SEMESTER II EXAMINATION 2009/2010

MAPH 40540
Synoptic Meteorology II

Extern examiner: Professor Keith Shine
Head of School: Professor Micheál Ó Searcóid
Lecturer: Professor Peter Lynch

Time Allowed: 2 hours

Instructions for Candidates
Answer all three (3) questions.
All questions carry equal marks.
Total: 60 marks.

Instructions for Invigilators
Non-programmable calculators may be used during this examination.
Question 1

(a) (6 marks) Write an account (approximately one page) of the use of weather radar in operational forecasting. Include a treatment of the following:

- The principles of determining target location.
- Scanning strategies (PPI, RHI, etc.)
- Scanning modes (Clear-air mode, precipitation mode).
- Value of Doppler component.
- Additional benefits from combined radars.
- Bright band echoes.
- Ground clutter and other spurious echoes.

(b) (4 marks) How does the average returned power vary with the signal wavelength? What factors determine the optimal operating wavelength?

(c) (6 marks) When the wavelength is fixed, the power is given by

\[ P_r = \frac{R_c Z_e}{r^2} \]

where \( P_r \) is the average returned power, \( R_c \) is the radar constant, \( Z_e \) is the reflectivity (equivalent radar reflectivity factor) and \( r \) is the distance from radar to target. How does the reflectivity vary with the size of the scattering targets?

(d) (4 marks) How is dBZ defined? What is its typical range, for meteors ranging from fog to heavy hail? Describe in general terms how \( Z - R \) relationship is used to convert echo intensity to rainfall rate. State some of the uncertainties associated with this inversion.

Question 2

By means of Taylor’s theorem, the wind in the vicinity of a point \((x_0, y_0)\) can be approximated as

\[
\begin{align*}
    u(x, y) &= u_0 + \frac{1}{2} (\delta + F_1) x - \frac{1}{2} (\zeta - F_2) y \\
    u(x, y) &= u_0 + \frac{1}{2} (\zeta + F_2) y + \frac{1}{2} (\delta - F_1) y
\end{align*}
\]

where \((u_0, v_0)\) is the wind at \((x_0, y_0)\) and the other quantities are defined as

\[
\begin{align*}
    \delta &= \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right) \\
    \zeta &= \left( \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} \right) \\
    F_1 &= \left( \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y} \right) \\
    F_2 &= \left( \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \right)
\end{align*}
\]
(a) (10 marks) Assuming for simplicity that $u_0 = v_0 = 0$, consider the four special cases in which just one of the quantities $\{\delta, \zeta, F_1, F_2\}$ is equal to unity and the other three vanish. Sketch the flow field in the neighbourhood of $(x_0, y_0)$ in each case, and comment on the relevance of such a flow for synoptic dynamics.

(b) (10 marks) Suppose that there is pure stretching deformation, with $F_1 = 1$ and $\delta = \zeta = F_2 = 0$, and warm air to the south and cold to the north. Assume that the temperature field is advected passively by the flow. Consider two cases: (i) Isotherms oriented at $20^\circ$ to the $x$-axis; (ii) Isotherms oriented at $70^\circ$ to the $x$-axis. In each case, how will the temperature field evolve in time? You may use the 2D-Frontogenesis function

$$F = -\frac{1}{|\nabla T|} \left[ \frac{\partial T}{\partial x} \left( \frac{\partial u}{\partial x} \frac{\partial T}{\partial x} + \frac{\partial v}{\partial x} \frac{\partial T}{\partial y} \right) + \frac{\partial T}{\partial y} \left( \frac{\partial u}{\partial y} \frac{\partial T}{\partial x} + \frac{\partial v}{\partial y} \frac{\partial T}{\partial y} \right) \right],$$

to explain and illustrate your response.

Question 3

(a) (3 marks) Describe the distinction between deterministic and probabilistic weather forecasting. Indicate circumstances in which each is more appropriate.

(b) (3 marks) What are the sources of uncertainty in numerical weather forecasts? List at least three specific sources of uncertainty.

(c) (4 marks) Briefly describe the phenomenon of “sensitive dependence on initial conditions”. Comment on its implications for short-range and for medium-range weather forecasting. Which elements are more predictable and which are less predictable at medium range?

(d) (10 marks) Consider the EPS-gram in Figure 1. Using only the evidence in this diagram, describe the probable weather conditions in Dublin for Easter weekend. Comment specifically on the probable weather conditions on:

(i) Easter Sunday, 4 April 2010
(ii) Easter Monday, 5 April 2010

What is your confidence in the predictions, based on the ensemble forecasts?

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Figure 1: