On admission to the examination room, you should acquaint yourself with the instructions below. You must listen carefully to all instructions given by the invigilators. You may read the question paper, but must 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.

DO NOT REMOVE THIS QUESTION PAPER FROM THE EXAM ROOM.

January 2016 **MTMA39 2015/16 A001**

Answer Book
Data Sheet

Any bilingual English language dictionary permitted
Any non-porgrammable calculator permitted

UNIVERSITY OF READING

Operational Forecasting Systems and Applications (MTMA39)

Two hours

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. (a) Discuss briefly why weather forecasts are subject to a "predictability limit" beyond which it is not possible to make deterministic forecasts. Your answer should include a definition of the term "deterministic" and an estimate in days of the predictability limit of a global operational NWP system.

[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.

[22 marks]

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

[6 marks]

(c) The UK Met Office runs a regional NWP model called the UKV, which covers a domain shown in figure 1. It runs forecasts 4 times a day out to T+36.

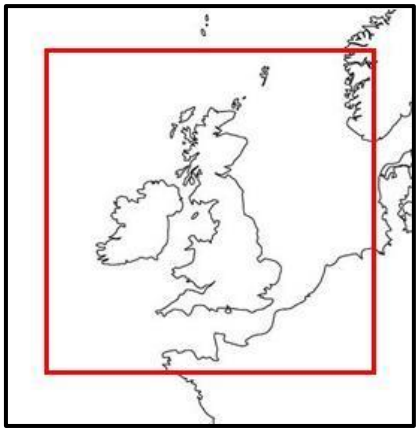

Figure 1. *The domain of the Met Office UKV model is shown by the red outline.*

Explain why this forecast model only runs out to T+36 and describe how the conditions at the boundaries are handled in order to allow weather from outside this domain to influence the forecast over the UK.

[10 marks]

The grid size of the UKV model is 1.5km x 1.5km across most of the domain. Discuss briefly the implications of this grid-box size on the choice of parametrization schemes within this model.

[5 marks]

2.
(a)

The equation for the rate of change of zonal velocity (u) is shown below, where the symbols all have their usual meteorological meanings

$$\frac{Du}{Dt} - 2\Omega v sin\phi + 2\Omega w cos\phi + \frac{uw}{r} - \frac{uvtan\phi}{r} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + F_x$$

(1) (2) (3) (4) (5) (6) (7)

(i) Which fundamental physical principle is this equation based upon?

[3 marks]

(ii) What is the physical meaning of each of the terms numbered 2 to 7? For each term state whether it represents a real force or whether it is an apparent force, present to account for the nature of the frame of reference in which the physical principle is being applied.

[18 marks]

(b) Describe in very simple terms how horizontal gradients of quantities such as pressure or temperature are calculated on a regular numerical grid.

[4 marks]

In such a model, what would the cost be, in computing terms, if the grid length was halved? Give reasons for your answer.

[3 marks]

(c) Several institutions run NWP models to produce seasonal range forecasts.
What modifications would need to be made to a global NWP model designed for forecasts out to 10 days in order to make it suitable to produce seasonal forecasts?

[10 marks]

By considering sources of seasonal predictability, name two geographical regions where you would expect seasonal forecasts to have a degree of skill. You should state in your answer the season in which this skill would be a maximum and the particular weather variable or variables that would be affected. You should also discuss briefly the physical mechanism or mechanisms that might lead to this skill.

[12 marks]

3.(a) Various meteorological agencies run numerical models which have as their input the output from an NWP model. One such model might be a road surface temperature model for provision of information on road icing for transport authorities.
List 3 *other* types of model that correspond to this class of models. State briefly what variables each model is designed to predict and what type of customer would be interested in the output from these models.

[9 marks]

For the road surface temperature model example mentioned above, what are the various elements needed to build such a model?
How might data assimilation be used with such a model to improve and update the forecasts of road surface temperature?

[10 marks]

(b) Many weather forecasts consist of a prediction of whether a particular event will occur or not (yes/no forecasts).

Draw and label a 2x2 contingency table which could be used in the verification of this type of forecast.
Using your table, state how the following quantities would be calculated .

(i) Hit Rate (HR)
(ii) False Alarm Rate (FAR)
(iii) Frequency Bias
(iv) Critical Success Index (CSI)

[12 marks]

A major supermarket chain uses probability forecasts to help with stock control. In the summer they are particularly interested in periods of warm, dry weather during which they know they will sell large quantities of ice-cream and barbecue related products.

They know that if the maximum temperature exceeds 20°C and it remains dry over a weekend they will make an additional £100K on these products as long as they have them in stock, which costs them £40K extra.
They pay a provider for a forecast of the probability of the maximum

temperature exceeding 20°C and the weather remaining dry for the coming weekend. This forecast is issued to them on Monday morning of each week, giving them enough time to stock up on the relevant products before the weekend.
If the forecasts are unbiased, at what probability level of the weather being good should they take action and buy in extra stock? Explain the reasoning behind your answer.

[6 marks]

(c) Explain briefly the reasons for using ensemble forecasting methods. Include in your discussion 3 major advantages of using ensemble methods over running a single NWP forecast.

[7 marks]

Describe the ECMWF Ensemble Prediction System (EPS). You should list the number of ensemble members, comment on the resolution of those members and state the method used to generate the perturbations to the initial conditions.

[7 marks]

[End of Question paper]