**Approved Course Pattern**

**In M. Tech. Atmospheric Science: w.e.f. 2008-2009 academic year.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| M. Tech. Atmospheric ScienceCourse No. & Title | **Sessional marks** | **Semester end marks** | **Total** | **Credits** |
|
| **I Semester**: | 30 | 70 | 100 | 4 |
| **Theory:** |
| **AS–501** Physics of the Atmosphere |
| **AS–502** Ocean-Atmosphere Interaction | 30 | 70 | 100 | 4 |
| **AS–503** Physics & Dynamics of Oceans | 30 | 70 | 100 | 4 |
| **AS–504** Data Processing Methods in Atmospheric and Oceanic Sciences | 30 | 70 | 100 | 4 |
| **AS–505** Geophysical Fluid Dynamics | 30 | 70 | 100 | 4 |
| **AS–506** Dynamics of the Atmosphere | 30 | 70 | 100 | 4 |
| **AS–507** General Circulation & Climate | 30 | 70 | 100 | 4 |
| **AS-508**  Boundary Layer & Air Pollution Meteorology |  |  |  |  |
| **Practicals:** | 25  25 | 25  25 | 50  50 | 4 |
| **AS–509** **Part A**: Atmospheric Science Computations  **Part B**: Oceanic Science Computations |
| **AS–510** **Part A :** Observation Techniques  **Part B :**Ocean- Atmosphere Interaction | 25  25 | 25  25 | 50  50 | 4 |
| **AS–511** Viva-voce | - | 50 | 50 | 2 |
| **Total ( \* Theory courses 5 + P + VV)** | **250** | **500** | **750** | **30** |
| **II Semester**: | 30 | 70 | 100 | 4 |
| **Theory:** |
| **AS–512** Numerical Weather Prediction |
| **AS–513** Climate Modeling & Climate Change | 30 | 70 | 100 | 4 |
| **AS–514** Synoptic Meteorology & Monsoon Dynamics | 30 | 70 | 100 | 4 |
| **AS–515** Remote Sensing & Satellite Meteorology | 30 | 70 | 100 | 4 |
| **AS–516** Agricultural Meteorology | 30 | 70 | 100 | 4 |
| **Practicals:** | 25  25 | 25  25 | 50  50 | 4 |
| **AS–517** **Part A**: Synoptic Analysis  **Part B:** Satellite Meteorology |
| **AS–518** **Part A** : Numerical Weather Prediction  **Part B**: Agricultural Meteorology Computations | 25  25 | 25  25 | 50  50 | 4 |
| **AS–519** Viva-voce Examination | - | 50 | 50 | 2 |
| **Total** | **250** | **500** | **750** | **30** |
| **III and IV Semesters** | 100 | 100 | 200 | 8 |
| **AS–520** Internship |
| **AS–521** Dissertation | 450 | 450 | 900 | 36 |
| **AS–522** Seminar | 150 | 150 | 300 | 12 |
| **AS–523** Viva-voce Examination | - | 100 | 100 | 4 |
| **Total** | **700** | **800** | **1500** | **60** |
| **Grand Total (1+2+3+4 Semesters)** | **1200** | **1800** | **3000** | **120** |

* **1st Semester theory: out of 8 theory courses 5 courses will be allotted to the student basing on their suitable educational back ground by the Departmental Committee (DC).**

# M. Tech. Atmospheric Science & Ocean Sciences

**The Model paper should be in the following pattern for all the subjects**

**Time: 3 hours Max. Marks: 70**

**Section-I**

**Answer all questions. 10x1 = 10**

**1 to 10 multiple choice questions**

**Section**-**II**

**Write** **short** **notes on any five of the following. 5x6 = 30**

1 to 8 short notes questions

**Section**-**III**

**Answer any three questions. 3x10 = 30**

1 to 5 essay questions including problems

**Note: The question papers should be set covering the entire syllabus and all the units uniformly.**

# M. Tech. Atmospheric Science

**Syllabi for I year – First Semester**

**AS 501: Physics of the Atmosphere**

**Atmospheric Thermodynamics-**

**Gas Laws**, **Hydrostatic Equation** – Geopotential, Reduction of pressure to sea level, **The First Law of Thermodynamics** – Joule’s law, specific heats, Enthalpy, **Adiabatic Processes** – the dry adiabatic lapse rate, potential temperature, thermodynamic diagrams, **Water Vapor in Air** – moisture parameters, latent heats, saturated adiabatic and pseudo adiabatic processes, the saturated adiabatic lapse rate, **Static Stability** – unsaturated air, saturated air, conditional and convective instability, **The second law of Thermodynamics** – the Carnot cycle, Entropy, the Clausius – Clapeyron equation.

**Radiative Transfer** –

**Tthe spectrum of radiation,** **Blackbody radiation** – the Planck function, Wien’s displacement law, the Stefan – Boltzmann law, Kirchhoff’s law, the green house effect, **Physics of scattering and absorption** and emission – scattering by air molecules and particles, absorption by particles, **Radiative Transfer in Planetary atmospheres** – Beer’s law, reflection and absorption by a layer of the atmosphere, absorption and emission of infrared radiation in cloud free air, **Radiation balance at the top of the atmosphere.**

**Cloud microphysics –**

**Nucleation of water vapor condensation** – cloud condensation nuclei, Curvature and solution Effects, **Growth of cloud droplets in warm clouds** – Growth by condensation, growth by collection, growth by condensation and Collision - Coalescence, **Microphysics of cold clouds** – nucleation of ice particles; ice nuclei, growth of ice particles in clouds, formation of precipitation in cold clouds, Bergeron – Findeisen process, **Artificial modification of clouds and precipitation**, **Thunderstorm Electrification** – Charge Generation, lightning and thunder, the global electrical circuit.

**Text Books:**

1. Atmospheric Science, 2nd ed., Academic Press - J.M. Wallace, P.V. Hobbs
2. Dynamical and Physical Meteorology - G.J.Haltiner and F.L.Martin
3. Compendium of Meteorology (WMO Pub.) - Physical Meteorology, 1973, Vol.1, No.2
4. Physical Meteorology - H.G.Houghton
5. Atmospheric Thermodynamics - J.V.Iribarne and W.L.Godson.
6. Meteorology for scientists and engineers –Roland B. Stull
7. Essentials of Meteorology – Donald Ahrens

**AS–502 / OS–502: Ocean-Atmosphere Interaction**

[Common syllabus for M Tech Atmospheric/ Oceanic Science - I semester]

Ocean-Atmosphere boundary layer.

Concept of Boundary Layer formation; Atmospheric Boundary Layer, Oceanic Boundary Layer, structure and Evolution, Temperature profile Evolution, wind profile Evolution, Turbulence, characteristics of Boundary Layer Spectrum. Integral scales of Eddies, Taylor micro scale, Kolmogorov scale and Larger Scale, K-theory and Monin Obukhov Similarity theory. (12 hours)

Different measurement Platforms. Measurement of wind, temperature, humidity, pressure, pilot balloon techniques, solar radiation. Rain Gauges, SODAR and LIDAR.

Methods for determination of vertical transports in the Maritime Friction Layer: Direct Method(Cross-correlation Method); Aerodynamic Methods- Aerodynamic Profile Method, Bulk Aerodynamic Method; Budget Method.

Oceanic Measurements: SST, measuring currents near the ocean surface- acoustic Doppler technique, ocean wave measurement techniques. Methods used for calculation all surface fluxes(wind stress, heat and salt) and their role in the air-sea interaction.

(12 hours)

The significance of Ocean-Atmospheric Interaction.

Atmospheric and Oceanic Boundary Layer Physics.

Atmospheric and Oceanic scales of motion and interaction at various scales.

Atmospheric Circulation, Oceanic Circulation.

Atmospheric Heat Budget, Oceanic Heat Budget

Measurement of surface stress, drag generation mechanisms. Wind stress and resultant drag coefficient with variation to wind speed.

Coupling Mechanisms – Small Scale and Large Scale Air-Sea Interactios:

Ocean-Atmosphere interaction in tropics. Characteristics of ENSO; ENSO and Air-Sea coupling; ENSO and the Indian Monsoon; Warm Pool in Indian and Pacific Oceans, Indian Ocean Dipole (IOD). (16 hours)

Books:

1. Atmosphere – Ocean Interactions by E.B. Kraus and J.A. Businger, Oxford University Press, 1994
2. Atmosphere and Ocean Our Fluid Environments by John G. Harvey; 1985.
3. Atmosphere – Ocean Dynamics, Adrian E. Gill, 1992.

Reference

1. Air-sea Interaction Instruments and Methods. Ed by F. Dobson, L. Hasse and R. Davis; 1980.
2. Climate and Circulation of the Tropics, S. Hastenrath, 1988.
3. Ocean – Atmosphere interaction and climate modeling, Beris A. Kagan, 1995
4. The Oceans and climate by G.R.Bigg, 1996.
5. Instrumentation for Atmospheric Boundary Layer Studies; K. G. Vernekar.
6. Meteorology for scientists and Engineers by Roland Stull; 2000
7. Wind Stress over the ocean by Jones, I.S.F and Y. Toba; 2001.

**AS- 503 /OS- 503: Physics and Dynamics of Oceans**

[Common syllabus for M Tech Atmospheric/ Oceanic Science - I semester]

Physical properties of Sea water: Definition of Salinity, Temperature, Geographical Distribution of Temperature and Salinity, The oceanic Mixed Layer and Thermocline, Density, Potential Temperature, and Neutral Density, Measurement of Temperature, Conductivity, Pressure, Measurement of Temperature and salinity With Depth, Light in the Ocean, Sound in the sea. (7 hours)

Equations of Motion: Dominant Forces for Ocean Dynamics, Coordinate Systems, Types of Flow in the Ocean, Conservation of Mass and Salt, The Total Derivative, Momentum Equation, Conservation of Mass: Continuity Equation, Solutions to the Equations of Motion. (5hours)

Equations of Motion with Viscosity: Influence of Viscosity, Turbulence, Reynolds Stresses, Stability in the Ocean, Mixing in the Ocean. (4 hours)

Response of the Upper Ocean to Winds: Inertial Motion, Ekman Layer and Ekman currents, Ekman Transports, Application of Ekman Theory. (5 hours)

Geostrophic Currents: Hydrostatic Equation, Geostrophic Approximation, Geostrophic Currents, Barotropic and Baroclinic Flow. (5 hours)

Wind Driven Ocean Circulation: Sverdrup's theory of the oceanic circulation, Stommel's Theory for western boundary currents, Basin-scale theory: Munk's solution.Vorticity definition, Conservation of vorticity, Vorticity and Ekman pumping. General circulation of oceans, water mass characteristics. (7 hours)

The Oceanic Heat Budget: Terms in the oceanic heat budget, Direct calculation of fluxes, Indirect Calculation of fluxes from bulk formulas and other sources, Geographical and seasonal distribution of fluxes, Meridional Heat Transport. (6 hours)

Deep circulation in the ocean: Importance of the deep circulation, role of the oceans in climate and abrupt climate change, Stommel-Arons' theory of the deep circulation, Antartic CircumpolarCurrent. (6 hours)

Equatorial Processes: Surface and subsurface currents, El Niño/La Niña: The variability of the equatorial currents El Niño influence global weather. (5 hours)

Text books:

1. Elements of physical Oceanography by McClellan.
2. Observing and forecasting of ocean waves – H.Q pub. No. 603, US Navy.
3. Introduction to principles of dynamic oceanography by Neumann and Pierson
4. Introductory dynamic oceanography by S. Pond and G.L. Pickard.
5. Introduction to principles of dynamical oceanography by Neumann and Pierson.
6. Descriptive physical oceanography by G.L. Pickard and W.J. Emery
7. Oceans by Sverdrup, Johnson and Flemming
8. Descriptive physical oceanography by M.P.M. Reddy

**AS- 504 / OS-504: Data Processing Methods in Atmospheric and Oceanic Sciences**

[Common syllabus for M Tech Atmospheric/ Oceanic Science - I semester]

DATA PROCESSING: Data presentation: Vertical profiles, Vertical sections, Horizontal maps, Map projections

STASTICAL METHODS: Sample distributions; Probability: Cumulative probability functions; Common probability density functions; Confidence intervals

Estimation methods: Minimum variance unbiased estimation, Method of moments, Maximum likelihood

Linear estimation (regression): Method of least squares, Standard error of the estimate, Multivariate regression; Relationship between regression and correlation

Hypothesis testing: Significance levels and confidence intervals for correlation, Analysis of variance and the F-distribution

Covariance and the covariance matrix: Covariance and structure functions, Multivariate distributions

THE SAPTIAL ANALYSIS:

Empirical orthogonal functions: Principal axes of a single vector time series (scatter plot), EOF computation using the scatter matrix method, EOF computation using singular value decomposition, Interpretation of EOF’s, Variations on conventional EOF analysis.

Normal mode analysis: Vertical normal modes

Inverse methods: General inverse theory

TIME-SERIES ANALYSIS:

Basic concepts; Correlation functions; Fourier analysis; Spectral analysis; Autoregressive power spectral estimation, Maximum likelihood spectral estimation; Cross-spectral analysis

Wavelet analysis: The wavelet transform

Digital filters: Basic concepts, Running-mean filters, Butterworth filters, Frequency-domain (transform) filtering.

Text Books:

1. Data analysis methods in Physical Oceanography by Wiliam J. Emery and Richard E. Thomson, 1997, Pergamon Press.

2. Statistical Methods in the Atmospheric Sciences, 1995, Daniel S. Wilks, Academic Press.

#### AS-505/ OS-505: Geophysical Fluid Dynamics

#### [Common syllabus for M Tech Atmospheric/ Oceanic Science I semester]

Fundamentals: Vorticity, the circulation, Kelvin’s theorem, the Taylor-Proudman theorm, geostrophic motion, consequences of the geostrophic and hydrostatic approximations

Inviscid shallow-water theory: The shallow-water equations, potential-vorticity conservation: shallow water theory, Poincare and Kelvin waves, the Rossby wave, dynamic diagnosis of the Rossby wave, the mechanism for the Rossby wave, the Beta-Plane, Rossby waves in a zonal current, energy and energy flux in Rossby waves, Rossby waves produced by an initial disturbance

Friction and viscous flow: Turbulent Reynolds stress, the Ekman layer, Ekman layer on a sloping surface, Ekman layer on a free surface, quasigeostrophic potential vorticity equation with friction and topography, the decay of a Rossby wave, the Ekman layer in a stratified fluid, Rossby waves in a stratified fluid,

Instability Theory: Instability, continuously stratified model, linear stability problem: conditions for instability, baroclinic instability: the basic mechanism, barotropic instability, instability of currents with horizontal and vertical shear, nonlinear theory of baroclinic instability

Reference:

Geophysical Fluid Dynamics: by Joseph Pedlosky, 1979

**AS 506: Dynamics of the Atmosphere**

Forces governing the atmospheric motions and their classifications as body and surface forces, conservative and nonconservative forces, equation of motion in rotating frame, Coriolis force and its physical nature, Rossby number.

Geostrophic flow and its application to meteorological chart analysis, gradient flow and its application to atmospheric vortices including tornadoes and tropical cyclones, continuity equation (conservation of mass), thermo dynamic equation, angular momentum and kinetic energy equation, total potential energy, conservation of total energy.

Hydrostatic approximation, corresponding approximation in the equation of horizontal motion, pressure as vertical coordinate, atmospheric equations in pressure coordinate system, shallow water equations.

Circulation, vorticity, divergence and deformations; circulation theorems of Kelvin and Bjerknes, applications of the circulation theorem - land and sea breezes and other examples; Helmholtz theorem; barotropic and baroclinic atmosphere; vorticity equation; potential vorticity of barotropic and baroclinic flow; divergence equation, linear and non-linear balance equations’ scale analysis of vorticity and divergence equations for planetary and synoptic scale motions; quasi-geostrophic approximation; quasi-geostrophic omega equation, thermal wind equation, backing and veering of wind in relation to horizontal temperature advection barotropic vorticity equation, beta-plane approximation, Rossby wave; quasi-geostrophic.

The mechanism of pressure change, kinematics of pressure system, pressure tendency equation; Holmboe theory of the motion of pressure systems; isallobars and isallobaric wind; Sutcliffe’s theory of the development of pressure systems and related ideas.

**Books for Study :**

1. An Introduction to Dynamic Meteorology, J.R.Holton
2. Numerical Prediction and Dynamic Meteorology, G.J.Haltiner and R.T.Williams.

**Books for Reference** :

1. Dynamical and Physical Meteorology, G.J.Haltiner and Martin
2. Dynamic Meteorology, B.Haurwitz
3. Dynamic Meteorology, Panchev
4. Dynamic Meteorology, Ed.Wiin Nielsen, WMO Publication

#### AS 507: General Circulation and Climate

Earth’s orbital characteristics - Seasonal and latitudinal variation of insolation - Net radiation - Heat balance of the atmosphere. Global, time mean fields of pressure, temperature and winds - troposphere and stratosphere - summer and winter.

Definition of the general circulation. Observed zonally averaged meridional and zonal circulations, hemispheric and zonally asymmetric components of the general circulation - standing eddies and Walker circulations, historical developments towards understanding the zonal mean circulations.

Basic equations - Toroidal and eddy fluxes - Angular momentum - sensible and latent heats and kinetic energy - balance requirements - maintenance of the zonal mean circulations.

Energetics of the atmosphere - Total potential energy, Available potential energy, zonal and eddy available potential energy - Energy exchanges.

Simple models of symmetric circulation and ITCZ; role of tropics in global general circulation. Results of dish pan experiments, Rossby and Hadley regimes.

Monsoon circulations in the meridional and zonal planes - Energy conservation cycle of the monsoon circulation, energy exchanges between ultra-long, synoptic and short waves in the tropical upper troposphere during northern summer.

Definition of climates - climate change on different time scales - decadal centuries and millennia. Forcings influencing the climate and their variations, feedback processes between different forcings - inter annual variability - QBO, ENSO, their mechanisms.

Simple climate models and their results - Introduction to large numerical models.

**Text Books:**

1. Causes of Climate, J.G.Lockwood
2. Fundamentals of Dynamic Meteorology
3. The Nature and Theory of General Circulation of the Atmosphere,

E.N.Lorenz, WMO Publication.

**AS-508 Boundary Layer Meteorology and Air Pollution**

Boundary Layer Definition and Importance: Boundary layer definition and scale, forcing mechanisms, meteorological scales , comparison to the free atmosphere, significance of the boundary layer, related areas of study

General Characteristics and Evolution of the Boundary Layer: Winds in the boundary layer, Turbulence and Taylors Hypothesis, Thermodynamic Variables, Boundary Layer Depth and Structure, Introduction to Evolution over Land, Daytime Convectively Mixed Boundary Layer, Nocturnal Boundary Layer, Summary of Boundary Layer Features

Boundary Layer Phenomena: coastal fronts, sea/land breeze circulations, lake breezes, gust fronts,

boundary layer convection - horizontal rolls, open/closed cell convection, urban heat island, local

circulations due to land heterogeneity, valley/drainage flows

Sources and Classification of air pollutants: Sources of air pollutants, Factors affecting air pollution,

Classification of air pollutants, air quality standards, and quality legislation. Scales of the air pollution problem: Local, Urban, Regional, continental and Global

Transport and dispersion of air pollutants: wind velocity, estimating concentration from point sources, dispersion instrumentation, dispersion models, plume rise – plume rise for buoyant plume theories developed by Barryland, Cowen, Hol and Briggs, Plume rise in unstable, neutral, stable and calm conditions.

Effects of air pollution: Effects of air pollution on human health, animals, vegetation, materials and

property. Air sampling and analysis: Factors to be considered in sampling, ambient or atmospheric air sampling; methods of analysis, Procedure of analysis of gaseous pollutants in atmospheric air.

Books:

Hand book of Applied meteorology – David D. Houghton (John Wiley & Sons, 1985)

Fundamentals of air pollution – A.C. Stern, RW Boubel, DB Turner and DL Fox.

(Academic Press, 1984)

Air Pollution - A.C. Stern, (Academic Press, 1976)

Air pollution – Threat and Response - David A Lynn (Addison – Wesley Publishing company)

Fundamentals of air pollution – BSN Raju (Oxford & IBH Publishing Co. PVT. LTD, 1997)

Air Environment and Pollution – SS Purohit and Bhanu Kakrani (Agrobios (India), 2002)

An Introduction to Boundary Layer Meteorology by R.B. Stull

**Practicals**

**AS-509/ OS-509: Part A: Atmospheric Science Computations**

1. Calculation of horizontal divergence, absolute vorticity from wind data- Irregular spaced points, regular grid points.
2. Calculation of Geostrophic wind and gradient wind.
3. Calculation of vertical velocity – Triangular, quadratic, regular spaced data.
4. T - Φ gram analysis: analysis of aerological data
5. Lifting condensation level
6. Equilibrium level
7. Stability indices
8. CAPE & CINE
9. Elsasser’s Radiation chart: Flux determination

**AS-509/ OS-509: Part B: Oceanic Science Computations**

1. Determination of Density and Specific volume anamoly.
2. Identification of upwelling and downwelling patterns
3. Computation of relative currents
4. Stability characteristics of water column and Richardson number
5. Estimation of tides
6. Preparation of T-S Diagram

**AS-510 / OS-510: PART A: Observation Techniques**

1. Measurement of temperature, pressure, humidity, wind and precipitation

2. Measurement of Solar radiation and duration of sunshine.

3. Measurement of Aerosol Optical depth, Total columnar ozone and precipitable water

vapour.

4. Estimation of upper wind from Pilot balloon observation.

5. Estimation of cloud cover.

6. Measurement of sea surface temperature and salinity and marine meteorological

parameters.

7. Measurement of Ocean currents.

8. Measurement of Ocean depth.

9. Study of rainfall using Doppler Radar Reflectivity.

10. Study of upper winds using velocity product of Doppler Radar.  
11. Identification of sea breeze setting time & Land breeze setting time using velocity

product of Doppler Radar.

**AS-510 / OS-510: PART B: Ocean-Atmosphere Interaction**

1. Computation of short-wave Radiation at the Ocean surface

a) Octa model b) Synoptic approach

2. Computation of Long-wave Radiation at the Ocean surface

a) Brunt's formula, b) Anderson's formula

3. Computation of Latent Heat Flux at the Ocean surface-

with variable coefficient of Ce

4. Computation of sensible heat flux at the ocean surface-

with variable coefficient of Ch

5. Computation of Atmospheric Heat Budget.

6. Computation of Wind Stress at the ocean surface-

with variable coefficient of Cd

7. Wind curl – Ekman transport

8. Computation of upper ocean heat content

**OS-511: Viva-voce**

**M.Tech II Semester**

**AS: 512 NUMERICAL WEATHER PREDICTION**

Basis of NWP: Fundamental equations; Derived Set of Equations; Types of pure Waves: Sound, gravity and Rossby waves; mixed Rossby- gravity waves. Filtering method.

Numerical methods: Finite difference methods- forward and Centered and Implicit schemes; CFL Criterion; Non-Linear Instability and Aliasing;

Numerical Models: Quasi-Geostrophic Models: Barotropic, Baroclinic and Multi Level Baroclinic Models; Linear and Non Linear Balance Models

Primitive Equation Models: Sigma Coordinates; Problem of initialization for PE models. Two Level PE Model in Momentum form;

Numerical methods: Relaxation methods; Arakawa Jacobian; Staggered Grid Systems- Arakawa C grid.

Parameterization of Physical Processes: Boundary Layer : Reynolds Equations, Bulk Formulae, and Deardorf Model ; Cumulus Convection : Convective Adjustment Scheme, Kuo Scheme; Radiation : Short and Long Wave radiations Clear and Cloudy Sky -Katayama scheme

Meso Scale Models: Non Hydrostatic equations, Grid and domain structure, Initialization , Boundary conditions, MM5 and WRF models, Calculation of model budgets, model sensitivity analyzing, Terrain induced and synoptically induced mesoscale systems, mesoscale data assimilations – Nudging, 3DVAR 4DVAR.

Methods of solution, upstream interpolation scheme, time implicit method

Model output statics – RMSE, BIAS, TS, Hanssen-Kuipers score, Heidke-Slice Score

Text Books:

1. An Introduction to Dynamic Meteorology, Third edition, James R. Holton, International Geophysical Series, Volume 48.
2. Numerical Weather Prediction and Dynamic Meteorology, Second Edition, George T. Haltiner, Rojer Terry Williams, John Wiley & Sons
3. Numerical Weather Prediction, George J. Haltiner, John Wiley & Sons
4. Numerical Weather Analysis and Prediction, Philip D. Thompson

**AS-513 Climate Modelling and Climate Change**

Climate Modelling: Introduction to Climate Modelling

Types of Climate Models: 0-D and 1-D models: Energy Balance Models; Radiative Convective

Models Two dimensional Statistical Dynamical Models.

Spectral Models: Spectral method, Spectral Transform Technique, Spectral Model of Shallow

Water Equations. Physics in spectral models

General circulation models 3-D GCMs. Design of 3-D GCMs- various components,

parameterization of sub-grid scale processes in GCMs. Philips two–layer GCM experiment.

Climate simulation with GCMs. Climate sensitivity experiments. Land surface parameterization

in GCMs and Coupled Ocean Atmospheric GCMs.

Climate Change: The change in climate, Measurement and evaluation of climate change,

The impacts of climate change on earth, The role of human activity on climate change, Decadal

to centennial climate change, The interactions between Ocean circulations and climate change.

Text Books:

1. A Climate Modelling Primer, A. Henderson – Sellers and K. McGuffie

2. An Introduction to Three-Dimensional Climate Modeling, University Science Books,

Washington, W.M. and C.L. Parkinson

3. Physics of Climate, Peisoto and Oort

**AS-514/OS514: Synoptic Meteorology and Monsoon Dynamics**

**[Common syllabus for M Tech Atmospheric/Oceanic Science - II semester]**

Synoptic data and collection: Surface and upper air weather data transmission- Code for inland, coastal and ship stations. Upper air data – PILOT and TEMP codes. Station models, Weather charts.

Air masses and fronts: Air mass production – Classification – Sources of air masses in winter and summer and their modification. Fronts and frontal surfaces – Principal frontal zones –frontogenesis and frontolysis. Extra-tropical cyclones- formation – Life cycle – Structure and movement. Anticyclones and blocking. Heat and cold waves.

Kinematics of the pressure field: Characteristic curves – General expressions for their velocity and acceleration – Movement of troughs, ridges and pressure centres, Intensification and Weakening, deepening and Filling of surface pressure systems.

Kinematics of the wind field: Relation between streamlines and trajectories. Trajectories in moving cyclones and anticyclones. Differential properties of the wind field. Application of geostrophic, gradient, thermal winds, divergence and vertical velocity computations.

Global Jet streams and their characteristics.

Indian monsoon: Land and sea breezes – Definition of monsoon – Synoptic features associated with onset, withdrawal, active and break monsoon situations. Rainfall distribution and rain bearing systems during summer monsoon season - monsoon depression, Mid-tropospheric cyclones and Onset vortex. Winter monsoon.

Seasonal prediction of onset and rainfall of summer monsoon: Multiple Regression models, ARIMA model etc.

Prediction of weather elements: Maximum and minimum temperatures – Fog – Hail storm.

Aviation Meteorology: Meteorological hazards to aviation – Take-off, landing, in-flight, - Icing, turbulence, CAT, SIGMET, visibility and fog.

**Text Books:**

1. Weather analysis and forecasting – Vol.1 & 2 by B. Patterson, Mc Graw Hill Book Company, 1956.

2. Climate and Weather in the Tropics - H. Riehl, Academic Press, INC Ltd., 1979.

3. Climate and circulation of the tropics - S. Hasternath, 1985.

4. Tropical Meteorology – Vol. 1 & 2 by G.C.Asnani, 1993.

5. Atmospheric Circulation Systems - E. Palmen and C.W.Newton, Academic Press, 1969.

6. Monsoon Dynamics - T.N. Krishnamurthi, 1978.

**Reference**:

1. Monsoon meteorology - C.S. Ramage

2. Jet stream meteorology - E.R. Reiter

**AS 515: Remote Sensing and Satellite Meteorology**

Principles of remote sensing, components of a remote sensing system, atmospheric transmission, atmospheric window region and absorption bands.

Black body radiation, the Planck function, non – black bodies, gaseous absorption, scattering, clouds, surface reflection / emission.

Satellite orbits – Newton’s law of motion, Keplarian orbits / laws, orientation in space, orbital elements, Sun Synchronous orbits, Geostationary orbits, polar orbits, low inclination (equatorial) orbits.

Indian remote sensing satellites related to Meteorology and Oceanographic parameters, INSAT, Oceansat, Megha – Tropiques.

Passive and active sensors: principles of observations

Passive: imaging radiometer / sounder / MW radiometer

Active : Scatterometer / Altimeter

Advanced Very High Resolution Radiometer (AVHRR), Advanced microwave scanning radiometer (AMSR), soil moisture and ocean salinity program (SMOS).

Satellite image interpretation and enhancement techniques, cloud type identification, synoptic scale weather systems. Mesoscale weather systems, tropical cyclones, tropical cyclone categorization of different stages, estimation of cyclone intensity using Dvorak’s technique.

Remote sensing of atmospheric variables: The radiative transfer equation and weighting functions , Schwarzchild’s equation and its solution, vertical sounding, Limb sounding, Radio occultation (GPS).

Rainfall estimation using VIS and IR radiometer data

Active and passive microwave sensors and their application for ocean surface winds, sea surface temperature, Rainfall and soil moisture.

Retrieval techniques for SST, Cloud top temperature, temperature and humidity profiles, Cloud motion wind vectors, Radiation budget, Ocean surface winds

Application of satellite data for monitoring south west monsoon – onset of monsoon, active and break cycle, seasonal monsoon rainfall, low frequency oscillations. Drought monitoring through NDVI, aerosol detection and monitoring.

**Reference:**

1. Satellite meteorology – An introduction – S.Q. Kidder and T.H. Vanderhour, academic Press, 1995.
2. Applications with meteorological satellites by W. Paul Menzel, July, 2004.
3. Fundamentals of remote sensing by George Joseph.
4. Satellite Meteorology by Kelkar
5. Introduction to Environmental Remote Sensing – E.C. Barette and L.F. Curtis, John Wiley and Sons, 1987.
6. Remote sensing of atmosphere – J.T. Houghton, F.W. Taylor and C.D. Rodgess, Cambridge University press, 1984.
7. Lecture notes for post graduate CSSTEAP course on Satellite Meteorology and Global Climate, vols 1, 2 and 3. ISRO Publications.

**AS-516: Agricultural Meteorology**

Aim, Scope and Objectives of Agrometeorology; Status of Agrometeorology; Principles of radiation; Thermal conductivity; Dew, frost, fog, mist, haze, thunderstorm and hail. Climatic classifications

Concept of micro-, meso- and macro-meteorology. Micrometerological processes near bare ground and crop surfaces. Roughness length, and zero plane displacement. Temperature, wind and CO2 profiles in crop canopies. Richardson number, Reynolds analogy, exchange coefficients, fluxes of momentum, water vapour, CO2 and heat. Windbreaks and shelterbelts and their effect on modification of microclimate. Spectral properties of vegeta­tion, light interception by crop canopies as influenced by leaf area index, leaf arrangement and leaf transmissibility; extinction coefficient.

Effects of thermal environment on growth and yield of crops. Cardinal temperatures, thermoperiodism, Meteorological factors associ­ated with incidence and development of crop pests and diseases such as rust diseases, potato blight, apple scab, groundnut red hairy caterpillar, Helicoverpa etc. Locust meteorology.

Climatic aspects of animal production and nutrition. Com­fort zones for different species and breeds of animals, Temperature Humidity Indices. Protection of animals from adverse weather and immunity against animal diseases and parasitic afflictions.

Hydrologic cycle and concept of water balance. Energy balance equation and sig­nificance of the components and their estimation. Concepts of evaporation. Evapotranspiration, potential and actual Evapotranspiration. Aerodynamic. eddy correlation, and combination approaches. Bowen ratio method; Thonthwaite and other cli­matic water balance methods. Advantages and limitation of different methods. Drought climatology.

Crop physiology and phenology, crop coefficients: Concepts of mechanistic and deterministic models. General features of dynamical and statistical modelling techniques. Weather data-based and physiology-based approaches to modelling of crop growth and yield. Advantages and limitations of modelling. Climatic change, greenhouse effect, CO increase. global warming, and their impact on agriculture. Physiological stress in crops. Remote sensing applications to Agrometeorology: spectral indices, canopy tempera­ture technique of estimation of Evapotranspiration, crop water stress index and crop stress detection

Principles, exposure conditions and operation of meteorological equipment in agrometeorological observatory; Principles and working of instruments for measurement of solar radiation; direct, diffuse and photosynthetically active radiation; soil heat flux; soil temperature; Weather forecasting and agro-advisories.

**References:**

1. Byers, H.R. 1959. General Meteorology. McGraw-Hill Inc., New York
2. Geiger, R. 1957. The Climate near the ground. Revised Edition. Cambridge, Mass. Harvard University, University Press. p.494
3. Mavi, H.S. 1994. Introduction to Agricultural Meteorology. Oxford & IBH Publishing Pvt. Ltd, New Delhi, p. 281
4. NCERT. 1985. Agrometeorology-A practical manual. NCERT publication.
5. Rao, G.S.L.H.V.P. 2007. Agricultural Meteorology. Second edition. Kerala Agricultural University, Thrissur, p. 326
6. Subrahmanyam, V.P. 1982. Water balance and its applications. Andhra University Press. Waltier, p. 120
7. Varshneya, M.C. and Pillai, P.B. 2006. Textbook of Agricultural Meteorology. Indian Council of Agricultural Research, New Delhi, p. 221
8. WMO. 1972. Agricultural Meteorology. Technical Note No. 310. World Meteorological Organization, Geneva, p. 357

**Practicals**

**AS-517**: **Part A: Synoptic Analysis**

1. Plotting surface and upper air data
2. Analysis of mean climatic data; Pressure, Temperature, Rain Rainy-days, Fog and Thunderstorms representative of winter
3. Analysis of mean climatic data; Pressure, Temperature, Rain, Rainy-days, Fog and thunderstorms representative of summer.
4. Analysis of surface and upper-air charts - Monsoon depressions
5. Analysis of surface and upper-air charts - Tropical Cyclones
6. Analysis of surface and upper-air charts - Western disturbances
7. Analysis of surface and upper-air charts - Break monsoon
8. Analysis of surface and upper-air charts - Active monsoon
9. Analysis of thermodynamic diagram (T- ø diagram)
10. Time and cross sections

**AS-517**: **Part B: Satellite Meteorology**

Analysis of satellite derived products:

1. Cloud characteristics
2. Sea Surface Winds – Cyclones
3. Dvorak Technique - Cyclones
4. Rainfall analysis
5. NDVI - Agromet applications
6. Air - sea fluxes

**AS-518 Part-A: Numerical Weather Prediction**

1. Computation of vorticity using geopotential height
2. Solution of Laplacian
3. Solution of Jacobian
4. Barotropic model
5. Computation of surface fluxes
6. Numerical computation of LCL
7. Numerical computation of moist adiabat
8. Computation of heating rates-Kuo scheme
9. Barotropic instability
10. Baroclinic instability

**AS-518 Part-B: Agricultural Meteorology Computations**

1. Computation of surface fluxes
2. Evaporation and evapotranspiration; Potential evapotranspiration
3. Soil temperature profile; Soil temperature gradients and estimation of soil heat flux
4. Calculation of the bulk density of the soil and soil water holding capacity
5. Computation of water balance – Thornthwaite / FAO models
6. Daily water balance model – irrigation and Analysis of drought through water budget method
7. Flood formulae and envelope curves
8. Length of Growing periods- Crop performance
9. Net radiation –Energy balance components
10. Climatic classification: Agroclimate and agro-ecological zones
11. Estimation of actual evapotranspiration by soil moisture and lysimeteric

**AS-519: Viva Voce**

**III and IV Semesters**

**AS-520: Internship**

**AS-521: Dissertation**

**AS-522: Seminar**

**AS-523: Viva-voce**