

Candidates are admitted to the examination room ten minutes before the start of the examination. On admission to the examination room, you are permitted to acquaint yourself with the instructions below and to read the question paper.

Do not write anything until the invigilator informs you that you may start the examination. You will be given five minutes at the end of the examination to complete the front of any answer books used.

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January 2013

MTMA39

Answer Book  
Data Sheet  
Additional sheet for question 2  
Any bilingual English language dictionary permitted  
Only Casio-fx83 calculators are permitted

UNIVERSITY OF READING

Operational Forecasting Systems and Applications (MTMA39)

Two hours

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Answer **ANY TWO** questions

The marks for the individual components of each question are given in [ ] brackets. The total mark for the paper is 100.

1. Most operational global NWP models take longer to run their data assimilation cycle than they do to actually produce the forecast once the initial conditions have been set. By considering the nature of atmospheric predictability, discuss why operational forecasting centres spend so much computing time (and therefore money) on setting the initial conditions for their forecasts. Include in your answer a brief description of the basic concept behind data assimilation.

[7 marks]

- (b) 4D-VAR data assimilation is a method used by several operational forecasting centres to set the initial conditions for NWP forecasts. Describe briefly how the process of 4D-VAR works, both in terms of the impact of single observations on the model state, and in terms of the impact of many observations on the model trajectory through the “assimilation window”. Use a sketch to illustrate your answer.

[19 marks]

State explicitly the factors that make up the cost function which 4D-VAR attempts to minimize.

[6 marks]

- (c) Name 4 sources of potential predictability for seasonal (i.e. up to 3 months) forecasts.

[8 marks]

What modifications would need to be made to a short-range NWP forecast model in order to convert it into a model suitable for seasonal range prediction?

[10 marks]

2.

- (a) Describe the ECMWF ensemble system. You should describe the method used to perturb the initial conditions, the number of ensemble members and the resolution of the ensemble members.

[10 marks]

Describe how an ensemble of forecasts can be used to generate probability forecasts. State the two major assumptions that need to be made in order to generate probability forecasts from an ensemble.

[3 marks]

- (b) Two building companies in Reading base their decisions on whether to hire equipment on probability forecasts of the weather for the next day.

Company A hires a small cement mixer at a cost of £100 per day which they can only use if there is no rain. They earn £500 per day if they are able to use the mixer.

Company B hires a mobile crane at a cost of £1000 per day which they can only use if the wind is less than 15 knots. They earn £2500 per day if they are able to use the crane.

On the basis of this information, at what probability levels in the forecast for the particular weather conditions of concern should the two companies hire this equipment if they want to make a profit? Show your working.

[6 marks]

- (c) The table *in the additional sheet* shows the forecast probabilities for the occurrence of precipitation of greater than 1mm per day in London from 6000 forecasts issued by a particular weather forecast provider, together with the observed frequency of rain at each forecast probability level.

Given the data in the table, fill in the missing data for the "Perfect Forecast Frequency" column.

[5 marks]

Using the blank grid provided with this exam paper, draw a reliability diagram for these data, showing the observed frequency of rain (in percentage terms) against the forecast probability, also in percentage terms. Ensure that you label your axes.

[12 marks]

State whether these forecasts are *under-confident* or *over-confident*. Briefly explain the reason for your answer.

[5 marks]

Indicate on the diagram the area that equates to the reliability of the forecasts.

[4 marks]

If the *climatological* occurrence of rain greater than 1mm per day in London is 20%, use your reliability diagram to calculate the *resolution* of *perfect* probability forecasts.

[5 marks]

- 3.(a) The equation below is the momentum equation for motion in the y-direction.

$$\frac{dv}{dt} + 2\Omega u \sin\phi + \frac{vw}{r} + \frac{u^2 \tan\phi}{r} = -\frac{1}{\rho} \frac{\partial p}{\partial y} + F_y$$

Explain the physical meaning of all 6 terms in this equation.

[10 marks]

- (b) Several of the dynamical equations which form the core of an NWP model include source and sink terms – for momentum, heat and moisture.

Explain briefly the method (parametrization) that is used in NWP models in order to quantify these sources and sinks.

Include in your answer a brief discussion of the following points;

- The typical spatial scales of the physical processes which act as sources and sinks.
- The methods used to calculate the effect of these processes on the grid-box variables without explicitly representing them in the model.

[8 marks]

List 5 physical mechanisms that could act as sources or sinks of either momentum, heat or moisture in the dynamical equations. For each mechanism state whether it would be a source/sink of momentum, heat or moisture (*Hint: some mechanisms may be sinks or sources of more than one of these quantities*).

[15 marks]

- (c) A National Meteorological Agency has an operational global NWP model with a grid-spacing of approximately 40km. The centre decides to implement a regional model over a small domain covering just its own country together with a small surrounding area. The grid-spacing of this model will be 1km. The Agency wishes to use the global model code as the basis for the regional model.

With particular consideration of the physical parametrizations and boundary conditions, discuss what modifications would need to be made to the global model in order to convert it into a regional model with a 1km grid spacing.

Your answer should include;

- A consideration of which parametrizations may need modifying to be appropriate at the new grid-scale.
- A description of how the position of the model boundaries should be chosen.
- A brief discussion of how information from the driving model and the regional model should be dealt with at the boundaries.

[17 marks]

[End of Question paper]