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 2013 **MTMG19**

Answer Book
Data Sheet
Blank tephigram for question 2
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) The version of the Shallow Water Equations (SWEs) used in the Gill model of the Tropical atmosphere is derived by making a number of assumptions and simplifications to the full dynamical equations which make the equations specifically applicable to the tropical atmosphere.

Without writing down any equations describe in words the assumptions which make the Shallow Water Equations in the Gill model applicable to the Tropics.

[6 marks]

The Gill Model uses the Shallow Water Equations to predict the atmospheric dynamical response to imposed diabatic heating in the Tropics. For an imposed heating region centred and maximized on the equator and extending across 40° of longitude and 40° of latitude, sketch contours of the geopotential height anomalies and vectors of the wind anomalies that you would expect to develop as a steady state response to the heating. State whether your sketch shows the response in the upper or lower troposphere.

[6 marks]

The Gill Model predicts that an equatorially trapped Kelvin wave would propagate to the east of a diabatic heating region centred on the equator.

Sketch a longitude-height section through an equatorial Kelvin wave showing both horizontal and vertical wind anomalies, upper and lower level geopotential height anomalies and mid-tropospheric temperature anomalies.

Explain why an equatorially trapped Kelvin wave must propagate towards the east.

[12 marks]

(b) Describe how equatorially trapped Kelvin waves in the Pacific *Ocean* might be instrumental in triggering the warm phase of an ENSO event. You should include a discussion of the following points in your answer.

- A mechanism that could initiate Kelvin waves in the West Pacific.
- The structure of the thermocline in the equatorial Pacific Ocean and how a Kelvin wave would affect that structure.
- The timescale on which Kelvin waves initiated in the west Pacific could affect the sea surface temperature (SST) in the east Pacific.
- How the timing of Kelvin waves in the seasonal cycle may be important to their impact on SST in the east Pacific.

[20 marks]

Describe briefly the role of Kelvin waves in *terminating* an El Niño event in the delayed oscillator model of ENSO. What is the source of these waves in the delayed oscillator model?

[6 marks]

2.(a) Give a definition for the *equivalent potential temperature* (θ_e) of an air parcel, and describe how you would calculate the value of θ_e for a parcel on a tephigram given the temperature and dewpoint of the parcel.

[4 marks]

Explain briefly why θ_e is a useful concept for meteorology in the Tropics.

[2 marks]

Sketch a diagram of the typical variation of θ_e with height in the Tropics and use this figure to explain why convective downdraughts tend to originate in the lower to mid-troposphere.

[8 marks]

(b) The table below gives data from a radiosonde ascent in the Tropics.

Plot these data onto the tephigram provided.

[9 marks]

Pressure (hPa)	Dry bulb temperature (°C)	Dewpoint temperature (°C)
1000	30	23
900	21	18
800	15	10
700	10	5
600	1	-5
500	-7	-40
400	-18	-50
300	-32	-60
200	-50	-60

By constructing a parcel curve for the air at 1000 hPa, make an estimate of the Convective Available Potential Energy (CAPE) in the atmospheric column, where CAPE is given by;

$$CAPE = \int_{LNB}^{LFC} R_d(T_p - T_a)dlnp$$

Where T_p is the temperature of a lifted air parcel, T_a is the temperature of the ambient atmosphere and the other symbols have their usual meteorological meanings.

You need to indicate your parcel curve construction clearly on the tephigram and show your working for the CAPE estimate.

[11 marks]

From your tephigram estimate the Level of Neutral Buoyancy (LNB) for the parcel ascent.
Suggest a physical mechanism that will probably mean that the cloud tops in the vicinity of this radiosonde profile will not extend as high as the LNB.

[6 marks]

(c) Describe briefly the WISHE theory for the growth of a Tropical Cyclone. Make sure that you include a description of the process by which CAPE is increased within a developing cyclone.

[10 marks]

3.(a) Monsoon systems represent the major mode of the annual cycle in the tropics with significant local impacts and far-reaching global teleconnections.

Define the main characteristics of a monsoon and describe the basic concept of its formation. What are the main regions in which they are found, at what times of year and why?

[13 marks]

(b) In the Indian monsoon, what are the changes in precipitation associated with local orographic and circulation features?

Climate models often have difficulty in simulating the heavy rainfall in north-eastern India. Why is this thought to be?

[7 marks]

(c) How large are typical year-to-year variations in mean precipitation in the Indian monsoon?

Describe the sign and timing of the so-called monsoon-ENSO teleconnection and the basic mechanism by which El Niño warming changes the circulation to affect monsoon rainfall over India.

[7 marks]

(d) Tropical cyclones are more prevalent over the northern Indian Ocean (Arabian Sea and Bay of Bengal) at certain times of year. When does this occur and what aspects of the monsoon seasonal cycle make conditions favourable for tropical cyclones at this time?

[5 marks]

(e) In the West African monsoon the sub-seasonal variations in weather (winds, cloudiness, humidity and precipitation) are dominated by disturbances on the African Easterly Jet (AEJ).

The presence of the AEJ is due to the thermal gradient between the hot land surface of the Sahara desert and the cooler ocean waters of the Gulf of Guinea. By making estimates of the surface temperature of the Sahara at 25°N and of the Gulf of Guinea at the equator, apply thermal wind balance to produce an estimate of the strength of the AEJ at 12.5°N, at a level of 600 hPa. Use the equation for thermal wind balance given below and state any assumptions you make.

$$\frac{\partial u}{\partial p} = \frac{R}{pf}\frac{\partial T}{\partial y}$$

[10 marks]

The Held and Hou model of the Hadley Cell is also based partly on the concept of thermal wind balance. In the Held and Hou model, prior to the onset of the Hadley Cell circulation, what state of balance is assumed to determine the variation of temperature with latitude?

[3 marks]

The meridional extent *Y(m)* of the Hadley Cell predicted by the Held and Hou model is given by

$$Y = \sqrt{\frac{5\Delta\theta g H}{3\Omega^2 \theta_0}}$$

Where $\Delta\theta$ is the pole-to-equator temperature gradient, H is a scale height for the tropical atmosphere (~8km), Ω is the Earth's rotation rate and θ_0 is the mean radiative equilibrium temperature for the Earth's atmosphere (~255K). By making an estimate of the value of $\Delta\theta$, calculate the meridional extent of the Hadley Cell. Comment on how well this agrees with observed estimates of Y.

[5 marks]

[End of Question paper]