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.

January 2014 **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

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) In order to set the initial conditions for numerical weather prediction, a numerical model requires a *first guess* of the atmospheric conditions at the initial time of the forecast (T+0), prior to the use of observational data in the data assimilation process.

State briefly how this first guess of the atmospheric state is obtained.

[4 marks]

Describe how the process of *4D variational data assimilation* (4D-VAR) works to modify the first guess into a more accurate representation of the initial state of the atmosphere for the forecast. Your answer should include a brief description of all the steps in the 4D-VAR process and a consideration of how these steps lead to the best possible specification of the initial conditions. You may wish to use a diagram to illustrate your answer.

[20 marks]

(b) Observations of the vertical distribution of atmospheric temperature are important for setting the initial conditions for a numerical weather forecast. *Satellite retrievals* and *radiosonde soundings* are two different ways of obtaining this information.

Discuss the relative merits of these two methods for obtaining temperature data for the initialization of a numerical weather forecast. Your discussion should consider;
(i) the methods used for obtaining temperature data in both cases,
(ii) spatial coverage,
(iii) vertical resolution

[10 marks]

(c) Predictability for deterministic weather forecasts is considered to have an upper limit of about 14 days. Despite this limit, forecasting agencies routinely issue NWP based predictions for longer time ranges (i.e. months to seasons).

Discuss briefly how NWP forecasts are made and presented for these longer time ranges in order to overcome the restrictions of the deterministic limit. Your answer should include some consideration of where the predictability at these ranges comes from, and how models must be modified in order to make use of this predictability.

[16 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)

Which fundamental physical principle is this equation based upon?

[3 marks]

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 present to account for the nature of the frame of reference in which the physical principle is being applied.

[18 marks]

The equation for the rate of change of vertical velocity (*w*) is shown below, where again all the symbols have their usual meteorological meanings.

$$\frac{dw}{dt} - \frac{u^2 + v^2}{r} - 2\Omega u cos\phi = -\frac{1}{\rho}\frac{dp}{dz} - g$$

State what is the *hydrostatic approximation* to this equation and indicate which terms are neglected if this approximation is made.

[6 marks]

Describe briefly what is meant by parametrization in the context of NWP. List 4 physical processes which must be dealt with through the use of parametrization in NWP models.

[13 marks]

(b) Discuss, using a diagram to illustrate your points, why the horizontal grid-length in an NWP model is not the same thing as the resolution of the model. For a sinusoidal weather feature such as a ridge and trough in the pressure field, state how many grid-points would be needed across the feature in order for it to be considered resolved by the model grid.

[10 marks]

3.(a) The UK Met Office runs a global model forecast out to 6 days ahead and a limited domain model forecast over the UK and surrounding area out to 36 hours ahead. What is the main reason why the limited domain forecast time range is so much shorter than the global model forecast time range?

[5 marks]

In a limited domain NWP model, describe how conditions at the boundaries of the domain are dealt with in order to;
(i) allow information to propagate into the domain from outside
(ii) prevent discontinuities at the boundaries and atmospheric features reflecting off the boundaries.

[10 marks]

(b) For weather forecasts which predict whether a particular event will occur or not (e.g. rain or no rain), show how a 2x2 contingency table can be used to verify these forecasts.

Your answer should include a verbal definition and an equation for each of the following terms
(i) Hit Rate
(ii) False Alarm Rate
(iii) Frequency Bias

[15 marks]

(c) For a probability forecasting system, the Brier score is often used as a verification method.

Write down the equation for the Brier score, defining all the terms in the equation.

[5 marks]

What will the Brier Score be for the following 2 forecasting systems?

(i) A forecasting system that *always* correctly predicts the occurrence of a particular event with a probability of 100% when the event occurs and a probability of 0% when it does not occur (i.e. a perfect forecast system),

(ii) A forecasting system that *always* predicts the occurrence of a particular event with a probability of 50%. (*note: this will be independent of whether the event occurs or not for any given forecast*).

[6 marks]

Based on the Brier scores you have calculated above, if you were a potential customer for a probability forecasting system, what range of values of Brier score would you want that system to be achieving in order to make it worthwhile using? Explain the reasons for your answer.

[6 marks]

Describe how the Brier Score can be converted to a *skill score*, comparing the skill of the forecast system to a forecast based on the *climatological frequency* of the particular event being forecast. How would you interpret this skill score?

[3 marks]

[End of Question paper]