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 2012

Answer Book
Data Sheet
Tephigram for question 3(b)
Any bilingual English language dictionary permitted
Only Casio-fx83 calculators are permitted

Final Examination for MSc

Course in Applied Meteorology
Course in Atmosphere, Oceans and Climate
Course in Applied Meteorology and Climate with Management

MTMG19

Tropical Weather Systems

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) A location in the Tropics records 1500mm of precipitation in a year. Assuming that this is evenly distributed throughout the year, calculate a tropospheric heating rate in $K.day^{-1}$ due to the latent heat release in condensation. State any assumptions you make.

In the absence of any large scale circulation pattern, this heating rate is likely to be in equilibrium with what other physical process?

[15 marks]

The Held and Hou model describes the effect of the Hadley cell in moving the temperature distribution in the Tropics away from this equilibrium. Draw a sketch of the zonal mean tropical potential temperature (θ) distribution in both the initial equilibrium state and the new state determined by the presence of the Hadley cell.

State how both distributions are related to distance from the equator (y).

Indicate on your sketch the poleward limit of the Hadley Cell and explain briefly why the Hadley cell cannot extend beyond this latitude.

[10 marks]

Write down the two physical principles that determine the new temperature distribution in the Held and Hou model and describe in words (i.e. without using any equations) how these principles are applied in order to derive a temperature distribution.

[10 marks]

(b) On the blank map provided, sketch the distribution of heavy precipitation in the Tropics in either Northern Hemisphere winter (DJF) or summer (JJA). State on your sketch which season you have chosen and use $5mm.day^{-1}$ and $10mm.day^{-1}$ as your contour values.

[10 marks]

State briefly why the ITCZ in the tropical East Pacific remains north of the equator throughout the annual cycle.

[5 marks]

2. (a) Describe the form of the Madden-Julian Oscillation (MJO). You should refer to scale, period, geographical location and perturbations to meteorological variables such as clouds and precipitation, low level and upper level winds. Use schematic diagrams if appropriate.

[18 marks]

Discuss briefly the impact of the passage of the MJO through the West Pacific basin on the state of the upper layers of the equatorial Pacific Ocean. How might this be related to the development of El Niño events?

[10 marks]

(b) The Delayed Oscillator model of El Niño (Suarez and Schopf, 1988) describes the evolution of the temperature anomaly *T* in the NINO3 region with the following equation.

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Where *α, β, δ* and *ε* are all positive constants.

Describe the physical mechanisms represented by the 3 terms on the right hand side of this equation. In particular state what the *δ* term represents and how it determines the evolution of *T*.

[10 marks]

Given the nature of interannual SST variability in the NINO3 region, comment on whether the Delayed Oscillator is a sufficient explanation of the observed variability.

[5 marks]

(c) Describe the impacts of El Niño events on tropical storm location and frequency in both the West Pacific and Atlantic basins.

[7 marks]

3. (a) Convective Available Potential Energy (CAPE) is a common concept in tropical meteorology.

Describe how the concept of CAPE is applied within the Quasi-Equilibrium (QE) theory of Arakawa and Schubert.

Comment on why QE theory is an ideal basis for a convective parametrization in a global climate model, but may be less successful in a high resolution weather forecasting model for the USA.

[10 marks]

List 4 physical processes that can modify the amount of CAPE in the tropical atmosphere.

[8 marks]

b) Figure shows a sounding from Truk Island in the West Pacific (7.5°N, 152°E). Estimate the amount of CAPE in the sounding between the Lifting Condensation Level and 200 hPa. State the units of your answer.

[10 marks]

If this CAPE were entirely converted into buoyancy driven vertical motion, calculate the vertical velocity at 200 hPa.
Comment on why this vertical velocity is unlikely to be achieved within a real cloud.

[6 marks]

(c) Sketch a vertical cross-section through a convective squall line showing the main flows of air through the system.

[8 marks]

What is the main process that drives the downdraught in a squall line?

Describe how the downdraught interacts with the low level inflow into a squall line in order to generate new convective cells within the overall system.

[8 marks]

[End of Question paper]