University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER II EXAMINATION 2009/2010

MAPH 40540

Synoptic Meteorology II

Extern examiner: Professor Keith Shine

Head of School: Professor Mícheál 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 stragegies (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

$$\begin{aligned} u(x,y) &= u_0 + \tfrac{1}{2}(\delta + F_1)x - \tfrac{1}{2}(\zeta - F_2)y \\ u(x,y) &= u_0 + \tfrac{1}{2}(\zeta + F_2)y + \tfrac{1}{2}(\delta - F_1)y \end{aligned}$$

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

$$\delta = \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) \qquad \zeta = \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$$

$$F_1 = \left(\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}\right) \qquad F_2 = \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)$$

(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° to the x-axis; (ii) Isotherms oriented at 70° to the x-axis. In each case, how will the temperature field evolve in time? You may use the 2D-Frontogenesis function

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

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*) Breifly 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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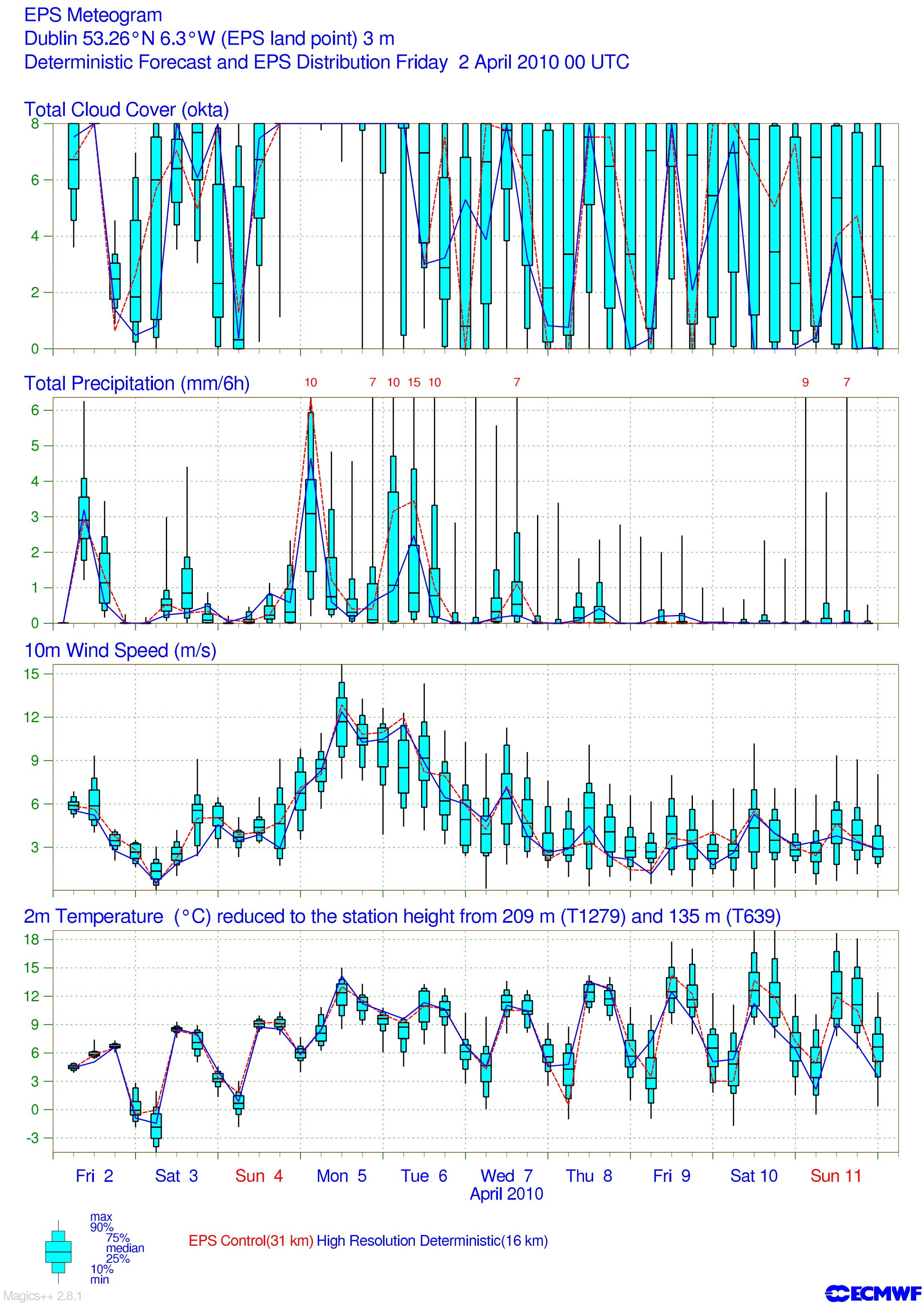
EPS Meteogram
Dublin 53.26°N 6.3°W (EPS land point) 3 m
Deterministic Forecast and EPS Distribution Friday 2 April 2010 00 UTC
Total Cloud Cover (okta)
Total Precipitation (mm/6h)
10m Wind Speed (m/s)
2m Temperature (°C) reduced to the station height from 209 m (T1279) and 135 m (T639)
Fri 2
Sat 3
Sun 4
Mon 5
Tue 6
Wed 7
Thu 8
Fri 9
Sat 10
Sun 11
April 2010
max
90%
75%
median
25%
10%
min
EPS Control(31 km) High Resolution Deterministic(16 km)
Magics++ 2.8.1
ECMWF

Figure 1: