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 2014 **MTMG19**

Answer Book
Data Sheet
Blank tephigram for question 2
Blank maps for question 1 and 3
Any bilingual English language dictionary permitted
Only Casio-fx83 calculators are permitted

UNIVERSITY OF READING

Tropical Weather Systems (MTMG19)

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) (i) On blank map A provided on the additional sheet, sketch the distribution of sea surface temperatures (SST) in the Tropics in *either* the JJA or DJF season. Your sketch does *not* need to include accurate, labeled isotherms but should give an indication of the locations of the warmest and coldest SST regions between 30ºN and 30ºS, and the positions of any significant temperature gradients.

[5 marks]

(ii) On blank map B, sketch the distribution of precipitation in the tropics for the same season as your SST sketch on map A. Again, you do not need to include accurate, labeled isopleths but your sketch should indicate the locations of heaviest rain.

[5 marks]

(iii) Comment on the similarities and differences between the SST and precipitation distributions over the oceans in your two sketches. Discuss briefly the mechanisms that would lead to the observed relationship between SST and precipitation. Your answer should include a consideration of how the Clausius-Clapeyron equation will affect the relationship between SST and precipitation.

[6 marks]

(b) (i) During an El Niño event, the SST distribution in the tropical Pacific changes very significantly. Using simple sketches, show how the changes in SST lead to significant changes in the distribution of precipitation and meridional atmospheric circulation patterns in the tropical Pacific sector in the DJF season.
Describe how the changes in winds and SST act together to produce a series of positive feedbacks which help an El Niño event to grow and be maintained.

[15 marks]

(ii) Describe a process by which a *westerly wind burst* occurring in the *western* equatorial Pacific could lead to a warming of the SSTs in the *eastern* equatorial Pacific. You answer should include an indication of the timescale on which this process occurs.

[10 marks]

(c) The delayed oscillator model of El Niño can be expressed mathematically by the equation below, where T is the temperature anomaly in the eastern equatorial Pacific, t is time and α, β, δ and ε are constants for the system.

$$\frac{\quad}{\quad} \qquad (1) \qquad (2) \qquad (3)$$

State what physical process is represented by each of the 3 terms on the right-hand side of this equation.
Give an estimate of the magnitude of the δ term for the delayed oscillator model of a typical El Niño event. Explain what the magnitude of the δ term implies for the duration and evolution of the event.

[9 marks]

2.(a) (i) Describe the meaning and significance of the term *Convective Available Potential Energy (CAPE)* in a column of the atmosphere. You should use a sketch to illustrate your answer.

[5 marks]

(ii) List 4 physical process by which CAPE can be increased in the tropical atmosphere.
In the trade-wind regions of the tropical oceans, state which of these mechanisms is likely to lead to the largest increases in CAPE.

[10 marks]

(iii) In a tropical radiosonde sounding the CAPE is calculated to be 2000J.kg^{-1}. If all of this CAPE were converted into vertical motion within a convective updraft, what would be the vertical velocity in the updraft?
Comment briefly on why this value of vertical velocity would be very unlikely to occur in a real updraft.

[5 marks]

(b) (i) State a mechanism whereby downdrafts can form beneath convective clouds.
Using a sketch to illustrate your answer, describe how downdrafts can act to prolong the life-time of a convective storm.

[10 marks]

(ii) The air beneath a convective storm at a level of 900 hPa has a temperature of 10ºC and a dewpoint of 5ºC. If a convective downdraft were to initiate at this level, use the tephigram provided to calculate what temperature the downdraft air would have on reaching the surface at 1000 hPa. Describe briefly the construction you have used on the tephigram and the physical processes that this construction represents.

[8 marks]

(c) Describe briefly the WISHE theory for the growth of a Tropical Cyclone. You may find it useful to draw a flow diagram indicating the sequence of processes involved.

[12 marks]

3.(a) The Held-Hou model gives a simple description of the formation of the Hadley cell. *Without writing any equations*, describe in words how the Held-Hou model is constructed. Your answer should include a list of assumptions made for the state of the tropical atmosphere and a sequence of the physical principles that are applied in order to derive the dimensions of the Hadley Cell.

[15 marks]

(b) (i) An equatorially trapped Kelvin wave is the simplest meaningful solution to the version of the shallow water equations applied to an equatorial β-plane as defined by Gill (1980). What specific condition must be applied in order to find the Kelvin wave solution?

[2 marks]

(ii) Sketch a vertical cross-section through an equatorially trapped Kelvin wave. Your sketch should include upper and lower level geopotential height and wind anomalies, vertical motion and temperature anomalies.

[6 marks]

(iii) Explain briefly why a Kelvin wave must move towards the east.

[5 marks]

(iv) In Gill's version of the shallow-water equations, the equation which combines the thermodynamic, hydrostatic and continuity equations can be written as

if there is no diabatic heating. Explain in words what this equation means for the relationship between the horizontal wind field and the geopotential height.

[5 marks]

(c) (i) During the Northern Hemisphere summer, a strong Tropical Easterly Jet develops in the upper troposphere.

On blank Map C on the additional sheet, sketch the position of this jet. Your sketch should include the location of the main jet core (the strongest winds) and the positions of the jet entrance and exit regions.

[5 marks]

(ii) Discuss the implications of the position of this jet for the relative strengths of the West African and Indian monsoons.

[6 marks]

(iii) During the Northern hemisphere summer another easterly jet appears in the tropical atmosphere.
In what geographical location and at what altitude does this jet occur?
What is the physical reason for the appearance of this jet and its easterly direction?

[6 marks]

[End of Question paper]