EAS372 Mid-term Exam 26 Feb., 2015

Professor: J.D. Wilson Time available: 80 mins Value: 15%

Open book exam. Please answer in the booklet provided.

A. Calculations (2 x 3 → 6%)

A1. Suppose that a sounding in the tropics indicated that at the 700 hPa level $T = 8^{\circ}$C, $T_d = 6^{\circ}$C and $\omega = -4\,\mathrm{Pa\,s^{-1}}$. Compute the resolved vertical flux density of water vapour

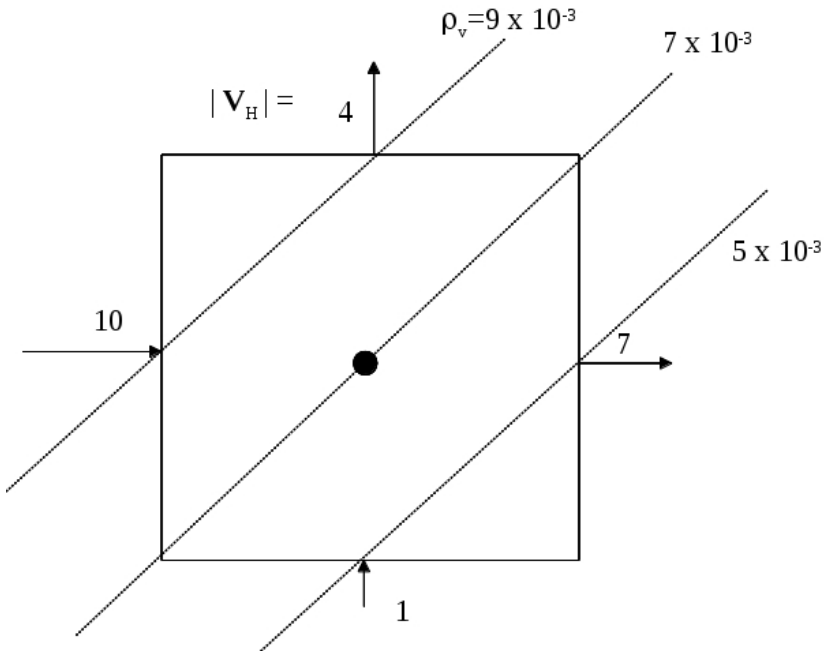
$$E\,[\mathrm{kg\,m^{-2}\,s^{-1}}] = W\,\rho_v \equiv -\frac{\omega\,q}{g}\,,$$

where $q\,[\mathrm{kg\,kg^{-1}}]$ is the specific humidity and $W\,[\mathrm{m\,s^{-1}}]$ is the vertical velocity. (A link to a saturation vapour pressure table is given on the EAS 372 course home page.)

Answer.

- From the s.v.p. table, the vapour pressure $e = e_*(T_d) = e_*(6^{\circ}\mathrm{C}) = 9.35\mathrm{mb} = 935$ Pa.
- Since $q = \epsilon\,e/p$ (with $\epsilon = R_d/R_v = 0.622$), we get $q = 8.3 \times 10^{-3}$.
- (or, less directly)
  - The absolute humidity is $\rho_v = 935/(462 \times (273.15 + 8)) = 7.20 \times 10^{-3}\,[\mathrm{kg\,m^{-3}}]$.
  - The density is $\rho = (700 \times 10^2)/(287 \times (273.15 + 8)) = 0.868\,[\mathrm{kg\,m^{-3}}]$.
  - Thus, the specific humidity $q = \rho_v/\rho = 8.3 \times 10^{-3}$.
- Finally, $E = 4 \times (8.3 \times 10^{-3})/9.81 = 3.4 \times 10^{-3}\,[\mathrm{kg\,m^{-2}\,s^{-1}}]$.

A2. The diagram below shows a square cell (a 2D "control volume") with sidelength 10 km. Arrows with affixed numbers give the direction and magnitude [$\mathrm{m\,s^{-1}}$] of the "horizontal" wind vector $\mathbf{V}_H$ at each interface, and the diagonals are contours of absolute humidity ρ_v [$\mathrm{kg\,m^{-3}}$]. Calculate the Laplacian of the humidity $\nabla^2\rho_v$ and the (2D) velocity divergence $\nabla\cdot\mathbf{V}_H$ at the centre of the cell. If the absolute uncertainty in the wind velocity measurements is stated as $\epsilon = 0.1\,\mathrm{m\,s^{-1}}$, then what is the *fractional* uncertainty in your result for the divergence?



Answer.

$$\nabla^2\rho_v = \frac{(2\times 9 + 2\times 5)\times 10^{-3} - 4\times(7\times 10^{-3})}{(10^4)^2} = \frac{(28-28)\times 10^{-3}}{10^8} = 0\,.$$

$$\nabla\cdot\mathbf{V}_H = \frac{7-10}{10^4} + \frac{4-1}{10^4} = \frac{-3+3}{10^4} = 0\,.$$

The absolute uncertainty in the velocity sum $(7-10+4-1)$ is $4\epsilon = 0.4\,\mathrm{m\,s^{-1}}$ giving an *infinite* fractional error in the sum... and therefore, also, in the divergence (one may assume there is no error in the distance 10^4 m).

B. "Live" web weather data (8 x 1/2 → 4%)

1. Figure 1 is the 24h NAM prog, valid at 12Z today. Comparing with this morning's RDPS 0h prog for 12Z, what was the *error* in NAM's forecast for the 1000-500 hPa thickness in the southeastern corner of Alberta? Answer. The RDPS 0h prog for 12Z gives about 507 to 508 dam for the thickness at the SE border of Alberta, whereas the NAM 24h prog indicated exactly 510 dam: so the error is about 2-3 dam.

2. What thickness contour on this morning's RDPS 0h prog valid 12Z is closest to The Pas (Manitoba; YQD)? Answer. 504 dam

3. What was the coldest cloud top temperature on the MSC/CMC GOES east ir image as of 1215Z this morning? (State a value or range.) Answer. Colder than -70^{o}C.

4. From the CYYC (Calgary Int'l Airport) METAR at 12Z today, what codes and remarks (RMK) are given in relation to cloud, and what do they mean?

   Answer. The metar reads: METAR CYYC 261200Z 17010KT 5SM -SN BKN008 OVC035 M14/M16 A3032 RMK SC6SC2 SLP352=

   Lowest cloud layer based at 800 feet AGL, 6/8 sky coverage of broken stratocumulus (SC); overcast at 3500 feet AGL due to a further 2/8 SC for a total of 8/8.

5. From the ~~temperature and dewpoint at 850 hPa given by the~~ YQD (The Pas, Manitoba) sounding for 12Z today, what is the 1000-500 hPa thickness? Answer. 5320 - 274 = 5046 m or 505 dam. (The words struck out above, appearing in the exam by oversight, had misled some students to perform a calculation using the hypsometric equation: those answers were accepted as correct, although clearly given data at one level alone one cannot correctly estimate a height-averaged virtual temperature).

6. From the UQAM meteogram for Winnipeg that is based on the GDPS run from 00Z today, determine the lowest and highest 2 m temperatures forecast to occur over the duration of the forecast. Answer. low of about -29^{o}C and high of about $+1^{o}$C.

7. Consult the NAM model run that was initialized at 06Z today (`http://www.cnrfc.noaa.gov/weather_m` Referring to the offshore storm just east of Newfoundland this morning, what does NAM indicate for the "bullseye" (maximum) 6 hour cumulative precipitation over the interval 06Z-12Z? Is this likely to be snow or rain? Answer. NAM had forecast 0.5 to 0.75 inches over 6 hours. Given that this was to fall on the warm side of the 540 dam thickness contour, it would be in the form of rain.

8. In Vizaweb, bring up the RDPS model run that was initialized at 06Z today: choose "Domain1 EAST_COAST". What does this prog give for the *maximum* accumulation [mm] of precipitation during 06-12Z associated with the storm east of Newfoundland? Answer. The RDPS forecast a small patch where 25 to 30 mm was expected over 6 hours, embedded within a larger patch with 15 to 20 mm. (Given that there are 25.4 mm to the inch, this is in the same ballpark as NAM.) Note: patently it is true that rain does not "accumulate" on the ground, however it does fill up a rain guage; therefore the terms "cumulative precipitation" and "accumulated precipitation" *do not exclude rain.*

C. Interpretation of Weather Charts ($\rightarrow$ 5%)

A colour figure (attached, at back) conveys some elements of the GDPS 72h forecast, valid at 12Z today, for conditions over Western Canada. Compare and contrast that 72 h forecast with actual conditions, as assessed on the basis of the RDPS 0h prog for this morning (12Z today, if available; and if not, 06Z; please state your choice). Explain any particularly significant features you observe, on either a forecast panel or on the RDPS 0h prog you have chosen to represent observed conditions.

Significant features as per 72h prog:

1. low 700 hPa heights in NE Canada have set up an upper flow from the far north
2. weak NW upper flow in AB, firmer northerly over Sask. & Manitoba
3. arctic ridge (or high) centred in Saskatchewan, dominating weather east of the Rockies
4. strong pressure gradient in much of Alberta (and Manitoba) – liable to be some wind
5. possible upslope surface wind in AB, may be related to forecast of cloud & precip near SW AB Rockies?
6. absence of any notable vertical motion aloft
7. subzero surface temperatures extend to the BC coast; surface temperature progressively colder as one moves eastward

(Better wording of the question would have conveyed the instructor's intent that a diagnosis be given, roughly along the above lines, as to the key elements of the meteorological scenario – painting the "big picture.").

Compare/contrast 72h GDPS prog with RDPS 0h prog:

1. good qualitative agreement as regards the flow aloft (e.g. 700 hPa level)
2. ditto positioning of the arctic high in Saskatchewan
3. total cloud patterns in reasonable accord, but 0h prog indicates cloud in central and eastern B.C. that had not been forecast by GFS
4. thickness patterns also very consistent
5. no striking disparity in surface temperature (colour scales tedious to quantitatively compare across hard copy and online image; T_{sfc} "grainier" on the 0h prog, presumably reflecting local detail driven by obs.)
6. 12h cumulative precip patterns in reasonable accord
7. some weak sink in Saskatchewan (0h prog) not seen on the 72h prog

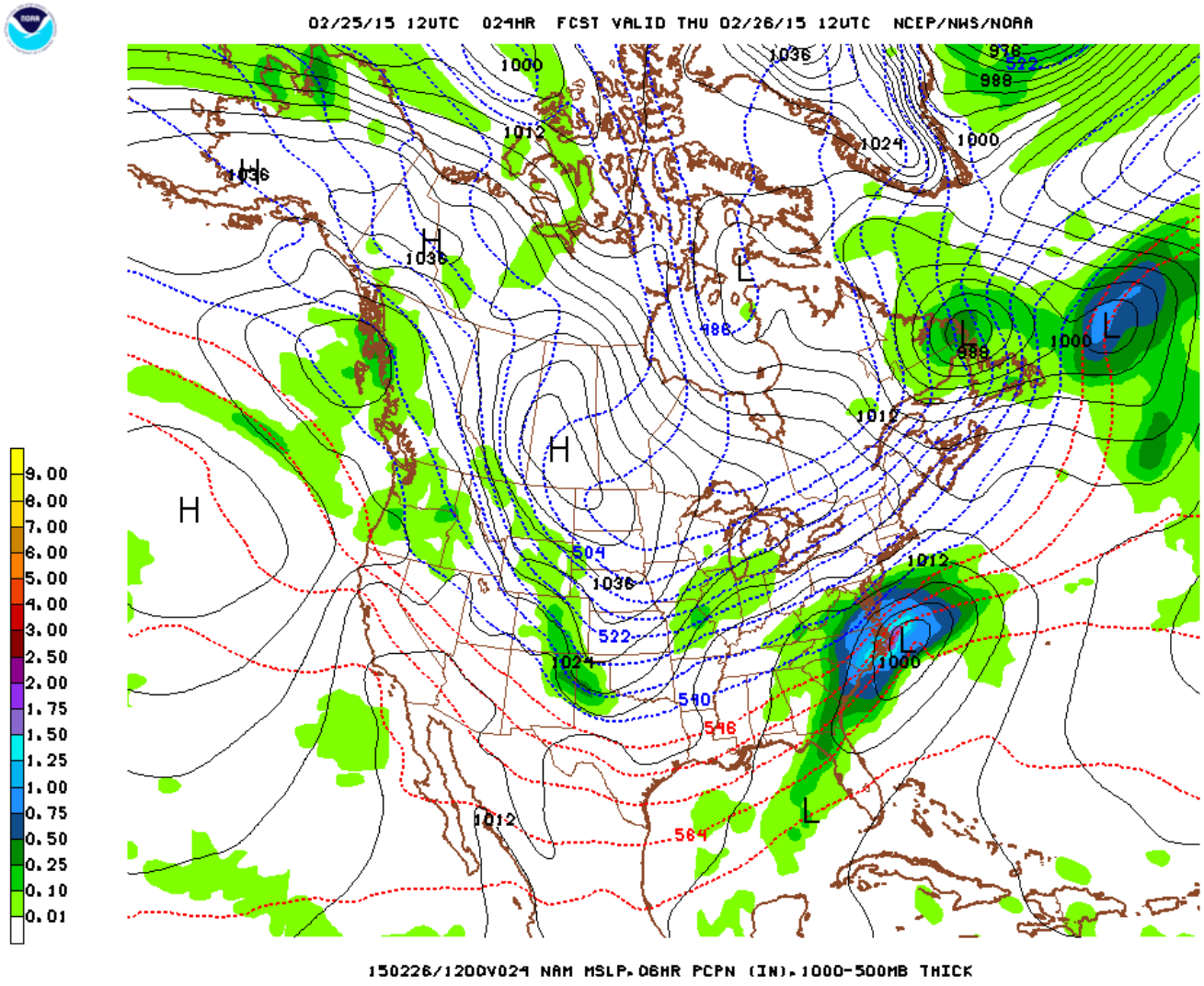


Figure 1: NAM 24h forecast, valid 12Z Thursday 26 Feb. 2015.