOI:10.1029/2007RG000245 7. Sharqawy, M. H., Lienhard, J. H., & Zubair, S. M. (2010). Thermophysical properties of seawater: a review of existing correlations and data. <i>Desalination and water treatment</i>, 16(1-3), 354-380. DOI:10.5004/dwt.2010.1079 8. Woodberry, K. E., Luther, M. E., & O'Brien, J. J. (1989). The wind-driven seasonal circulation in the southern tropical Indian Ocean. <i>Journal of Geophysical Research: Oceans</i>, 94(C12), 17985-18002. 			



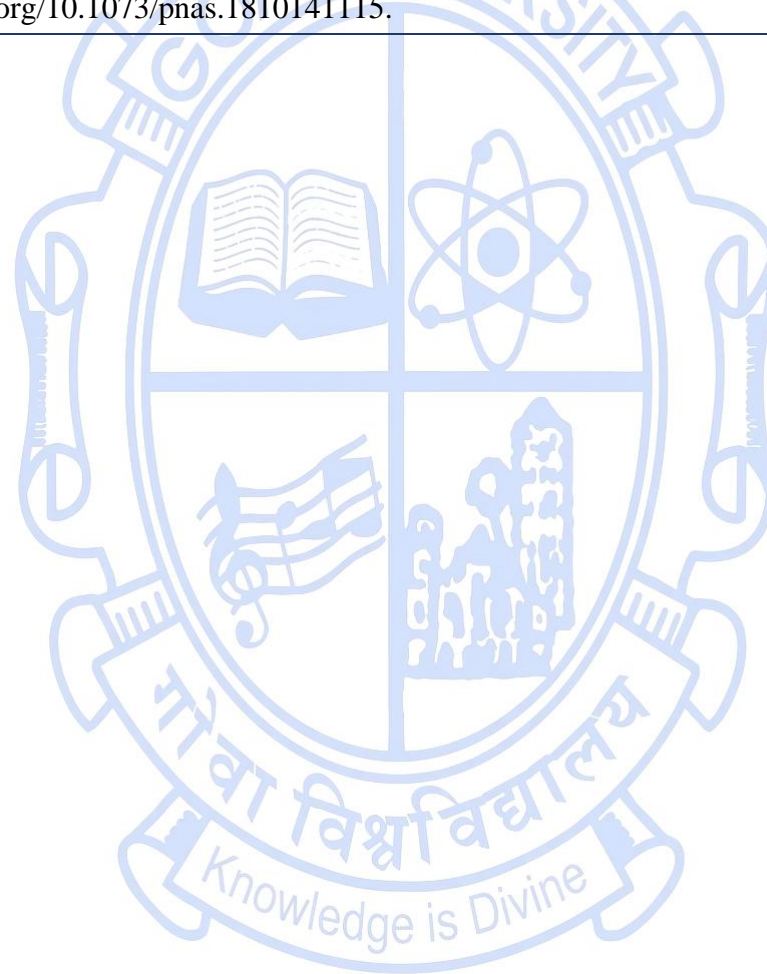
Title of the Course	Fundamentals of Earth System Science
Course Code	ATM-5202
Number of Credits	2
Theory/Practical	Theory
Level	400
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value-added Course:	No
Course for advanced learners:	Yes

Pre-requisites for the Course:	Nil	
Course Objectives:	To introduce the Earth as an integrated system by explaining the structure, functioning, and interactions among the atmosphere, ocean, land, cryosphere, and biosphere, with emphasis on Earth system cycles, energy and water budgets, feedbacks, variability, and human-driven change, enabling students to interpret Earth system observations in a physically consistent way.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Describe the major components of the Earth System (atmosphere, hydrosphere, lithosphere, cryosphere, biosphere) and the key interfaces through which energy and matter are exchanged.	PSO 1, PSO 2
	CO 2. Explain the Earth's energy and water budgets and interpret how fluxes and storage regulate weather, climate, and hydrological extremes at regional to global scales.	PSO 1, PSO 2
	CO 3. Explain the major biogeochemical cycles (carbon, nitrogen, phosphorus) and analyse	PSO 2, PSO 3, PSO 4

	how coupled cycle processes influence ecosystem function and climate variability.			
	CO 4. Analyse Earth system feedbacks and timescales, distinguishing natural variability from anthropogenic forcing, and interpret implications for climate change, hazards, and sustainability.		PSO 1, PSO 2, PSO 4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Earth System Components, Coupling, and Budgets	Earth System concept: spheres (atmosphere, hydrosphere, lithosphere, cryosphere, biosphere) and interfaces. Energy budget (incoming/outgoing, storage, partitioning) and why it drives circulation and climate. Water cycle as a coupled atmosphere-land-ocean process (storage and fluxes; extremes context: conceptual and applied). Reservoirs, fluxes, residence time; system thinking (stocks/flows). Expert overviews on Observational backbone: satellites, reanalysis, in situ networks.	15	CO 1, CO 2	K1, K2
Module 2: Biogeochemical Cycles, Feedbacks, Variability, and Human Forcing	Carbon cycle (fast vs slow; land-ocean partitioning; ocean uptake concept). Nutrient cycles (N, P: core idea of limitation and coupling to productivity). Feedbacks and tipping behaviour (conceptual): ice-albedo, water vapour, carbon: climate feedback, vegetation-climate links. Natural variability (seasonal/interannual) vs anthropogenic change (GHGs, land-use, aerosols: conceptual links and forced variability). Expert overview on Earth system responses: ocean heat content, sea level components, cryosphere loss, ecosystem impacts. Simple conceptual models: boxes/reservoirs, feedback loops, and timescales.	15	CO 3, CO 4	K1, K2, K3, K4, K5
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments			
Texts:	<ol style="list-style-type: none"> 1. Jacobson, M., Charlson, R. J., Rodhe, H., & Orians, G. H. (2000). <i>Earth System Science: from biogeochemical cycles to global changes</i> (Vol. 72). Academic Press. 2. Kump, L. R., Kasting, J. F., & Crane, R. G. (2004). <i>The earth system</i> (Vol. 432). Upper Saddle River, NJ, USA:: Pearson Prentice Hall. 3. Lenton, T. (2016). <i>Earth system science: a very short introduction</i> (Vol. 464). Oxford University Press. 			
References/ Readings:	<ol style="list-style-type: none"> 1. Rockström, J., Steffen, W., Noone, K. et al. (2009). A safe operating space for humanity. <i>Nature</i> 461, 472-475. https://doi.org/10.1038/461472a 			

2. Steffen, W., Richardson, K., Rockström, J. et al. (2020). The emergence and evolution of Earth System Science. *Nat Rev Earth Environ* 1, 54-63. <https://doi.org/10.1038/s43017-019-0005-6>
3. W. Steffen, J. Rockström, K. Richardson, T.M. Lenton, C. Folke, D. Liverman, C.P. Summerhayes, A.D. Barnosky, S.E. Cornell, M. Crucifix, J.F. Donges, I. Fetzer, S.J. Lade, M. Scheffer, R. Winkelmann, & H.J. Schellnhuber. (2018). Trajectories of the Earth System in the Anthropocene, *Proc. Natl. Acad. Sci. U.S.A.* 115 (33) 8252-8259, <https://doi.org/10.1073/pnas.1810141115>.

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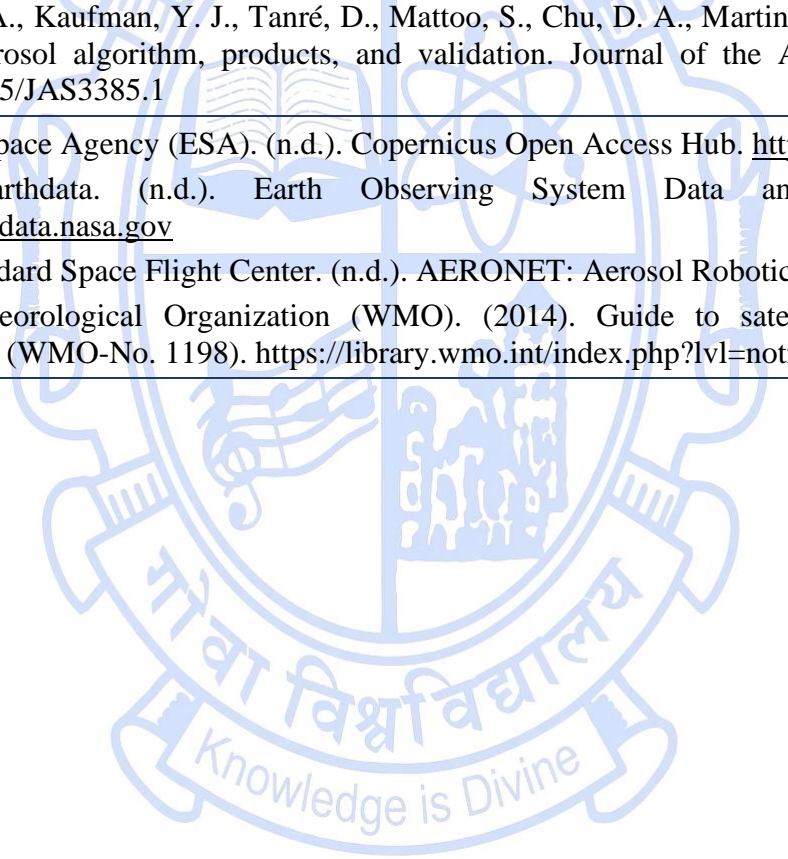
Title of the Course	Satellite Meteorology and Atmospheric Sensing (<i>Interdisciplinary Course</i>)
Course Code	ATM-5203
Number of Credits	2
Theory/Practical	Theory
Level	400
Effective from AY	2025-2026
New Course:	Yes
Bridge Course/ Value-added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course introduces the fundamental principles of satellite-based atmospheric sensing and radiative transfer, with a focus on retrieving atmospheric parameters from satellite and ground-based instruments. It includes hands-on training in processing satellite datasets for weather, aerosol, and trace gas analysis, and demonstrates their application in environmental monitoring.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Understand satellite-based data processing techniques to retrieve atmospheric parameters such as aerosols, ozone, and temperature profiles.	PSO 1, PSO 2
	CO 2. Understand spatial and temporal patterns in atmospheric data.	PSO 2
	CO 3. Demonstrate understanding of geospatial tools and their application in processing and visualizing atmospheric datasets.	PSO 2, PSO 5
	CO 4. Apply satellite data access and pre-processing techniques to retrieve atmospheric	PSO 2, PSO 3, PSO

	constituents.		4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Atmospheric Physics and Satellite Observations	Fundamentals of Satellite Meteorology and Atmospheric Sensing; Structure and composition of the atmosphere; Electromagnetic radiation interaction with the atmosphere (absorption, scattering, emission); Radiative transfer principles and sensor characteristics; Overview of meteorological satellites and sensors (e.g., MODIS, AIRS, TROPOMI, OMI, GOSAT, Imager and Sounder INSAT series); Ground-based networks: LIDAR, AERONET; Retrieval of aerosol optical depth, ozone, and vertical profiles.	15	CO 1, CO 2	K1, K2
Module 2: Applied Atmospheric Remote Sensing	Applications of satellite meteorology, e.g., air quality monitoring, dust storms, and crop burning; Role of remote sensing in weather forecasting and early warning systems; Climate variability and atmospheric dynamics from satellite observations; Case studies: Indian Summer Monsoon, urban pollution events, aerosol transport.	15	CO 3, CO 4	K2, K3
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture/Tutorials/Assignments			
Texts:	<ol style="list-style-type: none"> 1. Ackerman, S. A., & Knox, J. A. (2021). Meteorology: Understanding the atmosphere (5th ed Burlington, Massachusetts: Jones & Bartlett Learning. 2. Campbell, J. B., & Wynne, R. H. (2023). Introduction to remote sensing (6th ed.). New York, New York: The Guilford Press. 3. Elachi, C., & van Zyl, J. J. (2021). Introduction to the physics and techniques of remote sensing (4th ed.). Hoboken, New Jersey: Wiley. 4. Rees, W. G. (2022). Physical principles of remote sensing (4th ed.). Cambridge, United Kingdom: Cambridge University Press. 5. Robinson, P., & Henderson-Sellers, A. (2020). Contemporary climatology (3rd ed.). Abingdon, United Kingdom: Routledge. 			
References/ Readings:	<ol style="list-style-type: none"> 1. Holben, B. N., Eck, T. F., Slutsker, I., Tanré, D., Buis, J. P., Setzer, A., ... & Smirnov, A. (1998). AERONET-A federated instrument network and data archive for aerosol characterization. Remote Sensing of Environment, 66(1), 1–16. DOI:10.1016/S0034-4257(98)00031-5 			

	<ol style="list-style-type: none"> 2. Joiner, J., Veihelmann, B., Loyola, D., Worden, H. M., Kim, J., Boesch, H., ... & Röckmann, T. (2021). TROPOMI on Sentinel-5 Precursor: first year in operation (AMT/ACP inter-journal SI). 3. King, M. D., Menzel, W. P., Kaufman, Y. J., Tanré, D., Gao, B. C., Platnick, S., ... & Nakajima, T. (2003). Cloud and aerosol properties, precipitable water, and profiles of temperature and water vapor from MODIS. <i>IEEE Transactions on Geoscience and Remote Sensing</i>, 41(2), 442–458. DOI:10.1109/TGRS.2002.808226. 4. Levelt, P. F., van den Oord, G. H., Dobber, M. R., Mälkki, A., Visser, H., de Vries, J., ... & Veefkind, J. P. (2006). The Ozone Monitoring Instrument. <i>IEEE Transactions on Geoscience and Remote Sensing</i>, 44(5), 1093–1101. DOI:10.1109/TGRS.2006.872333 5. Remer, L. A., Kaufman, Y. J., Tanré, D., Mattoo, S., Chu, D. A., Martins, J. V., ... & Holben, B. N. (2005). The MODIS aerosol algorithm, products, and validation. <i>Journal of the Atmospheric Sciences</i>, 62(4), 947–973. DOI:10.1175/JAS3385.1
Web Resources:	<ol style="list-style-type: none"> 1. European Space Agency (ESA). (n.d.). Copernicus Open Access Hub. https://scihub.copernicus.eu/ 2. NASA Earthdata. (n.d.). Earth Observing System Data and Information System (EOSDIS). https://earthdata.nasa.gov 3. NASA Goddard Space Flight Center. (n.d.). AERONET: Aerosol Robotic Network. https://aeronet.gsfc.nasa.gov/ 4. World Meteorological Organization (WMO). (2014). Guide to satellite applications in meteorology and climatology (WMO-No. 1198). https://library.wmo.int/index.php?lvl=notice_display&id=15659

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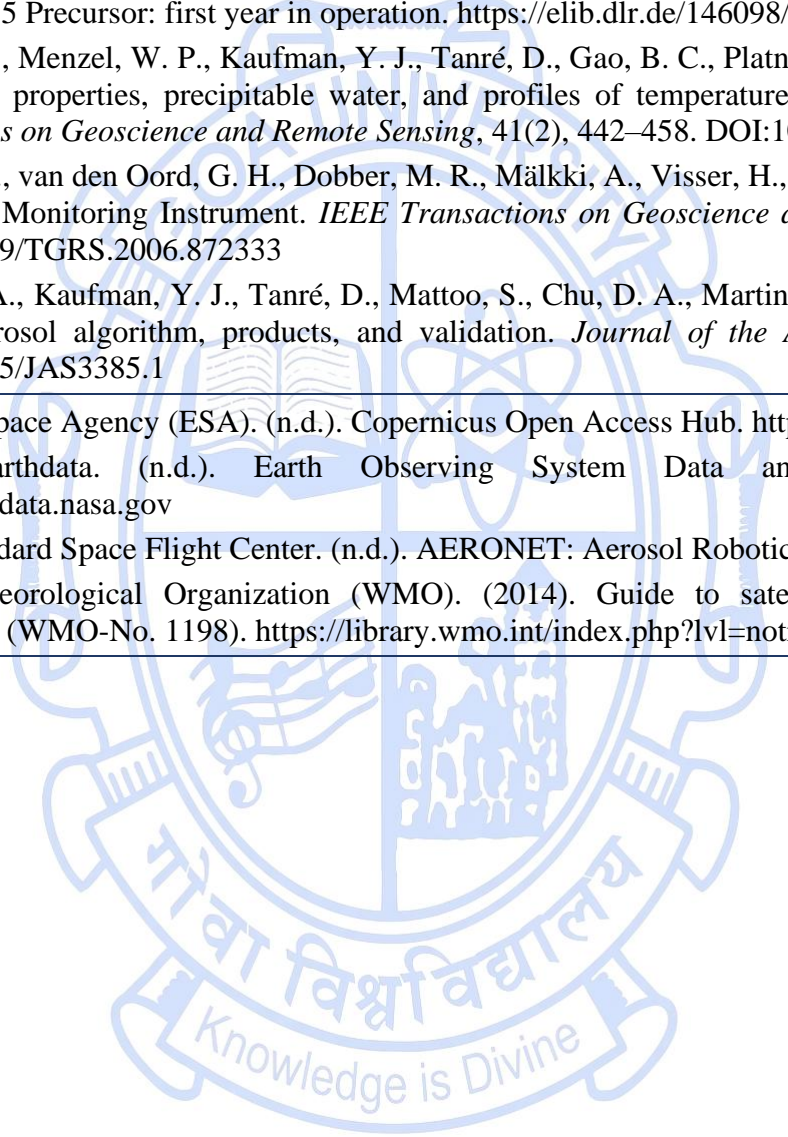
Title of the Course	Satellite Meteorology and Atmospheric Sensing Practical (<i>Interdisciplinary Course</i>)
Course Code	ATM-5204
Number of Credits	2
Theory/Practical	Practical
Level	400
Effective from AY	2025-2026
New Course:	Yes
Bridge Course/ Value-added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course introduces the fundamental principles of satellite-based atmospheric sensing and radiative transfer, with a focus on retrieving atmospheric parameters from satellite and ground-based instruments. It includes hands-on training in processing satellite datasets for weather, aerosol, and trace gas analysis, and demonstrates their application in environmental monitoring.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Understand satellite-based data processing techniques to retrieve atmospheric parameters such as aerosols, ozone, and temperature profiles.	PSO 1, PSO 2
	CO 2. Understand spatial and temporal patterns in atmospheric data.	PSO 2
	CO 3. Demonstrate understanding of geospatial tools and their application in processing and visualizing atmospheric datasets.	PSO 3

	CO 4. Apply satellite data access and pre-processing techniques to retrieve atmospheric constituents.		PSO 3	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Tools and Techniques	Familiarisation with software packages Panoply/SeaDAS/.SNAP/QGIS/ERDAS/ArcGIS/Python/MATLAB; Satellite data access, e.g., NASA Giovanni, Copernicus, MODIS/AIRS portals; Data Visualisation and interpretation using standard remote sensing and GIS tools; Retrieval and plotting of AOD, NO ₂ , and ozone; Profiles of temperature, subsequent estimations of standard meteorological parameters, humidity, Temperature and humidity profiling from AIRS and radiosonde datasets.	30	CO 1, CO 2	K1, K2
Module 2: Atmospheric Event Analysis with Remote Sensing	Air quality trend analysis using multi-year remote sensing data; Regional event analyses of dust transport, smog and airborne pollutants; Integration of LIDAR and AERONET data in ground validation; Final-project: Analysis of a selected atmospheric event with report and presentation.	30	CO3, CO 4	K2, K3, K4, K5
Pedagogy:	Use of Conventional, Online and ICT Methods. Hands-on Practical			
Texts:	<ol style="list-style-type: none"> Ackerman, S. A., & Knox, J. A. (2021). <i>Meteorology: Understanding the atmosphere</i> (5th ed Burlington, Massachusetts: Jones & Bartlett Learning. Campbell, J. B., & Wynne, R. H. (2023). <i>Introduction to remote sensing</i> (6th ed.). New York, New York: The Guilford Press. Elachi, C., & van Zyl, J. J. (2021). <i>Introduction to the physics and techniques of remote sensing</i> (4th ed.). Hoboken, New Jersey: Wiley. Rees, W. G. (2022). <i>Physical principles of remote sensing</i> (4th ed.). Cambridge, United Kingdom: Cambridge University Press. Robinson, P., & Henderson-Sellers, A. (2020). <i>Contemporary climatology</i> (3rd ed.). Abingdon, United Kingdom: Routledge. DOI:10.4324/9781315842660 			
References/ Readings:	<ol style="list-style-type: none"> Holben, B. N., Eck, T. F., Slutsker, I., Tanré, D., Buis, J. P., Setzer, A., ... & Smirnov, A. (1998). AERONET-A federated instrument network and data archive for aerosol characterization. <i>Remote Sensing of Environment</i>, 66(1), 1–16. DOI:10.1016/S0034-4257(98)00031-5 			

	<ol style="list-style-type: none"> 2. Joiner, J., Veihelmann, B., Loyola, D., Worden, H. M., Kim, J., Boesch, H., ... & Röckmann, T. (2021). TROPOMI on Sentinel-5 Precursor: first year in operation. https://elib.dlr.de/146098/ 3. King, M. D., Menzel, W. P., Kaufman, Y. J., Tanré, D., Gao, B. C., Platnick, S., ... & Nakajima, T. (2003). Cloud and aerosol properties, precipitable water, and profiles of temperature and water vapor from MODIS. <i>IEEE Transactions on Geoscience and Remote Sensing</i>, 41(2), 442–458. DOI:10.1109/TGRS.2002.808226_ 4. Levelt, P. F., van den Oord, G. H., Dobber, M. R., Mälkki, A., Visser, H., de Vries, J., ... & Veefkind, J. P. (2006). The Ozone Monitoring Instrument. <i>IEEE Transactions on Geoscience and Remote Sensing</i>, 44(5), 1093–1101. DOI:10.1109/TGRS.2006.872333 5. Remer, L. A., Kaufman, Y. J., Tanré, D., Mattoo, S., Chu, D. A., Martins, J. V., ... & Holben, B. N. (2005). The MODIS aerosol algorithm, products, and validation. <i>Journal of the Atmospheric Sciences</i>, 62(4), 947–973. DOI:10.1175/JAS3385.1
Web Resources:	<ol style="list-style-type: none"> 1. European Space Agency (ESA). (n.d.). Copernicus Open Access Hub. https://scihub.copernicus.eu/ 2. NASA Earthdata. (n.d.). Earth Observing System Data and Information System (EOSDIS). https://earthdata.nasa.gov 3. NASA Goddard Space Flight Center. (n.d.). AERONET: Aerosol Robotic Network. https://aeronet.gsfc.nasa.gov/ 4. World Meteorological Organization (WMO). (2014). Guide to satellite applications in meteorology and climatology (WMO-No. 1198). https://library.wmo.int/index.php?lvl=notice_display&id=15659

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Title of the Course	Climate Science and Services
Course Code	ATM-5205
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value-added Course:	No
Course for advanced learners:	Yes

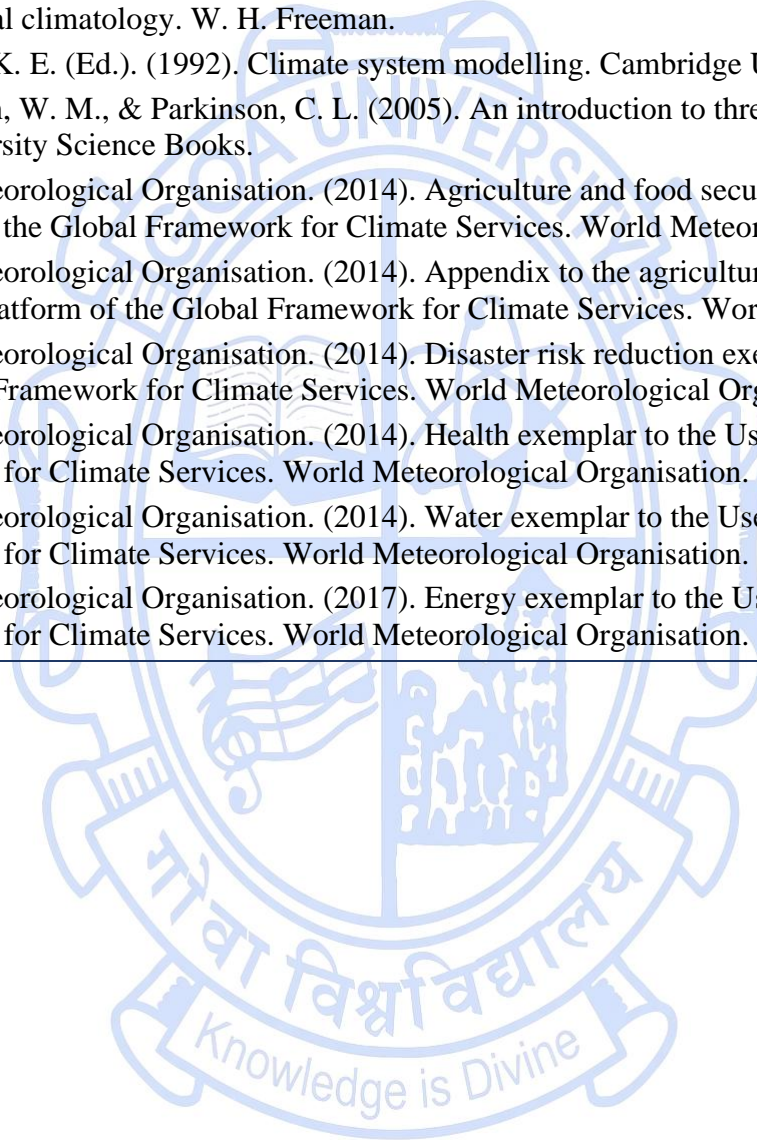
Pre-requisites for the Course:	Nil	
Course Objectives:	To introduce the Earth as an integrated system by explaining the structure, functioning, and interactions among the atmosphere, ocean, land, cryosphere, and biosphere, with emphasis on Earth system cycles, energy and water budgets, feedbacks, variability, and human-driven change, enabling students to interpret Earth system observations in a physically consistent way.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Explain the climate system and its components, and describe past climate variability using paleoclimate evidence and reconstruction methods.	PSO 1, PSO 2
	CO 2. Distinguish climate variability from climate change and analyse the physical processes, feedbacks, and forcings that regulate climate across temporal and spatial scales.	PSO 1, PSO 2
	CO 3. Describe the evolution and hierarchy of climate models (from energy balance models to Earth system models) and apply the logic of model experiments to interpret projections	PSO 2, PSO 3, PSO 4

	of future climate.			
	CO 4. Evaluate climate services for decision-making by interpreting climate risk, early warning approaches, and sectoral adaptation/mitigation strategies for agriculture, forestry, water, health, and energy under a changing climate.		PSO 1, PSO 2, PSO 4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Climate Change & Variability	Components of the climate system, Difference between climate change and variability, Overview of the climatic history of the earth, long-term changes (Climate of the Past century, past millennium, past glacial period). Methods of determining past climate. Possible causes of climate change - External (Milankovitch variation and Solar activity) and Internal (natural and anthropogenic), Air-sea interactions on different space and time scales. General idea of internal dynamical processes of different components of the Earth system, radiation budget of the Earth system. Climate feedback processes and mechanisms, low-frequency variability. Climate tipping points; introduction to the carbon cycle; water cycle (on the climate scale). Role of anthropogenic activities on the current climate change, understanding future climate & climate predictions, potential consequences, extreme events and climate disasters	15	CO 1, CO 2	K1, K2
Module 2: Climate Modelling	Definition of Climate Models, evolution of climate models (hierarchy of models), Simple climate model 0-D & 1-D climate models, Energy balance models and sensitivity studies (in the context of CMIP/IPCC). Intermediate complexity models, General Circulation models. Coupled ocean-atmosphere system, Earth system models, Future scenarios of ESM (in the context of CMIP/IPCC). International efforts to minimise climate change: the general ideas of sustainability, adaptability, and mitigation. General idea of climate vulnerability and resilience, discussion on the multifold impact of climate change. Indian scenario.	15	CO 3, CO 4	K1, K2, K3, K4, K5
Module 3: Climate Services	Concept of different sectors and climate services, Agriculture and Food Security: Climate Variability of Sunshine, Rainfall and Temperature. Agricultural policies, practices, and technologies contribute to the vulnerability of the forestry and agricultural sectors. Disaster Risk Reduction: Risk Assessment, Loss Data, Early Warning Systems,	30		

	Risk Reduction in sectors (Health, Water, Agriculture), Climate Risk Management. Energy: Interactions of the energy sector with other sectors (Ecosystems, Settlements, Health, Transport, Coastal Areas, Forestry, Agriculture). Impact on different energy subsectors to climate change projections and its implications. Health: Factors relating weather and climate to health, current trends and gaps. Water: Planning and management of water supplies and water management strategies under changing scenarios. WMO framework and GFCS for climate services			
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments			
Texts:	<ol style="list-style-type: none"> 1. Global Atmospheric Research Programme, Joint Organising Committee. (1975). The physical basis of climate and climate modelling: Report of the International Study Conference in Stockholm, 29 July–10 August 1974 (GARP Publications Series No. 16). World Meteorological Organisation. 2. Goodess, C. M., Palutikof, J. P., & Davies, T. D. (1992). The nature and causes of climate change: Assessing the long-term future. Lewis Publishers. 3. Houghton, J. T., Jenkins, G. J., & Ephraums, J. J. (Eds.). (1990). Climate change: The IPCC scientific assessment. Cambridge University Press. 4. Intergovernmental Panel on Climate Change. (2021). Climate change 2021: The physical science basis (Working Group I contribution to the Sixth Assessment Report). Cambridge University Press. 5. Intergovernmental Panel on Climate Change. (2022). Climate change 2022: Impacts, adaptation and vulnerability (Working Group II contribution to the Sixth Assessment Report). Cambridge University Press. 6. Intergovernmental Panel on Climate Change. (2022). Climate change 2022: Mitigation of climate change (Working Group III contribution to the Sixth Assessment Report). Cambridge University Press. 7. Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report (Contribution of Working Groups I, II and III to the Sixth Assessment Report). IPCC. 8. Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report (Contribution of Working Groups I, II and III to the Sixth Assessment Report). IPCC. 9. Lamb, H. H. (1977). Climate: Present, past and future (Vol. 2, Climatic history and the future). Methuen. 10. McGuffie, K., & Henderson-Sellers, A. (2005). A climate modelling primer (3rd ed.). John Wiley & Sons. 11. Pant, G. B., & Rupa Kumar, K. (Eds.). (1997). Climates of South Asia. John Wiley & Sons. 12. Sellers, W. D. (1965). Physical climatology. University of Chicago Press. 			

13. Stringer, E. T. (1972). Foundations of climatology: An introduction to physical, dynamic, synoptic, and geographical climatology. W. H. Freeman.
14. Trenberth, K. E. (Ed.). (1992). Climate system modelling. Cambridge University Press.
15. Washington, W. M., & Parkinson, C. L. (2005). An introduction to three-dimensional climate modelling (2nd ed.). University Science Books.
16. World Meteorological Organisation. (2014). Agriculture and food security exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organisation.
17. World Meteorological Organisation. (2014). Appendix to the agriculture and food security exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organisation.
18. World Meteorological Organisation. (2014). Disaster risk reduction exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organisation.
19. World Meteorological Organisation. (2014). Health exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organisation.
20. World Meteorological Organisation. (2014). Water exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organisation.
21. World Meteorological Organisation. (2017). Energy exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organisation.

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SEMESTER II

Discipline Specific Core (DCS) Courses

Title of the Course	Ocean Dynamics	
Course Code	ATM-5005	
Number of Credits	3	
Theory/Practical	Theory	
Level	500	
Effective from AY	2026-2027	
New Course:	Yes	
Bridge Course/ Value-added Course:	No	
Course for advanced learners:	Yes	
Pre-requisites for the Course:	Nil	
Course Objectives:	To develop a conceptual and quantitative understanding of the physical processes governing ocean circulation and variability, including upper-ocean stratification and mixing, air-sea forcing and heat budgets, wind-driven and buoyancy-driven circulation, and wave-vorticity dynamics, enabling students to interpret observations and diagnose ocean-climate interactions using core dynamical principles.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Explain the physical properties of seawater, static stability, stratification, mixed-layer processes, and water-column structure using observational profiles.	PSO 1, PSO 2

	CO 2. Apply heat, momentum, and freshwater flux concepts to interpret mixed-layer budgets, SST variability, and the relative roles of wind-driven and buoyancy-driven processes.		PSO 1, PSO 2
	CO 3. Analyse governing equations, approximations, scale analysis, and geostrophic/thermal-wind balance to interpret large-scale ocean circulation regimes.		PSO 1, PSO 2
	CO 4. Analyse Ekman layer processes, wind-driven gyres, vorticity and potential vorticity dynamics, and wave types relevant to large-scale adjustment.		PSO 1, PSO 2, PSO 4
Content:		No of hours	Mapped to CO
Module 1: Upper-Ocean Structure, Stratification, and Mixing	Ocean state variables and vertical structure: temperature, salinity, density, pressure; qualitative equation of state and buoyancy. Stratification and stability: Brunt-Väisälä frequency (interpretation), mixed-layer depth and variability, thermocline (seasonal vs permanent), barrier-layer formation and relevance (tropics/monsoon regions), mixing and entrainment (wind stirring, buoyancy forcing). Vertical mixing processes (turbulent vs molecular; link to surface forcing) and conceptual introduction to vertical modes. Observational interpretation context: CTD/Argo profiles and satellite SST (interpretation).	15	CO 1, CO 2 K1, K2
Module 2: Air-Sea Forcing, Mixed-Layer Heat Budget, and Overturning/Gyre	Air-sea fluxes as ocean forcing: shortwave/longwave, latent/sensible heat; wind stress and surface drag; freshwater flux and buoyancy flux. Mixed-layer heat budget: tendency terms (surface flux, entrainment, advection, diffusion), seasonal cycle of SST and MLD. Ocean heat transport and climate relevance (meridional heat transport concept). Large-scale circulation context: wind-driven vs buoyancy-driven contributions; overview of gyres and global overturning (formation of intermediate/deep waters; role of mixing and surface buoyancy forcing).	15	CO 2, CO 3 K1, K2, K3
Module 3: Wind-Driven Circulation, Vorticity/PV Constraints, and Wave Adjustment	Ekman dynamics (ocean application): Ekman transport and Ekman pumping/suction; coastal upwelling/downwelling (process interpretation). Interior wind-driven circulation: Sverdrup balance (conceptual), western boundary intensification, subtropical/subpolar gyres (dynamical interpretation). Vorticity and PV in the ocean: relative vs planetary vorticity; stretching as dominant mechanism; PV as a constraint and its role in gyres/jets (conceptual and diagnostic thinking). Ocean waves and adjustment:	15	CO 3, CO 4 K1, K2, K3, K4, K5

	surface gravity waves (dispersion concept), Kelvin waves (coastal/equatorial trapping), Rossby waves (westward propagation; role in basin adjustment), linkage to large-scale variability.			
Pedagogy:	Use of Conventional, Online and ICT Methods.			
Texts:	<ol style="list-style-type: none"> 1. Cushman-Roisin, B., & Beckers, J. M. (2011). <i>Introduction to geophysical fluid dynamics: physical and numerical aspects</i> (Vol. 101). Academic Press. ISBN-13: 978-0120887590 2. Gill, A. E. (2016). <i>Atmosphere-ocean dynamics</i>. Elsevier. ISBN-13: 978-0122835223 3. Pedlosky, J. (2013). <i>Geophysical fluid dynamics</i>. Springer Science & Business Media. ISBN: 978-1-4612-4650-3 			
References/ Readings:	<ol style="list-style-type: none"> 1. Munk, W. H. (1950). On the wind-driven ocean circulation. <i>Journal of Meteorology</i>, 7(2), 80–93. DOI:10.1175/1520-0469(1950)007%3C0080:otwdoc%3E2.0.co;2 2. Rhines, P. B. (1975). Waves and turbulence on a beta-plane. <i>Journal of Fluid Mechanics</i>. 69(3):417-443. DOI:10.1017/S0022112075001504 3. Stommel, H. (1948). The westward intensification of wind-driven ocean currents. <i>Transactions</i>, 29(2), 202–206. DOI:10.1029/tr029i002p00202 4. Sverdrup, H. U. (1947). Wind-driven currents in a baroclinic ocean; With application to the equatorial currents of the Eastern Pacific. <i>Proceedings of the National Academy of Sciences of the United States of America</i>, 33(11), 318–326. DOI:10.1073/pnas.33.11.318 5. Wunsch, C. & Ferrari, R. (2004). Vertical mixing, energy, and the general circulation of the oceans. <i>Annual Review of Fluid Mechanics</i>, 36(1), 281–314. DOI:10.1146/annurev.fluid.36.050802.122121 			

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Title of the Course	Atmospheric Chemistry and Air Pollution
Course Code	ATM-5006
Number of Credits	3
Theory/Practical	Theory
Level	500
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/Value added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To build understanding of atmospheric chemistry and transport, covering photochemical ozone/smog formation, aerosol sources and sinks, stratospheric ozone depletion processes, and chemical-climate interactions supported by modelling, remote sensing and observations.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Explain lower-atmospheric structure, tropopause dynamics, and variability modes important for chemistry and transport.	PSO 1
	CO 2. Apply chemical concepts to analyse ozone formation, smog, and aerosol properties, sources, and sinks.	PSO 1, PSO 2
	CO 3. Analyse stratospheric ozone chemistry, catalytic cycles, heterogeneous reactions, and mechanisms of ozone depletion.	PSO 1, PSO 2, PSO 3
	CO 4. Examine how atmospheric chemical processes affect climate, and how models help	PSO 2, PSO 3, PSO

	understand these effects.		4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Lower-Atmosphere Structure, Tropopause Dynamics, and Variability Modes	Structure and composition of the lower atmosphere; climatology of the lower atmosphere (temperature, winds, minor constituents); tropopause concepts, tropical tropopause layer (TTL), dynamical tropopause, and why the tropopause matters for tropospheric weather and stratosphere-troposphere exchange (STE). Atmospheric variability relevant to chemistry and transport: diurnal cycle; annual and semi-annual oscillations; interannual and intraseasonal oscillations; quasi-biennial oscillation (QBO). Zonal-mean circulation framework: mean meridional winds, zonally averaged mass circulation. Stratosphere-troposphere dynamical phenomena with chemical relevance: sudden stratospheric warming (SSW); polar stratospheric clouds; Arctic and Antarctic Oscillations; Northern/Southern Annular Modes (NAM/SAM).	10	CO 1	K1, K2
Module 2: Tropospheric Chemistry, Ozone Smog, and Aerosols as Air Pollutants	Oxidising capacity of the troposphere; tropospheric ozone, sources, sinks, and budgets; photochemical ozone production in polluted environments; roles of NO _x and hydrocarbons/VOCs; transport of ozone from the stratosphere and implications for background ozone and episodes. Air pollution and ozone smog. Atmospheric aerosols: concentration and size distributions; sources (natural/anthropogenic), formation pathways, and transformation (gas-to-particle conversion, ageing); chemical composition; transport and sinks (wet/dry deposition); residence times; geographic distribution; atmospheric effects.	15	CO 2	K1, K2, K3, K4
Module 3: Stratospheric Chemistry, Ozone Depletion, and Chemistry-Climate Linkages	Stratospheric ozone: Chapman mechanism and its limitations; ozone photochemistry (photolysis, catalytic control); key reactants and rate coefficients. Catalytic loss cycles: HO _x , NO _y /NO _x , halogen chemistry; heterogeneous reactions and aerosol chemistry in the stratosphere; chlorine-nitrogen activation/deactivation; ClO-ClO ozone loss pathway; methane photodissociation and links to HO _x chemistry. Stratospheric particles: sulfate aerosols; PSC composition and role; basis and seasonal evolution of polar ozone depletion; Antarctic ozone hole and Arctic variability; ozone layer future and recovery stages. Short-lived climate pollutants	20	CO 3, CO 4	K1, K2, K3, K4, K5

	(SLCPs) and greenhouse gases: global tropospheric air pollution context; anthropogenic emissions and biomass burning; black carbon emissions and emission inventories; chemistry-climate interactions and links to regional/global climate change; Atmospheric Composition and the Asian Monsoon (ACAM) overview; Chemistry-Climate Model Initiative (CCMI) overview; fundamentals of chemistry-climate modelling and climate projections.			
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments			
Texts:	<ol style="list-style-type: none"> 1. Brasseur, G. P., Orlando, J. J., & Tyndall, G. S. (Eds.). (1999). <i>Atmospheric chemistry and global change</i> (Vol. 654). New York: Oxford University Press. https://api.semanticscholar.org/CorpusID:94266820 2. Finlayson-Pitts, B. J., & Pitts Jr, J. N. (1999). <i>Chemistry of the upper and lower atmosphere: theory, experiments, and applications</i>. Elsevier. ISBN: 978-0-12-257060-5 3. Seinfeld, J. H., & Pandis, S. N. (2016). <i>Atmospheric chemistry and physics: from air pollution to climate change</i>. John Wiley & Sons. ISBN: 9781119221173, 111922117X 			
References/ Readings:	<ol style="list-style-type: none"> 1. Farman, J. C., Gardiner, B. G., & Shanklin, J. D. (1985). Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction. <i>Nature</i>, 315(6016), 207-210. DOI:10.1038/315207a0 2. Fiore, A. M., Naik, V., Spracklen, D. V., Steiner, A., Unger, N., Prather, M., ... Zeng, G. (2012). Global air quality and climate. <i>Chemical Society Reviews</i>, 41(19), 6663-6683. DOI:10.1039/c2cs35095e 3. Molina, M. J., & Rowland, F. S. (1974). Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone. <i>Nature</i>, 249(5460), 810-812. DOI:10.1038/249810a0 4. Solomon, S. (1999). Stratospheric ozone depletion: A review of concepts and history. <i>Reviews of Geophysics</i> (Washington, D.C.: 1985), 37(3), 275-316. DOI:10.1029/1999rg900008 			

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Title of the Course	Atmospheric Chemistry and Air Pollution Practical
Course Code	ATM-5007
Number of Credits	1
Theory/Practical	Practical
Level	500
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/Value added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To develop practical skills in acquiring, processing, and interpreting atmospheric composition and air-quality data (ozone and aerosols), applying standard analytical and visualisation methods, and producing reproducible lab reports that link observations to chemical processes and impacts.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Acquire, log, and manage ground-based aerosol measurements and related observational metadata.	PSO 1
	CO 2. Perform basic quality checks and filtering on surface/column aerosol data to remove artefacts and identify usable periods.	PSO 1, PSO 2
	CO 3. Compute standard aerosol products such as AOD, Ångström exponent, black carbon proxies, scattering coefficients, and moisture/cloud indicators.	PSO 1, PSO 2, PSO 3
	CO 4. Analyse and interpret relationships between column aerosol variability, surface	PSO 2, PSO 3, PSO

	optical properties, and moisture/cloud conditions to produce a short diagnostic report.		5
Content:		No of hours	Mapped to CO
			Cognitive Level
Module 1: Ground Aerosol Observations and Analysis	Aerosol observations using column and surface optical measurements and radiometric moisture/cloud indicators, covering measurement purpose and retrieved quantities; routine data acquisition and logging; basic data handling and quality screening (e.g., identifying clear-sky periods for column observations and recognizing obvious artefacts in time series); generation of standard outputs such as aerosol optical depth and Ångström exponent, black carbon proxy, aerosol scattering coefficient, and integrated water vapour/liquid water path; and an integrated analysis exercise comparing column aerosol variability with surface absorption/scattering proxies and concurrent moisture/cloud conditions, culminating in a brief practical report with a small set of diagnostic plots and interpretation.	30	CO 1, CO 2, CO 3, CO 4 K1, K2, K3, K4
Pedagogy:	Use of Conventional, Online and ICT Methods. Hands-on Practicals		
Texts:	<ol style="list-style-type: none"> 1. Brasseur, G. P., Orlando, J. J., & Tyndall, G. S. (Eds.). (1999). <i>Atmospheric chemistry and global change</i> (Vol. 654). New York: Oxford University Press. https://api.semanticscholar.org/CorpusID:94266820 2. Finlayson-Pitts, B. J., & Pitts Jr, J. N. (1999). <i>Chemistry of the upper and lower atmosphere: theory, experiments, and applications</i>. Elsevier. ISBN: 978-0-12-257060-5 3. Seinfeld, J. H., & Pandis, S. N. (2016). <i>Atmospheric chemistry and physics: from air pollution to climate change</i>. John Wiley & Sons. ISBN: 9781119221173, 111922117X 		
References/ Readings:	<ol style="list-style-type: none"> 1. Farman, J. C., Gardiner, B. G., & Shanklin, J. D. (1985). Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction. <i>Nature</i>, 315(6016), 207-210. DOI:10.1038/315207a0 2. Fiore, A. M., Naik, V., Spracklen, D. V., Steiner, A., Unger, N., Prather, M., ... Zeng, G. (2012). Global air quality and climate. <i>Chemical Society Reviews</i>, 41(19), 6663-6683. DOI:10.1039/c2cs35095e 3. Molina, M. J., & Rowland, F. S. (1974). Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone. <i>Nature</i>, 249(5460), 810-812. DOI:10.1038/249810a0 4. Solomon, S. (1999). Stratospheric ozone depletion: A review of concepts and history. <i>Reviews of Geophysics</i> (Washington, D.C.: 1985), 37(3), 275-316. DOI:10.1029/1999rg900008 		

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Title of the Course	Dynamic Meteorology
Course Code	ATM-5008
Number of Credits	3
Theory/Practical	Theory
Level	500
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To develop a mechanistic understanding of large-scale and synoptic atmospheric dynamics using vorticity and potential vorticity frameworks, quasi-geostrophic diagnostics, and boundary-layer structure and turbulence for interpreting weather systems.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Explain circulation, vorticity, and potential vorticity concepts and their role in large-scale atmospheric motions.	PSO 1
	CO 2. Analyse vorticity and divergence equations, their physical terms, and balance relationships in different coordinate systems.	PSO 1, PSO 2
	CO 3. Apply quasi-geostrophic theory, vorticity and omega equations, and Q-vector diagnostics to interpret synoptic-scale weather systems.	PSO 1, PSO 3, PSO 4

	CO 4. Describe boundary-layer structure, turbulence characteristics, and wind behaviour in the atmospheric boundary layer.		PSO 1	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Circulation, Vorticity Theorems, and Potential Vorticity	Circulation and vorticity fundamentals; Stokes' theorem; Kelvin's circulation theorem; Helmholtz theorems; barotropic vs baroclinic fluids; absolute vs relative circulation; Bjerknes circulation theorem and interpretation; potential vorticity (PV) and conservation; PV applications (airflow over mountain barriers); Taylor-Proudman theorem (concept and relevance).	10	CO 1	K1, K2
Module 2: Vorticity and Divergence Dynamics; Balance Relations	Vorticity equation in Cartesian and isobaric coordinates; physical significance of terms (stretching, tilting, baroclinic generation, friction); divergence and vorticity of geostrophic wind; vector vorticity equation; scale analysis of vorticity dynamics; constant absolute vorticity (CAV) trajectories; divergence equation; balance equation.	10	CO 2	K1, K2, K3
Module 3: Quasi-Geostrophic Theory and Synoptic-Scale Systems	Dynamics of midlatitude synoptic-scale motions; quasi-geostrophic (QG) vorticity equation; geopotential tendency equation; QG potential vorticity equation; omega equation; Q-vector method; ageostrophic circulation; idealised model of a baroclinic disturbance (structure and evolution).	10	CO 3	K1, K2, K3, K4
Module 4: Atmospheric Boundary Layer Dynamics	Fundamentals of the atmospheric boundary layer (ABL); ABL sub-layers; winds in the boundary layer; surface layer and Ekman spiral layer; turbulence basics and Taylor hypothesis; boundary-layer depth and structure; convectively mixed boundary layer; nocturnal boundary layer.	15	CO 4	K1, K2
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments			
Texts:	<ol style="list-style-type: none"> Holton, J. R., & Hakim, G. J. (2013). <i>An introduction to dynamic meteorology</i> (Vol. 88). Academic Press. Salby, M. L. (1996). <i>Fundamentals of atmospheric physics</i> (Vol. 61). Elsevier. ISBN-10: 0126151601 Stull, R. B. (2012). <i>An introduction to boundary layer meteorology</i> (Vol. 13). Springer Science & Business Media. ISBN-13: 978-94-009-3027-8 Vallis, G. K. (2017). <i>Atmospheric and oceanic fluid dynamics</i>. Cambridge University Press. ISBN-13: 978-1107065505 			

	<p>5. Wallace, J. M., Battisti, D. S., Thompson, D. W., & Hartmann, D. L. (2023). <i>The atmospheric general circulation</i>. Cambridge University Press. ISBN-13: 978-1108474245</p>
<p>References/ Readings:</p>	<p>1. Charney, J. G. (1947). The dynamics of long waves in a baroclinic westerly current. <i>Journal of Meteorology</i>, 4(5), 136–162. DOI:10.1175/1520-0469(1947)004%3C0136:tdolwi%3E2.0.co;2</p> <p>2. Hoskins, B. J., Draghici, I., & Davies, H. C. (1978). A new look at the ω-equation. <i>Quarterly Journal of the Royal Meteorological Society</i>. <i>Royal Meteorological Society (Great Britain)</i>, 104(439), 31–38. DOI:10.1002/qj.49710443903</p> <p>3. Hoskins, B. J., McIntyre, M. E., & Robertson, A. W. (2007). On the use and significance of isentropic potential vorticity maps. <i>Quarterly Journal of the Royal Meteorological Society</i>. <i>Royal Meteorological Society (Great Britain)</i>, 111(470), 877–946. DOI:10.1002/qj.49711147002</p> <p>4. Kuo, H.-L. (1956). Forced and free meridional circulations in the atmosphere. <i>Journal of Meteorology</i>, 13(6), 561–568. DOI:10.1175/1520-0469(1956)013%3C0561:fafmci%3E2.0.co;2</p> <p>5. Thorncroft, C. D., Hoskins, B. J., & McIntyre, M. E. (1993). Two paradigms of baroclinic-wave life-cycle behaviour. <i>Quarterly Journal of the Royal Meteorological Society</i>. <i>Royal Meteorological Society (Great Britain)</i>, 119(509), 17–55. DOI:10.1002/qj.49711950903</p>

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Title of the Course	Meteorological Instruments and Observational Technique
Course Code	ATM-5009
Number of Credits	4
Theory/Practical	Practical
Level	500
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To develop hands-on competence in meteorological observations and quality control, synoptic analysis using station/reanalysis datasets, diagnosis of seasonal-monsoon and extreme-weather patterns, and interpretation of NWP outputs for producing concise, case-based weather reports.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Operate and record data from standard meteorological instruments and towers, and perform basic quality control.	PSO 1, PSO 2
	CO 2. Plot and interpret station models, surface weather observations, synoptic charts, and reanalysis visualisations.	PSO 1, PSO 2, PSO 4
	CO 3. Analyse seasonal atmospheric patterns, monsoon onset, circulation indices, jet streams, tropical cyclones, and climate modes using observational and reanalysis datasets.	PSO 2, PSO 3, PSO 5
	CO 4. Interpret and evaluate short- to medium-range NWP outputs and prepare concise case-	PSO 1, PSO 2, PSO

	based synoptic reports.		4, PSO 5	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Meteorological Observations and Data Analysis	Meteorological instruments and observing practice overview; meteorological tower data acquisition and handling (temperature, humidity, wind at multiple levels; basic QC; diurnal profiles); station models; plotting and interpretation of surface observations; plotting/reading synoptic charts; introduction to reanalysis datasets and basic visualisation using GRADS/NCL/Python.	30	CO 1, CO 2	K1, K2, K3
Module 2: Atmospheric Circulation and Climate Diagnostics	Seasonal analysis (JF, MAM, JJAS, OND) of temperature and winds using reanalysis; diagnostics of Hadley and Walker circulations (simple indices/streamfunction-based interpretation); ITCZ mean position and propagation using TRMM/GPM rainfall products (basic mapping and time-latitude sections).	30	CO 2, CO 3	K1, K2, K3, K4
Module 3: Applied Atmospheric Dynamics	Identification of Monsoon Onset using reanalysis-derived indices/criteria; jet stream analysis (position/intensity diagnostics); tropical cyclone diagnostics (track/intensity proxies from reanalysis and satellite-derived fields where available); composite SST analysis for El Niño/La Niña and positive/negative IOD years	30	CO 3	K1, K2, K3, K4
Module 4: Applied Weather System Monitoring with NWP Models	Analysis and monitoring of weather systems using short- to medium-range NWP model outputs; basic verification-style checks (track comparison, timing of rainfall peaks, spatial consistency of wind/pressure patterns); case-study workflow from forecast fields to synoptic interpretation and brief reporting.	30	CO 4	K1, K2, K3, K4, K5
Pedagogy:	Use of Conventional, Online and ICT Methods. Hands-on Practicals			
Texts:	1. Brock, F. V., & Richardson, S. J. (2001). Meteorological Measurement Systems. DOI:10.1093/oso/9780195134513.001.0001 2. Stull, R. B. (2012). <i>An introduction to boundary layer meteorology</i> (Vol. 13). Springer Science & Business Media. ISBN-13: 978-94-009-3027-8			
Web Resources:	World Meteorological Organisation (2024). Provisional 2024 Edition of the Guide to Instruments and Methods of Observation (WMO-No.8). https://wmo.int/new-provisional-2024-edition-of-guide-instruments-and-methods-of-observation-wmo-no8			

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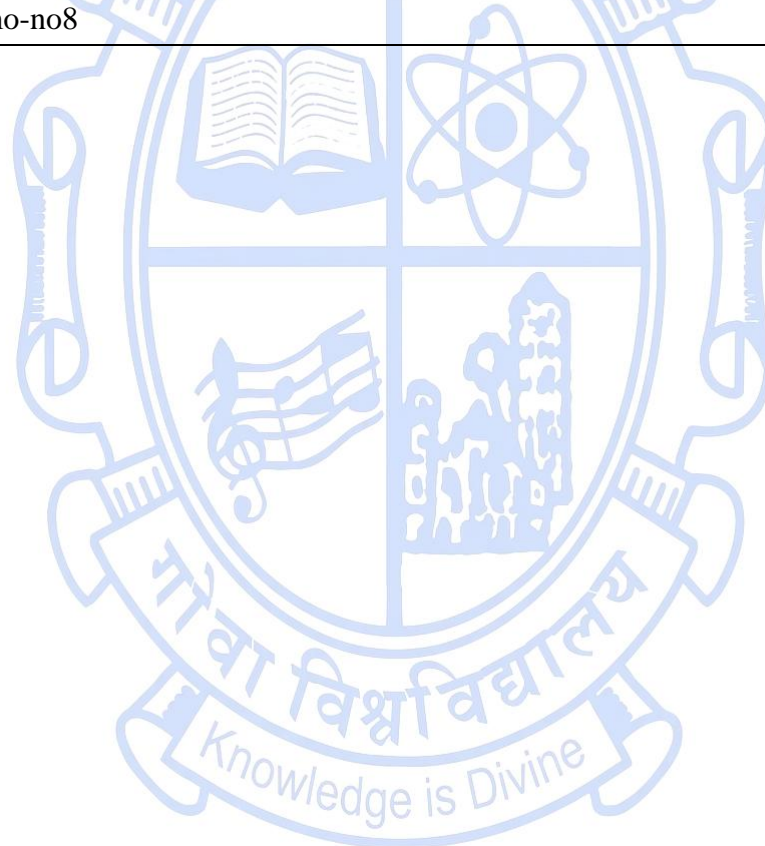
Title of the Course	Extreme Weather and Natural Hazards
Course Code	ATM-5010
Number of Credits	2
Theory/Practical	Theory
Level	500
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value added Course:	No
Course for advanced learners:	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To introduce the physical mechanisms driving extreme weather and related hazards (heavy rainfall, heat/cold extremes, floods, droughts), and to develop practical capability to diagnose, predict, and evaluate extremes using observational/reanalysis data and prediction approaches ranging from statistical methods to AI/ML models.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Explain the atmospheric processes and drivers that generate extreme rainfall, temperature extremes, floods, and droughts, including the role of moisture, instability, circulation, and land-atmosphere interactions	PSO 1, PSO 2
	CO 2. Analyse extreme-event datasets using appropriate metrics and indices (e.g., threshold exceedance, return periods, ETCCDI-style indices) and interpret spatial-temporal patterns and compound-event behaviour.	PSO 1, PSO 2, PSO 4
	CO 3. Apply prediction strategies for extremes using forecasting and statistical techniques,	PSO 2, PSO 3, PSO

	including event-based diagnostics, analog methods, and probabilistic prediction concepts.		5	
	CO 4. Build and evaluate statistical and AI/ML-based models for predicting extremes, using sound validation practices (hindcasts, cross-validation, skill scores) and communicating uncertainty for hazard-relevant decisions.		PSO 1, PSO 2, PSO 4, PSO 5	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Extreme Weather	Types of extremes. Quality and quantity of data and data analysis. Frequency, intensity, spatial extent, duration, and timing of extreme events. Observed and projected changes in weather and climate extremes. Modelling impacts of weather and climate extremes. Statistical aspects of extremes. Science of extreme precipitation, precipitation associated with storms such as cyclones and thunderstorms, cloud bursts, extreme temperatures, floods and droughts. Heatwaves and cold waves. Climate change and extreme events. Flash floods and landslides.	15	CO 1, CO 2	K1, K2, K3
Module 2: Mitigation and Management	Managing Weather and Climate Extremes. Traditional knowledge. Preparedness and planning. Risk Management. Information and communication strategies. Policies and practices for adaptation to weather and climate extremes. Resilience to adverse impacts of extremes. Issues and opportunities at the local, national and international levels. Technological innovations and improved practices. Reducing societal vulnerability to weather and climate extremes. Case Studies,	15	CO 2, CO 3	K1, K2, K3, K4
Pedagogy:	Use of Conventional, Online and ICT Methods. Hands-on Practicals			
Texts:	<ol style="list-style-type: none"> 1. Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (2004). At risk: Natural hazards, people's vulnerability and disasters (2nd ed.). Routledge. 2. Cutter, S. L. (2006). Hazards, vulnerability and environmental justice. Earthscan. 3. Intergovernmental Panel on Climate Change. (2012). Managing the risks of extreme events and disasters to advance climate change adaptation (SREX) (C. B. Field et al., Eds.). Cambridge University Press. 4. United Nations Office for Disaster Risk Reduction. (2015). Sendai Framework for Disaster Risk Reduction 2015-2030. United Nations. 			

	<p>5. United Nations Office for Disaster Risk Reduction. (2022). Global assessment report on disaster risk reduction 2022: Our world at risk-Transforming governance for a resilient future. UNDRR.</p> <p>6. World Meteorological Organisation. (2018). Multi-hazard early warning systems: A checklist. World Meteorological Organisation.</p> <p>7. World Meteorological Organisation. (2011). Global framework for climate services: Empowering the most vulnerable. World Meteorological Organisation.</p>
Web Resources:	<p>World Meteorological Organisation (2024). Provisional 2024 Edition of the Guide to Instruments and Methods of Observation (WMO-No.8). https://wmo.int/new-provisional-2024-edition-of-guide-instruments-and-methods-of-observation-wmo-no8</p>

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Discipline Specific Elective (DSE) Courses

Title of the Course	Aerosol and Climate	
Course Code	ATM-5206	
Number of Credits	4	
Theory/Practical	Theory	
Level	400	
Effective from AY	2026-2027	
New Course:	Yes	
Bridge Course/ Value added Course:	No	
Course for advanced learners:	No	
Pre-requisites for the Course:	Nil	
Course Objectives:	To develop an understanding of aerosol sources, composition, size distributions, and lifecycles, and how aerosols influence Earth's radiation budget, clouds and precipitation, air quality, and climate variability, using observations and models to assess aerosol forcing, uncertainty, and regional impacts.	
Course Outcomes:	Students will be able to,	Mapped to PSO
	CO 1. Explain aerosol types, size distributions, composition, sources, and removal processes, and relate these to optical and physical properties.	PSO 1
	CO 2. Describe aerosol optical properties, AOD concepts, and the measurement principles of ground-based, in-situ, and satellite aerosol observing systems.	PSO 1, PSO 2
	CO 3. Analyse aerosol–radiation and aerosol–cloud interactions, including direct and indirect	PSO 1, PSO 2, PSO

	effects, hygroscopicity, CCN activity, and climate linkages.		3
	CO 4. Evaluate global and regional aerosol budgets, major sources and sinks, uncertainties in emission/retrieval processes, and implications for climate change.		PSO 1, PSO 2, PSO 4
Content:		No of hours	Mapped to CO
	Cognitive Level		
Module 1: Aerosol Fundamentals and Characterisation	Aerosol definition and classification; size distributions (number/area/mass perspectives); chemical composition; sources (natural vs anthropogenic) and primary vs secondary aerosols; transformations (aging, gas-to-particle conversion, coagulation); sinks and removal pathways (dry/wet deposition) and residence time concepts; link between aerosol optical properties and visibility; aerosol optical depth (AOD) concept and interpretation.	15	CO 1
Module 2: Aerosol Optical Properties and Observations	Optical properties (scattering, absorption, extinction; single scattering albedo concept; Ångström exponent); relationship of optical properties to visibility and radiative effects (conceptual). Aerosol measurements overview: ground-based column observations (AERONET-type networks: concept and products); in situ surface measurements (mass/BC/scattering); satellite aerosol measurements (AOD retrieval concept, limitations, and uncertainty drivers such as clouds and surface reflectance).	15	CO 2
Module 3: Aerosol Impacts	Environmental effects and climate links: aerosol direct radiative forcing and indirect effects via clouds (CCN concept; cloud albedo/lifetime ideas); hygroscopicity and CCN activity; aerosol-cloud-climate interactions (qualitative mechanisms and uncertainties). Chemical roles: heterogeneous reactions (intro); polar stratospheric cloud formation context; link to ozone depletion and ozone hole (overview at concept level). Health and air-quality context: urban aerosols, ultrafine particles, haze episodes; National Ambient Air Quality Standards	15	CO 3
Module 4: Aerosol Budgets, Lifetimes, Global Distributions, and Uncertainty	Budget of atmospheric particulate matter: global/regional source estimates by major aerosol types; sinks, lifetimes, and large-scale distributions; interpretation of observed patterns; key uncertainties in aerosol budgets (emissions, chemistry, removal, measurement/retrieval uncertainty) and implications for climate attribution and projections.	15	CO 4
			K1, K2, K3, K4
			K1, K2, K3, K4, K5

Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments
Texts:	<ol style="list-style-type: none"> 1. Hinds, W. C., & Zhu, Y. (2022). <i>Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles</i>. (n.d.). ISBN: 978-1-119-49404-1 2. IPCC, 2021: <i>Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change</i> [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, DOI:10.1017/9781009157896. 3. Seinfeld, J. H., & Pandis, S. N. (2016). <i>Atmospheric chemistry and physics: from air pollution to climate change</i>. John Wiley & Sons. ISBN: 9781119221173, 111922117X
References/ Readings:	<ol style="list-style-type: none"> 1. Albrecht, B. A. (1989). Aerosols, cloud microphysics, and fractional cloudiness. <i>Science</i> (New York, N.Y.), 245(4923), 1227–1230. DOI:10.1126/science.245.4923.1227 2. Andreae, M. O., & Rosenfeld, D. (2008). Aerosol–cloud–precipitation interactions. Part 1. The nature and sources of cloud-active aerosols. <i>Earth-Science Reviews</i>, 89(1–2), 13–41. DOI:10.1016/j.earscirev.2008.03.001 3. Bond, T. C., Doherty, S. J., Fahey, D. W., Forster, P. M., Berntsen, T., DeAngelo, B. J., ... Zender, C. S. (2013). Bounding the role of black carbon in the climate system: A scientific assessment. <i>Journal of Geophysical Research: Atmospheres</i>, 118(11), 5380–5552. DOI:10.1002/jgrd.50171 4. Charlson, R. J., Schwartz, S. E., Hales, J. M., Cess, R. D., Coakley, J. A., Jr, Hansen, J. E., & Hofmann, D. J. (1992). Climate forcing by anthropogenic aerosols. <i>Science</i> (New York, N.Y.), 255(5043), 423–430. DOI:10.1126/science.255.5043.423 5. Twomey, S. (1974). Pollution and the planetary albedo. <i>Atmospheric Environment</i>, 8(12), 1251–1256. DOI:10.1016/0004-6981(74)90004-3

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Title of the Course	Modelling of the Atmosphere and Ocean
Course Code	ATM-5207
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value-added Course:	No
Course for advanced learners:	Yes

Pre-requisites for the Course:	Nil	
Course Objectives:	To develop a strong foundation in atmosphere-ocean modelling through the study of geophysical fluid dynamics, model hierarchies, numerical techniques, parameterization schemes, data assimilation methods, and coupled modelling strategies.	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. Explain the primitive-equation framework, key approximations, and nondimensional scaling central to atmosphere-ocean system modelling.	PSO 1, PSO 2
	CO 2. Describe and compare the hierarchy of atmosphere-ocean models, their assumptions, and the roles of initial/boundary conditions and forcing.	PSO 1, PSO 2, PSO 3
	CO 3. Apply numerical techniques (finite-difference, spectral, semi-Lagrangian) and stability concepts (CFL, filtering, aliasing) used in geophysical modelling systems.	PSO 1, PSO 2, PSO 3
	CO 4. Evaluate model components such as parameterisations, data assimilation methods, and	PSO 1, PSO 2, PSO 3

coupled-model strategies, and assess their influence on model performance.		3		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Governing Equations, Scaling, and Core Approximations	Basic dynamics of atmosphere and ocean; primitive-equation framework for ocean dynamics and thermodynamics (momentum, continuity, tracer/thermodynamic equations); scaling considerations and nondimensional numbers (e.g., Rossby/Froude/Reynolds); key approximations used in geophysical modelling (hydrostatic, Boussinesq, shallow-water, traditional approximation; linearization and small-amplitude assumptions); implications of approximations for resolved processes.	15	CO 1	K1, K2
Module 2: Model Hierarchy, Reduced Models, and PE Model Setup	Hierarchy of models and why it is used; barotropic and equivalent barotropic models; 1-D ocean models (bulk mixed-layer ideas, shear instability concept, turbulent closure models); two-level baroclinic model; shallow-water equation models; primitive-equation models (structure and common approximations). Practical modelling considerations: initial and boundary conditions (IC/BC types), forcing, and time integration concepts	15	CO 2	K1, K2, K3, K4
Module 3: Numerical Discretisation, Stability, and Grid Issues	Numerical methods overview; finite-difference techniques; explicit vs implicit vs semi-implicit schemes; filtering problem and common filtering ideas; CFL criterion and stability analysis; spectral and semi-Lagrangian techniques; staggered grids; nonlinear instability and aliasing and why numerical choices influence solutions.	15	CO 3	K1, K2, K3, K4
Module 4: Advanced Frameworks, Parameterization, Assimilation, and Coupled Modelling	Spectral and finite-element models: Galerkin idea, transform method; spectral shallow-water model; overview of multilayer spectral primitive-equation models; finite-element method (intro). Parameterisation of subgrid processes: cloud-convection, radiation, boundary-layer effects, land-surface processes; ocean mixed-layer parameterisation. Data Assimilation: Objective Analysis Overview; Panofsky, Cressman, and Optimum Interpolation Concepts; Initialisation Approaches (Static, Dynamic, Normal-Mode). Coupled ocean-atmosphere models: ocean general circulation model context; wind-driven and thermohaline box models; basin-scale vs global coupled models; coupling strategies and spin-up problems.	15	CO 4	K1, K2, K3, K4, K5
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments			

Texts:	<ol style="list-style-type: none"> 1. Durran, D. R. (2010). Numerical methods for fluid dynamics: With applications to geophysics (Vol. 32). Springer Science & Business Media. ISBN: 978-1-4419-6411-3 2. Kalnay, E. (2003). Atmospheric modelling, data assimilation and predictability. Cambridge University Press. ISBN: 9780511802270 3. Randall, D. A. (2000). General circulation model development: past, present, and future (Vol. 70). Elsevier. ISBN: 9780080507231
References/ Readings:	<ol style="list-style-type: none"> 1. Arakawa, A. (1975). General circulation of the atmosphere. <i>Reviews of Geophysics</i>, 13(3), 668-680. DOI:10.1029/RG013i003p00668 2. Arakawa, A., & Lamb, V. R. (1977). Computational design of the basic dynamical processes of the UCLA general circulation model. In <i>Methods in Computational Physics: Advances in Research and Applications</i> (pp. 173–265). DOI:10.1016/b978-0-12-460817-7.50009-4 3. Cordero, E., & Staniforth, A. (2004). A problem with the Robert–Asselin time filter for three-time-level semi-implicit semi-Lagrangian discretizations. <i>Monthly Weather Review</i>, 132(2), 600–610. DOI:10.1175/1520-0493(2004)132%3C0600:apwtrt%3E2.0.co;2 4. Cressman, G. P. (1959). An operational objective analysis system. <i>Monthly Weather Review</i>, 87(10), 367–374. DOI:10.1175/1520-0493(1959)087%3C0367:aooas%3E2.0.co;2 5. Williamson, D. L., Drake, J. B., Hack, J. J., Jakob, R., & Swarztrauber, P. N. (1992). A standard test set for numerical approximations to the shallow water equations in spherical geometry. <i>Journal of Computational Physics</i>, 102(1), 211–224. DOI:10.1016/s0021-9991(05)80016-6

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Title of the Course	Hydrometeorology
Course Code	ATM-5208
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2026-2027
New Course:	Yes
Bridge Course/ Value-added Course:	No
Course for advanced learners:	Yes

Pre-requisites for the Course:	Nil	
Course Objectives:	To develop an integrated understanding of hydrometeorological processes governing the water cycle and to apply observations and analysis methods for water resources assessment and management, including evaluation of variability and climate-change impacts.	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. Explain key hydrometeorological processes (precipitation formation, evapotranspiration, runoff generation, infiltration, groundwater recharge) and their role in catchment-scale water balance.	PSO 1, PSO 2
	CO 2. Analyse hydrometeorological datasets (rain gauges, streamflow, soil moisture, reanalysis/satellite products) to quantify spatial-temporal variability, extremes, and trends relevant to water resources.	PSO 1, PSO 2, PSO 3
	CO 3. Apply hydrologic and water-balance methods to estimate water availability and demand	PSO 1, PSO 2, PSO 3

	indicators, supporting planning for reservoirs, irrigation, flood control, and drought preparedness.			
	CO 4. Evaluate climate-change scenario information (GCM/RCM projections and downscaled products) to assess impacts on hydrometeorological processes and recommend adaptation options for water resources management.		PSO 1, PSO 2, PSO 3	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: Hydrological Cycle, Runoff Generation, and Hydro-Meteorological Hazards	Hydrological cycle and catchment water balance (storage-flux concepts). Weather and hydrological hazards: droughts and floods (process overview). Factors affecting runoff: rainfall-runoff components, infiltration, land use, soil/terrain controls. Hydrograph methods: rainfall-runoff response, peak flow estimation (unit hydrograph/empirical peak-flow equations: concept and applications). Runoff variability (seasonal/interannual; human influences). Urban runoff: imperviousness effects, stormwater response, and urban runoff modelling. Flood basics: types (flash/riverine), floodplain concept, impacts.	15	CO 1, CO2	K1, K2
Module 2: Observations, Frequency Analysis, and Climate-Change Impacts for Water Management	Measurement and observation systems: Precipitation measurement: gauges and errors; rainfall network design; optimisation of rainfall observations. Radar rainfall estimation (principle, bias sources, gauge adjustment). Areal rainfall over catchments: area-depth methods, areal averaging, and maximum probable rainfall (conceptual). Evapotranspiration measurements: pan evaporation and pan coefficient; water-budget and energy-budget approaches; mass transfer method; combined aerodynamic-energy methods. Soil and plant evaporation: lysimetry (principle). Soil moisture measurement methods (in situ and remote sensing). Frequency analysis and design events. Frequency analysis of rainfall/floods; probability distributions (conceptual selection and fitting). Design storms and design floods (return period concept; uncertainty and limitations). Climate change and water resources management. Climate-change impacts on precipitation, ET, runoff, floods/droughts (process-level and scenario interpretation). Water resources management linkages: planning under uncertainty, adaptation options (storage, demand management, flood risk reduction, drought preparedness)	15	CO 3, CO 4	K1, K2, K3, K4

Module 3: Land– Atmosphere Interactions and Subsurface Hydrometeorology	Soil-vegetation-atmosphere continuum (SVAC): coupling of precipitation, evapotranspiration, and soil moisture. Energy balance at the land surface: radiation components, sensible and latent heat fluxes. Role of soil moisture in controlling evapotranspiration and runoff generation. Infiltration processes and vadose zone dynamics: soil moisture movement, field capacity, wilting point, and plant water uptake. Groundwater recharge processes and its linkage with meteorological drivers. Surface–subsurface interactions: baseflow generation, stream-aquifer interactions (gaining and losing streams). Land-atmosphere feedbacks: impact of soil moisture and vegetation on precipitation and boundary-layer processes. Drought processes: meteorological, agricultural, and hydrological droughts and their interconnections.	15	CO 1, CO 4	K1, K2, K3, K4
Module 4: Hydro-Meteorological Modelling, Forecasting, and Applications	Hydro-meteorological modelling frameworks: coupling of atmospheric and hydrological models (conceptual overview). Weather inputs to hydrological models: observed, radar-derived, and satellite-based precipitation. Flood forecasting systems: real-time data assimilation, early warning systems (conceptual). Drought monitoring and prediction: indices (SPI, SPEI), soil moisture anomalies, and seasonal forecasting. Role of remote sensing and GIS in hydro-meteorology: precipitation estimation, evapotranspiration mapping, and soil moisture retrieval. Climate model outputs (GCM/RCM) in hydrological applications: downscaling (statistical/dynamical-conceptual) and uncertainty. Hydro-meteorological extremes: analysis of extreme rainfall, floods, and drought events under changing climate. Applications: basin-scale water assessment, climate-resilient water management, and risk-informed decision making.	15	CO 2, CO 3, CO 4	K1, K2, K3, K4, K5
Pedagogy:	Use of Conventional, Online and ICT Methods. Lecture / Tutorials / Assignments			
Texts:	<ol style="list-style-type: none"> 1. Bowles, D. S., & O’Connell, P. E. (Eds.). (1991). Recent advances in the modeling of hydrologic systems (NATO ASI Series C: Mathematical and Physical Sciences, Vol. 345). Springer. 2. Bruce, J. P., & Clark, R. H. (1966). Introduction to hydrometeorology. Pergamon Press. 3. Lakshmi, V., Albertson, J. D., & Schaake, J. (Eds.). (2001). Land surface hydrology, meteorology, and climate: Observations and modeling (Water Science and Application Series, Vol. 3). American Geophysical Union. 4. Singh, V. P. (Ed.). (1982). Modelling components of hydrologic cycle. Water Resources Publications. 			

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| 5. Upadhyay, D. S. (1995). Cold climate hydrometeorology. New Age International. |
| 6. Viessman, W., Jr., & Lewis, G. L. (2003). Introduction to hydrology (5th ed.). Pearson. |

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