University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER II EXAMINATION 2006/2007

MAPH 40250
Climate Dynamics and Synoptic Meteorology

Extern examiner: Prof. Frank Hodnett

Head of School: Prof. Sean Dineen

Examiner: Dr. Rodrigo Caballero*

Time Allowed: 3 hours

Instructions for Candidates

Answer **four (4)** of the following six questions. Each question carries 25 marks.

Instructions for Invigilators

Non-programmable calculators may be used during this examination.

Question 1

- (*15 marks*) Give a detailed qualitative account of the factors determining the observed equator-pole temperature difference on Earth.
- (*10 marks*) The Hadley cells transport a large amount of energy from the equator to the subtropics. Describe the mechanisms underlying this transport. (You do not need to discuss how the circulation is maintained, but only the way the circulation transports energy).

Question 2

- (*10 marks*) Consider the simple model for the greenhouse effect in which the atmosphere is composed of n discrete layers, each transparent to solar radiation but a black body to longwave radiation. Derive the radiative equilibrium temperature for this model as a function of n and the insolation S.
- (*15 marks*) Now consider the more realistic, vertically continuous model consisting of the Schwarzschild equations for a plane-parallel gray gas:

$$\frac{dI^+}{d\tau} = \sigma T^4 - I^+$$
$$\frac{dI^-}{d\tau} = -\sigma T^4 - I^-,$$

where τ is the optical depth. Derive the radiative equilibrium temperature for this model and show how it relates to the solution of the layer model above.

Question 3

- (*15 marks*) Describe qualitatively the stages of synoptic development in the Norwegian cyclone model. For each stage, sketch the disposition of fronts, pressure and precipitation fields.
- (*10 marks*) Describe the mechanisms leading to the formation of fronts in synoptic cyclones.

Question 4

- (*15 marks*) Describe the phenomenon known as the El Niño/Southern Oscillation, including and account of the basic underlying mechanism.
- (*10 marks*) Explain the concept of a "teleconnection pattern". Give an example of a prominent teleconnection pattern and its effects on regional weather.

Question 5

- (*15 marks*) List the main reservoirs of carbon in the Earth system (including an indication of their relative size), and discuss the processes whereby carbon is exchanged among the reservoirs.
- (*10 marks*) Explain how human activities may affect the carbon cycle.

Question 6

- (*15 marks*) Describe the process of baroclinic cyclone development (baroclinic instability) in terms of interaction between upper- and lower-level PV anomalies.
- (*10 marks*) Describe the typical pattern of geopotential height anomalies observed when air moves over a mountain range, and explain it using PV conservation.

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