INDIA METEOROLOGICAL DEPARTMENT

QUESTION BANK

OF

ADVANCED METEOROLOGICAL TRAINING COURSE (AMTC)

SEMESTER-II EXAMINATION

BASED ON 174-181 BATCHES

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PAPER-II: Numerical Weather Prediction

India Meteorological Department
Meteorological Training Institute
Advanced Meteorological Training Course
SEMESTER- II Final Examination
PAPER-II *Numerical Weather Prediction (NWP)*

1. Fill in the blanks

1. ---------- is an input for storm surge modelling.
2. ---------- truncation has different resolution in zonal and meridional direction.
3. ---------- truncation has uniform resolution in zonal and meridional direction.
4. ---------- type model can be used for explicit forecast of vertical motion.
5. _____ in _____ first recognized the problem of weather forecasting is an IVP.
6. _____ refers to a procedure that adjusts the data at a single time level.
7. _____Jacobian conserves _____ .
8. A hydrostatic model can make a good prediction of ---------- systems.
9. Arakawa Schubert considered entrainment at _____ and detrainment at _____ level.
10. Associated _____Polynomials are _____ harmonics .
11. Back ground field variables and ----------are converted via ---------- operator.
12. Bjerknes in ---------- recognized weather forecasting as an IVP
13. BLUE stands for----------.
14. Bowen ratio in the arid zone is _____ than in grass land.
15. Bowen's ratio is the ratio of _____ to _____.
16. CFL criteria is----------.
17. Checking observations against the observations from neighbouring region is a part of _____ consistency check.
18. Continuity equation represents conservation of ----------.
19. Cressman analysis scheme uses successive _____ method.
20. Cumulus clouds transport _____ _____ _____ _____ and _____ from lower to upper level.

21. Divergence & Vorticity are _____ products where as wind, temperature are _____ products in NWP.
22. Equivalent barotropic model is applied at a level -------- above the ----------.
23. Explicit scheme is solved using---------- method.
24. First successful operational NWP model could forecast ----------.
25. For sub grid scale processes cannot be resolved _____ in GCM.
26. Forecast from the previous model run is used as ---------- in the Data assimilation.
27. Forward difference scheme is an ---------- scheme.
28. Global Data assimilation scheme of NCMRWF is a six hourly _____ data assimilation scheme.
29. Global model identified as T574L64, where T stands for ----------.
30. Ground heat flux during the day time is directed from _____ to _____.
31. Ground heat flux is directed from _____ to _____ during night time.
32. Horizontal consistency check is the checking observations against the observations from _____ region.
33. If number of unknowns are more than the number of equations, such problem is known as _____.
34. If resolution of a model increases the time step will be ----------.
35. If the actual horizontal grid spacing of WRF model is 3 km, the effective horizontal is resolution is _____ than grid spacing but _____ times of the grid distance.
36. In _____ method _____ basis functions are used.
37. In a ---------- data assimilationa ---------- is minimized.
38. In a baroclinic model we divide the atmosphere into ___ layers and quasi geostrophic vorticity equation is used _____ of the two layers.
39. In a Barotropic model -------- & --------- remains conserved.
40. In an equivalent barotropic model wind speed is assumed to _____ with height and direction remain _____ with height.
41. In Arakawa – Shubert's scheme entrainment is used in _____.
42. In Arakawa Schubert scheme more the entrainment _____ is the cloud.
43. In Grell's scheme there is mixing between clouds and environment only at _____ .

44. In IMD, Global data Assimilation (GDAS) cycle runs 4 times a day using NCEP's Grid Point _____ Interepolation scheme.
45. In initialization _____ is eliminated.
46. In Kain Fritsch scheme convection is determined by _____ at a grid point.
47. In Now casting model ----------input is very essential.
48. In optimal interpolation method. Weights are determined from the data on the _____ of the parameter being analyzed.
49. In sigma co-ordinate the sigma value at the surface is ----------.
50. In the climate model _____ _____ plays most important role along with initial condition.
51. Manabe assumed that when the saturation is reached the temperature distribution is adjusted instantaneously under the constraint _____.
52. Manabe's scheme is a _____ scheme.
53. Mathematically formula of CFL criteria can be written as ----------.
54. Mesoscale models are ---------- in nature.
55. Meteorological observations are transmitted from one part of the globe to other via Global _____ System of WMO.
56. Moving nest configuration is used in case of ----------.
57. Nonlinear equations are _____ to initial conditions.
58. Nudging method for assimilation are not generally used for _____ scale data assimilation scheme .
59. Numerical method admits of _____ solutions for _____advection equation.
60. NWP models need a _____ spaced and balanced initial condition at starting time.
61. NWP models run on multiprocessors using …… programming.
62. Observations received after data _____ time are generally has no impact on the quality of objective analysis.
63. One limitation in applying NWP in practice is _____.
64. Optimal interpolation can provide initial condition to the model after----------
65. Parameterization is used for _____ processes.
66. Post processing of model initial fields at the standard pressure level is called ----------field at the given observation time.
67. Satellite instruments measure the _____ that reaches the top of the atmosphere.

68. Satellite data retrieval is a/an---------- problem.
69. Satellite instruments measure the radiances that reaches the ____ of the atmosphere.
70. Smallest feature that can be resolved by observations has a scale ---------- the distance between the observing sites.
71. statistics (MOS) approach is ----------.
72. Sub grid scale processes are _____ in a numerical model.
73. Surface energy budget is composed of four terms namely, Net radiation, _____, _____ and _____.
74. The approximate horizontal and vertical resolution of T1534L64 GFS model is _____ km and _____ levels.
75. The cloud-resolving model uses additional equation for _____ _____ to represent the convective processes.
76. The concept of mixing line is used in _____ scheme.
77. The effect of trapped gravity wave on the mean flow is to_____.
78. The elevation preserving topography is called _____
79. The error arises from the finite difference approximations of differential equations are commonly known as ----------.
80. The largest impact of using parameterization schemes is usually on ----------
81. The latent heat released due to condensation of water vapour _____ the surrounding.
82. The maximum peak storm surge usually appears to the _____ of the landfall in the Northern Hemisphere.
83. The most common statistical techniques that are used to develop the relationships in model output.
84. The name of the popular binary code for transmitting observations is _____.
85. The NWP models in IMD are run on _____ computing environment of high _____ computing systems (HPCS).
86. The Purpose of NWP model forecast verification is to provide an …… measure of model skill.
87. The surface in σ coordinate system follow _____.
88. The term objective analysis in meteorology means the process of _____ observed meteorological variables to _____.

89. The use of _____ _____ system is necessary to counter the issue of uncertainty in predicting extreme weather events
90. Thermodynamic energy equation is a ---------- equation.
91. Threat score is an entity for ---------- verification of forecast rainfall.
92. To fit a nth degree polynomial at least _____ observations are required.
93. Turbulence or individual cumulus cells whose _____ are called dynamically small system.
94. Turbulent Kinetic Energy (TKE) parameterization scheme is used for parameterization of ---------- processes.
95. Type of forecast generated using WDSSII is ----- ----------
96. Type of forecast generated using ARPS is ----------
97. U momentum equation is a ---------- equation.
98. Vertical hybrid coordinate of GFS T1534L64 has ---------- vertical coordinate at the bottom of the model.
99. Vertical hybrid coordinate of GFS T1534L64 has ---------- coordinate at the bottom and ---------- coordinate at the top of the model.
100. Vertical hybrid coordinate of GFS T574L64 has ---------- coordinate at the bottom of the model.
101. Wallace etal. (1983) added sub grid scale _____ to the grid scale _____ over a terrain to get envelope orography.
102. When there is no synoptic scale low level convergence, only _____ can form above the _____.
103. WRF model run uses initial and boundary conditions from ----------model

2. State true or false with brief justification

1. σ is better than p as a vertical co-ordinate to resolve the issue of LBC representation.
2. 2-layer baroclinic model uses vertical staggered grid.
3. 4DVAR assimilation technique does not need initialization.
4. A stable solution for linear advection model requires $c\frac{\partial t}{\partial x} > 1$.
5. Aircraft observations are generally asynoptic observations.
6. An atmospheric column with more moisture in the top and drier layer below is unstable.

7. An initialization procedure is used to create balanced initial conditions for the model forecast.
8. An unsaturated parcel follows a dry adiabatic lapse rate. (Yes/No)
9. Anthes gave an empirical formula for moistening parameter in Kuo's scheme.
10. Anthropogenic emission is one component of Hydrological model.
11. Arakawa Schubert assumed normalized mass flux as a function of entrainment.
12. Arakawa Schubert defined cloud work function as a function of entrainment rate.
13. Arakawa Schubert Scheme is a deep layer control and instability control scheme.
14. Arakawa-Schubert scheme is a dynamic scheme.
15. Arakawa-Schubert scheme is based on quasi-equilibrium approximation.
16. As a vertical co-ordinate 'p' is better than 'σ'.
17. Better initial conditions improve forecast skill of NWP model
18. Betts-Miller scheme is an adjustment scheme.
19. BIAS < 1 indicates over prediction by a forecaster.
20. BUFR code is an ASCII code.
21. CFL criteria in terms of resolution and time step of integration is not required for a balanced NWP model.
22. Cloudiness has a large influence on solar radiation.
23. Cloudy nights are warmer while the cloudy days are cooler.
24. Coupled models are used for Nowcasting.
25. Cumulus parameterization can work in a dry atmosphere. (Yes/No)
26. Cumulus parameterization only deals with cumulus cloud. (Yes/No)
27. Cumulus parameterization works well for very high resolution (~5km) model. (Yes/No)
28. Downstream of mountain ranges gravity wave drag has great impact on lee side trough.
29. EPS is used for deterministic forecasts.
30. Equivalent Barotropic model is applied at the level of non-divergence.
31. Equivalent barotropic model is not either a barotropic or a baroclinic model.
32. Error covariance matrix is a symmetric matrix.
33. Extended range forecast is an initial value problem.
34. Finite element method is free from non-linear instability.
35. Fluxes associated with land surface processes are net radiation, sensible heat flux, latent heat flux and ground heat flux.
36. For a single scalar field objective analysis, SCM is better than OI method.

37. For Integrated Agro Advisory Service of India, IMD implemented multi-model ensemble based district level quantitative forecasts**.** **[True / False]**
38. Forecasting weather at a place is an initial value problem.
39. GFS is a non-hydrostatic model
40. Global data assimilation system at NCMRWF runs once a day.
41. In a dynamic initialization model is kept static
42. In a equivalent barotropic model thermal wind has the same direction as that of mean wind
43. In Arakawa Schubert Scheme, lesser the entrainment deeper will be the cloud depth.
44. In Arakawa-Schubert scheme lower the entrainment shallower will be the cloud.
45. In Betts Miller scheme, convective precipitation is determined by difference in humidity before and after the occurrence of convection.
46. In general in-situ observations have large areal coverage compared to satellite observations.
47. In Grell's scheme convective precipitation is defined as function of cloud base mass flux and the shear of the horizontal wind in the layer between cloud base and cloud top.
48. In operational NWP centre data-cut off time is generally very large (~24-48 hours)
49. In some cases, data assimilation can lead to the rejection of good observation or acceptance of the false observation.
50. In σ – co-ordinate lower boundary condition is represented in a better way than in pressure co-ordinate.
51. Kuo assumed conditionally unstable atmosphere and large scale moisture convergence.
52. Kuo assumed the atmosphere to be conditionally unstable.
53. Kuo did not use entrainment in his parameterization scheme.
54. Kuo in his parameterization scheme assumed large scale moisture convergence and conditionally unstable atmosphere.
55. KUO parameterization scheme is a ass flux based scheme.
56. Kuo scheme considers the entrainment and detarinment within cloud.
57. Kuo scheme does not consider the surface wind drag.
58. Kuo scheme of convective parameterization is a mass flux scheme.
59. LCL is considered to be the base of the cloud. (Yes/No)
60. Leap frog scheme is an absolutely stable scheme.
61. Leap frog scheme is an absolutely stable scheme.
62. Manabe's scheme is a convective adjustment scheme.

63. Maximum likelihood estimate and optimally interpolated estimate are different.
64. Meso-scale models are non-hydrostatic in nature.
65. Model integration time step in WRF (9km) is smaller than GFS(12km) not only due to smaller horizontal grid spacing
66. Model Output Statistics (MOS) is superior to Perfect Prognostic Model (PPM)
67. Non-divergent barotropic model is a kinetic energy conserving model.
68. O. I method is better than Cressman method.
69. Observing System Simulation Experiments are carried out to assess the impact of future observations on analysis-forecast system.
70. One of the assumptions in Kuo's scheme is large scale moisture convergence.
71. Operational 'Warning Decision Support Integrated Information (WDSS-II)' being used in IMD can not process RADAR data. [**True** / **False]**
72. Optimally interpolated estimate of a scalar field is the best estimate.
73. Perfect Prognostic Method (PPM) is superior to Model Output Statistics (MOS).
74. Physical initialization aims at initializing the rotational wind.
75. Pilot Balloon observations are remote sensing observations.
76. Radar could not detect fog?
77. Radar is passive remote sensor?
78. Radiosonde observations are remotely sensed observations.
79. Rainfall and QPF are used as inputs in hydro-logical modelling.
80. Satellite observations are generally synoptic observations.
81. Sea bed friction is the only driving force to generate storm surge
82. Semi implicit time differencing scheme is stable.
83. Short range forecasting is a boundary value problem.
84. Spectral model is better for a limited region than over the entrie globe.
85. Sub-grud scale process needs to be parameterized.
86. T128 model has a better horizontal resolution than R 200 model.
87. Temperature within the cloud is warmer than temperature of the surrounding environment at the same level.
88. The primitive equation system is a closed system. [**True** / **False**]
89. The GFST1534L64 is spectral model and has equal grid distances at all latitude circles.
90. The invers Froude number(Fr) $\geq$ 1 the air flows around the obstacle.

91. The model hindcasts are not necessary in the extended range prediction system.
92. The time step in model integration is independent of model resolution.
93. The time step in model integration is independent of model resolution.
94. The vertical pressure coordinate used in WRF model
95. The vertical velocity is not a prognostic variable in the GFS model of IMD.
96. The WRF model uses Eta co-ordinate as its vertical co-ordinate for the representation of the model state variables over complex terrain.
97. Time step of integration of GFS T574L64 = 5 Minutes.
98. Tornado can be simulated in a meso-scale model .
99. Trapezoidal semi-implicit scheme is an absolutely stable scheme.
100. Two level baroclinic model was not very successful in forecasting.
101. Using barotropic model moderately successful forecast could be made for 500 hPa level.
102. Vortex initialization is essential for forecasting a thunderstorm.
103. Vorticity is a direct product of WRF model
104. WDSS-II (Warning Decision Support System–Integrated Information) is a tool to use Satellite data for Nowcasting.
105. Wein's displacement may be used as an observational operator for converting observed irradiance to temperature field.
106. When Brunt Vaisala frequency $N^2<0$ air can easily flow over any obstacle.
107. When we consider visible light for radiative transfer over earth surface the re-emission is negligible.
108. Whether or not the air will flow over or around on obstacle of height h depends on the value of inverse Froude number.
109. WRF model is a hydrostatic model to predict thunderstorm.

3. Answer any one.

1. What is data assimilation? And why we need it, give few examples?
2. What are the importances of satellite sounding channels?
3. Write a short note on atmospheric data assimilation.
4. What are the advantages and limitations of satellite observations in context of operational atmospheric data assimilation?
5. Write the expression of convective mass flux
6. Write the expression of column moisture transport in KUO's scheme

7. Define parameterization
8. Explain with schematic the quasi-equilibrium framework of Arkawa-Schubert
9. Explain with schematic KUO's closure
10. Explain with schematic the closure of Arakawa-Schubert scheme
11. Show that optimally interpolated estimate is same as maximum likelihood estimate.
12. Explain with schematic diagram ocean and land processes and their interaction. Also state which processes to be parameterized.
13. Derive Beer's law of radiativetransfer. What modification can be made for infrared light in the atmosphere.
14. Discuss about compatibility of a finite difference scheme and convergence of a Numerical solution of an IVP to its analytical solution. Discuss the necessary and sufficient condition for convergence of a numerical solution of an IVP to its analytical solution.
15. Name different quality control checks used in NWP.
16. Define cost function? Write down the expression of cost function for a single scalar field 'Z' and hence or otherwise obtain the analyzed value of a scalar field Z. (2+2+6=10)
17. Discuss different major finite difference schemes. Define an explicit and implicit time differencing scheme. For the linear advection model, show that Trapezoidal Semi-implicit scheme is unconditionally stable. (3+2+5=10)
18. Define consistency or compatibility of a finite difference scheme. Define convergence of a numerical solution. State Lax equivalence theorem. Using a one-dimensional non-linear advection equation, discuss Aliasing and non-linear instability. Define Arakawa-C grid, Arakawa Jacobian and discuss its importance. (1+1+2+3+3=10).
19. What are the different components of data assimilation? Discuss each component.
20. Write the difference between 3D-VAR and 4D-VAR methods for data assimilation.
21. Briefly explain with schematic diagram the concept of quasi equilibrium of Arakawa-Schubert Cumulus scheme
22. Briefly explain with schematic diagram the principle of KUO scheme.
23. Interaction of various land and ocean processes with the help of a schematic diagram.
24. Define and explain compatibility of a FDS. Define & explain convergence of a numerical solution. State & explain equivalence theorem. (1+1+2=4)
25. Define CFL criteria for stability of numerical solution of linear advection equation.
26. write brief note on use of finite element method in NWP.

27. What is barotropic model ? Obtain prognostic equation for the barotropic model
28. What is σ coordinate system ? What are the advantages of this coordinate system ? Obtain the transformation relation between p-coordinate and σ coordinate.
29. Explain Arakawa Schubert convective scheme. Bring out clearly all assumption and also include the concept of mass flux as well as cloud work function.
30. Describe Kuo's scheme including modification by Anthes.
31. Ensemble forecasts
32. Why do we need model output statistics (MOS)? Explain the most important issues facing both the development and operational use of MOS?
33. Write a short note on NWP model forecast verification. Explain the techniques and data sources to represent atmospheric truth for forecast verification.
34. Orographic forcing and gravity wave drag.
35. Explain Kuo's convective parameterization scheme. How Kuo and Anthes modified the scheme?
36. What are subgrid scale processes? Why convective parameterization is needed? Explain Manabe's parameterization scheme.
37. Explain in brief the Arakawa-Schubert scheme. Include the concept of work function used in the scheme.
38. Write a step by step algorithm for prediction of geopotential field using a non-divergent barotropic model.
39. Obtain the model equations for a 2 layer baroclinic model.
40. What is meant by variational data assimilation? Why variation technique is best technique for data assimilation? Discuss about 4-DVAR data assimilation technique.
41. Obtain the model equation for a non-divergent barotropic model. Discuss how this model can be used to predict 500 hPa geopotential height field.
42. Write down the linear advection equation. Discuss the stability of numerical solution of this equation. Hence obtain CFL criteria for the same.
43. Obtain the optimally interpolated estimate of a field variable from its two independent unbiased estimates. Write down the expression for cost function.
44. Obtain the model equation for a 2 layer baroclinic model. Discuss how this model can be used to predict mean & thermal field.

45. Define compatibility of a finite difference scheme and convergence & stability of numerical solution. Discuss the stability of Trapezoidal semi-implicit scheme.
46. Show that optimally interpolated estimate is same as maximum likelihood estimate.
47. Derive CFL criteria.
48. Discuss about compatibility of a finite difference scheme and convergence of a numerical solution of an IVP to its analytical solution.
49. Discuss the necessary and sufficient condition for convergence of a numerical solution of an IVP to its analytical solution
50. What is a barotropic model? Obtain the prognostic equation for a barotropic model.
51. What is the r coordinate system? What are the advantages of this coordinate system? Obtain the transformation relation between ρ-coordinate and σ-coordinate.
52. What are the different physical processes that play major role in numerical modeling and what are the different schemes to parameterize these processes.
53. Initilization of tropical cyclone in NWP modeling.
54. With schematic diagram explain various fluxes in land surface processes.
55. Explain interactions of Atmosphere-ocean processes.
56. "Quasi-equilibrium" is it a closure or a trigger?
57. What is meant by Convective mass flux at cloud base?
58. What is the physical meaning of "cloud work function"?
59. Write the expression of precipitation computation in KUO scheme. b) Why is the Betts-Miller is called an adjustment scheme? Briefly explain
60. Why does the quasi-equilibrium theory fail at high resolution?
61. Why does the Kain-Fritsch scheme work better for higher resolution (~25km) model?
62. Write short notes on assimilation window and data-cut off in context of data assimilation.
63. Name different quality control checks used in operational NWP centre
64. Write down the mathematical expression of cost function [J(x)] for 4D-VAR system and explain each terms.
65. Briefly explain OSSE and the advantages vis-à-vis limitations of satellite observations in context of operational atmospheric data assimilation.

A a) Brier score (BS) and Brier skill score (BSS) b) Systematic Error and Bias Correction techniques B c) Differences between weather and Climate models d) Steps of vortex initialization in HWRF model e) Spin up time of NWP model

4. Describe the following :

1. Global Forecast System of IMD
2. Multi-Model Ensemble Forecast
3. Hurricane WRF
4. Write short notes on observation operator in context of data assimilation.
5. Write a short note on land data assimilation.
6. Major steps involved in operational GFS in IMD.
7. Briefly describe operational storm surge modeling in IMD.
8. What are the Sources of Error in NWP Forecasts and explain intrinsic predictability limitations.
9. Verification of probability forecast. Brier Score and Brier Skill Score.
10. What is data assimilation? Name few popular objective analysis methods/procedures and describe any one of those methods.
11. What is cost/objective function in context of data assimilation? Write down the mathematical expression of cost function [J(x)] for 4D-VAR and explain each terms.

5. Write short notes

1. Brier Score and Brier Skill Score
2. Compare grid point model and spectral model
3. Cresman's objective analysis technique
4. Differences between static and dynamic initialization
5. Dynamic initialization
6. Ensemble forecasting
7. Initialization (Bogussing & Relocation) of Tropical Cyclones in Numerical Prediction Systems
8. Initialization technique
9. Interpretation and application of model outputs : vorticity advection and thermal advection.
10. Physical initialization

11. Primitive equation model
12. TS and ETS scores of forecast verification
13. Two layer baroclinic model
14. Variational data assimilation