You are allowed ten minutes before the start of the examination 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 2009

Answer Book
Data Sheet

Any bilingual English language dictionary permitted
Calculators and programmable calculators are permitted

UNIVERSITY OF READING

Final Examination for MSc

Course in Applied Meteorology

MTMA39

Operational Forecasting Systems and Applications

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) Weather forecasting can be described as an “Initial Value Problem”. Explain briefly what is meant by this term and hence explain why the careful use of observational data to set the initial conditions for a weather forecast is such an important part of the forecasting process. [5 marks]

(b) List 5 different sources of observational data that are routinely used in the generation of initial conditions for weather forecasts. For each of these sources state briefly what you believe to be their main advantage and disadvantage. [15 marks]

(c) As well as observational data, the short range forecast from the previous run of an NWP model is also used to provide the “background field” with which the observations are blended to produce the initial conditions.

Approximately what proportion of the information in the initial conditions typically comes from the background field and what proportion comes from the observations?

[3 marks]

Describe the “4D-VAR” process by which the observations and the background field are combined to produce the initial conditions for the forecast. You should include some discussion on how sources of error are taken into account. Also explain how the process ensures that inserting the observational data does not result in an atmospheric state which is unbalanced and hence may be subject to unrealistically large oscillations during the initial stage of the forecast as the model attempts to restore a balanced state.

[27 marks]

2.

(a) All NWP models are based on solving the "dynamical equations" which govern the evolution of the state of the atmosphere with time. Shown below is the equation which describes the evolution of the zonal component of the wind.

$$\frac{du}{dt} - 2\Omega v \sin\phi + 2\Omega w \cos\phi + \frac{uw}{r} - \frac{uv\tan\phi}{r} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + F_x$$

State briefly what each of the terms in this equation is representing.

Apart from the 3 equations which describe the time evolution of the *u*,*v* and *w* components of the wind, what other equations are included in the dynamical equation set of an NWP model? [15 marks]

(b) The dynamical equations form an *almost* complete set of equations for predicting how the state of the atmosphere will evolve in time. What terms appear in the equations which mean that the equation set is not completely closed? How are these terms dealt with within an NWP model? [5 marks]

(c) A particular NWP forecast model running over a land region has as its initial conditions an initially cloudless, windless summer morning. By considering the physical processes involved and starting at sunrise, describe how the various *parameterization schemes* processes in the model would work together to produce a forecast of the surface air temperature through the course of the day. You may assume that the wind remains calm throughout the day. [25 marks]

(d) The grid-spacing of an NWP model is often referred to as the model *resolution*. Explain why this is misleading, as a model with a grid-spacing of Δx will not be able to resolve weather features which have a horizontal scale of Δx. [5 marks]

3.

(a) A single run of an NWP model can only provide one "deterministic" forecast of the state of the atmosphere. Describe, using diagrams where appropriate, how the forecasting technique of *ensemble prediction* allows quantitative assessments of the *probability* of a particular forecast outcome to be made. What is the main factor that would prevent the use of this method by an operational forecasting centre? [20 marks]

(b) Several forecasting centres around the world produce monthly or seasonal forecasts. Given that the *predictability limit* for deterministic weather forecasting is generally thought to be somewhere around 2 weeks, what factors in the Earth-Atmosphere system would provide some degree of predictability to these longer period forecasts?
By considering these factors, describe how an NWP model which is used to provide forecasts for periods of 10 days or less would need to be adapted to produce longer range predictions. State briefly in which geographical regions you would expect there to be the best chance of seasonal forecasts having useful forecast skill.
[20 marks]

(c) One measure of forecast model accuracy might be to calculate the *root-mean-square error* (RMSE) of a particular field such as surface pressure over a particular region such as the northern hemisphere, i.e.

$$RMSE = \sqrt{\sum_{i=1}^{n}\left(x_{forecast} - x_{truth}\right)^2}$$

Show how this measure might be used to calculate a *skill score* for the forecasts, considering *persistence* to be a forecast with zero skill.
Explain what is meant by persistence in this case. In what circumstances might the use of persistence as a measure of zero skill actually lead to misleadingly poor skill scores being calculated for an NWP forecast? [10 marks]

(End of Question Paper)