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.

April 2011

Answer Book
General Data Sheet
Figure 1
Tephigram
Any bilingual English language dictionary permitted
Only Casio-fx83 calculators are permitted

THE UNIVERSITY OF READING

MSc Examination for Courses in Sciences

Tropical Weather Systems

MTMG19

2 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) When studying large-scale circulation patterns in the Tropics, the Shallow Water equations (SWE's) provide a good description of the flow that develops as a response to deep, convectively generated heating.

Describe in words (i.e. without writing down any equations) the various approximations to the state of the tropical atmosphere that need to be made in order to derive the SWE's from the full dynamical equations in the Tropics.

What are the main processes in the Tropics that act to *weaken* circulation patterns generated by deep convective heating?

[8 marks]

(b) Sketch an equatorial longitude-height cross-section through an equatorially trapped Kelvin wave. Indicate regions of warm and cold temperature anomalies, pressure surfaces at upper and lower levels and include arrows showing the zonal and vertical components of motion within the wave.

With reference to your sketch, state why the Kelvin wave must move towards the east.

[17 marks]

(c) Figure 1 shows a wavenumber-frequency decomposition of equatorial Outgoing Longwave Radiation (OLR) taken from the website of Matt Wheeler from the Australian Bureau of Meteorology. 3 major clusters of wave activity are indicated on this figure by the thick green, blue and black outlines. State what type of wave activity corresponds to each of the highlighted clusters.

[6 marks]

The MJO has a phase speed which is slower than that for a dry Kelvin wave. Name and briefly describe two theories that help to explain the intraseasonal (30-90 day) period of the MJO.

[19 marks]

2.

(a) The South Asian and West African monsoons occur at similar latitudes and times of year. However, the Asian monsoon is generally stronger in terms of low level circulation and precipitation amounts. Discuss the various reasons why the Asian monsoon is stronger than the West African monsoon. Use sketch diagrams to illustrate your discussion.

[22 marks]

(b) Hastenrath and Lamb (1980) estimate that, during the Indian Monsoon, the Somali Jet transports 170×10^{13} W of latent heat across the equator. If all of this latent heat is released in deep convection over South Asia and the Bay of Bengal (an area of approximately 20×10^{6} km^2) estimate an area average precipitation rate in mm per day for the South Asian monsoon region. Comment on the magnitude of your estimate compared to the actual precipitation rates observed in this region during the monsoon.

[12 marks]

Question 2 continues overleaf

Question 2 continued

(c) Suggest and briefly describe a mechanism whereby the *intraseasonal* variability in the Indian monsoon may have a large impact on the seasonal mean precipitation.

[6 marks]

On *synoptic* timescales, considerable variability can be attributed to monsoon depressions. Describe the formation region and typical track of a monsoon depression, and state which parts of India are most likely to be affected by such systems.

Explain briefly why monsoon depressions are extremely unlikely to develop into tropical cyclones during the main monsoon season.

[10 marks]

3.

(a)

In a developing tropical depression, explain how CAPE is modified by the low level flow of air parcels from the edges of the system in towards the centre across an ocean surface of uniform temperature. Sketch a portion of a tephigram to illustrate your answer.

With reference to WISHE, what is the other important consequence of low level flow into the centre of the depression across a warm ocean surface?

[12 marks]

Question 3 continues overleaf

Question 3 continued

(b) Using the tephigram provided, calculate how much extra CAPE is released in lifting a *saturated* air parcel from just above an ocean surface at a temperature of 30°C and a surface pressure of 1000hPa, up to a level of 900hPa, compared to the same process for a *dry* air parcel.
Compare this to the extra CAPE released during the same process for a saturated parcel of air just above an ocean surface at 10°C.

If all the extra CAPE released by the rising air parcel is converted into kinetic energy of vertical motion, what would the vertical velocity of the air parcel starting at 30°C be by the time it reached 900hPa?

Please show your constructions on the tephigram and remember to hand it in with your answer booklet.

[12 marks]

(c) By considering the net radiation balance of the Tropics, explain the existence of the meridional overturning Hadley Cell in the zonal mean.

Now, by considering the relationship between temperature and geopotential height described by hydrostatic balance, show that meridional pressure gradients must exist which drive the horizontal branches of the Hadley Cell. Use a diagram to illustrate your answer.

[21 marks]

The zonal mean picture of the Hadley Cell masks a lot of zonal asymmetries. State where you would expect the major rising branches of the Hadley Cell to be during the northern hemisphere summer season.

[5 marks]

(End of Question Paper)