Curriculum and Syllabus

Bachelor of Science (4-year Honors) in Meteorology

Department of Meteorology
Faculty of Earth and Environmental Sciences
University of Dhaka

B.S. Session 2021-2022

June 2022

1. Introduction to the Institution

On the first day of July 1921 the University of Dhaka opened its doors to students with Sir P.J. Hartog as the first Vice-Chancellor of the University. The University was set up in a picturesque part of the city known as Ramna on 600 acres of land. At present the University consists of 13 Faculties, 83 Departments, 12 Institutes, 20 residential halls, 3 hostels and more than 56 Research Centers. The number of students and teachers has risen to about 37018 and 1992 respectively. The University of Dhaka is dedicated to the advancement of learning, and is committed to promoting research in all fields of knowledge. As there are plans for continuous expansion of facilities to open new avenues and opportunities, the course curricula are updated and new research projects are undertaken every year. As the pioneer and the largest seat of learning in the country, the University of Dhaka has taken the task to foster the transformation processes of the individual students and the country as a whole through its educational and research facilities keeping up with demands of the day.

The Department of Meteorology was established on 17^{th} July 2016 under the Faculty of Earth and Environmental Sciences by the syndicate of Dhaka University in accordance with Dhaka University Ordinance and Regulations 1973, to meet the growing demands for skilled graduates in the field of Meteorology. The department aims to develop a cohort of professionals who can help foster public or private sector delivery of meteorological and related services. In Bangladesh, meteorologists are needed for weather forecasting, disaster mitigation, climate change assessment and adaptation and generating user tailored weather and climate services in the vital areas of the economy such as agriculture, fisheries, water resources sector, navigation, aviation, weather insurance, power and industries sectors, climate resilient infrastructure designs and development and saving ecology and environment. Due to the impacts of climate change and disaster risks on the livelihood, it is crucial to address the above areas for sustainable development of the country and achieving the Millennium Development Goals of the nation.

2. Introduction to the Program

2.1 Title of the Program

The title of the program is Bachelor of Science (B.S.) in Meteorology. The program is being introduced on the basis of increased need of graduates in the field of Meteorology and related areas.

2.2 Duration of the Program

It is a 4 years program with 8 semesters and it includes two semesters per year with the duration of 6 months each.

2.3 Eligibility for admission

A candidate has to fulfill the following minimum requirement to be considered eligible to get admitted in Meteorology:

Grade of H.S.C./Equivalent Examination	Mark of University Admission Test
Mathematics – A **Physics – A** **Chemistry – A**	**Mathematics – 10** **Physics – 10** **Chemistry - 10**

2.4 General objectives of the program

The objective is to produce expert meteorology graduates for full filling the increasing demands of meteorology graduates in the country. The program has been designed with basic to advance modules on Meteorology. Besides, the physics, mathematics and chemistry are included as foundation modules to prepare the background of the students for enabling them to capture the highly dynamical and heterogeneous atmosphere interfaced with land and sea and extremely inhomogeneous topography and land coverage.

2.5 Learning outcomes of the program:

Graduates will:

- Understand the physical basis and dynamical principles that govern a wide range of atmospheric phenomena and be able to express their knowledge and understanding clearly.
- Be able to describe and explain the origin and evolution of tropical and extra tropical weather systems across a range of scales.
- Know the basic physics and mathematics of application to understanding the atmosphere.
- Understand the weather and climate prediction techniques including their limitations.
- Learn to produce well-written, independently produced reports including the writing of Thesis.
- Learn to produce quality weather analysis charts and to interpret forecast products accurately and in a timely way, including verbally summarizing their details.
- Be able to participate effectively in team works.
- Understand the importance of early warning systems, how they are set up and their critical information relayed to users.
- Understand the processes important for Aviation Meteorology, produce charts and advisories for aviation.
- Know the relationship between agriculture and weather and climate; provide early warning and advisory to agriculture services for crop management.
- Know the basics of hydrology, hydrometeorology and their applications in water resources and flood modeling
- Will be able to analyze the causes of climate change and impacts, adaptation and mitigation strategy.
- They will have knowledge on the NWP modeling techniques and will be able run models for research and operational purpose.
- Will have knowledge to perform research in different areas of meteorology and applications.

3. Structure of Curriculum

Course credit: Total credit 134 (Theory+ Practical, viva and project).

Course number, title and credit hours (Total credit-134)

Year 1: Total Credit (15 +17=32)

Semester 1 (15 credits)			**Semester 2** (17 credits)		
Course Code	**Course Name**	**Credit hour**	**Course Code**	**Course Name**	**Credit hour**
MetTh 101	Physical Characteristics of Earth and The Atmosphere	3	MetTh 106	Physical Meteorology	3
MetTh 102	Linear Algebra	3	MetTh 107	Meteorological Observing System	3
MetTh 103	Fundamentals of Physics	3	MetTh108	Differential and Integral Calculus	3
MetTh 104	Operating Systems /Programming Languages	3	MetLb 109	Meteorological Instrumentation Lab	3
MetLb 105	Physics Lab	3	MetLb 110	Laboratory on Operating System/Programming-I	3
			MetV 111	Field Experiment + Viva-voce	1+1=2
Total Credit		**15**	**Total Credit**		**17**

Year 2: Total Credit (18 +20=38)

Semester 3 (18 credits)			**Semester 4** (20 credits)		
Course Code	**Course Name**	**Credit hour**	**Course Code**	**Course Name**	**Credit hour**
MetTh 201	General Circulation of Atmosphere	3	MetTh 207	Mathematical methods in Solving Meteorological Problems	3
MetTh 202	Fluid Dynamics	3	MetTh 208	Radiative Processes in Earth and Atmosphere	3
MetTh 203	Differential Equations	3	MetTh 209	Atmospheric Chemistry	3
MetTh 204	Dynamic Meteorology	3	MetTh 210	GIS and Remote Sensing	3
MetLb 205	Fluid Lab	3	MetLb 211	Laboratory on Mathematical Methods	3
MetLb 206	Laboratory on Operating System/ Programming-II	3	MetLb 212	GIS and Remote Sensing Lab	3
			MetV 213	Field Experiment + Viva-voce	1+1=2
Total Credit		**18**	**Total Credit**		**20**

Year3: Total Credit (17 +18=35)

Semester 5 (17 credits)			**Semester 6** (18 credits)		
Course Code	**Course Name**	**Credit hour**	**Course Code**	**Course Name**	**Credit hour**
MetTh 301	Boundary layer Meteorology	3	MetTh 307	Tropical and Monsoon Meteorology	3
MetTh 302	Introduction to Statistics	3	MetTh 308	Meso and Synoptic Scale Meteorology	3
MetTh 303	Cloud Physics	3	MetLb 309	Tropical and Monsoon Meteorology Lab	3
MetTh 304	Radar and Satellite Meteorology	3	MetLb 310	Radar and Satellite Meteorology Lab	3
MetLb 305	Laboratory on Plotting and Analyzing of Meteorological Fields	3	MetLb 311	Synoptic Analysis Lab	3
MetLb 306	Laboratory on Advanced Meteorology	2	MetV 312	Field Trip + Viva-voce	2+1=3
Total Credit		**17**	**Total Credit**		**18**

Year 4: Total Credit (17+12=29)

Semester 7 (17 credits)			**Semester 8** (12 credits)		
Course Code	**Course Name**	**Credit hour**	**Course Code**	**Course Name**	**Credit hour**
MetTh 401	NWP Modeling	3	MetTh 407	Applications of NWP Modeling	2
MetTh 402	Climatology and Climate Modeling	3	MetTh 408	Operational Weather Forecasting	2
MetTh403	Hydrometeorology	3	Met 409	Project including internship	6
MetTh 404	Agrometeorology	3	MetV 410	Viva-voce	2
MetTh 405	Aviation Meteorology	2			
MetLb 406	Laboratory Applications of Statistics in Meteorology	3			
Total Credit		**17**	**Total Credit**		**12**

Grand Total 4-year credit (32+38+35+29=134)

Course and Credit Distribution

Course/Credit	Total Theory	Total Practical	Total Field/Project and Viva	Total
Course	28	13	05	**46**
Credit	81	38	15	**134**

4. Assessment System

4.1 Theory courses

Class attendance	05%
In-course assessment	25%
Course final examination	Subjective: 50%
	Objective: 20%

4.2 Practical course

In-course assessment + class attendance	40% + 10 %
Course final examination	50%

4.3 Marks of attendance

Attendance (%)	Marks
95 and above	05
90 to 94	04
85 to 89	03
80 to 84	02
75 to 79	01
Less than 75	00

4.4 In-course assessment for theory courses

(a) In-course Assessment may be done by taking class test and/or by giving assignments.

(b) The course teacher will announce the dates of in-course examinations at the beginning of the course (as per semester calendar). The in-course assessment will be of one hour duration and the teacher concerned will be responsible to assess the students sitting in his/her course. There will be 2 tests for 3 credit course and 1 test for 2 credit course.

(c) Maximum duration of in-course test will be one class hour.

4.5. Course Final Examination (Theory and practical Courses)

(a) Student having 75% or more attendance on average (collegiate) are eligible to appear in the final examination.

(b) Student having 60-74% attendance are considered to be non-collegiate and will be eligible to sit for the final examination on payment on fine Tk. 1,000/= (One thousand).

(c) Student having attendance less than 60% will not be allowed to sit for the final examination but may ask seek readmission in the program.

(d) The duration of theoretical course final examinations will be as follows:

Credit	Duration of examination
4 credit course	3.5 hours
3 credit course	3.5 hours
2 credit course	2.5 hours

(e) Duration of practical examinations will be between 3-5 hours irrespective of credit hours.

The Class Test(s) for first In-course Assessment will be taken usually after covering 40% of the course topics and second In-course Assessment will be taken usually after covering 80% of the course topics. The Course Final Examination will be taken upon completion of the entire course. **In** Final Examination, each theory course will be evaluated by two teachers of the Department. If a single teacher teaches a course then the semester final test scripts must also be evaluated by two teachers, one of whom must be the course teacher, and another, a suitable second examiner who may be either from DU or outside DU. **In** the semester final examination if the difference of marks in any course is more than 20%, the script will be evaluated by a third examiner. The final marks obtained will be averaged of the nearest two marks, or third examiners marks if the difference between his/her marks and the two other examiner's marks are the same.

The total marks in a course will be converted into letter grade as under:

Numerical Marks	Letter Grade	Grade Point
80 above	A+	4.00
75 -79	A	3.75
70-74	A-	3.5
65 -69	B+	3.25
60-64	B	3.00
55 -59	B-	2.75
50 -54	C+	2.50
45 -49	C	2.25
40-44	D	2.00
Below 40	F	0.00

4.6. Degree Requirements

For the B.S. Honors degree, each student is required to:

i) Complete 134 credit hours without a F grade in any course

ii) Earn a minimum CGPA of 2.50: and

iii) Complete the program in maximum six consecutive academic years including the year of first admission into the program.

For appearing at the each semester final examination, every student is to fill in examination entry form supplied by the Controller of Examination on payment of dues.

5. Structure of Courses

Year 1: Semester 1

MetTh101: Physical Characteristics of Earth and the Atmosphere (03 Credit)

Rationale: The course introduces the basics of earth-atmospheric system, distribution of land and oceanic features and gradually builds up the information on atmospheric gaseous layers in the vertical and their physical structures and chemical composition.

Objectives: The objective is to provide the knowledge to the students about the basic features of land, ocean and atmosphere.

Syllabus Content: Sun-earth system: Motion of earth relative to sun in elliptic orbit, characteristics of spin of earth around on own axis. Causes of seasonal and latitudinal variation of Insolation. An overview on earth system-land, ocean and atmospheric systems, geographical coordinates and shape of earth, distribution of land and ocean in the earth system, topographical feature of continents and bathymetry of oceans, role of solar system in the formation of earth's energy variation and formation of weather and climate. Vertical structure of the atmosphere- distribution of vertical temperature and atmospheric layers. Composition of the atmosphere – major and trace gases, particulate matters. Elements of weather, weather phenomena, climate controls. Ocean currents, location of desserts and forests.

Learning Outcomes: The students will learn about the earth-ocean-atmospheric system, topography, role of solar system in atmospheric circulation and physical structure and chemical composition of the atmosphere.

Unit-wise title, subtitle and number of classes per unit:
Earth system-land, ocean and atmospheric systems: 1 credit (15 classes)
Role of solar system in the formation of earth's energy variation: 2 credit (24 classes)
Vertical structure and Composition of the atmosphere: 0.5 credit (06 classes)
Total class:45

Unit-wise learning outcome:
- Students will learn how four spheres interact with each other.
- They will also learn how energy from the sun drives the planet earth.
- They will know about the composite gases, vertical distribution of the atmosphere

Instruction strategy:
Lecture
Problem Practice in class
Live Streaming/virtual learning
Audio/Video Recording of the lectures

Recommended Text(s):
Eric E. Small, The Earth System: An Introduction to Earth Systems Science
Aida Awad, Charles Dodd, Peter Selkin**,** Introduction to Earth Systems Science
Craig F. Bohren; Eugene E. Clothiaux, Fundamentals of Atmospheric Radiation, Wiley 2006.
Pidwirny, Michael J. Fundamentals of Physical Geography
Liou, An Introduction to Atmospheric Radiation. Elsevier Science 1981.
James Petersen, Dorothy Sack, Robert E. Gabler. Fundamentals of Physical Geography 2nd Edition.

MetTh102: Linear Algebra (03 Credit)

Rationale: This course covers vectors, matrix theory and linear algebra, emphasizing topics useful in other disciplines. Linear algebra is a branch of mathematics that studies systems of linear equations and the properties of matrices.

Objectives: The objective is to use matrix techniques to represent and solve a system of simultaneous linear equations and understand the use of vectors in describing lines and planes in solid geometry.

Syllabus Contents: Matrix: Matrix Algebra, Determinant of Matrix; Concept on System of linear equations, Solution of System of linear equations using Matrix. Row reduction and echelon forms, Matrix operations, including inverses, Block matrices, Linear dependence and independence, Subspaces and bases and dimensions, Determinants and their properties, Cramer's Rule. Eigenvalues and eigenvectors, Diagonalization of a matrix, Symmetric matrices and Positive definite matrices. Solution of linear equations using Gaussian eliminations and LU decomposition method. Iterative methods: Jacobi method, Gauss Seidel method, SOR method and their convergence analysis.
Vectors: Geometric vectors, vectors in a coordinate plane, position vector, sum and difference of vectors, magnitude, unit vectors, graphs of the sum and difference. Dot product and Cross product: physical interpretation of the dot product(applications and extensions), orthogonal vectors, component and projection of vectors, cross product of basis vectors, right hand rule, physical interpretation of the cross product (applications and extensions) areas, scalar triple product, volume of a parallelepiped, coplanar vectors.

Learning outcomes: Students will have the concepts on matrices with different kind of matrix operations. They will be able to solve real life problems by converting them into a system of linear equations with the help of different matrix methods. They will have the knowledge to solve a system of linear equations by numerical iterative methods. They would also be able to interpret various operations of vectors.

Unit-wise title, subtitle and number of classes per unit:
Systems of linear equations: 1 credit (15 classes)
Diagonalization of a matrix: 1 credit (15 classes)
Vectors: 1 credit (15 classes)
Total Classes: 45

Unit-wise outcomes:
After the completion of the course, the students are expected to be able to

- Perform various matrix operations and solve system of linear equations using Cramer’s rule, Gaussian elimination and LU decomposition method
- Solve system of linear equations using iterative methods: Jacobi method Gauss Seidel, SOR methods
- Perform vector operations

Instruction strategy:
Lecture
Problem Practice in class
Live Streaming/Virtual learning
Audio/Video Recording of the lectures

Recommended Text(s):
Anton. Elementary Linear Algebra, 8th edition.
Introduction to Linear Algebra, Fifth Edition (2016), Gilbert Strang
Sheldon Axler, Linear Algebra Done Right

MetTh103: Fundamentals of Physics (03 Credit)

Rationale: This is the introductory course of Physics, which gives basic foundation of Newtonian Physics. This course is concerned with the behavior of physical bodies when subjected to forces or displacements, and the subsequent effects of the bodies on their environment. Classical mechanics describes the motion of macroscopic objects, from projectiles to parts of machinery, and astronomical objects, such as spacecraft, planets, stars and galaxies. This course also covers the basic fluid dynamics and properties of matter.

Objectives: Specific objective is to buildup foundation of classical Newtonian mechanics to the students and provide understanding of the properties of matter. Another objective is to give the students basic idea about how do fluids flow.

Syllabus Contents: Motion in two or three dimensions, e.g. projectile motion, circular motion. Notion of Force and Newton's laws of motion. Application of Newton's Law, Fundamental Forces, Frictional Forces, Conservation of momentum. Center of Mass and its Motion. Collision: Elastic and Inelastic collisions in one dimension. Impulse. Work and Energy. The Work-kinetic energy theorem. Conservative Forces and Potential Energy and their relation. Conservation of Energy. Rotational Kinematics, Moment of Inertia and its calculation, Radius of Gyration, Parallel-axis theorem, Perpendicular-axis theorem.
Surface Tension and Viscosity. Adhesive and Cohesive Forces, Molecular origin of Surface Tension, Excess pressure due to surface tension at an interface. Capillarity, Surface Tension of a Mercury Drop. Variation of Surface Tension with Temperature. Newton's Law of Viscosity, Poiseulle's Formula, Applications. Stokes Law. Terminal Velocity for Falling Bodies. Variation of Viscosity with Temperature. Fluid Dynamics. Streamline Flow, Turbulence. Reynold's Number. Bernoulli's Equation. Applications. Equation of Continuity, Euler's Equation.

Learning Outcomes: Students will have very good exposure to basics of classical mechanics. They will be able to solve problems on force, momentum, energy conservation, moment of inertia, rotational kinematics. They will acquire the basic knowledge of fluid dynamics, which will help them understand the fluid motion in the atmosphere and ocean. Students will predict by the laws of classical mechanics how it will move in the future (determinism) and how it has moved in the past (reversibility).

Unit-wise title, subtitle and number of classes per unit:
Force and momentum: 1 credit (13 classes)
Work and energy: 1 credit (12 classes)
Surface tension and viscosity: 1.5credit (20 classes)
Total 45 classes

Unit-wise learning outcome:

- Students will have very good exposure to basics of classical mechanics.
- They will be able to solve problems of energy conservation, moment of inertia, and rotational kinematics.
- They will learn problems related to surface tension, viscosity, fluid flow and equations that provides clues for future prediction

Instruction strategy:
Lecture
Problem Practice in class
Practical Laboratory
Live Streaming/virtual learning
Audio/Video Recording of the lectures

Recommended Text(s):
David Halliday& Robert Resnick Physics for Students of Science & Engineering Pt 1&2 combine
David Halliday& Robert Resnick, Fundamentals of Physics
Robert Resnic, David Halliday and Keneth S. Krane: Physics, Vol-I & II
Giasuddin Ahmed: Properties of Matter-
Giasuddim Ahmed – Electricity and Magnetism
Giasuddin Ahmed, Physics Practical
Robert Resnic, David Halliday and Keneth S. Krane: Physics, Vol I
Properties of Matter, B. H. Flower
Mechanics; Symon, KR
General Properties of Matter, Newman, FH and Searle, VHL
Gases, Liquids and Solids; D. Tabor, Cambridge University Press, Cambridge
The Mechanical Properties of Matter: M. T. Sprackling.
The General Properties of Matter: F. W. Newman and V. H. L. Searle. , Edward Arrold Publishers, London.
Properties of Matter: S. Ahmed and A. K. Nath.

MetTh104: Operating Systems and Programming Languages (03 Credit)

Rationale: This module provides the basics of computer systems and programming which is essential for the meteorology students.

Objectives: The objective to teach the student computer programming. But this is very basic which will help the students to learn programming.

Syllabus Contents: Introduction to Computing: Introduction to Digital Computers, Operating Systems, Programming and Problem Solving. Fundamentals of Computer Programming: Programming basics, Introduction to C, FORTRAN and MATLAB, Python, Fortran Evolution, how to write, process and run program, Programming and Problem Solving. Problem-solving techniques using computers: Flowcharts, Algorithms, Pseudo code. Programming in FORTRAN and MATLAB: Syntax and semantics, Data Types, Constants, and Variables, Operation and Intrinsic Functions, Expressions and Assignment Statements, Numeric, Relational and Logical operations, Operator Precedence, single and mixed mode arithmetic, Fortran I/O and External files. Control Constructs: IF Constructs, Nested and Named IF Constructs, SELECT CASE Construct, Do Loops, Named and Nested Loops, Implied do loops. Arrays and Array Operations: Declarations, Array Constructors, Array Sections, Array operations, Allocatable Arrays.

Learning Outcomes: Students will gain some knowledge about operating systems and be able to install them. They will be capable use few programming languages.

Unit-wise title, subtitle and number of classes per unit:
Operating systems: 1.5 credit (18 classes)
C++ and Fortran: 1 credit (18 classes)
MATLAB: 0.5 credit (09 classes)
Total class: 45
Unit-wise learning outcome: After the completion of the course, the students are expected to be able to -

- Describe different programming languages: C, FORTRAN and MATLAB
- Explain any problem using Flowcharts, Algorithms and Pseudo code
- Define variables, constants, data and perform various loops

Instruction strategy:
Lecture
Programming in Computer Lab
Live Streaming/virtual learning
Audio/Video Recording of the lectures

Recommended Text(s):
Operating Systems in Depth: Design and Programming, 1st Edition by Thomas W. Doeppner
Teach Yourself C, 3rd Edition, HerbertSchildt
Steyn. Introduction to atmospheric modeling. Cambridge University Press.

MetLb105: Physics Lab (03 Credit)

Rationale: This is the introductory course to demonstrate the basic foundation of Newtonian Physics, capillarity and viscosity.

Objectives: Specific objective is the demonstration of the laws of classical Newtonian mechanics, capillarity as well as viscosity of a viscous fluid to the students.

Syllabus Contents:
1. To determine the modulus of rigidity of a wire by the method of oscillations (dynamic method).
2. To determine the spring constant and effective mass of spring and hence calculate the rigidity modulus of the material of the spring.
3. To determine the value of *g*, acceleration due to gravity, by means of a compound pendulum.
4. To determine the surface tension of water by capillary tube method.
5. To determine the co-efficient of viscosity of a liquid by its flow through a capillary tube.
6. To verify Stoke's law and hence to determine the viscosity of a liquid (glycerine).

Learning Outcomes: Students will understand the basics of classical mechanics more. They will be able to determine the value of *g*, and verify Stoke's Law. They will better understand the characteristics of a viscous fluid which will eventually help them to understand motion and the terminal velocity of raindrop in the air.

Unit-wise title, subtitle and number of classes per unit:
Mechanics: 1.5 credit (25 classes)
Properties of matter: 1.5 credit (20 classes)
Total class:45
Unit-wise learning outcome:

- Students will understand the basics of classical mechanics. They will be able to determine *g*.
- They will be able to better understand the laws related to elasticity, spring force, viscosity and terminal velocity of raindrops
- They will be able to determine the value of g, and verify Stoke's Law. They will better understand the characteristics of a viscous fluid which will eventually help them to understand motion and the terminal velocity of raindrop in the air.

Instruction strategy:
Lecture
Practical Laboratory
Live Streaming/virtual learning
Audio/Video Recording of the lectures

Recommended Text(s):
Giasuddin Ahmed, Physics Practical
Tyler, F; Laboratory Manual of Physics
Worsnop, BL and Flint, HT; Advanced Practical Physics

Year 1: Semester 2
MetTh 106: Physical Meteorology (03 Credit)

Rationale: This subject deals with the study of optical and thermodynamic phenomena in the atmosphere, including the physics of clouds and precipitation. It usually deals with the basic of the optical and thermodynamic phenomena of the troposphere, its chemical composition, the laws of radiation and the physics of clouds and precipitation.

Objectives: It is designed to provide a foundation in atmospheric physics suitable for advanced study in atmospheric sciences and professional employment.

Syllabus Contents: Definition, scope, subject matter and short history of meteorology; Atmospheric constituents and physical variables of the atmosphere, equation of state for dry and moist air, humidity (mixing ratio) and relative humidity and virtual and potential temperature, dew point temperature, vertical distribution of moisture, barometric formula; General concept of the radiative processes of the atmosphere-atmospheric system: solar radiation, albedo of the earth surface, spatial variation of albedo, solar radiation absorbed by the surface, long wave radiation from the earth surface to atmosphere and that from atmosphere to earth surface, energy balance in the earth surface; Basic concept of atmospheric motion: pressure gradient forces generating atmospheric flow; modification of flow by Coriolis and Frictional forces; First law of Thermodynamics, Adiabatic processes of dry and wet atmosphere, potential temperature, lapse rate, atmospheric instability, thermodynamic charts (Skew-T log-P diagram), Estimation of Convective Potential Energy (CAPE); General concept of precipitations, cloud types, weather events and forecasting of weather.

Learning Outcomes: Students will learn Physical principles that provide the foundation for meteorology that means Absorption, scattering, and transmission of radiation in the atmosphere, basic of cloud physics and precipitation process and some fundamental and apparent forces governing the atmosphere. Students will be able to use Atmospheric thermodynamic diagrams as tools in the forecasting of storm development.

Unit-wise title, subtitle and number of classes per unit:
Radiation: 1 credit (15 classes)
Thermodynamics and thermodynamic chart: 1 credit (15 classes)
Forces in the atmosphere: 0.5 credit (9 classes)
Cloud and precipitation: 0.5 credit (6 classes)
Total class: 45

Unit-wise learning outcome:

- Students will learn Physical principles that provide the foundation for meteorology that means Absorption, scattering, and transmission of radiation in the atmosphere
- Students will be able to use Atmospheric thermodynamic diagrams as tools in the forecasting of storm development
- They will also have basics of cloud physics, precipitation process and some fundamental and apparent forces governing the atmosphere

Instruction strategy:
Lecture
Atmospheric Observatory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Henry G. Houghton, Physical Meteorology
Wallace and Hobbs, *Atmospheric Science*, Second Edition
Andrea V. Jackson, Handbook of Atmospheric Science by C. Nick Hewitt; Wiley 2008.
Peter Hobbs. Clouds Their Formation, Optical Properties, and Effects, Elsevier Science 2012.
Craig F. Bohren; Eugene E. Clothiaux, Fundamentals of Atmospheric Radiation, Wiley 2006.

Liou, An Introduction to Atmospheric Radiation. Elsevier Science 1981.
Maarten H. P. Ambaum, 2010: Thermal Physics of the Atmosphere (Wily). ISBN: 978-0-470-74515-1; 252pages.
Rogers and Yau: *A Short Course in Cloud Physics*, Third Edition
Fleagle and Businger, *An Introduction to Atmospheric Physics*, Second Edition
Robert Houze, Cloud Dynamics (Chapter-3)
Robert A. Houze Jr. Cloud Dynamics (ISSN Book 104) 2nd Edition, Kindle Edition
Horace Robert Byers, General Meteorology 4th Edition

MetTh 107: Meteorological Observing System (03 Credit)

Rationale: Acquaintance with the meteorological instruments is crucial for weather forecasting. The instruments also need a regular maintenance at the observatory.

Objectives: The purpose of this course is to teach students how to install, assemble meteorological instruments at observatory. They will be taught the way of calibration too.

Syllabus Contents: Acquaintance with the meteorological instruments in the laboratory and in the Meteorological Observatory. Measurements of air temperature, dew point temperature, air pressure and relative humidity, precipitation, soil temperature, solar and thermal radiation and then derive the equivalent temperature, mixing ratio, vapor pressure and radiation balance and calibration of the equipment.

Learning Outcomes: Students will be able to not only identify and take readings from different meteorological instruments but also to install them and calibrate them on a regular time interval.

Unit-wise title, subtitle and number of classes per unit:
Study of the equipment: 1.5 credit (20 classes)
Observations and analysis: 1.5 credit (25 classes)
Total class: 45

Unit-wise learning outcome:
- Acquaintance with the equipment
- Take observations, analysis, and archiving of the data and calibration of the equipment

Instruction strategy:
Lecture
Atmospheric Observatory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Shaw, Sir Napier. Manual of Meteorology, Vol. I. Cambridge University Pr, Cambridge, 1942.Google Scholar.
Harrison. Meteorological measurements & instrumentation, Wiley.
Liou, An Introduction to Atmospheric Radiation. Elsevier Science 1981.
Fred V. Brock; Scott J. Richardson, Meteorological Measurement Systems Oxford University Press 2001.
Dwayne Heard. Analytical Techniques for Atmospheric Measurement Wiley 2008.
Giles Harrison, Meteorological Measurements and Instrumentation (Wiley) ISBN: 978-1-118-74580-9; 280 pages, November 2014, Wiley-Blackwell.
Fred V. Brock; Scott J. Richardson, Meteorological Measurement Systems, Oxford University Press 2001.

MetTh108: Differential and Integral Calculus (03 Credit)

Rationale: This course provides the foundation in differential and integral calculus to the students. In mathematics, an integral assigns numbers to functions in a way that can describe displacement, area, volume, and other concepts that arise by combining infinitesimal data. Integration and differentiation are the two main operations of calculus and are inverse operation to each other. Since Meteorology is a highly mathematical subject, this course is very important.

Specific Objective: Specific Objective is to provide the basics of differential and integral calculus to the students and help them to use definite and indefinite integral properly.

Syllabus Contents: Definition of derivative. One-sided derivatives. Rules of differentiation. Successive differentiation and Leibnitz theorem. Role's Theorem, Lagrange's and Cauchy's mean value theorems. Power series expansion: Taylor's theorem with general form of the remainder; Lagrange's and Cauchy's forms of the remainder. Taylor's series. McLaurin series. Indeterminate forms, L'Hospital's rules and Partial differentiation. Topics in vector calculus: Vector Fields, Gradient, Divergence, curl and their physical meanings, Line Integrals, Green's Theorem, Surface Integrals, The Divergence Theorem, Stokes' Theorem, Applications of Surface Integrals. Numerical methods of differentiation.
Concept on integration; Indefinite integral: Integration of sine, cosine, exponential, logarithmic, hyperbolic functions, Integration by substitution, Integration by parts and partial fractions, computing definite integrals: Areas, volumes, Averages; Double Integrals in Polar Coordinates, Triple Integrals in Cylindrical and Spherical Coordinates, Improper integrals of different kinds. Gamma and Beta functions. Numerical methods of integration.

Learning outcome: The basic idea on differentiation and integration will be developed. Students will use numerical methods of integration in solving differential equations and will compare with exact solution. They will learn to find derivative of various functions and different theorems relating to differentiation with their real-life applications. They will get knowledge on numerical differentiation.

Unit-wise title, subtitle and number of classes per unit:
Indefinite and Definite integral: 1 credit (15 classes)
Integrate by parts: 1 credit (15 classes)
Numerical methods of integration: 1 credit (15 classes)
Total 45 classes

Unit-wise learning outcome:
After the completion of the course, the students are expected to be able to

- Explain basic concept of differentiation and integration
- Perform differentiation and integration of different functions
- Evaluate line integrals, surface integrals, area and volume under curves

Instruction strategy:
Lecture
Problem Practice in class
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Howard Anton, IrlBivens and Stephen Devis, Calculus, John Wiley and Sons.
M. R. Spiegel. Calculus and Analysis, Schaums's outline series.
H. Anton et al, Calculus with Analytic Geometry.
E.W. Swokowski, Calculus with Analytic Geometry.
Michael Sulivan, Pre-Calculus
Deborah Hughes-Hallett, Applied Calculus.
Stefan Waner and Steven Costenoble, Applied Calculus
G. Strang, Calculus

MetLb109: Meteorological Instrumentation Lab (03 Credit)

Rationale: The course is highly important for the students for learning the various atmospheric observing systems and instruments for measuring the atmospheric parameters on regular basis. The students will study the equipment and the data collected by the equipment. Thus, they will have the primary acquaintance with the observing systems and meteorological data and their characteristics.

Objectives: The purpose of this course is to provide the acquaintance of the meteorological observing systems, their functionality and the nature of the atmospherics parameters to the students.

Syllabus Contents
Surface Observation:

1. Measurements of air temperature, dew point temperature, air pressure and relative humidity and then derive the equivalent temperature, mixing ratio, vapor pressure.
2. Data of pressure, temperature, humidity and wind (magnitude and direction) from AWS are used to investigate the diurnal variability of these parameters.
3. Measure the soil temperature at different depth for different time of the day and estimate the coefficient of conductivity of heat in the soil.
4. Measure the incident and reflected solar radiation using Pyranometer and calculate the albedo of bare soil, vegetated area (crops), sandy soil and wet soil.
5. Measure the incoming and outgoing long-wave radiation and estimate the radiance. temperature of the surface during 7:00 to 10:00 am at 10 minutes interval.
6. Monitor radiation balance and increase of temperature from 7.00 am to 10.00 am for selected surfaces.
7. Tabulation and analysis of Aviation Met Instrument including transmissometer and application, agrometeorological instruments.

Upper Air Observations:

1. Study the principles of upper air observations using pilot balloons and radiosonde
2. Measuring atmospheric parameters (pressure, temperature, humidity, winds, along the vertical up to stratosphere using pilot balloons and radiosonde instruments.
3. Assess the parameters for standard atmospheric levels.

Learning Outcome: The students will be able to learn about the observing instrument and meteorological parameters and can keep record and will be able of handling and processing of surface and upper air meteorological data. They will get acquainted with the meteorological instruments in the laboratory and in the Meteorological Observatory. They will learn the general principles of observations: representativeness of observations, Metadata of Observations and general requirement of meteorological observatory.

Unit-wise title, subtitle and number of classes per unit:
Surface observing systems: 1credit (15 classes)
Upper air observing system: 1credit (15 classes)
Remote sensing or Satellite and Radar observations: 1credit (15 classes)
Total Class: 45

Unit-wise learning outcome:

- Students will learn about the meteorological observing systems and data handing and archiving for surface observations
- Students will learn the same for the upper air observations

Instruction strategy:
Lecture
Atmospheric Observatory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):

Shaw, Sir Napier. Manual of Meteorology, Vol. I. Cambridge University Pr, Cambridge, 1942.Google Scholar.
Harrison. Meteorological measurements & instrumentation, Wiley.
Fred V. Brock; Scott J. Richardson, Meteorological Measurement Systems Oxford University Press 2001.
Dwayne Heard. Analytical Techniques for Atmospheric Measurement Wiley 2008.
Giles Harrison, Meteorological Measurements and Instrumentation (Wiley) ISBN: 978-1-118-74580-9; 280 pages, November 2014, Wiley-Blackwell.
Fred V. Brock; Scott J. Richardson, Meteorological Measurement Systems, Oxford University Press 2001.

MetLb 110: Laboratory on Operating Systems/Programming Languages – I (03 Credit)

Rationale: This module provides the advanced knowledge of computer systems and programming which is essential for the meteorology students. For meteorologists it is a must to have a clear idea on programming languages and operating systems.

Objectives: The objective is to teach the student computer programming and help them to perform numerical operation of integration and differentiation through different programming software.

Syllabus Contents: Four assignments on integration and differential equations will be given to solve numerically using C, FORTRAN & MATLAB, Python.

Learning Outcome: Students will learn to integrate numerically and will be able to solve differential equations numerically using C, FORTRAN and MATLAB, Python. They will successfully incorporate forward integration technique.

Unit-wise title, subtitle and number of classes per unit: Programing LanguageC:1 credit (12 classes)
Fortran 90:1 credit (25 classes)
MATLAB: 1 credit (20 classes)
Total Class:45

Unit-wise learning outcome:

After the completion of the course, the students are expected to be able to

- Perform numerical differentiation and integration using C, FORTRAN and MATLAB
- Evaluate differential equations numerically using C, FORTRAN & MATLAB

Instruction strategy:

Lecture
Programming in Computer Lab
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):

Operating Systems in Depth: Design and Programming, 1st Edition by Thomas W. Doeppner
Teach Yourself C, 3rd Edition, HerbertSchildt.
Steyn. Introduction to atmospheric modeling. Cambridge University Press.
Thomas Tomkins Warner, Numerical Weather and Climate Prediction 1st Edition
Peter Inness and Steve Dorling. Operational Weather Forecasting
David J. Stens. Parameterization Schemes: Keys to Understanding Numerical Weather Prediction Models Reissue Edition
Holton. Introduction to dynamical meteorology, Academic Press.

MetV 111: Field Experiment + Viva-voce (02 Credit)

Fieldwork (day trip) in a suitable area in order to study relevant topics to the courses taught. Comprehensive oral examination of the courses taught. Real-time meteorological observations are studied together with laboratory experiments.

Year 2: Semester 3

MetTh 201: General Circulation of Atmosphere (03 Credit)

Rationale: The circulation of wind in the atmosphere is driven by the rotation of the earth and the incoming energy from the sun. It is very important to study the general circulation incorporated in the atmospheric motion.

Objectives: The objective is to let students learn about the wind circulation in each hemisphere which help transport energy and heat from the equator to the poles.

Syllabus Content: Global radiation-seasonal distribution of annual and seasonal radiation fields – solar and terrestrial radiation, Outgoing long wave radiation and radiation balance.
Large scale fluxes - Large-scale annual and seasonal fluxes of heat and moisture, and transport mechanisms.
General circulation of the atmosphere over the globe - Pressure and wind belts, Distribution of pressure and temperature over the surface of the earth, Equatorial trough and Inter tropical convergence zone (ITCZ), subtropical high.
Large Scale Circulation-Large-scale mean circulation features including the Hadley and Walker Circulations, Understanding of north-south vertical circulation- Hadley, Ferrel and Polar cells.
Climate Indices-Climate variability indices including teleconnections; ENSO, IOD, NAO, MJO, PDO, the Quasi- Biennial Oscillation (QBO).

Learning outcomes: Students will learn about the circulation pattern involved in three cells of each hemisphere. They will get to know about the large-scale transport of heat and moisture by means of which thermal energy redistribute over the earth.

Unit-wise title, subtitle and number of classes per unit:
Global radiation and large-scale fluxes: 0.5 credit (8 classes)
General circulation of the atmosphere over the globe: 0.5 credit (7 classes)
Large Scale Circulation: 1 credit (15 classes)
Climate Indices: 1 credit (15 classes)
Total class:45

Unit-wise learning outcome:
On completion of this unit students will be able to:
Global radiation and large-scale fluxes:
Heat and energy balance and their variation of daily, annual and seasonal time scale.
General circulation of the atmosphere over the globe:
Distribution of pressure and temperature over the surface of the earth and related parameters which govern the weather
Large Scale Circulation:
Understand the causes and mechanism of north-south and east-west large-scale circulation system of the atmosphere which helps to transport heat, energy and moisture.
Climate Indices:
Understand the causes and mechanism of various Teleconnections like ENSO, IOD, NAO, MJO, QBO etc. and their impact on regional as well as global weather.

Instruction strategy:
Lecture
Atmospheric Observatory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
James, Introduction to circulating atmospheres, Cambridge University Press.
Hoskins &James, Fluid dynamics of the mid-latitude atmosphere, Wiley.
E. Palmén and C. W. Newton, Circulation Systems. Their Structural and Physical Interpretation. Academic Press, New York.
OchananKushnir (2000). The Climate System: General Circulation and Climate Zones.
Satoh, Masaki. Atmospheric Circulation Dynamics and General Circulation Models, Springer.
David Randall. An Introduction to the Global Circulation of the Atmosphere, Princeton University Press.
Global Atmospheric Circulations, by R. Grotjahn, Oxford Univ. Press.
N. James. Introduction to Circulating Atmospheres (Cambridge Atmospheric and Space Science Series).
Atmospheric and Oceanic Fluid Dynamics: Fundamentals and Large-scale Circulation Hardcover– 6 Nov 2006, by Geoffrey K. Vall.

MetTh202: Fluid Dynamics (03 Credit)

Rationale: Fluid mechanics describes the flow of fluids- liquids and gases which is very important to understand the fluid dynamics and prerequisite to study dynamic meteorology. It has several sub disciplines, including aerodynamics (the study of air and other gases in motion) and hydrodynamics (the study of liquids in motion).

Objectives: The objective is to describe how forces affect the flow of fluids. The course will also encompass the area of vortex forming.

Syllabus Contents: Governing Equations of Fluid Motion: Review of important basic concepts (definition of a Fluid, Eulerian vs. Lagrangian, etc); Review of some important mathematical theorems (Stokes, Gauss, Leibniz, etc.); Derivation of the differential form of conservation of mass, momentum and energy equations; Simplification of equations (Bernoulli's equation) and interpretation of various terms; Scaling and Scale Analysis: Basic dimensional analysis including Buckingham *Pi*-Theorem; Boundary Layers: Laminar Boundary Layers,Turbulent Boundary Layers, Momentum balance in a turbulent boundary layer, pipe and channel flow, Boundary Layer Problem sincluding Blasius Solution; Introduction to Vorticity Dynamics: Introduction to basic vorticity concepts, Derivation of the vorticity transport equation, Kelvin's circulation theorem, Biot-Savart Law; Introduction to Turbulence: Basic concepts, definitions and description; Derivation of time averaged equations; Discussion of stresses and closure problem.

Learning Outcomes: Students will learn the basics of fluid dynamics, laminar and turbulent flow, momentum equations of fluid, energy and mass conservation, boundary layer interactions and turbulence in fluid, which will help them to solve real life and naturally occurring fluid dynamical problems.

Unit-wise title, subtitle and number of classes per unit:
Governing Equations of Fluid Motion: 1.5 credit (25 classes)
Boundary Layer: 1.0 credit (20 classes)
Turbulence: 0.5 credit (12 Classes)
Total class: 45

Unit-wise learning outcome:

- Students will learn the basics of fluid dynamics, laminar and turbulent flow, momentum equations of fluid, energy and mass conservation
- They will also learn Boundary layer interactions for fluids
- Turbulence motion in fluid dynamics

Instruction strategy:
Lecture
Practical Laboratory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Daugherty, R.L., Franzini, J.B. and Finnemore, E.J., **Fluid Mechanics with Engineering Applications**, McGraw-Hill Book Co, Singapore-1989

John J. Bloomer, **Practical Fluid Mechanics for Engineering Applications**, Marcel Dekker Inc.

Roger Peyret, **Handbook of Computational Fluid Mechanics**, Academic Press-1996

MetTh203: Differential and Integral Equations (03 Credit)

Rationale: A differential equation is a mathematical equation that relates some function with its derivatives. In applications, the functions usually represent physical quantities, the derivatives represent their rates of change, and the differential equation defines a relationship between the two. Since Meteorology is a high mathematical subject, this course is very important.

Objectives: The objective is to help students to develop essential methods for obtaining numerical solutions and exploring the use of differential equations as models in various applications and the use of series methods to solve problems with variable coefficients and the methods of solving initial value problems.

Syllabus Contents: Types of Differential equation (DE): Ordinary Differential Equation (ODE) and Partial Differential Equation (PDE), Linear and nonlinear ODE, Order of differential Equation, Second order Partial Differential Equations, Solution of First-Order Differential Equations: Separable, Homogenous, Linear, Exact, Solutions by substitutions,, Solution of Higher-Order Differential Equations: Undetermined coefficients, Variation of parameters, Inverse operator method, Series solution, Solution of Ordinary and partial differential Equations using numerical technique.

Learning outcomes: Students will apply their knowledge to the functions which usually represent physical quantities, the derivatives representing their rates of change, and the equation defines a relationship between the two. They will Model a simple physical system to obtain a first order differential equation. They will Test the plausibility of a solution to a differential equation (DE) which models a physical situation by using reality-check methods such as physical reasoning, looking at the graph of the solution, testing extreme cases, and checking units.

Unit-wise title, subtitle and number of classes per unit:
Ordinary Differential Equation: 0.5 credit (8 classes)
Partial Differential Equation: 1 credit (15 classes)
Higher-Order Differential Equations: 1 credit (15 classes)
Solve the Differential Equations using Numerical Techniques 0.5 credit (7 classes)
Total 45 classes

Unit-wise learning outcome: After the completion of the course, the students are expected to be able to -

- Identify ODE & PDE with its order and linearity

- Solve first order ODE using different methods
- Solve higher order ODE using different methods
- Find solution of ODE & PDE using numerical techniques

Instruction strategy:
Lecture
Problem Practice in class
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Howard Anton, IrlBivens and Stephen Devis, Calculus, John Wiley and Sons.
M. R. Spiegel. Calculus and Analysis, Schaums's outline series.
H. Anton et al, Calculus with Analytic Geometry.
E.W. Swokowski, Calculus with Analytic Geometry.
Michael Sulivan, Pre-Calculus
Deborah Hughes-Hallett, Applied Calculus.
Stefan Waner and Steven Costenoble, Applied Calculus
G. Strang, Calculus

MetTh204: Dynamic Meteorology (03 Credit)

Rationale: It is the branch of meteorology dealing with the study of atmospheric motion and its causal relation to various forces. It deals primarily with the atmospheric processes based on the fundamental equations of dynamic meteorology. It forms the primary scientific basis for weather and climate prediction, and thus plays a primary role in the atmospheric sciences.

Objectives: The main task of dynamic meteorology is weather forecasting by numerical simulation. This course aims at providing the in-depth knowledge of dynamic meteorology.

Syllabus Contents: Fundamental forces in the atmosphere-Pressure gradient, gravity force, frictional forces; apparent forces affecting atmospheric motions. Equation of motion in inertial and rotating coordinate systems. Relative equation of motion and its components in different coordinate systems (Cartesian, Pressure, Natural, Spherical Co-ordinates, UTM.). Scale analysis of the equation of motion. Geostrophic, quasi-geostrophic and hydrostatic approximations. Horizontal frictionless flow of balanced motions: Geostrophic flow, inertial flow, cyclostrophic flow and gradient flow. Thermal wind, barotropic and baroclinic atmosphere. Divergence and Vorticity theorems, their scale analyses. **Circulation and Vorticity-** Kelvin's theorem; The vorticity equation; Barotropic and Baroclinic potential vorticity (PV) equations; planetary vorticity, Absolute & potential vorticity conserving trajectories across mountain barriers; Kinematics of 2-D flows. Kinetic and Potential energy in atmospheric processes.

Learning outcomes: Students will have a study of atmospheric motions as solutions of the fundamental equations of hydrodynamics or other systems of equations appropriate to special situations, as in the theory of turbulence.

Unit-wise title, subtitle and number of classes per unit:
Fundamental forces in the atmosphere: 1 credit (15 classes)
Equations governing the atmospheric motion: 1 credit (15 classes)
Circulation and Vorticity: 1 credit (15 classes)
Total Class: 45

Unit-wise learning outcome:
Students will have the knowledge of:
- The fundamental forces generating the atmospheric motion
- Equations governing the hydrodynamics of the atmosphere and the derived fields such as divergence and vorticity

- Theory of boundary layer and turbulence

Instruction strategy:
Lecture
Problem Practice in class
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
J. Holton. Introduction to dynamical meteorology Academic Press.
Ambaum, Thermal physics of the atmosphere, Wiley.
Hoskins & James, Fluid dynamics of the mid-latitude atmosphere,Wiley.
Hastenrath, Climate dynamics of the tropics. Kluwer.
George J. Haltiner and Frank. L. Martin, Dynamic and Physical Meteorology.
Maarten H. P. Ambaum, 2010: Thermal Physics of the Atmosphere (Wily). ISBN: 978-0-470-74515-1; 252 pages.
Dynamic and Physical Meteorology by George J Haltiner and Frank. L. Martin.

MetLb 205: Fluid Lab (03 Credit)

Rationale: It is a bridge between theoretical and practical knowledge to understand atmospheric motions.

Objectives: The main purpose of this lab include determination of forces generated when fluid flow takes place over a solid object, demonstration of the momentum, energy equations and viscosity measurement. It will help to demonstrate laminar flow and turbulent flow.

Syllabus Contents:
1: Rotating / Non-Rotating Convection: To observe the effects of rotation on convection and count the number of convective waves with respect to rotation.
2: Density Currents: To observe and measure the properties of density currents as a function of density excess and water depth.
3: Rotation & Stratification: To observe the nature of the centrifugal and Coriolis accelerations, and the gross effects of rotation and stratification on fluid flows.
4: Thermals: To show the effects of density in forming thermals. Students use different densities of salt solution and time the movement of the thermal past graduations on a shadowgraph.
5: Surface Water Waves: Surface Water Waves: To measure the speed of wave propagation in water, frequency of wave generated by a stationary source and to observe the effect of superposition of waves generated from two stationary sources
6: To simulate the density current using Computational Fluid Dynamics simulator.

Learning outcomes: students will have clear conception on complicated nature of fluid flow and will be able to apply the knowledge in the real-life problems.

Unit-wise title, subtitle and number of classes per unit:

Mixing of heavy and light fluids: 1 credit (15 classes)
Rotating effect on fluid circulation: 1 credit (5 classes)
Experiments on fluid dynamics: 1 credit (15 classes)
Total class: 45

Unit-wise learning outcome:
Student will learn the following aspects of fluid dynamics:
- Laminar and turbulent boundary layer mixing
- Mixing of heavy and light fluids
- Rotating effect on fluid circulation

Instruction strategy:
Lecture
Laboratory Experiment
Report Writing
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):

- Islam, M. Q. and Islam, A. K. M. S. (1993) *Fluid Mechanics Laboratory Practice*. BUET. Dhaka, Bangladesh.
- Holman, J. P. (2014) *Experimental Methods for Engineers* (7^{th} edition). MGH Education. New Delhi, India.
- Elsayed, M. M., Zaki, H.E.A. and Radhwan, A.M. (1993) *An Experimental Course in Basic Fluid Mechanics* (Volume II). Scientific Publishing Centre. King Abdul Aziz University, Jeddah, Saudi Arabia.
- Aris, R. (1962) *Vectors, Tensors and the Basic Equations of Fluid Mechanics*. PH. NJ, USA.
- Batchelor, G.K. (1967) *An Introduction to Fluid Dynamics*. CUP. Cambridge, UK.
- Tritton, D. J. (1988) *Physical Fluid Dynamics*. OUP. New York, USA.
- Sultanian, B.K. (2016) *Fluid Mechanics: An Intermediate Approach*. CRC Press, Taylor and Francis Group. New York, USA.
- Landau, L.D. and Lifshitz, E.M. (1959) *Fluid Mechanics* (2^{nd} edition). Elsevier. USA.

MetLb206: Laboratory on Operating Systems/Programming Languages-II (03 Credit)

Rationale: This programming course is designed to teach students the basics & advanced level of program design, coding and testing. Many programming models for massively parallel machines exist; programming is more than simply learning or getting acquainted with a simulation or programming language: good programs start with a thorough analysis of the problem, since this induces thinking about structure. FORTRAN is a general-purpose, compiled imperative programming language that is especially suited to numeric computation and scientific computing. The modern programming using C and other programming such as Perl, Python and MATLAB will also be introduced in solving meteorological problems.

Objectives: To teach programming language FORTRAN, C and other languages such as Perl, python, MATLAB.

Syllabus Contents: Five assignments on Linear Algebra and Differential Equations will be given to solve numerically using C, FORTRAN, Perl, python, MATLAB.

Learning Outcome: Students gain aptitude in writing computer programs in solving mathematical problems using different programming languages.

Unit-wise title, subtitle and number of classes per unit:
C: 1 credit (15 classes)
Fortran: 0.5 credit (7 classes)
Python: 1 credit (15 classes)
MATLAB: 0.5 credit (8 classes)
Total class:45

Unit-wise learning outcome: Students will learn the following:

- The programming language FORTRAN
- Programming using Python

- Programming with MATLAB

Instruction strategy:
Lecture0.5 credit (6 classes)
Programming in Computer Lab
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Operating Systems in Depth: Design and Programming, 1st Edition by Thomas W. Doeppner.
Teach Yourself C, 3rd Edition, HerbertSchildt.
Steyn. Introduction to atmospheric modeling. Cambridge University Press.

Learning outcomes: Students will use FORTRAN &MATLAB for solving meteorological problems and preparing NWP Models.

Recommended Text(s):
Numerical Recipes in Fortran: Volume 2, Volume 2 of Fortran Numerical Recipes: The Art of Parallel Scientific Computing / Edition 2 by William H. Press, Saul A. Teukolsky, William T. Vetterling, Brian P. Flannery, Michael Metcal.
Fortran 95 Handbook: Complete Iso/Ansi Reference / Edition 1 by Jeanne C. Adams, Jerrold L. Wagener, Walter S. Brainerd, Brian T. Smith, Jeanne T. Martin
Fortran Techniques with Special Reference to Non-numerical Applications by A. Colin Day, A. C. Day
MATLAB Programming for Engineers by Stephen J. Chapman

Year 2: Semester 4

MetTh 207: Mathematical methods in Solving Meteorological Problems (03 Credit)

Rationale: Quantitative problem-solving is a challenging aspect of any physical science course. Application of these concepts in the study of meteorological problems are provided.

Objectives: To teach students various mathematical techniques so that they can use those techniques to solve complex meteorological problems easily.

Syllabus Contents: Fundamentals of Fourier series, Fourier Transform, Laplace Transform, Henkel and Hilbert Transform, Wavelet Transform, Greens Function with application to meteorology and climatology. Solution of partial differential equations and their physical interpretation in meteorological problems. Laplace equations, heat and diffusion equation in atmospheric dynamics problem.
Learning outcomes: It would be very much beneficial for the student to incorporate mathematical problem-based learning in weather forecasting.

Unit-wise title, subtitle and number of classes per unit: Fourier series: 2 credit (24 classes)
Simultaneous linear equations: 1 credit (13 classes)
Laplace equations, heat and diffusion equation in atmospheric dynamics problem: 0.5 credit (8 classes)
Total 45 classes.

Unit-wise learning outcome: The students will learn the following:
- Fundamentals of Fourier series, Fourier Transform, Laplace Transform, Henkel and Hilbert Transform, Wavelet Transform, Greens Function with application to meteorology and climatology.
- Solution of partial differential equations and their physical interpretation in meteorological problems.
- Laplace equations, heat and diffusion equation in atmospheric dynamics problem.

Instruction strategy:
Lecture
Problem Practice in class
Computer Lab
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Thompson, Philip D. Numerical Weather Analysis and Prediction. Macmillan, New York, 1961.Google Scholar.
Richardson, Lewis F. Weather Prediction by Numerical Process. Cambridge University Pr, Cambridge, 1922.
Ducan Thompson, Philip D. A history of numerical weather prediction in the United States. In History of Meteorology in the United States: 1776–1976. American Meteorology Society, 1978.
Teach Yourself C by Herbert Schildt

MetTh 208: Radiative Processes in Earth and Atmosphere (03 Credit)

Rationale: This course is focused on fundamental understanding of radiation processes such as absorption and scattering on the molecules, aerosols, and clouds. The main part of these lectures is devoting on the radiative transfer in atmosphere and global radiation balance.

Objectives: To know about heat transfer processes originating from the sun or the Earths.

Syllabus Contents: Absorption, emission and scattering of radiation by the atmosphere. Depletion of solar radiation (direct/diffused) under cloudless and cloudy conditions, mean depletion, interaction with the earth's surface and oceans. Radiative transfer equation for the solar radiation and emitted radiation from earth and atmospheric system, Heat balance of the earth-atmosphere system and the role of carbon-dioxide, water vapor, and ozone on radiation quality and quantity. Radiation charts. Interaction of the solar radiation in the atmosphere, attenuation of solar radiation- molecular and aerosol scattering, absorption, transmission, interaction with clouds and surface, radiative transfer equation, down-welling and upwelling radiation, radiative balance and heat equation. Radiation measurement techniques.

Learning outcomes: Students will understand radiative equilibrium, radiative-convective equilibrium, and radiative forcing discussed as an aspect of climate change.

Unit-wise title, subtitle and number of classes per unit:
Solar and terrestrial radiation: 1.0credit (15 classes)
Interaction of Radiation with the Atmosphere and surface 1.0 Credit (15 Classes)
Radiative balance in the earth Atmospheric system: 1.0 credit (15classes)
Total class: 45

Unit-wise learning outcome:
- Solar and terrestrial radiation
- Interaction of Radiation with the Atmosphere and surface
- Radiative balance in the earth Atmospheric system

Instruction strategy:
Lecture
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):

Ambaum, Thermal physics of the atmosphere, Wiley.
R. M. Goody; Y. L. Yung, Atmospheric Radiation, Oxford University Press 1995.
Craig F. Bohren; Eugene E. Clothiaux, Fundamentals of Atmospheric Radiation, Wiley 2006.
Liou, An Introduction to Atmospheric Radiation. Elsevier Science 1981.

MetTh209: Atmospheric Chemistry (03 Credit)

Rationale: This module provides the Chemistry of Atmosphere with specific attention to study the atmospheric and environmental chemistry, which is very important for meteorologists.

Objectives: To provide understanding of chemistry related to the composition of the atmosphere, radiative forcing due to GHG emission causing climate change.

Syllabus Content: Atmospheric Chemistry Overview – physical properties and structure of the troposphere and the stratosphere, temperature profile, concentration profiles
Atmospheric Chemistry of the Troposphere – tropospheric chemical cycles, hydroxyl and chlorine radical, chemical cleansing, oxidation, hydrocarbons in the troposphere, sources and sinks
Atmospheric Chemistry of the Stratosphere – stratospheric ozone cycle, depletion, NOx, halogencycles, polar stratospheric cloud chemistry
Urban Smog - VOC/NOx/COx/SOx/SF6– Historical account of air pollution, progress and problems in experiments and modeling, assessing human impact on the atmosphere
The Global Carbon Cycle; Biogeochemical Cycles of Methane and Nitrous Oxide, ABC
Pollution: Air Quality, Acid Rain, and Aerosols
Aerosols and Heterogeneous Reactions: Aerosol size distribution and composition; Aerosol and the formation of clouds; The optical properties of aerosols and clouds; Reactions of gases with particles; Impact of aerosols on weather, climate and human health; effect of aerosol on climate change
The Greenhouse Effect: Radiative Transfer; Cloud and Water Vapor Feedbacks
Chemistry of Global Climate Change – Historical account of greenhouse gas and aerosol concentrations, carbon dioxide, ozone and altitude, aerosol uncertainties, sulfur cycle
Climates of the Past

Learning Outcomes: Students will learn air pollution, atmospheric chemistry and GHGs responsible for global warming. They will also learn influences of chemical reactions and Acid and basic properties.

Unit-wise title. Subtitle and number of classes per unit:

Atmospheric Composition and vertical structure: 0.5 credit (06 classes)
Atmospheric chemistry of troposphere and Stratosphere: 1 credit (15 classes)
Atmospheric aerosol, GHG emission and Climate Change: 2 credit (24 classes)
Total class:45

Unit-wise learning outcome:

Students will know the following about the atmospheric Chemistry:

- Atmospheric Composition and vertical structure
- Atmospheric chemistry of troposphere and Stratosphere
- Atmospheric aerosol, GHG emission and Climate Change

Instruction strategy:

Lecture
Practical Laboratory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):

Visconti, Guido: Fundamentals of Physics and Chemistry of the Atmosphere, Springer

Peter V. Hobbs, University of Washington, Basic Physical Chemistry for the Atmospheric Sciences, 2ndEdition
Chemistry of the Upper and Lower Atmosphere, B. J. Finlayson-Pitts, J. N. Pitts, Jr., Academic Press, 2001
Global Warming: The Complete Briefing 5th Editionby John Houghton
Green Chemistry: An Inclusive Approach, edited by BélaTörök and Timothy Dransfield

MetTh210: GIS and Remote Sensing (03 Credit)

Rationale: A geographic information system (GIS) is a computer-based tool for mapping and analyzing feature events on earth. Remote sensing is the art and science of making measurements of the earth using sensors on airplanes or satellites.

Objectives: The objective is to integrate common database operations, such as query and statistical analysis, with maps by GIS technology. This course will provide tools to visualize, query, and overlay those databases in ways not possible with traditional spreadsheets which will ultimately help explaining and predicting various atmospheric events.

Syllabus content: Geographical Information System (GIS):Introduction to GIS: Components of GIS, Software, GUI, Symbolization and Map Design; Spatial and attribute data: Spatial Entities, Topology, Spatial Data Models (vector and raster), Data quality, Attribute Data Management; Acquisition and preprocessing of Geo-referenced Data: Coordinate Systems; Transformations and map projections; Digitizing, Editing and structuring map data; Primary data acquisition; Database Structures: Database approaches, Data models, Database Management Systems; Spatial Analysis: Organizing and classifying Geographic Data for analysis, Analysis of Spatial Data
Remote Sensing: Introduction: Definition and Scope, Remote Sensing data acquisition, stages of remote sensing; Remote Sensing and EMR Interactions: Electromagnetic Radiation (EMR), Electromagnetic Spectrum, EMR Quantities, Radiant Energy, Radiant Flux, Irradiance, Emittance, Radiation Laws, Black-body Radiation, Interaction with Atmosphere, Atmospheric haze/aerosol, Scattering and Contrast Reduction, Spectral Signature, Hemispheric Reflectance, Transmittance and Absorption; Platforms, Sensors and Resolution: Platforms: Ground base, air borne, space borne, Sensors: Types of Sensors; Optical, Thermal, and microwave: sensor systems: Whiskbroom and push broom; Digital Image Processing (DIP): Concept of digital image, steps in DIP, Image corrections: radiometric, geometric and atmospheric corrections, Image registration; Image Classification-Unsupervised classification: techniques, advantage and disadvantage; Supervised classification: techniques, advantage and disadvantage

Learning outcomes: Student will be able to access location specific Geographical information and display and analyze overlays of weather, climate and other geographical information and obtain various statistical and relational solutions using GIS. The Remote Sensing sensors on board satellites or aircrafts collecting data in the form of images willprovidespecializedinformation, which may be manipulated, analyzed, and visualized using Digital Image Processing systems.The course willallowthe students to link databases and maps to create dynamic displays. They will learn mapping of land use and land cover using remote sensing and geographical information systems (GIS).

Unit-wise title, subtitle and number of classes per unit:
Handling GIS database with relational data: 1.5 credit (20 classes)
Remote Sensing Applications and Digital Data/Image Analyze using Digital Image Processing System: 2 credit (25 classes)
Total class:45

Unit-wise learning outcome:
- Students will learn GIS and its application
- Students will also learn the Remote Sensing Technique as a tool for generating spatial data and information

Instruction strategy:
Lecture
Computer Laboratory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
ArcGIS manual
IBL Visual Weather Documentations
IBL Aero Weather Documentations
ERDAS Imagine and ENVI Image Processing Mannual
Digital Image Processing by Rafael C. Gonzalez
Algorithms for Image Processing and Computer Vision by James R. Parker
Fundamentals of Digital Image Processing: A Practical Approach with Examples in MATLAB (Paperback)by Chris Solomon
Image Processing by Henri Maitre
Principles of Digital Image Processing by Wilhelm Burger
Principles of Digital Image Processing: Advanced Methods by Wilhelm Burger
The Image Processing Handbook by John C. Russ
Fundamentals of Digital Image Processing by Anil K. Jain

MetLb211: Laboratory on Mathematical methods (03 Credit)

Rationale: The mathematical methods covered by this laboratory module are the core analytic methods that are useful for modeling the meteorological problems.

Objectives: An understanding of some of the techniques for solving PDEs numerically, and the considerations involved in choosing methods (stability, efficiency, obeying conservation laws, etc.).

Syllabus Contents: Four assignments on Fourier Transform, Laplace Transform and Wavelet Transform, Greens Function with application to meteorology, Laplace equations, diffusion equation and vorticity equation in atmospheric dynamics. Problem will be given to solve numerically using C, FORTRAN, Perl, Python, R statistics and MATLAB.

Learning outcomes: Students will have the knowledge to explain the different methods of data analysis and some computer programming in meteorology. They will be able to solve PDEs and meteorological phenomena related complex equations numerically.

Unit-wise title, subtitle and number of classes per unit:
1. Assessment of coefficients of transformation using Fourier, Laplace's etc.: 1.5 credit (25 hours)
2. Solving PDE for solving Meteorological problems:1.5 credit (20 hours)
Total class: 45

Instruction strategy:
Lecture
Computer Laboratory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Thompson, Philip D. Numerical Weather Analysis and Prediction. Macmillan, New York, 1961.Google Scholar.

Richardson, Lewis F. Weather Prediction by Numerical Process. Cambridge University Pr, Cambridge, 1922.
Ducan Thompson, Philip D. A history of numerical weather prediction in the United States. In History of Meteorology in the United States: 1776–1976. American Meteorology Society, 1978.
Teach Yourself C by Herbert Schildt

MetLb212: GIS and Remote Sensing Lab (03 Credit)

Rationale: Remote sensing provides us with a continuous and constant source of information about the Earth, and geographic information systems (GIS) are a methodology for handling all of this geographic data. The marriage of the two disciplines has allowed us to carry out large scale analyses of the Earth's surface and, at the same time, provide increasingly detailed knowledge on many planetary variables and improve our understanding of its functioning.

Objectives: This is invaluable to monitor the earth's resources and assess the effect of human activity on them. Remote sensing systems deployed on Satellites provide repetitive and consistent view of the earth. These analyses are essential for decision-making on the sustainable management of natural resources, designing networks of protected areas, and addressing the threats of global change.

Syllabus content:
Geographic Information System: Building Geo data base: Build, Modify, Join Tables, Aggregate, Export other ArcCatalog utilities; Importing Spatial and Attribute Data: Sources of Maps and Data, Vector Spatial Data Format, Identify and Change Projections, Examine Metadata, View Attribute Data.
Digitizing: Digitize and Edit Polygon layer, digitize a Point Layer, digitize a Line layer, spatially adjust features.
Spatial Data Processing: Extract, Clip, Union, Dissolve, Append layers, Model Builder
Map layout: Creating Maps, Symbolizing Data, Labeling Maps, Graphs, Laying out and Printing Maps

Remote sensing: Introduction with remote sensing software; Remote sensing data acquisition process; Spectral signature of soil, water and vegetation, Composition of True Color Image and False Color Image, Image registration, Radiometric and geometric corrections of image, Image Enhancement, Image Classification, Image Analysis, Interpretation and composition of thematic maps.

Learning Outcome: Students will learn create spatial and attribute data, which are geographically connected and will learn manipulate for decision making in earth sciences including climatic areas.

Unit-wise title, subtitle and number of classes per unit:
1. Labs with GIS: 1.5 Credit (20 classes))
2. Lab Sessions with RS: 1.5 Credit (25 Classes)

Total class:45

Unit-wise Learning Outcome:
- Students will learn create spatial and attribute data, which are geographically connected
- and will learn to extract, process and manipulate remote sensing data for decision making in earth sciences including weather and climate areas.

Instruction strategy:
Lecture
Computer Laboratory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
ArcGIS manual
ERDAS Imagine and ENVI Image Processing Manual
IBL Visual Weather Documentations
IBL Aero Weather Documentations
Digital Image Processing by Rafael C. Gonzalez
Algorithms for Image Processing and Computer Visionby James R. Parker
Fundamentals of Digital Image Processing: A Practical Approach With Examples In Matlabby Chris Solomon
Image Processing by Henri Maitre
Principles of Digital Image Processing by Wilhelm Burger
Principles of Digital Image Processing: Advanced Methods by Wilhelm Burger
The Image Processing Handbook by John C. Russ
Fundamentals of Digital Image Processing by Anil K. Jain

MetV 213: Field Experiment + Viva-voce (02 Credit)
Fieldwork (day trip) in a suitable area in order to study relevant topics to the courses taught. Comprehensive oral examination of the courses taught. Real-time meteorological observations are studied together with laboratory experiments.

Year 3: Semester 5
MetTh301: Boundary Layer Meteorology (03 Credit)

Rationale: In meteorology the planetary boundary layer (PBL), also known as the atmospheric boundary layer (ABL), is the lowest part of the atmosphere. Its behavior is directly influenced by its contact with a planetary surface. In this layer physical quantities such as flow velocity, temperature, moisture, etc., display rapid fluctuations (turbulence) and vertical mixing is strong. Above the PBL is the "free atmosphere" where the wind is approximately geostrophic (parallel to the isobars) while within the PBL the wind is affected by surface drag and turns across the isobars.

Objectives: The aim of the course is to describe the structure and characteristics of the atmospheric boundary layer (ABL) and the turbulent transport into it. ABL consists of the lowest part of the atmosphere that is directly influenced by the land surface. Within the ABL, the fluxes between the surface of the earth and the atmosphere of momentum, heat and water vapor occur. These fluxes are essential components in the hydrologic cycle. This layer is also important for wind energy community since the wind turbines extract energy from the ABL wind.

Syllabus Contents: Concept, mixing length theory, wind profile and surface drag, bulk aerodynamic method; role of atmospheric boundary layer in meteorology; formulation of turbulence, Dimensionless numbers e.g. Reynolds number, Richardson’s number, Obukov-Monin theory, fluxes of mass, momentum, vertical variation of fluxes, and K approach; Ekman Layer, inhomogeneous PBL over land; modeling of PBL, bulk formulation of PBL. Mapping of Land surface cover and its connection to PBL features.
Observational aspects of the boundary layer, simple model of the tropical boundary layer, Surface similarity theory, Scale analysis of the large-scale tropical boundary layer, Cross-equatorial flows and planetary boundary layer dynamics. Ocean boundary layer: vertical distribution of temperature, density and salinity, The Ekman transport, Wind-driven circulations: Sverdrup’s relation and Stommel’s model, Thermocline circulations and western boundary currents - the Gulf Stream, Upwelling and down welling.
Ocean-atmospheric interaction.

Learning outcome: Students will learn different aspects of atmospheric boundary layer, land-surface / ocean surface interaction with atmosphere. This knowledge will help them understand different processes in the boundaries and formulate the boundary layer processes in the NWP models.

Unit-wise title, subtitle and number of classes per unit:
Unit1: Describe and explain the basics of the physical processes (and their dynamics) controlling the turbulent fluxes in the ABL: credit 1.5 (6 classes)
Unit2: Describe and explain how land surfaces influence the flow in the ABL: 1.5 credit (6 hours of classes)

Unit-wise title. Subtitle and number of classes per unit:
Planetary boundary layer, basics: 1.0 credit (15 classes)
How land surfaces influence the flow in Boundary Layer: 1.0 credit (15 classes)
Fluxes of physical parameters: 0.5 credit (08 classes)
Analyze of observed parameters in ABL:0.5 credit (07 classes)

Total class: 45

Unit wise Learning outcomes: After the completion of the course, the students are expected to be able to -

- Describe and explain the basics of the physical processes (and their dynamics) controlling the turbulent fluxes in the ABL.
- Describe and explain how land surfaces influence the flow in the ABL
- Solve simple modeling problems in the ABL (e.g., similarity theory) analytically and/or numerically
- Analyze turbulence data taken in the ABL using statistical tools

Instruction strategy:
Lecture
Problem Practice in class
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
J. Holton. Introduction to dynamical meteorology Academic Press.
Dynamic and Physical Meteorology by George J Haltiner and Frank. L. Martin
Introduction to Boundary Layer Meteorology Weather and Unmanned Aircraft Systems (UAS) Management Workshop (UTM) July 19-21, 2016 NASA Ames Conference Center Moffett Field, CA Bob Sharman National Center for Atmospheric Research (NCAR) Boulder CO

MetTh302: Introduction to Statistics (03 Credit)

Rationale: Statistical methods have been used in meteorological research. Numerical weather prediction was not the only forecasting technique to face opposition in the 1950s. Progress in meteorology leans heavily on data and observations; consequently, statistical techniques have been widely applied to a variety of meteorological problems.

Objectives: To advocate the use of statistics in weather prediction, weather research and climatological analysis.

Syllabus Content: Introduction of Statistics, Application of Statistics in Meteorology. Population, Sample, Parameter, Statistic, Variable. Frequency Distribution construction, Graphical Representation: Line graph, Bar diagram, Histogram, Stem and leaf plot. Measures of Central

tendency: Mean, Median, Mode, Application of Measures of Central Tendency in Meteorology, Measures of Dispersion: Different absolute and relative measures. Skewness, Kurtosis, Moments, Usage in Meteorology.
Correlation Analysis: Scatter diagram, Pearson's Coefficient of Correlation, Regression Analysis, Estimation of parameter estimation and interpretation of output analysis. Non-linear relation and non-linear regression.Probability: Introduction, classical probability, frequency approach, subjective probability, conditional probability, Bayes' theorem. Usage in Meteorology.
Probability Distribution: Probability distribution (Binomial distribution, Poisson distribution, Exponential Distribution, Gamma distribution, Beta distribution). **Bayesian distribution** Usage in Meteorology, Sampling: Introduction, SRS, Stratified Random Sampling and Cluster Sampling.
Learning Outcome: Students will learn introductory statistics and learn how to compute the different statistical parameters for application in climatology, weather prediction. Data management, analysis and applications.

Unit-wise title. Subtitle and number of classes per unit:
Statistical moments: 1.0 credit (15classes)
Statistical probability distribution: 0.5 credit (08 classes)
Correlations and regression analysis: 1 credit (15 classes)
Data Processing and management 0.5 credits (7classes)

Total class:45

Unit-wise Learning Outcome: The students will learn the statistical applications of the following in Meteorology and climate:

- Statistical moments
- Statistical probability distribution
- Correlations and regression analysis
- Data Processing and management

Instruction strategy:
Lecture
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Epstein, e. S. (ed) (1985) statistical inference and prediction in climatology.
Time series analysis in meteorology & climate.Duchon& hales, wiley.
Daniel s. Wilks. Statistical methods in the atmospheric sciences.
Epstein, e. S. (ed) (1985). Statistical inference and prediction in climatology.
Claude duchon; robert hale. Time series analysis in meteorology and climatology, an introduction.

MetTh303: Cloud Physics (3 Credit)

Rationale: Atmospheric thermodynamics is the study of heat-to-work transformations (and their reverse) that take place in the earth's atmosphere and manifest as weather or climate. Atmospheric thermodynamics use the laws of classical thermodynamics, to describe and explain such phenomena as the properties of moist air, the formation of clouds, atmospheric convection, boundary layer meteorology, and vertical instabilities in the atmosphere.

Objectives: As Atmospheric thermodynamics forms the basis for cloud microphysics and convection parameterizations used in numerical weather models and is used in many climate considerations, including convective-equilibrium climate models, we should learn about it properly.

Syllabus Content: Clouds–An Overview, Cloud classification schemes; Thermodynamic Basics, variables of atmospheric thermodynamic Processes, Saturation; Droplet Activation, Supersaturation over curved surfaces, Solute effects, The Köhler equation and its properties.

Properties of an Isolated cloud drop, Diffusional growth, Temperature corrections, Drop size effects on droplet growth, Terminal fall speeds of drops and droplets; Populations of Particles, Converting distribution and density functions Time derivatives of densities, Common distributions and their density functions, Collection through Collision and Coalescence, Gravitational collection, Smoluchowski (stochastic) collection equation, The collection kernel.
Warm clouds and drop spectral evolution, Exogenous theories of warm rain, Drop spectral preconditioning, Endogenous theories of warm rain, Turbulence enhancement to collision efficiencies and Turbulent mixing.
Atmospheric ice and its initiation, molecular structure of water and ice, Ice initiation; Homogeneous nucleation, Heterogeneous nucleation; Ice crystal growth, Diffusional growth theory; Ice crystal terminal fall speeds, Growth by collection, Further ice-microphysical processes. The atmospheric aerosol, Types of aerosol particle, Microphysical models of cloud and aerosol. Particle based methods, Distribution based methods, Parametric distributions, Aerosol and cloud measurement systems: In situ Methods, Single particle sampling, Expansion Chambers, Particle Counters, Particle Spectrometers, Active remote sensing, Cloud and Precipitation Radars. Thunder storm and atmospheric electricity.

Learning outcomes: Students will be able to use Atmospheric thermodynamic diagrams as tools of predicting clouds and forecasting of storm development. They will be able to identify different kinds of clouds and prediction of lightning and thunderstorm by analyzing clouds.

Unit-wise title, Subtitle and number of classes per unit:
An overview of clouds-Thermodynamic basis: 1.5 credit (20 classes)
Atmospheric stability: 1 credit (15 classes)
Role of aerosols in cloud formation: 0.5 credit (10 classes)
Total class:45.

Unit-wise Learning Outcomes: The students will have knowledge on the following:

- An overview of clouds-Thermodynamic basis
- Atmospheric stability
- Role of aerosols in cloud formation

Instruction strategy:
Lecture
Problem Practice in class
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s)
Maarten H. P. Ambaum, 2010: Thermal Physics of the Atmosphere (Wily). ISBN: 978-0-470-74515-1; 252 pages.
General Meteorology, Horace Robert Byers
The Atmosphere: An Introduction to Meteorology, 13th Edition, Frederick K. Lutgens, Edward J. Tarbuck, Dennis G. Tasa
A Short Course in Cloud Physics (International Series in Natural Philosophy) 3rd Edition, by M.K. Yau , R R Rogers
The physics of clouds, (Oxford monographs on meteorology) Hardcover – 1971 by B. J Mason
Physics and Dynamics of Clouds and Precipitation 1st Edition by Pao K. Wang (Author)
Cloud Physics: A Popular Introduction to Applied Meteorology (Dover Earth Science) Paperback – June 17, 2003 by Louis J. Battan (Author)
Cloud Physics and Modeling, Atmospheric Science, University of Wisconsin, Milaukee.

MetTh 304: Radar and Satellite Meteorology (03 Credit)

Rationale: This course provides an overview of basic principles of radar meteorology and satellite remote sensing for Meteorological analysis.
Objectives: This course is meant to summarize the characteristics and capabilities of the various types of satellite and radar images, which to be covered in this lesson.

Content: Weather Radar- Principles of weather Radar, types of weather Radar, calibration of Radar return, estimation of precipitation, estimation of wind velocity using Doppler Radar. Manipulation and calibration of radar data. Extract important weather elements from Doppler Radar.
History of satellite technology – instrumentation and orbits.
Rationale of satellite observations – visible, infrared and multispectral sensing.
Derived parameters – albedo and temperature of cloud-free surfaces and cloud tops, vertical profiles of temperature and humidity, cloud drift winds, water vapor fields and motion vectors, precipitation.
Application in Tropical Cyclone Analysis-Tropical cyclone monitoring and assessment using the advanced Dvorak method and AMSU observations.
Satellite born SAR (Synthetic Aperture Radar)- application of SAR in Meteorology, Radar Scatterometer and radar precipitation sensors onboard satellites and their applications.
Integration with NWP- Interpretation of satellite imagery, uses and impact of data in NWP modeling systems.

Learning outcomes: Students will be able to decide which remote sensing product (visible, infrared, or water vapor satellite imagery, or radar imagery) is appropriate given a particular need.

Unit-wise title, subtitle and number of classes per unit:
Satellite technology: 1.5 credit (18 classes)
Weather Radar: 1.5 credit (18 classes)

Unit-wise learning outcome:
- The students will learn application of Radar images for weather monitoring and precipitation assessment
- Students will learn about the technology od weather monitoring and weather studies using satellite data

Instruction strategy:
Lecture
Live Streaming through website

Recommended Text(s):
Richard J. Doviak, Dusan S. Zrnic (Author). Doppler Radar and Weather Observations: Second Edition (Dover Books on Engineering) Paperbac, 2006.
Meischner, Peter (Ed.). Weather Radar: Principles and Advanced Applications.
FrédéricFabry. Radar Meteorology: Principles and Practice.
Stanley Q. Kidder, Thomas H. VonderHaar, Satellite Meteorology: An Introduction 1st Edition.
R RKelkar, Satellite Meteorology, Second Edition.
Mölders, Nicole, Kramm, Gerhard, Lectures in Meteorology, Springer.
Su-Yin Tan, Meteorological Satellite Systems. Springer.
Remote Sensing Applications in Meteorology and Climatology, Vaughan, R. A. (Ed) (1987).
Deepak, A., Inversion Methods in Atmospheric Remote Sounding, Elsevier Science 2012.

MetLb305: Laboratory on Plotting and Analyzing of Meteorological Fields (03 Credit)

Rationale: Meteorological output data needs to plot and analyze to provide approximate prediction of atmosphere.
ObjectivesBy analyzing those visualized data, making an approximate weather prediction and dissemination.

Syllabus Contents:

Basic elements of map ;Scale; DifferentMap Projections (Graphical and Mathematical) along with their Merits and Demerits; Understanding the Weather Maps; Signs and Symbols of Weather Maps; Contouring; Characteristics of Contour; Methods of Contouring and Interpolation; Plotting and analyzing Station model for surface and upper air data using WMO standard; Plotting surface and upper air chart of different meteorological parameters (pressure, temperature and geopotential heights);Concept of Vertical thermodynamic profile of atmosphere; plotting T-phigam and Skew-T, Log-P; Plotting meteorological data using different visualization software (GrADS, R, NCL)

Learning outcomes: Students will be able to plot and analyze different weather map and chart. Students will learn weather and climate data processing and visualization techniques

Unit-wise title. Subtitle and number of classes per unit:
Basic information about weather map: 0.5 credit (3classes)
Surface and upper air chart and map:1.5 credit (7 classes)
Visual Analyze:1credit (5 classes)

Unit-wise Learning Outcomes:
- Students will learn weather and climate data processing and visualization techniques
- They will learn analysis, manipulation and interpretation of the data

Instruction strategy:
Lecture
Problem Practice in class
Practical Laboratory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
- GrADSand CDAT User's Guide
- Visualization and analysis software documentations
- Documentation of Meteorological processing system

MetLb306: Advanced Meteorology Laboratory (Credit 2)

Rationale: It is a bridge between theoretical and practical knowledge to understand boundary layer of the ocean and atmosphere such as current generated from the temperature and density variations and wind driven circulation. It is imperative to provide practical knowledge to the students on the spectral properties of the land surface for the incident solar radiation, measuring the incoming and outgoing short and longwave radiation at the surface, experimental study of the cloud formation processes, experiments on properties of matter and soil physical, chemical characteristics and assessment of surface runoff. Having practical experience and understanding of the above parameters are of high importance for weather, agro-, hydro-meteorological / soil moisture/droughts and floods modelling.

Objectives: The main purpose of this lab include determination of boundary layer of the ocean and atmosphere and to provide practical knowledge to the students on the spectral properties of the land surface for the incident solar radiation, measuring the incoming and outgoing short and longwave radiation at the surface.

Syllabus Contents:

Fluid Dynamics: Stommel's model, The Ekman transport, Wind-driven circulations, Effect of rotation of fluid dynamics

Radiation Measurement: Measurement of the spectral properties of earth surface features, Spectral analysis of natural light, measurement incoming and reflecting solar radiation using pyranometer and rotating shadow band pyranometer and assessment of surface albedo for different surfaces; Measurement of absorption and attenuation of solar radiation by the atmosphere; Measurement of incoming and outgoing thermal radiation using Pyranometer and calculation of radiation balance
Cloud experiment: Experiment to investigate cloud formation processes
Soil Experiment: Determination of Soil Texture, soil compaction, water flow within soil (percolation and seepage characteristics) and runoff measurement; water conservation/hydrodynamic
Properties of matter: Surface tension of liquids, measurement of viscosity of liquids

Learning outcomes: Students will have practical knowledge and clear conception onboundary layer of the ocean and atmosphere such as current generated from the temperature and density variations and wind driven circulation. They will have practical knowledge on the spectral properties of the land surface for the incident solar radiation, measurement of the incoming and outgoing short and longwave radiation at the surface, cloud formation processes, experiments on properties of matter, soil physical, chemical characteristics and assessment of surface runoff, which are important for agro-, hydro-meteorological / soil moisture/droughts and floods modelling. Students will also learn water cycles and some useful properties of matter (such as surface tension, viscosity measurement.

Unit-wise title, subtitle and number of classes per unit:
Fluid Dynamics: 0.5 credit (8 Classes)
Radiation Measurement:0 .5credit (8classes)
Cloud experiment: 0.5 Credit (7 Classes)
Soil Experiment and Properties of matter: 0.5 credit (7 Classes)

Total class:30
Instruction strategy:
Lecture
Laboratory Experiment
Report Writing
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):

- Holman, J. P. (2014) *Experimental Methods for Engineers* (7th edition). MGH Education. New Delhi, India.
- Elsayed, M. M., Zaki, H.E.A. and Radhwan, A.M. (1993) *An Experimental Course in Basic Fluid Mechanics* (Volume II). Scientific Publishing Centre. King Abdul Aziz University, Jeddah, Saudi Arabia.
- Batchelor, G.K. (1967) *An Introduction to Fluid Dynamics*. CUP. Cambridge, UK.
- Tritton, D. J. (1988) *Physical Fluid Dynamics*. OUP. New York, USA.
- Ambaum, Thermal physics of the atmosphere, Wiley.
- R. M. Goody; Y. L. Yung, Atmospheric Radiation, Oxford University Press 1995.
- Craig F. Bohren; Eugene E. Clothiaux, Fundamentals of Atmospheric Radiation, Wiley 2006.
- Liou, An Introduction to Atmospheric Radiation. Elsevier Science 1981.

Year 3: Semester 6

MetTh 307: Tropical and Monsoon Meteorology (03 Credit)

Rationale: Tropical meteorology is the study of the atmosphere in areas with tropical climates while monsoon meteorology is the study of the atmosphere in areas with monsoon climates. These areas are also situated near the equator and have a tropical climate, but they experience the effects of the seasonal change in wind direction which makes up a monsoon.

Objectives: The objective is to study various characteristics of tropical meteorology including monsoon system.

Syllabus Content: Features of the tropical atmosphere – subtropical anticyclones, trade winds, equatorial trough/ITCZ, and subtropical westerly jet, Tropical easterly jet and African easterly jet, Easterly Waves;
Tropical Climate: Air–Sea Interaction in Shaping Tropical Mean Climate, Sea Breeze and Diurnal Change over the Tropics, Squall Lines and its effects on deep convection in tropical weather systems;
Madden-Julian Oscillation: Observations, Mechanisms and interaction with tropical weather;
Dynamics of El Niño–Southern Oscillation and its influence on tropical weather
Tropical disturbances – geographical and seasonal incidence;
Tropical Cyclone- Formation, movement and landfall process, Regional distribution;
North Indian Ocean cyclones and storm surges: Tropical Cyclone track, intensity and impact forecasting
Monsoon Dynamics and its interactions with Ocean;
Monsoon variability; Global monsoon systems – The South Asian Monsoon – Tibetan High, seasonal & inter-annual variability of monsoon, Role of Heat Low, Monsoon; Trough, Mascarene High, Somali Jet and the Himalayas, onset and withdrawal phases of monsoon, monsoon low and depressions; Onset and advancement of monsoon, Strong and weak phases of monsoon, influence of monsoon system

Learning outcomes: Students will learn features of tropical atmosphere, meteorological processes and disturbances. They will learn about the various characteristics of tropical monsoons, onset and withdrawal and intra-seasonal variability of the monsoonal activity. They will learn about the active monsoon and breaks monsoon and the synoptic conditions associated with active and breaks. They will learn about the transient systems such as monsoon lows and depressions and their movements.

Unit-wise title, subtitle and number of classes per unit:
Features of the tropical atmosphere: 1 credit (8classes)
Global monsoon systems: 1.5 credit (22 classes)
Tropical disturbances: 1credit (15 classes)
Total class:45

Unit-wise learning outcome: Students will learn -

- Features of the tropical meteorology – subtropical anticyclones, trade winds, equatorial trough/ ITCZ/monsoon trough, subtropical westerly jet, Tropical easterly jet and African easterly jet
- Characteristics of Global monsoon systems with special emphasis of southwest monsoon
- Tropical disturbances and their seasonal and geographical distributions

Instruction strategy:
Lecture
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
J. F. P. Galvin. An Introduction to the Meteorology and Climate of the Tropics.
T.N. Krishnamurti, Lydia Stefanova, VasubandhuMisra. Tropical Meteorology: An Introduction (Springer Atmospheric Sciences), 2013 Edition.
Forecasters' Guide to Tropical Meteorology: Gary D. Atkinson.
Introduction to Tropical Meteorlogy by Dr. Arlene Laing, Dr.Jenni-Louise Evans.
Introduction to climate change - WMO Library.
David D. Houghton. Introduction to Climate Change.

Geoffrey K. Valli. Atmospheric and Oceanic Fluid Dynamics: Fundamentals and Large-scale Circulation 1st Kindle Edition
Monsoons, December 2012 DOI: 10.1007/978-1-4020-4399-4_242 In book: Encyclopedia of Natural Hazards by Song Yang, Viviane Silva, Wayne Higgins
Monsoon Meteorology *C. S. Ramage (Eds.)*

MetTh308: Synoptic and Mesoscale Meteorology (03 Credit)

Rationale: The synoptic scale in meteorology (also known as large scale or cyclonic scale) is a horizontal length scale of the order of 1000 kilometers (about 620 miles) or more.
Mesoscale meteorology is the study of weather systems smaller than synoptic scale systems but larger than microscale and storm-scale cumulus systems. Horizontal dimensions generally range from around 5 kilometers to several hundred kilometers.

Objectives: To learn about the synoptic and mesoscale weather phenomenon.

Syllabus Content: Scales of meteorological systems, Dynamical distinctions between the mesoscale and synoptic scale; Synoptic weather systems, structure and behavior of the real atmosphere; Basic Equations and Tools; dynamic equation for moist convection, Mass conservation, Thermodynamic diagrams, Hodographs; Microphysics; Air Mass Boundaries- Synoptic fronts, Drylines, Tropical and extra tropicalcyclones and their associated fronts and jet streams; Lower Tropospheric Mesoscale Phenomena; Mesoscale Convection& Parcel Stability; Boundary Layer; Mesoscale boundaries originating from differential surface heating; Moist Convective Systems; Dynamics of Clouds - Cloud parameters, Severe Local Storms.
Conceptual models-Conceptual models of significant synoptic and mesoscale systems including their formation, evolution and associated extreme weather events includes thunderstorms/hailstorms/tornadoes and other related severe weathers.

Learning outcomes: Students will learnsynoptic and mesoscale weather systems, and also will learn about the formation and evolution process of various weather phenomena like tropical and extratropical cyclone, cloud, tornado and thunderstorm.

Unit-wise title, subtitle and number of classes per unit:
Synoptic-scale weather features: 1. credit (15 classes)
Mesoscale weather features: 1credit (15 classes)
Models of significant synoptic and mesoscale systems: 1 credit (15 classes)
Total class:45

Unit-wise learning outcome:
Synoptic-scale weather features:Learn the causes, mechanisms and impacts of synoptic scale weather feathers like tropical cyclones, extra-tropical cyclones and western disturbances
Mesoscale Phenomena: Learn the lower tropospheric mesoscale instability, convection and associated severe extreme weather events
Conceptual models: Upper air mapping and weather forecasting; derive the parameters such as vorticity, divergence and inferred vertical velocity from the upper air map

Instruction strategy:
Lecture
Problem Practice in class
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):

Mesoscale Meteorology in Midlatitudes by P. Markowski and Y. Richardson
Mesoscale Meteorology and Forecasting, P. Ray, editor

Cloud Dynamics, R. Houze, Academic Press. Storm and Cloud Dynamics, W. Cotton and R. Anthes, Academic Press.
Inness &Dorling.Operational forecasting, Wiley.
McIlveen, Robin. Fundamentals of weather and climate, Chapman and Hall.
Thompson, Philip D. Numerical Weather Analysis and Prediction. Macmillan, New York, 1961. Google Scholar.
Richardson, Lewis F. Weather Prediction by Numerical Process. Cambridge University Pr, Cambridge, 1922. MATH Google Scholar.
Ducan Thompson, Philip D., A history of numerical weather prediction in the United States. In History of Meteorology in the United States: 1776–1976. American Meteorology Society, 1978.
Peter Michael Inness, Steve Dorling. Operational Weather Forecasting, January 2013, Wiley-Blackwell.
Toby Carlson, Paul Knight, Celia Wyckoff, 2014, An Observer's Guide to Clouds and Weather (A Northeastern Primer on Prediction).
C. Nick Hewitt; Andrea V. Jackson, Handbook of Atmospheric Science, Wiley 2008.
Gerald R. North; Tatiana L. Erukhimova, Atmospheric Thermodynamics, Cambridge University Press 2009.

MetLb309: Tropical and Monsoon Meteorology Lab (03 Credit)

Rationale: Tropical meteorology is the study of the atmosphere in areas with tropical climates while monsoon meteorology is the study of the behavior and structure of the atmosphere in areas with monsoon climates. Both use weather instruments, weather stations, and satellites to study the atmosphere.

Objectives: The objective is to study the **Tropical and Monsoon** system; annual and seasonal variation and associated disturbances

Syllabus Content:

Tools and techniques of Tropical Cyclone forecasting; Analyze Strong and break monsoons (pressure, temperature and cloud fields); Annual and seasonal variations of tropical cyclone; Distribution of Tropical cyclones over north Indian Ocean; Tropical Cyclone Track; intensity and frequency analysis of tropical cyclone over the Bay of Bengal, magnitude of storm surges; Idealized Simulation of tropical cyclone and selected cases of active and break monsoons

The course teacher may assign any other assignment to the student to solve as practical work.

Learning outcomes: Students will familiar with tropical and monsoon features; they will identify various characteristics of tropical monsoons. They will learn the techniques of Tropical Cyclone forecasting; will able to analyze strong and break monsoon and able to track tropical Cyclone; they will learn to simulate an idealized tropical cyclone

Unit-wise title, subtitle and number of classes per unit:

Tropical Cyclone forecasting, tracking: 1 credit (15 classes)
Tropical monsoons: 1 credit (15 classes)
Idealized Simulation of tropical cyclone and Strong and break monsoons: 1 credit (15 classes)
Total class: 45

Unit-wise learning outcome: Students will learn the following aspects of tropical monsoons -

Familiar with tropical and monsoon features;
Identify various characteristics of tropical monsoons.
Learn the techniques of tropical cyclone forecasting;
Analyze strong and break monsoon
Able to track tropical cyclone
Simulate an idealized tropical cyclone

MetLb 310: Synoptic Analysis Lab (03 Credit)

Rationale: Synoptic meteorology has traditionally been concerned with the analysis and prediction of large-scale weather systems, such as tropical cyclones, extra tropical cyclones and their associated air masses, fronts and jet streams and mesoscale weather systems such as thunderstorms squall lines, and mesoscale convective complexes.

Objectives: An important aim of synoptic analysis lab is to acquaint the student with the structure and behavior of the real atmosphere. This will be accomplished formally through this coursework with the help of weather information extracted from station reports, RADAR and satellite imageries and a wide variety of weather maps and prognostic charts.

Course Contents:
Plotting GTS data for the South Asian and adjacent regions including the Arabian Sea and the Bay of Bengal, quality check and plotting the data using standard meteorological symbols.
Analysis of charts of Pressure, geopotential height and Temperature data for lower and upper troposphere. Identify the low pressure, high pressure zones, jet streams and subtropical fronts (horizontal and vertical profile)
Prediction of synoptic and mesoscale weather analyzing low pressure, high pressure zones, troughs, ridges, jet streams for lower and upper troposphere;
Techniques of plotting and analysis of Vertical thermodynamic indices;
Prepare the vertical thermodynamic charts based on radiosonde observation and calculate Convective Available Potential Energy (CAPE).
Identify the pressure and temperature tendency in the charts, and analyze advection of the parameters by the winds; prepare prediction for mesoscale and synoptic scale weather based on all past (1-2 days before) and present information.
Incorporate satellite and RADAR imagery for preparing now-casting future prediction.
Prepare text for predictions of weather and make presentations.

Learning outcomes: Students will be able to code and decode the surface and upper level meteorological data as per WMO guidelines, plot and analyze the surface and upper level synoptic chart using standard meteorological symbols as per WMO guidelines, identify the low pressure, high pressure, trough, ridge, jet stream etc and interpret the tropical and subtropical disturbances, extratropical cyclones, thunderstorms, the interactions between tropical and extratropical system.They will also be able to prepare the vertical thermodynamic chart and identify the LFC, LCL, EL and calculate the values of atmospheric indices including CAPE. The students will learn in a way in which modeling and observational analyses are combined with RADAR and Satellite imageries in an integrated approach to synoptic meteorology. Finally, the students will be able to prepare text for prediction based on present and past meteorological data and information.

Unit-wise title, subtitle and number of classes per unit:
Tools and techniques and WMO guideline for forecasting: 0.5 credit (7 classes)
Coding and decoding meteorological data 0.5 credit (8 classes)
Plotting and analysis surface and upper air charts: 1 credit (15classes)
Plotting vertical thermodynamic charts: 0.5 credit (7classes)
Weather prediction and presentation: 0.5 credit (8classes)
Total class:45

Unit-wise learning outcome:
Students will have hands on practical exercise and will learn about -
Tools and techniques and WMO guideline: Able to interpret different weather phenomena and will able to understand different disturbances like tropical and subtropical disturbances, tropical and extratropical cyclones, thunderstorms, the interactions between tropical and extratropical system
Coding and decoding meteorological data: Able to code and decode meteorological data using standard meteorological symbols based on WMO guidelines.

Techniques of plotting surface and upper air charts: Able to prepare and analysis the surface and upper air station model as well as to plot and analysis the surface and upper air chart.
Plotting vertical thermodynamic charts: Able to prepare and analysis the vertical thermodynamic chart and derived parameters.
Weather prediction and presentation: Able to prepare the text for weather prediction based on the surface and upper air chart, and vertical thermodynamic chart as well as to make presentation on weather.

Instruction strategy:
Audio/Video Recording of the lectures
Lecture
Computer Laboratory
Live Streaming through website

Recommended Text(s):
Inness &Dorling.Operational forecasting, Wiley.
McIveen, Robin. Fundamentals of weather and climate, Chapman and Hall.
Thompson, Philip D. Numerical Weather Analysis and Prediction. Macmillan, New York, 1961. Google Scholar.
Richardson, Lewis F. Weather Prediction by Numerical Process. Cambridge University Pr, Cambridge, 1922. MATH Google Scholar.
Ducan Thompson, Philip D., A history of numerical weather prediction in the United States. In History of Meteorology in the United States: 1776–1976. American Meteorology Society, 1978.
Peter Michael Inness, Steve Dorling. Operational WeatherForecasting, January 2013, Wiley-Blackwell.
Toby Carlson, Paul Knight, Celia Wyckoff, 2014, An Observer's Guide to Clouds and Weather (A Northeastern Primer on Prediction).
C. Nick Hewitt; Andrea V. Jackson, Handbook of Atmospheric Science, Wiley 2008.
Gerald R. North; Tatiana L. Erukhimova, Atmospheric Thermodynamics, Cambridge University Press 2009.

MetLb311: Radar and Satellite Meteorology Lab (03 Credit)

Rationale: This course will provide a demonstration of basic principles of radar meteorology and interpretation of the radar and satellite imagery.
Objectives: This course aims at discussing principles of radar operation, design and implementation of satellite missions, interpretation of imagery across a range of electromagnetic frequencies from the ultraviolet to microwave, and retrieval of atmospheric basic variables from active and passive systems.

Syllabus Contents: Perform the following experiments:
Interpretation of Radar imagery for analyzing depressions, tropical cyclones and mesoscale systems.
Visual interpretation of satellite imagery in reflective, thermal infrared (window channels) and water vapor absorption bands for meteorological interpretation: use Imagery from Polar Orbiting Satellites available at Department of Meteorology, University of Dhaka through the Satellite Ground Station; and also Local as well as Global Imagery from Geostationary Satellites.
Use imagery of full resolution for local details of surface characteristics from multispectral polar orbiting satellites.
Study the convective clouds using digital imagery- cloud top temperature at different stages of evolution of the convective clouds, thunderstorm systems and tornado system.
Use the hardcopy and digital images of satellite imagery for tropical cyclone interpretation (Dvorak techniques).
Draw vertical temperature and humidity profiles for tropical convective systems, depressions and tropical cyclones using the retrievals of the ATOVS and AMSU data; received through Satellite Ground Station available at Department of Meteorology, University of Dhaka.

Interpretation of Scatterometer data for the assessment of wind speed of tropical cyclone.

Learning outcomes: Through a combination of classroom instruction and hands-on computer exercises, students will learn to apply basic radiative transfer theory to identify the "fingerprints" of weather-related phenomena in measurements from satellite and ground-based instruments.

Unit-wise title, subtitle and number of classes per unit:
Radar imagery analysis and interpretation: 1 credit (15 classes)
Convective cloud identification and analysis: 1 credit (15 classes)
Satellite imagery and interpretation: 1 credit (15 classes)
Total Class: 45

Unit-wise learning outcome: The students will learn the following:

- Radar imagery analysis and interpretation
- Convective cloud identification and analysis
- Satellite image analysis and interpretation for atmospheric systems of different scales

Instruction strategy:
Lecture
Practical Laboratory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Richard J. Doviak, Dusan S. Zrnic (Author). Doppler Radar and Weather Observations: Second Edition (Dover Books on Engineering) Paperback, 2006.
Meischner, Peter (Ed.). Weather Radar: Principles and Advanced Applications.
FrédéricFabry. Radar Meteorology: Principles and Practice.
Stanley Q. Kidder, Thomas H. VonderHaar, Satellite Meteorology: An Introduction 1st Edition.
R RKelkar, Satellite Meteorology, Second Edition.
Mölders, Nicole, Kramm, Gerhard, Lectures in Meteorology, Springer.
Su-Yin Tan, Meteorological Satellite Systems. Springer.
Remote Sensing Applications in Meteorology and Climatology, Vaughan, R. A. (Ed) (1987).
Deepak, A., Inversion Methods in Atmospheric Remote Sounding, Elsevier Science 2012.

MetV 312: Field Trip + Viva-voce (02 Credit)

Field Trip (2 days) in a suitable area in order to study relevant topics to the courses taught. Comprehensive oral examination of the courses taught. Real-time meteorological observations are studied together with laboratory experiments.

MetLb309: Tropical and Monsoon Meteorology Lab (03 Credit

Year 4: Semester 7

MetTh 401: NWP Modeling (03 Credit)

Rationale: At time scales of a few hours to a month or more, numerical weather prediction (NWP) is the dominant forecasting technique. The result of this analysis is used to improve output from future model forecasts of similar situations.

Objectives: The aim is to use Weather Analysis and Forecasting as a practical guide to interpret different meteorological fields to elucidate complex weather patterns and train students to improve operational forecasting.

Syllabus Contents: Numerical modeling techniques: Numerical approximations of different terms in the equation of motion, Taylor series expansion, Horizontal Grids and vertical layers, finite difference formulation of atmospheric equations, finite element methods and spectral modeling techniques, time integration techniques, Solution of prognostic equations (primitive equations and vorticity and quasi-geostrophic vorticity equation).
Governing equation and Parameterization: The Governing equations of numerical model. Parameterization of the sub-grid scale processes includingConvection Parameterization, PBL Parameterization and Radiation Parameterization.
Numerical Weather Prediction Models: WRF-ARW model, Linear& Non-Linear balanced models, Fine mesh modeling, baroclinic spectral models. Ocean Dynamics and Modeling, Forecast based on non-divergent barotropic model.

Learning outcomes: Students will learn mathematical models based on the same physical principles that can be used to generate short-term weather forecasts. In the end, they will learn the generic aspects of numerical model design and formulation.

Unit-wise title, subtitle and number of classes per unit:
Numerical Modeling techniques and equation: 1credit (15 classes)
The Governing Equations and Parameterization: 1credit (15 classes)
Numerical Weather Prediction Models:1 credit (15 classes)
Total class: 45

Unit-wise learning outcome:

- Numerical Modeling techniques and equations: Students will be able to understand the basic parameters, techniques and equations used in numerical model.
- The Governing Equations and Parameterization: Students will be able to understand the governing equations of numerical weather prediction model and different sub-grid scale parameterization schemes used in numerical weather prediction model.
- Numerical Weather Prediction Models: Acquire an overall idea on the internal working procedure of different numerical weather prediction models which are commonly used in weather simulation and prediction.

Instruction strategy:
Lecture
Problem Practice in class
Computer Lab
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Thompson, Philip D. Numerical Weather Analysis and Prediction. Macmillan, New York, 1961.Google Scholar.
Richardson, Lewis F. Weather Prediction by Numerical Process. Cambridge University Pr, Cambridge, 1922.
Ducan Thompson, Philip D. A history of numerical weather prediction in the United States. In History of Meteorology in the United States: 1776–1976. American Meteorology Society, 1978.
George J. Haltiner and Roger T. Williams. Numerical Prediction and Dynamic Meteorology
WRF, RegCM and other NWP manuals
Weather Analysis and Forecasting Handbook by Tim Vasquez
Weather Analysis and Forecasting: a Textbook on Synoptic Meteorologyby S Petersen
Mid-latitude Synoptic Meteorology: Dynamics, Analysis, and Forecasting by Gary Lackmann

MetTh 402: Climatology and Climate Modeling (03 Credit)

Rationale: Climate is the statistics of weather over long periods of time. Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (i.e., decades to millions of years). Certain human activities have been identified as primary causes of ongoing climate change, often referred to as global warming. Earth's climate is always changing.

Objectives: This course is designated to measure climate variability by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time.

Course Contents: Concept- Concept of climate, classifications of climate, global, annual and seasonal distribution of surface climatic variables – MSL pressure, Sea SurfaceTemperature (SST), wind, air temperature, humidity and precipitation.
Air-masses- Land and ocean air-masses – source regions and large-scale circulation.
Climatology of natural disasters – tropical cyclones, nor'westers, tornadoes, lightning, floods, droughts and their impacts.
Global warming and its causes-emission of enhanced Greenhouse Gases (GHGs) and sources and sinks of these emissions.
Past and future climate change- global, regional & sub-regional.
Climate Change Impacts-Potential impacts of global, regional and sub-regional climate change.
Physical/dynamical reasoning to explain variability and change in climate.
Climate information: products and services specific to application.
Introduction to climate models:Earth System Models (ESMs), Understanding Global Climate Models; Representative Concentration Pathways (RCPs), dynamical and statistical downscaling of GCM results. Testing model results, bias correction and future scenario development; applications for assessing/projecting future climate change.

Learning outcomes: Students will learn climatology of climate variables and present pattern of natural disasters. They will learn climate change scenarios by using mathematical models based on some physical principles which can be used to generate longer-term climate predictions. This can be widely applied for understanding and projecting climate change. Students will demonstrate discernment among a wide variety of data sources and evaluate their applicability to climate modeling.

Unit-wise title, subtitle and number of classes per unit:
Climate variables:1 credit (15 classes)
Climate science, GHG emission: 0.5 credit (6 classes)
Climate Modelling under enhanced GHG forcing and downscaling of the climate projections: 2 credit (24 classes)
Total class: 45

Unit-wise learning outcome: The students will learn the following aspects of climate modelling
- Climate science, GHG emission
- Climate Modelling under enhanced GHG forcing and downscaling of the climate projections

Instruction strategy:
Lecture
Live Streaming through website
Computer Laboratory
Audio/Video Recording of the lectures

Recommended Text(s):
Hastenrath, Climate dynamics of the tropics. Kluwer.
IPCC, 2013, AR5 report: Climate Change. Physical Science Basis.
IPCC 2013, AR5 report: Climate Change, Impacts, Adaptation and vulnerability.
IPCC 2013, AR5 report: Mitigation of climate change.
Hartmann, Global physical climatology.Academic Press.
Helmis, C., Nastos, P. T. Ed (2013) Advances in Meteorology, Climatology and Atmospheric Physics.
John Marshall; R. Alan Plumb, Atmosphere, Ocean and Climate Dynamics by Elsevier Science 1979.
David D. Houghton. Introduction to climate change: Lecture notes for Meteorologist

Warren M. Washington (Author), Claire L. Parkinson (Author)
Introduction to Three-dimensional Climate Modeling 2nd Revised ed.

MetTh403: Hydrometeorology (03 Credit)

Rationale: Hydrometeorology is a branch of meteorology and hydrology that studies the transfer of water and energy between the land surface and the lower atmosphere. The whole field of water quality and supply is of growing importance in hydrometeorology.

Objectives: The objective is to establish an operational hydrometeorological capability to assist with forecasting, warning and informing the public of these developing hazards. These analyses will serve as the bases for the design of flood-control and water-usage structures, primarily dams and reservoirs. Other concerns include the determination of rainfall probabilities, the space and time distribution of rainfall and evaporation, the recurrence interval of major storms, snow melt and runoff, and probable wind tides and waves in reservoirs.

Syllabus Content: Introduction: Definition, Hydrological cycle and water balance equations, development of hydrological study in Bangladesh.
Precipitation: causes, forms and types, measurement of rainfall (recording, non recording, rain data logger, weather radar, totalizers), network design (optimum number of rain-gauge station, ideal location), estimation of missing data (arithmetic, normal ration, weighted average of four station, interpolation from isohyet maps, regression method), double mass curve, computation of average rainfall (isohyet, Thiessen polygon, arithmetic).
Hydrological losses: Initial losses (interception and depression storage), Evaporation process Meteorological parameters (Radiation, temperature, vapor pressure, humidity, wind), Energy budget methods and mass transfer approach (Dalton's law), Evaporometers, evapotranspiration, actual evapotranspiration (Thornthwaite, Blaneycriddle, penman's equation), Infiltration, Factors affecting infiltration, Horton's equation, Infiltration indices infiltrometers.
Surface Runoff: Drainage basins and its quantitative characteristics, Factors affecting runoff from a catchment, Rainfall-Runoff relationship, stream gauging (selection of sites, types of gauges and measurement), Stream flow measurement by area and velocity method (current meters, and floats), Stream flow computation by slope area method, development of rating curve and its uses, estimation of monthly flows from rainfall, Droughts.
Hydrograph: concept, factors affecting of hydrograph and shape of hydrograph, component of hydrograph, base flow separation, effective rainfall, theory of unit hydrograph, assumption, uses and limitation of unit hydrograph, derivation of unit hydrograph. Flood prediction using hydrograph.
Hydrometeorological hazards: concept, soil characteristics and composition, flood, drought, landslides, types of erosion, storm surge, tidal hazards, local severe storms, heat wave, cold spells, etc.
Hydrometeorological models and their applications: geomorphological modeling and floodplain estimation, hydrological models and modeling, drought/soil moisture modeling, stream flow modeling, flood modeling, storm surge modeling, severe storm and precipitation modeling, atmospheric and hydrological models useful for Bangladesh condition (e.g. MPAS, WRF-Hydro, WRF-Chem, WRF-ELEC etc.)

Learning outcomes: Students will come to know about of natural hazards of hydrometeorological origin and the mitigation of their effects. Among these hazards are the results of natural processes or phenomena of atmospheric, hydrological or oceanographic nature such as floods, tropical cyclones, drought and desertification. Students will develop basic on hydrometeorology, branch of meteorology that deals with problems involving the hydrologic cycle, the water budget, and the rainfall statistics of storms.

Unit-wise title, subtitle and number of classes per unit:
Precipitation: 1 credit (11 classes)
Hydrological losses: 1 credit (12 classes)
Surface Runoff and Hydrograph 1 credit (12 classes)
Hydrmeteorological Hazard: 0: 0.5 credit (5 classes)

Hydrometeorological Modeling and application: 0.5 credit (5 classes)
Total class: 45
Unit-wise learning outcome: The students will learn the following:

- Precipitation and its characteristics
- Hydrological losses, droughts and floods
- Surface Runoff, rainfall-runoff relationship
- Hydrograph and flood prediction
  (will get basic understanding of Hydro models)

Instruction strategy:
Lecture
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):

- Hydrometeorology: Forecasting and Applications, Authors: Sene, Kevin
- Introduction to Hydrometeorology, 1st Edition, Authors: J. P. Bruce R. H. Clark
- Terrestrial Hydrometeorology 1st Edition by W. James Shuttleworth

Rationale: In spite of the impressive advances in agricultural technology over the last half a century, agricultural productivity is still dependent on the prevailing atmospheric processes around the cultivation systems. Agrometeorology, being an interdisciplinary science bridging atmospheric science to the service of agriculture, have become essential for agricultural sustainability and food security through mitigation of the challenges imposed by the increasing climatic variability and extreme events against the agricultural production system in Bangladesh.

Objectives: The main objective is to equip the graduates by acquiring knowledge on climatic resources for effective planning of climate smart agriculture through studying crop weather relationships of important arable crops. The course would also help evolving the capacity on weather based effective farm operations towards sustainable agricultural production in Bangladesh.

Syllabus content:
Agriculture: Introduction to agriculture (Definition, Importance, Branches of agriculture, past and present forms of agriculture), Crops and their classification, cropping seasons, Cropping intensity and patterns, major pest and diseases of major crops, crop rotation.
Agrometeorology: Definition, practical utility and scope. Impacts of climate on crops and livestock distribution and production.Impact of weather in agricultural value chain.
Agroclimatic indices – definitions and applications in agriculture.Effect of environmental factors on crop growth.Crop weather calendar.Estimation of evaporation/evapo-transpiration, soil moisture, solar radiation and their relationship with agriculture. The water balance calculation for tropical regime.
Weather hazards in agriculture. Climate smart agriculture.Agroclimatic regions of Bangladesh.Agroecological resources of Bangladesh. Effects of climate change on crops, soil, fisheries, livestock and poultry in Bangladesh. Weather forecast and issuing of agro-meteorological advisory bulletins for crop risk management.
Satellite application in irrigation, crop monitoring and crop loss assessment due to floods, diseases.Assessment of rainfall over river catchments from satellite.Warning vulnerable communities of impending floods, heat waves and cold waves.
Crop Modelling: concept and applications.

Learning outcomes:
The students will be able to learn on brief introduction to agriculture and its relation to the weather and climate in terms of crop growth, production and food security of Bangladesh. The students would be able to estimate the crop losses due to weather hazards, droughts as well as pest and diseases. Moreover, the graduates would be in a position to forecast weather, agro-met advisories and warning vulnerable farm-communities against the extreme weather events in Bangladesh.

Basic Information of Agriculture and Agrometeorology: 0.5 credit (7 classes)
Agroclimatic indices:0.5 credit (8 classes)
Weather hazards and impacts in agriculture: 1.0 credit (12 classes)
Satellite application: 1 credit (12 classes)
Crop Modelling: 0.5 credit (6 classes)
Total class: 45

Unit wise Learning outcomes: After the completion of the course, the students are expected to be able to –

- Describe and explain the basics of the agriculture and its relation to the weather and climate
- The students would be able to estimate the crop losses due to weather hazards, droughts as well as pest and diseases.
- Understand weather forecast for agriculture, agro-met advisories and warning vulnerable farm-communities against the extreme weather events in Bangladesh.
- Application of satellite imageries for irrigation, crop monitoring and crop loss assessmentdue to different hazards
- Basic understanding of crop models

Instruction strategy:
Lecture
Live Streaming through website
Audio/Video Recording of the lectures
Practical knowledge through field visit (Visual identification of crops by visiting a crop museum (Agricultural University / Research Institute in Bangladesh.

Recommended text books:

Murthy, K.R.V. 2018.Basic Principles of Agricultural Meteorology.BS Publication, Hyderabad – 500 095, India pp261.
Mahi, G.S. and Kingra, P.K. 2015.Fundamentals of Agrometeorology, Kalyani Publishers, New Delhi.
Reddy, S. R. and Reddy, D.S. 2014.Agrometeorology, Kalyani Publishers New Delhi.
Mahi, G.S. and Kingra, P.K Comprehensive Agrometeorology.
Reddy, S. R. 2014.Introduction to Agriculture and Agrometeorology, Kalyani Publishers, New Delhi.
KeesStigter (Ed.), 2010. Applied Agrometeorology.Springer, xxxviii + 1101.
Climate Change Impact and Adaptation in Agricultural Systems — Last modified July 22, 2014 09:18 Edited by J Fuhrer, Agroscope Research Station, Zurich, Switzerland, P Gregory, University of Reading, UK. June 2014 / Hardback / 298 Pages / 9781780642895
Mcfarland, M. J. & Strand, J. F. 1994.Weather-Wise Planning in Farm Management. In: Handbook of Agricultural Meteorology. J. F. Griffiths (ed.), Oxford University Press, Oxford, New York, 264-272.
Rijks, D., Terres, J.M. &Vossen, P. (Eds.) 1998.Agrometeorological applications for regional crop monitoring and production assessment, Official Publications of the EU, EUR 17735, Luxembourg, 516 pp
Rojas, O., Rembold, F., Royer, A. &Nègre, T. 2005.Real-time agrometeorological crop yieldmonitoring in Eastern Africay.Agron. Sustain. Dev. 25:63-77.

MetTh 405: Aviation Meteorology (02 Credit)

Rationale: Aviation sector has great significance over the economy of any country. Weather has influence over the aviation sector and therefore the need for aviation meteorology is widely recognized all over the world.

Objectives: The objective is to establish operational capability in order to assist with forecasting, warning and informing the public about the aviation hazards as well as aviation sector.

Syllabus content:

The atmosphere and aviation – historical perspective, Meteorological organizations.
Effect of pressure, density and temperature on flying– change of pressure, air density and temperature with altitude - altimetry terminology - ICAO standard atmosphere - QNH, QFE, QFF standard setting - transition altitude.
Impact of wind in aviation – Wind shear, cross wind, effect of wind gradient and wind shear on take-off and landing, turbulence and gustiness - mountain and valley winds.
Upper air observation, thermodynamic charts and stability analysis.
Atmospheric turbulence eddies and CAT.
Flying with Cloud- cloud types and flying conditions with special emphasis on thunderstorm flying.
Significance of fog, mist and haze- reduction of visibility due to mist, snow, smoke, dust and sand.
Impact of Air mass and front on flying–Types and formation of air mass and associated weather.
Ice accretion - conditions conducive to ice formation - effects of icing on aero-plane performance - precautions and avoidance.
Meteorological forecasts for aviation –TAF, METAR, ATIS, SIGMET and VOLMET.
Visit to BAF Met office

Learning outcomes:

The students will be able to learn on brief introduction to aviation meteorology and its relation with the weather and climate in terms of operational management of aviation sector in Bangladesh. The students would be able to understand the concepts regarding the aviation sector that has close connection to meteorological knowledge. Also, they will gain idea about techniques of operational weather forecasting particularly related with aviation sector.

Unit-wise title, subtitle and number of classes per unit:
Basics of aviation meteorology0.5 credit (6 classes)
Atmospheric phenomenon related to aviation 1 credit (12 classes)
Meteorological forecasts for aviation0.5 credit (6 classes)
Operational management of aviation (6 classes)
Total class: 30

Unit wise Learning outcomes: After the completion of the course, the students are expected to be able to –

- Describe and explain the basics of the aviation meteorology and its relation with the weather and climate
- Understand the concepts regarding the aviation sector that has close connection to meteorological knowledge.
- Learn the techniques of operational weather forecasting particularly related with aviation sector.
- Practical knowledge of operational management of aviation by visiting BAF Met office

Instruction strategy:
Lecture
Live Streaming through website

Audio/Video Recording of the lectures
Visit toBAF Met office

Recommended Text(s):

Handbook of Aviation Meteorology: By Meteorological Office (UK) – amazon.co.uk.
Terry T. Lankford. Aviation Weather Handbook by K.H. Hack.Aviation Meteorology.

MetLb 406: **Laboratory Applications of Statistics in Meteorology (03 Credit)**

Rationale: Statistical methods have been used in meteorological research since a long time. Numerical weather prediction was not the only forecasting technique to face opposition in the 1950s. Progress in meteorology leans heavily on data and observations; consequently, statistical techniques have been widely applied to a variety of meteorological problems.

Objectives: To advocate the use of statistics in weather prediction as meteorologists.

Syllabus Contents: Time Series Analysis: ARIMA model, SARIMA model. Output analysis and interpretation.
Spectral Analysis: Use of Spectral analysis for weather and climate study through R programming.
Wavelet analysis and application.
Data Processing and Management: Introduction, combining two or more files, collapsing data, generating variables, Value labels, recoding variables, sorting data, besides these the functions which are helpful in the discipline of Meteorology.
Factor analysis, PCA, CCA, Cluster analysis.
Data Science: Introduction, Relationship between data science and statistics. How data science enhances the weather forecasting. Techniques of data science: Linear regression, ANN model. Language of data science: Python and R.

Learning outcomes: Students will be able to perform spatial and temporal analysis and find out the climatology**.** They will be able to estimate the correlation between different atmospheric parameters.

Unit-wise title, subtitle and number of classes per unit:
Statistical moments and distribution: 1 credit (15 classes)
Time series analysis: 1 credit (15 classes)
Correlations and regression analysis: 1 credit (15 classes)

Total class: 45

Unit-wise learning outcome:
The students will learn the following aspects of statistics as applied for meteorology

- Statistical moments and distribution
- Time series analysis
- Correlations and regression analysis

Instruction strategy:
Lecture
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
EPSTEIN, E. S. (ED) (1985) STATISTICAL INFERENCE AND PREDICTION IN CLIMATOLOGY.
TIME SERIES ANALYSIS IN METEOROLOGY & CLIMATE.DUCHON& HALES, WILEY.
DANIEL S. WILKS. STATISTICAL METHODS IN THE ATMOSPHERIC SCIENCES.
EPSTEIN, E. S. (ED) (1985). STATISTICAL INFERENCE AND PREDICTION IN CLIMATOLOGY.

CLAUDE DUCHON; ROBERT HALE.TIME SERIES ANALYSIS IN METEOROLOGY AND CLIMATOLOGY, AN INTRODUCTION.

Year 4: Semester 8

MetTh 407: Application of NWP Models (02 Credit)

Rationale: Numerical weather prediction (NWP) uses mathematical models of the atmosphere and oceans to predict the weather based on current weather conditions. A number of global and regional forecast models are run in different countries worldwide, using current weather observations relayed from radiosondes, weather satellites and other observing systems as inputs.

Objectives: The objective is to perform computer simulation using various numerical weather prediction models which will produce realistic results. This course will describe different aspects of numerical mode*l* design and formulation.

Syllabus Content: Linux O.S, Configuring of NWP models, experiment with nesting and nest down techniques, Data assimilation, initializing model with GFS / FLN data, WRF Pre-processing, and model running.
Case study of pre monsoon systems, monsoon depression, cyclone storm, severe weather systems using of NWP models
Model diagnosis- Graphics package for post-processing and illustration of NWP products.

Learning outcomes: Students will learn to use mathematical models based on the same physical principles which can be used to generate either short-term weather forecasts or longer-term climate predictions; the latter are widely applied for understanding and projecting climate change. They will be able to use numerical models which will allow significant improvements in tropical cyclone track and air quality forecasts.

Unit-wise title, subtitle and number of classes per unit:
Model Domain setup including 2 to 3-way nesting grids: 1.0 credit (12 classes)
Initialization and model running: 1.0 credit (12 classes)
Post processing, interpretation of the results and report writing: 0.5 credit (6 classes)
Total class: 30

Unit-wise learning outcome: The students will run the following aspects of weather modeling -

- Model Domain setup including 2 to 3-way nesting grids
- Initialization and model running
- Post processing, interpretation of the results and report writing

Instruction strategy:
Lecture
Problem Practice in class
Practical Laboratory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Thompson, Philip D. Numerical Weather Analysis and Prediction. Macmillan, New York, 1961.Google Scholar.
Richardson, Lewis F. Weather Prediction by Numerical Process. Cambridge University Pr, Cambridge, 1922.
Ducan Thompson, Philip D. A history of numerical weather prediction in the United States. In History of Meteorology in the United States: 1776–1976. American Meteorology Society, 1978.

George J. Haltiner and Roger T. Williams. Numerical Prediction and 202, Haltiner/dp/0471059714. Numerical-Prediction-Dynamic-Meteorology-on Amazon.com.

MetTh 408: Operational Weather Forecasting(2Credit)

Rationale: Weather forecasting and early warning of meteorological disaster is a highly important task required for planning social, development and economic activities and saving human lives and properties. Students can demonstrate the ability to lead discussions and verifications of mesoscale and synoptic forecasts using satellite, radar, and surface observations.

Objectives: The main purpose is to let the students demonstrate the ability to use their knowledge of synoptic climatology, teleconnections and medium-range NWP guidance to identify potential weather hazards with lead times up to three weeks. The objective is to analyze current weather condition and forecast weather using different techniques.

Syllabus content: Operational Weather forecasting at different ranges (short-mid-long range) using all possible weather analysis of ground and upper observation data and those from satellite and radar observations, products from NWP and other models such as statistical probabilistic techniques. A Real-time data analysis and maximize professional experience through "learning by doing". Forecasting may include probabilistic techniques and statistical regressions. Statistical analysis of prediction errors and forecast verification; develop texts for describing and disseminating forecasts and disaster warnings along with advisories (when and where necessary) for risk management in different sectors and for the vulnerable communities.

Learning Outcome: Students will demonstrate a knowledge of a variety of forecast verification tools and measures of forecast skill. They will demonstrate the ability to create and disseminate a useful real-time mesoscale and synoptic weather prediction under time constraints, based on current observations and numerical forecasts of the atmosphere

Unit-wise title, subtitle and number of classes per unit:
Weather forecasting techniques for short- and medium-term forecasting; 1 credit (6 classes)
Familiarity with tools used for weather forecasting including Statistical, NWPs, satellite and radar techniques: 1 credit (15 classes).
Real-time data analysis to maximize the "learning by doing" experience: 0.5 credit (5 classes).
Forecast verification and assessment or errors: 0.5 credit (5 classes)

Total class: 30

Unit-wise learning outcome:

- The students will learn the following for forecasting meteorological processes:
- Weather forecasting techniques for short- and medium-term forecasting
- Familiarity with tools used for weather forecasting including Statistical, NWPs, satellite and radar techniques
- Real-time data analysis to maximize the "learning by doing" experience
- Forecast verification and assessment or errors

Instruction strategy:
Lecture
Computer Laboratory
Live Streaming through website
Audio/Video Recording of the lectures

Recommended Text(s):
Thompson, Philip D. Numerical Weather Analysis and Prediction. Macmillan, New York, 1961.Google Scholar.

Richardson, Lewis F. Weather Prediction by Numerical Process. Cambridge University Pr, Cambridge, 1922.
Ducan Thompson, Philip D. A history of numerical weather prediction in the United States. In History of Meteorology in the United States: 1776–1976. American Meteorology Society, 1978.
George J. Haltiner and Roger T. Williams. Numerical Prediction and Dynamic Meteorology
WRF, RegCM and other NWP manuals

Met 409: Project with internship (06 Credit)

Rationale: The students will have professional knowledge through internship and will have adequate research knowledge on the meteorological processes though project. They will be introduced to some data processing tools and data analysis with some research objectives but so intensive as the thesis**.**

Objectives: Objective is to provide professional experience and some research ideas in the fields of meteorology and applications.

Syllabus content: The project topics are to be determined by the team of supervisors. These are guided research involving a comprehensive literature review and some contents related to original work based on data analysis, lab work or case studies. Students with relatively lower academic performance are selected for project. The student will perform 4 months internship at related organizations/universities in country.

Learning Outcome: The students will learn the professional culture and be introduced with some research.

Unit-wise title, subtitle and number of classes per unit:
Project title to be selected by a group of supervisors: 6 credits

Unit-wise learning outcome:

- Students will have research experience in meteorology
- They will acquire sense of professional culture from the internship

MetV 410: Viva-voce (02 Credit)
All students will have a viva examination on Project work: They will prepare a power point presentation and present it before a board of experts.