EAS372 Mid-term Exam 27 Feb., 2014

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

Open book exam. Please answer in the booklet provided.

A. "Live" web weather data (6 x 1/2 → 3%)

1. What was the height (ASL) of the 500 hPa surface over Edmonton at 12Z this morning? [541 dam]

2. What was the 1000-500 hPa thickness over Edmonton at 12Z this morning? [Surprisingly — but inexplicably — there was an inconsistency between the thickness given on the Stony Plain sounding (5140-75=533.5 dam) and as given on the CMC 500 hPa analysis, which placed the 528 dam thickness contour very close to Edmonton. Either answer (533.5 dam or ∼ 529 dam) was accepted. (Though not relevant to the exam, note that the value based on the analysis should be regarded as more representative, for the analysis incorporates *all* data and makes adjustments to satisfy the equations of motion, etc.)]

3. According to this morning's sounding, what was the true surface pressure at Stony Plain? [918 hPa (surface is 766 m ASL, given at end of sounding)]

4. According to the most recent METAR for CYEG (Edmonton International Airport), what were the surface wind speed and direction? [Question ought to have asked students to specify the *time* of the METAR. Answers were cross-checked against the list of CYEG METARs copied to the class web site alongside this copy of the exam]

5. What is the "coldest" value [dam] of the 1000-500 hPa thickness that is forecast to occur over Edmonton within the range of the GEM global forecast initialized at 00Z today (00Z Thurs 27 Feb. 2014), and when (GMT) is it to occur? [As noted by the instructor during the exam, it was not possible to assign a very definite value for the *time* of the coldest predicted thickness. The easiest and quickest way to answer this question was to look at the Meteogram (based on the GEM glbl prog) for Edmonton (since uploaded to course web page), where a minimum thickness of around 485-490 dam was predicted for the interval spanning roughly 00Z March 1 to 12Z March 2]

6. What is the range bracket (mm liquid equivalent) for the largest forecast value of 24-hr cumulative precipitation at Edmonton, within the range of the GEM global forecast initialized at 00Z today (00Z Thurs 27 Feb. 2014)? On several panels of the GEM glbl prog, from about 12Z March 6 through 12Z March 7 (most clearly 12Z March 7), values in the range [2.5 - 5 mm] were forecast over or very near Edmonton

B. Calculations (3 x 3 → 9 %)

1. Suppose that at 700 hPa the vertical velocity $W = 0.05\,\mathrm{m\,s^{-1}}$, and that the temperature and dewpoint at the same level were 0°C and −3°C. Compute the vapour pressure e, the absolute humidity ρ_v and the resolved vertical vapour flux density E $[\mathrm{kg\,m^{-2}\,s^{-1}}]$. (Use the equilibrium vapour pressure table provided on the EAS 372 web site).

   From the vapour pressure table, the (actual) vapour pressure $e \equiv e_*(T_d) = 475.7\,\mathrm{Pa}$, thus $\rho_v = 475.7/(462 \times 273.15) = 3.77 \times 10^{-3}\,\mathrm{kg\,m^{-3}}$. Therefore the vertical flux is $E = w\,\rho_v = 1.88 \times 10^{-4}\,\mathrm{kg\,m^{-2}\,s^{-1}}$.. (Some students — contrary to instruction — did not use the given table, but instead invoked one or another version of Bolton's formula. This being an open book exam, the marker didn't know what differing variants of Bolton's law might have appeared in students' notes, thus any reasonable value whose origin had been documented was accepted)

2. Referring to Figure (1), compute the Geostrophic 700 hPa windspeed at the station (The Pas, YQD) in Manitoba that is about midway along the Saskatchewan-Manitoba border

   The horizontal distance Δn between adjacent 700 hPa height contours is

$$\Delta n \approx \frac{9.5\,\mathrm{mm}}{64\,\mathrm{mm}} \times 11 \times 111 \times 10^3 = 1.81 \times 10^5\,[\mathrm{m}] ,$$

   where $9.5/64 = 0.15$ is the ratio of ruler measurements of the distance between height contours, and the distance between the north and south borders of (any) prairie province. The latitude at The Pas is about $49 + (60 - 49)/2 = 54.5^o$, so the Coriolis parameter $f \approx 2\Omega \sin(54.5) = 2 \times (2\pi/(24 \times 3600)) \times \sin(54.5) \approx 1.18 \times 10^{-4}$ s. Finally, the Geostrophic wind speed is

$$V = \frac{g}{f}\frac{\Delta h}{\Delta n} \approx \frac{9.81}{1.18 \times 10^{-4}} \times \frac{60}{1.81 \times 10^5} = 27.5\ \mathrm{m\,s^{-1}}$$

   (where it is crucial to remember to enter the height difference in [m], not [dam]). This value, $\approx 28\,\mathrm{m\,s^{-1}}$, is very consistent with the wind speed at 700 hPa over The Pas as measured by the radiosonde.

3. Referring to Figure (2), estimate (by way of a calculation, if needed) the advective contribution to the rates of temperature change near the radiosonde stations at (a) Edmonton (WSE); (b) Fort Smith (YSM; in NWT, near Alberta's northern border); (c) The Pas (YQD, just east of the Saskatchewan/Manitoba border).

The "if needed" is a hint, an invitation to use your judgement. At both Edmonton and Fort Smith, the isotherm is roughly parallel to the wind vector, so the rate of thermal advection is to a first approximation, negligible. At The Pas, clearly cold advection is occuring. The wind speed is known (a solid triangle plus one long barb: thus the speed $|\mathbf{V}| \approx 30\,\mathrm{m\,s^{-1}}$, though if a student neglected the "long barb", which wasn't very clear and could have been thought a half-barb, no penalty was exerted).

So now, knowing the wind speed, we only need the temperature gradient *parallel to the wind vector*; though clearly whatever number we cite for this is going to be very approximate. Near The Pas the distance (parallel to the wind) between neighbouring isotherms is very roughly

$$\Delta s \sim \frac{7.5\,\mathrm{mm}}{84\,\mathrm{mm}} \times 11^{\mathrm{o}} \times 111,000\,[\mathrm{m\ per\ ^o}] = 1.1 \times 10^5\ [\mathrm{m}]\ .$$

Thus the rate of thermal advection is

$$\frac{\Delta T}{\Delta t} = -\,|\mathbf{V}|\,\frac{\Delta T}{\Delta s} \sim -\,30\,\frac{5}{1.1 \times 10^5} = -\,1.4\ \times 10^{-3}\,\mathrm{K\,s^{-1}}\ .$$

This sort of estimate is better expressed in $[\mathrm{K\,hr^{-1}}]$: we have an advective cooling rate of about 5 $[\mathrm{K\,hr^{-1}}]$, though there could be up to about a $\pm 50\%$ uncertainty in this deduction from the 850 hPa analysis. Some students (legitimately) averaged the temperature gradient over a wider region, obtaining a more regionally-representative figure.

C. Interpretation of Weather Charts (3%)

Figures (3, 4) contrast the meteorological regimes of 16 Feb. and 23 Feb. 2014 over Western Canada. Give your interpretation of the differences, with a particular focus on Central Alberta.

Table 1: Instructor's compilation of differences between the meteorology of 16 Feb. ("mild") and 23 Feb. ("cold") over central Alberta.

Conditions	16 Feb.	23 Feb.
Aloft (700 hPa)	SW wind over mntns; mild; dry	weak, cold, moist N. wind
	moist flow off Pacific – Chinook?	dry flow from far north
	trough on B.C. coast, ridge thru Ab.	ridge thru Yukon & northern B.C.
850 hPa	mild, firm S wind	weak, cold WNW wind
	uniformly mild temp.	uniformly cold temp.
Surface	lee trough	arctic ridge
	overcast, mild for 12Z in Feb.	very cold
	(ovcst. reduced overnight cooling?)	clear; weak W wind; (ideal
	ESE wind	conditions for nocturnal cooling)
Cloud	clear in lee of Rockies, elsewhere	no high cloud
	high cloud (Chinook arch?)	

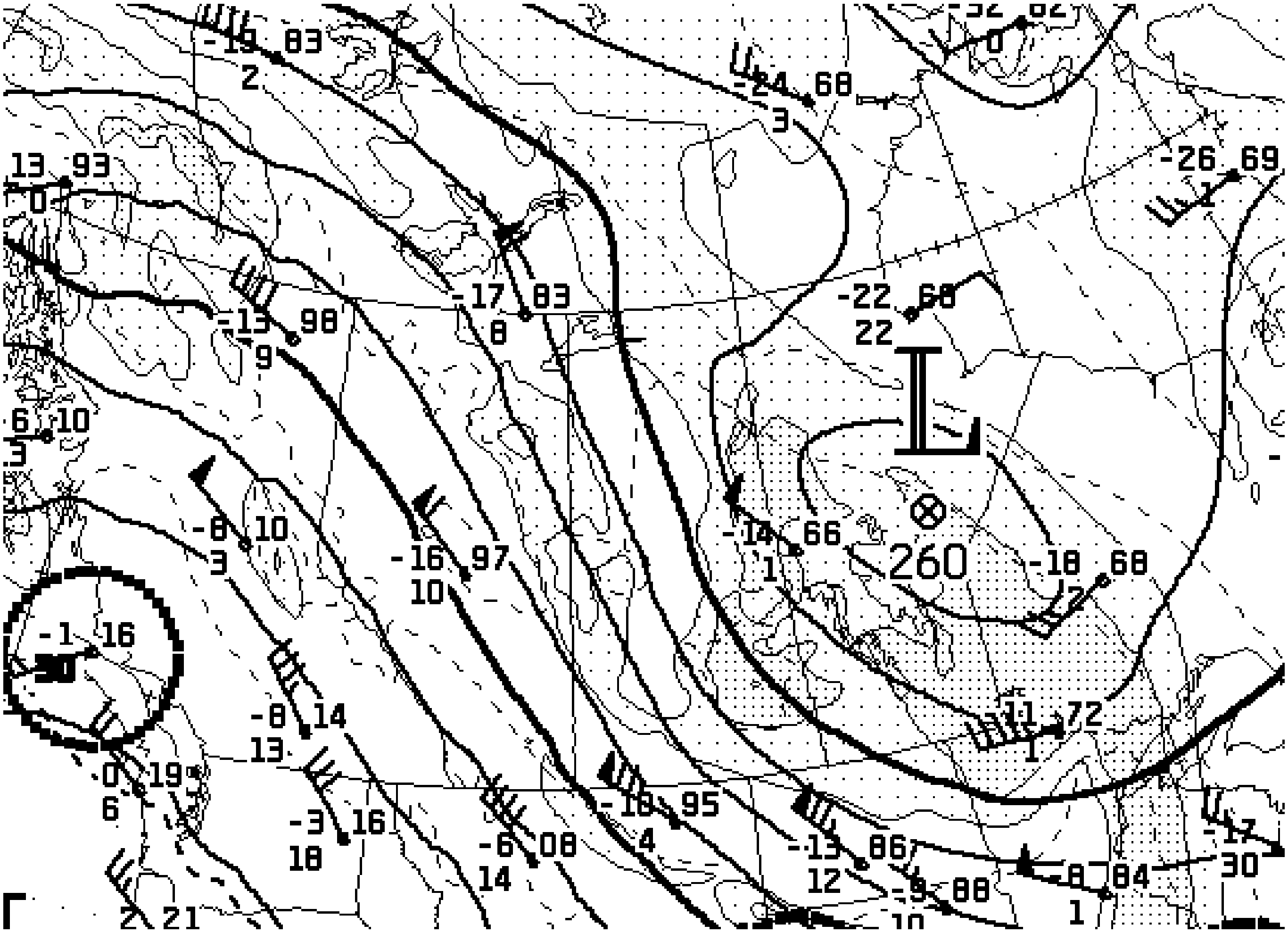


Figure 1: CMC 700 hPa analysis (cropped) for 00Z, 16 Jan. 2014.

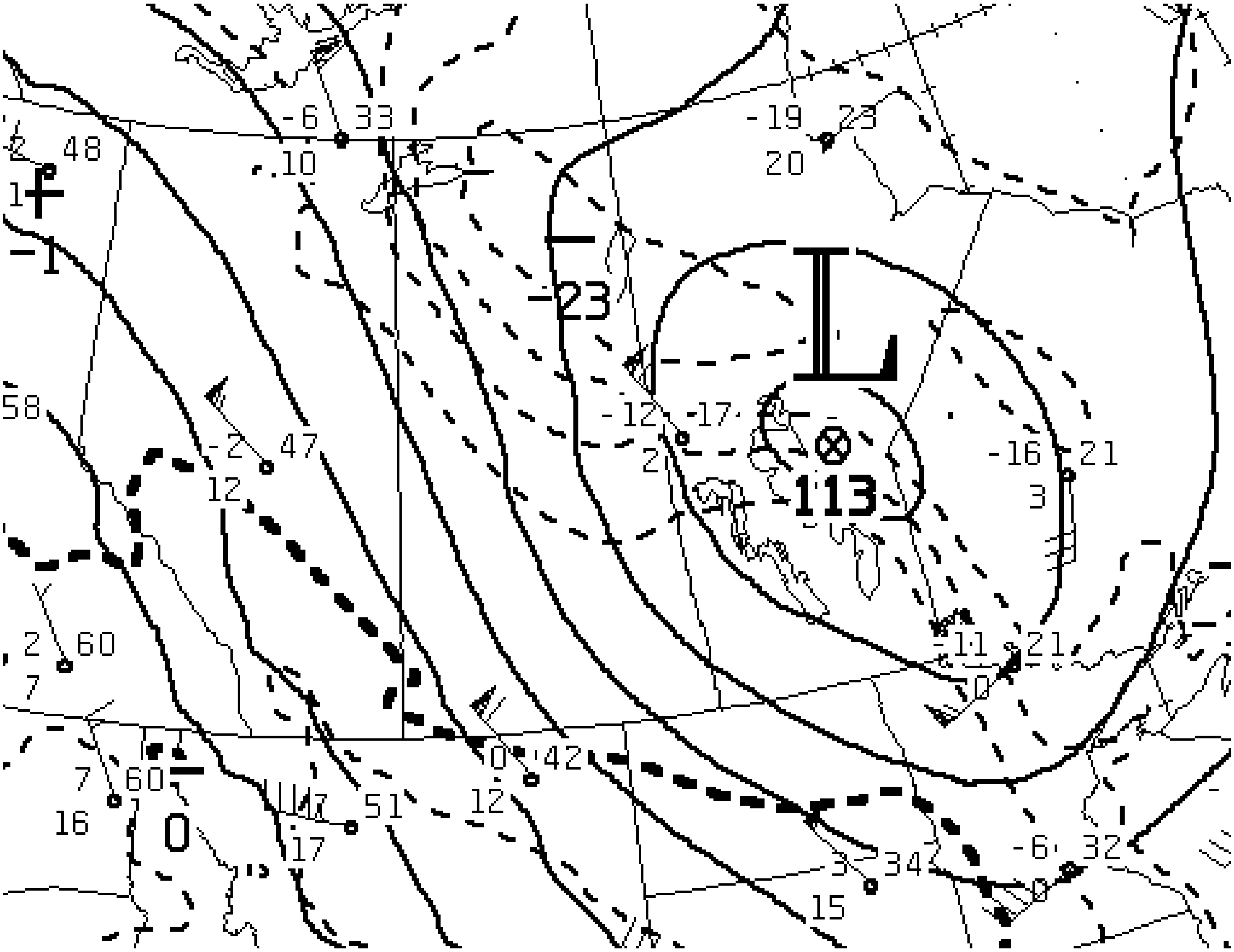
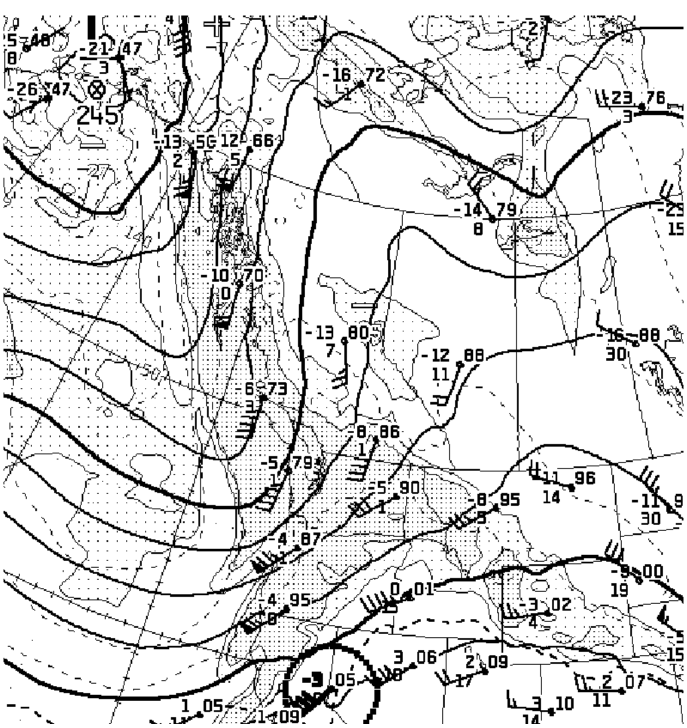
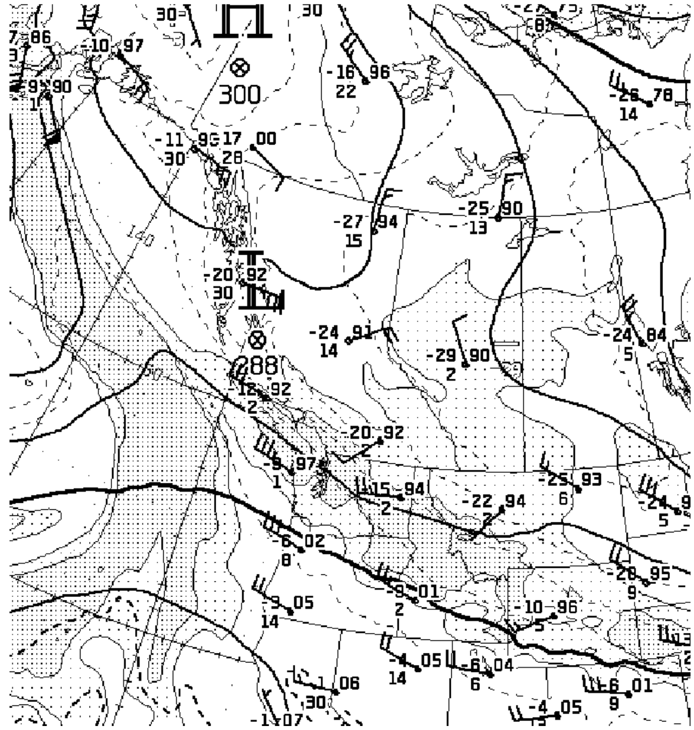


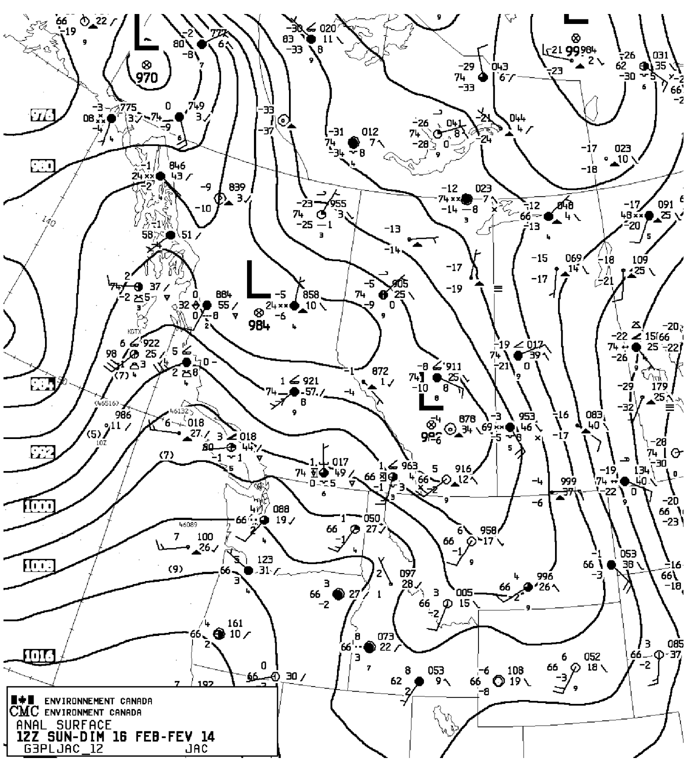
Figure 2: CMC 850 hPa analysis (cropped) for 00Z, 16 Jan. 2014.



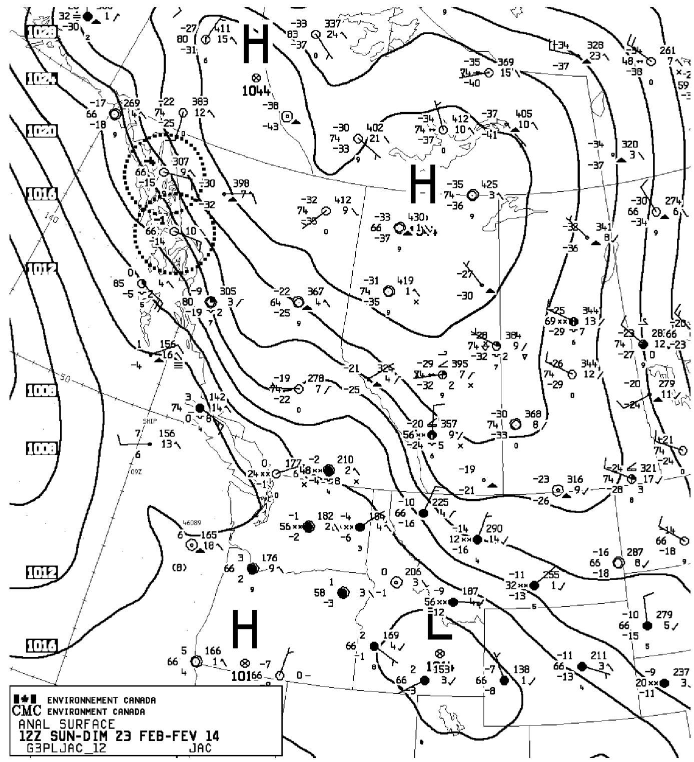
(a) 700 hPa, 00GMT 16 Feb.



(b) 700 hPa, 12GMT 23 Feb.

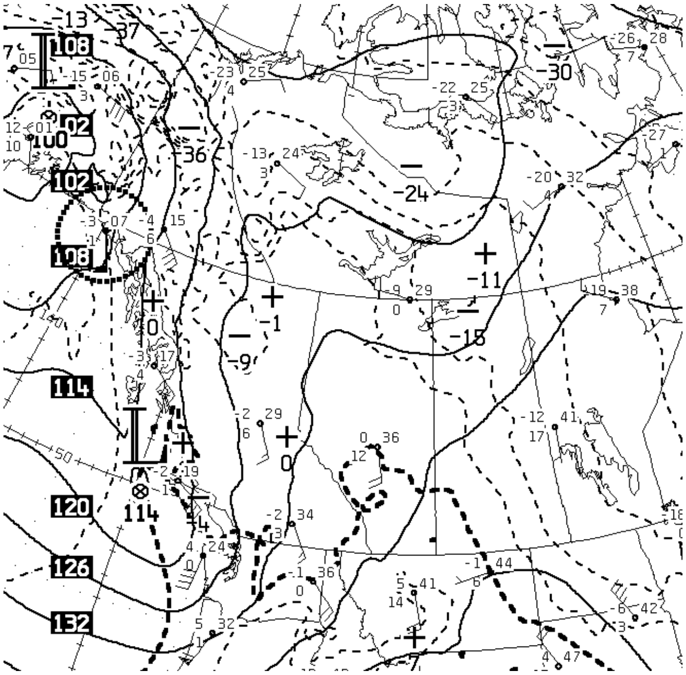


(c) Sfc, 12GMT 16 Feb.

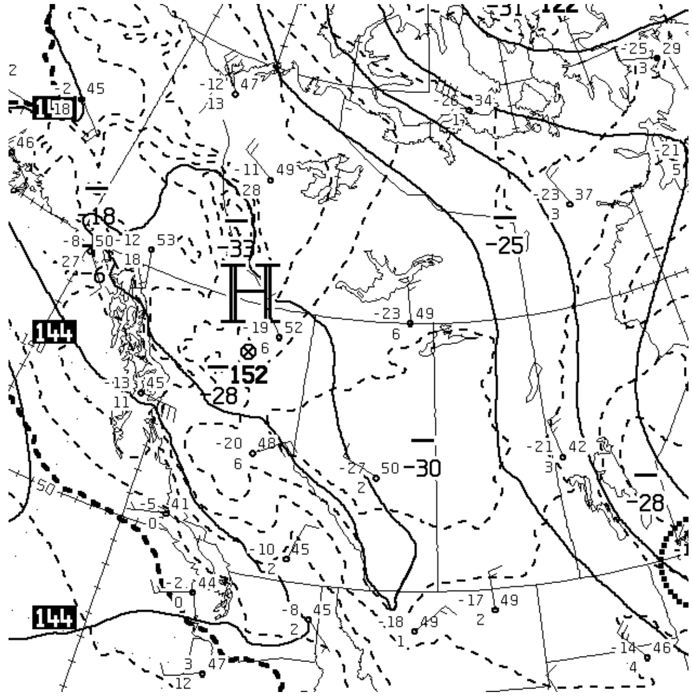


(d) Sfc, 12GMT 23 Feb.

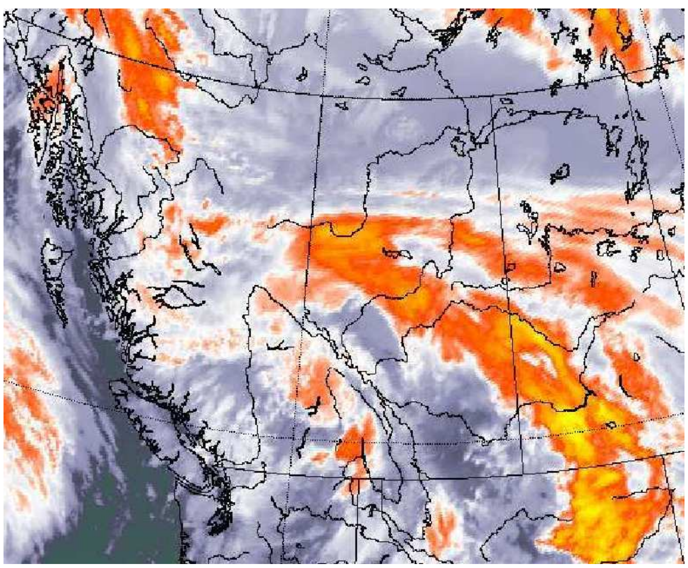
Figure 3: CMC analyses at 700 hPa and at the surface, for two consecutive Sundays bracketing U. Alberta Winter Term Reading Week, 2014.



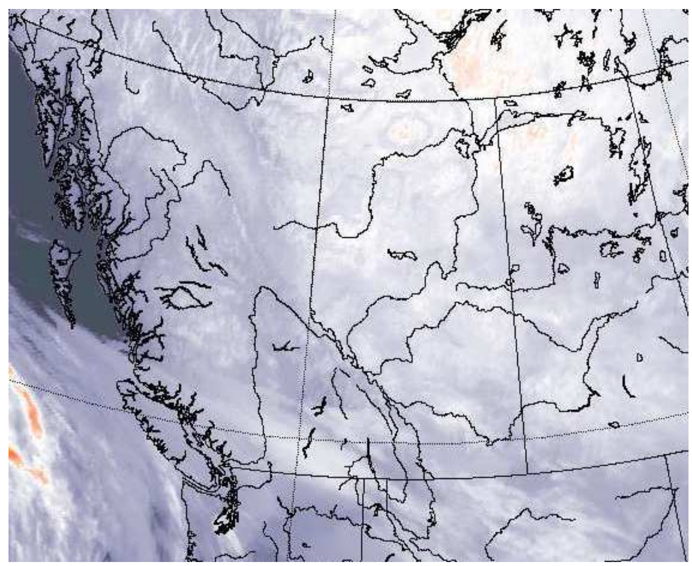
(a) 850 hPa, 00GMT 16 Feb.



(b) 850 hPa, 12GMT 23 Feb.



(c) GOES IR, 13:30GMT 16 Feb.



(d) GOES IR, 13:30GMT 23 Feb.

(e) GOES IR colour scale.

Figure 4: CMC analysis at 850 hPa and GOES IR satellite images, for two consecutive Sundays bracketing U. Alberta Winter Term Reading Week, 2014.