EAS372 Mid-term Exam 9 Mar., 2010

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

Please answer in the booklet provided; please attach your hodograph, and any other figure(s) that illustrate your working. Equations and data given at back.

A. "Live" web weather data (10 x 1/2 → 5%)

1. 1000-500 hPa thickness at Edmonton at 12Z this morning was: $5400 - 145 = 5255$ m or **about 525 dam** (*answer could be obtained from the Stony Plain sounding; or by interpolation off the CMC 500 hPa analysis or GEM 00-hr prog, giving more like 523 dam.*)

2. As of 12Z today, the maximum analyzed depth of precipitable water anywhere over Alberta or Saskatchewan was in the range of about **10-15 mm** (GEM 00hr prog valid 12Z).

3. According to the GEM Regional Model run initialized at 12Z today, the 1000-500 hPa thickness over Edmonton at 12Z Wed 10 Mar. will be about: just a little lower than 528 dam, say **about 527 dam**

4. According to the GEM Regional Model run initialized at 12Z today, the maximum 12 hour accumulated precipitation anywhere in Alberta or Saskatchewan should be in the range of about ____ . *Question is ambiguous, as I omitted to specify* which *12 hour period.*

5. According to this morning's Edmonton sounding, true surface pressure was: **926 hPa**

6. According to this morning's conditions at Edmonton, if a parcel of air from the 700 hPa level were to descend adiabatically to the 925 hPa level, its temperature would be about **+5 degrees Celcius**. *Those who gave +8 must, I think, have descended* vertically *rather than slantwise from 925 hPa to the temperature scale — therefore obtaining a value that is too warm.*

7. Use Vizaweb to access the 0h panel of the GEM Regional Run initialized at 12Z today; choose N_America as Domain. The strongest updraft at the 850 hPa level has a magnitude in the range **-2 to -4 Pa/s**

8. According to the NAM model run initialized at 06UTC today, the central (sea-level corrected) pressure of the deepest low in the forecast domain (at 12Z today) is: by counting contours, one deduces a pressure that was **lower than 972 hPa but higher than 968 hPa** (I also accepted 966 dam; the label was hard to read, but perhaps it was 966)

9. According to the most recent METAR for CYEG (Edmonton International Airport), surface windspeed and direction were **2 knots and 220 degrees**

10. Present weather conditions at Lloydminster are ____ (please note the time for which your answer applies): *see accompanying record*

B. Interpretation of weather situation. (2 x 2 → 4%)

1. Referring to Figures (1, 2), briefly summarize the meteorological situation over the Canadian prairies at 12Z on Saturday 7 March 2010.

   (a) Upper ridge axis running roughly through Saskatchewan

   (b) Light and dry SW upper flow over Rockies and Alberta

   (c) Interaction with Rockies inducing a lee trough

   (d) 850 hPa temperature field shows several features

   - Centre of mild, dry air aloft in lee of Rockies (trowal), *possibly* due to adiabatic compression
   - On a larger regional scale, a ridge of milder air over the prairies – a ridge whose axis is a little upstream (west) of the ridge in height
   - Well defined baroclinic zone in region of Northern Manitoba, but not much advection results

   (e) Weak low-level warm advection in some regions, e.g. SW Saskatchewan

2. Plot the sounding data for Churchill (Table 1, below) onto the blank hodograph, and indicate the thermal wind vectors connecting each pair of levels. Interpret your finding relative to Figures (1, 2).

   (a) One needed to alter the scale for speed on the hodograph to accommodate the large windspeeds. The thermal wind vector connecting the pairs of levels was in every case within the quadrant of NW directions, and for example (more specifically) the thermal wind $\vec{V}_{700} - \vec{V}_{850}$ had a WNW orientation, meaning that in that range of height the cold air should (theoretically) lie to the NNE of the Churchill

   (b) Both at 850 hPa and at 700 hPa the orientation of the isotherms near Churchill was NW-SE with cold air lying towards the NE — broadly consistent with the orientation of the thermal wind, as deduced from the hodograph

Table 1: Abbreviated YYQ sounding (Churchill, Manitoba) for 12Z Saturday 7 March 2010: giving pressure, height, temperature, wind direction and speed (knots) at mandatory levels.

p	z	T	β	v
850	1369	-7.9	335	20
700	2877	-6.5	315	41
500	5420	-23.9	320	57
250	10110	-59.9	330	87

C. Calculations (3 x 2 → 6 %)

For the following calculations please refer to Figure (4). Note that your computations will be *approximate*, i.e. *unique* and *exact* answers do not exist. Please record any assumption(s) you make in your working.

1. Estimate the Geostrophic wind speed at (latitude, longitude)=($40^o, 147^o$).

   (a) $f = 2\Omega \sin(40) = 9.4 \times 10^{-5}$ s^{-1}

   (b) Measuring the distance between the 300 dam and the 288 dam contours ($\Delta h = 12$ dam) gives $\Delta n \approx 5.7 \times 10^5$ m

   (c) Resulting Geostrophic windspeed $v \approx 22$ m s^{-1}

2. Estimate the stretching contribution $\partial v/\partial s$ to the horizontal divergence D_p along the 294 dam height contour at (latitude, longitude)=($40^o, 147^o$).

   (a) Downstream of the point of interest the reported speeds (on each side of the 294 dam contour) are $v \approx 20$ m s^{-1}, while upstream they are (symmetrically) $v \approx 27.5$ m s^{-1}, giving $\Delta v \approx -7.5$ m s^{-1}.

   (b) The corresponding alongstream distance is about $\Delta s \approx 8.0 \times 10^5$ m

   (c) Thus $\partial v/\partial s \approx -9.4 \times 10^{-6}$ s^{-1}, corresponding to *convergence* (which is obvious visually, since in the region of interest the wind is slowing as it moves downstream)

3. In the same region of the map, i.e. latitude and longitude of roughly ($40^o, 147^o$), estimate the diffluence contribution $v\, \partial\beta/\partial n$ to the horizontal divergence D_p. Treat the nearby 300 and 288 dam height contours as the basis for the calculation.

   (a) We already know the speed, $v \approx 22$ m s^{-1} (computed above)

   (b) Measuring the change in contour orientation entails a lot of uncertainty. Draw tangents to the 300 dam and the 288 dam contours at suitable points

   (c) My calculation gave a *difference* in orientation (between the two tangent lines) of $\Delta\beta = +17^o$, with the plus sign meaning the height contours move apart with downstream distance. Converted to radians, $\Delta\beta = 0.3$ rad

   (d) Although this is not necessarily very accurate, I assumed I could apply that deviation over the length of a line through ($40^o, 147^o$) separating the two contours. For the length of that line I took a distance equivalent to about six degrees of latitude, i.e. $\Delta n \approx 6.7 \times 10^5$ m

   (e) Then $v\, \partial\beta/\partial n \approx +22\ 0.3/(6.7 \times 10^5) \approx 10^{-5}$ s^{-1}, corresponding to divergence

   (f) Interesting to note that the two contributions to total divergence have opposite sign — as is typical

   (g) Also interesting to note that these contributions are of the same order of magnitude as f

Equations and Data.

- one full barb on the wind vector corresponds to about 5 m s^{-1}, and 1 degree of latitude corresponds to a distance of 111 km

- $\theta = T \left(\frac{p_0}{p}\right)^{R/c_p}$, the potential temperature θ [K] of air whose actual pressure and temperature are (p, T), ie. the temperature that air would have if compressed adiabatically to pressure p_0. The exponent involves the gas constant for air ($R = 287$ J kg^{-1} K^{-1}) and the specific heat of air at constant pressure ($c_p \approx 1000$ J kg^{-1} K^{-1}). Temperatures must be expressed in the Kelvin unit.

- $v = \frac{g}{f} \frac{\Delta h}{\Delta n}$

  The Geostrophic wind equation. Δh [m], the change in height of a constant pressure surface over distance Δn [m] normal to the height contours; $f = 2\Omega \sin\phi$ [s^{-1}] the Coriolis parameter (where Ω is the angular velocity of the earth, and ϕ is latitude); g acceleration due to gravity.

- $D_p \equiv \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$

  The horizontal divergence, expressed in Cartesian coordinates (x parallel to lines of latitude, increasing towards the east; y parallel to lines of longitude).

- $D_p \equiv \frac{\partial v}{\partial s} + v \frac{\partial \beta}{\partial n}$

  The horizontal divergence, expressed in natural coordinates. The unit vector $\hat{s}$ points downstream, i.e. it is parallel to height contours in the free atmosphere. The unit vector $\hat{n}$ is normal to $\hat{s}$ and points to its left. The angle β is the inclination of flow relative to lines of latitude, with $\beta = 0^o$ being a zonal flow and $\beta = 90^o$ being a meridional flow. The first term is the stretching term. The second term is the diffluence term, and is positive if the channel widens downstream (ie. widens with increasing s).

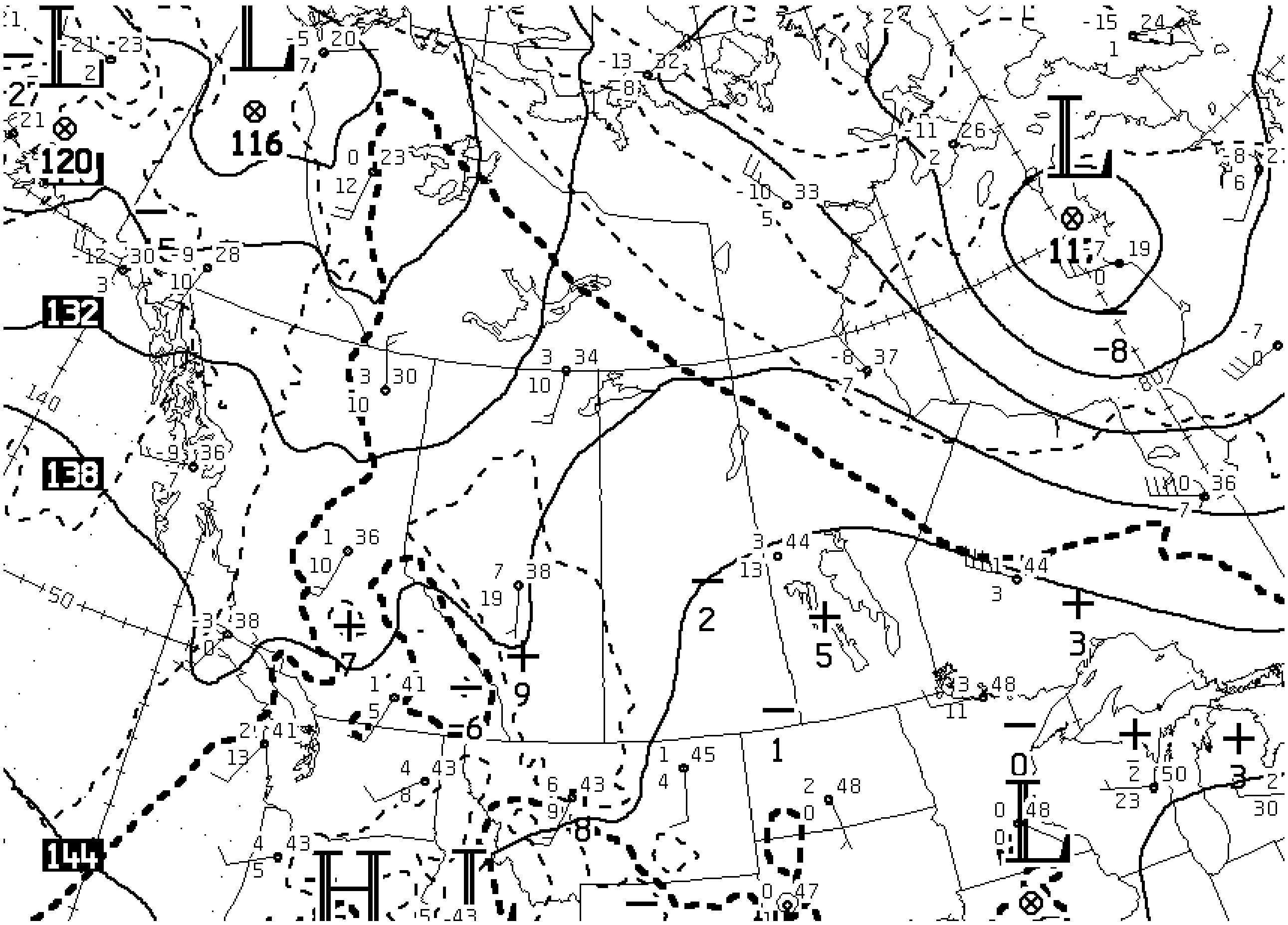

Figure 1: CMC 850 hPa analysis for 12Z on Saturday 7 Mar., 2010.

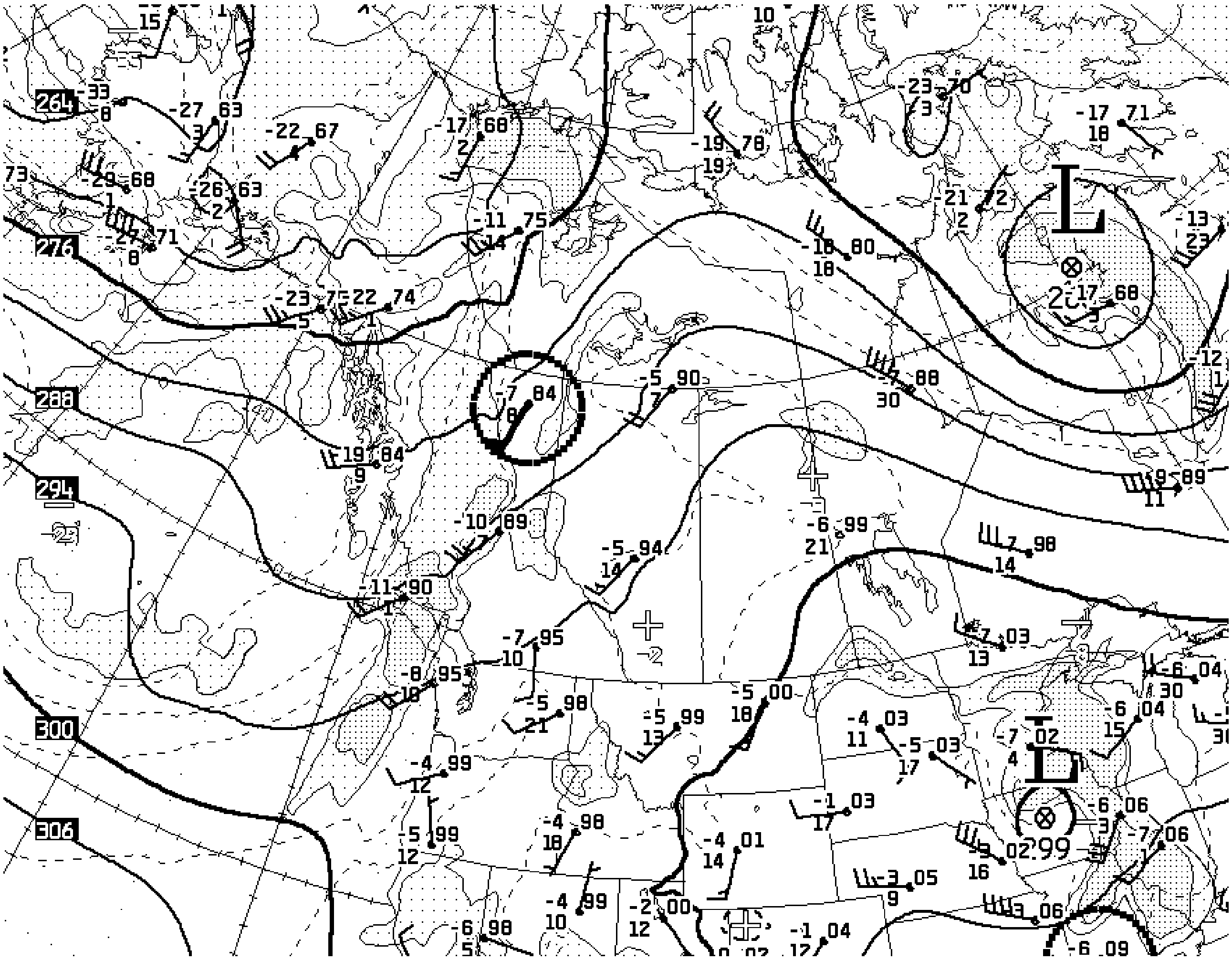

Figure 2: CMC 700 hPa analysis for 12Z on Saturday 7 Mar., 2010.

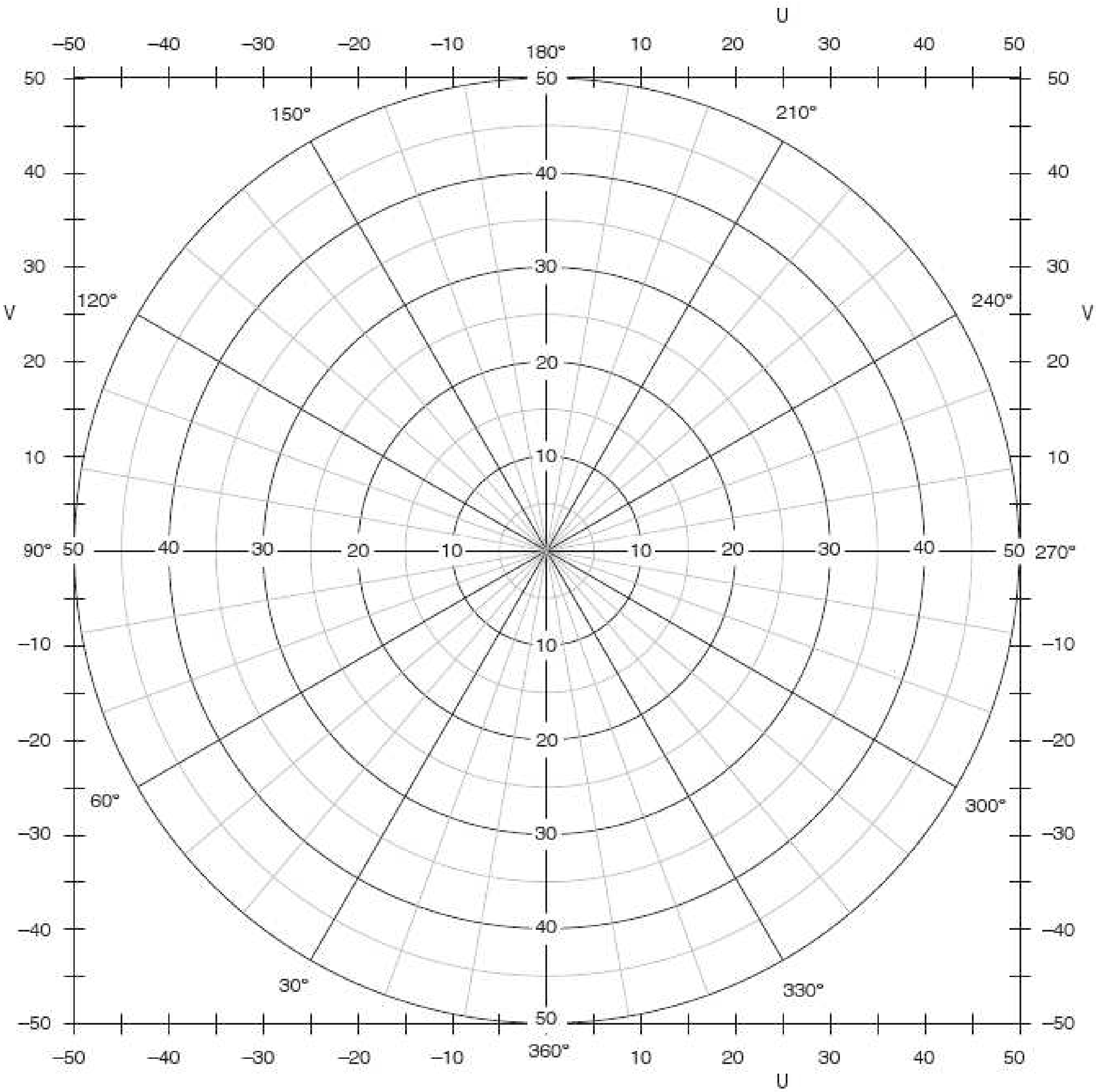

Figure 3: Blank hodograph (courtesy R. Stull, UBC).

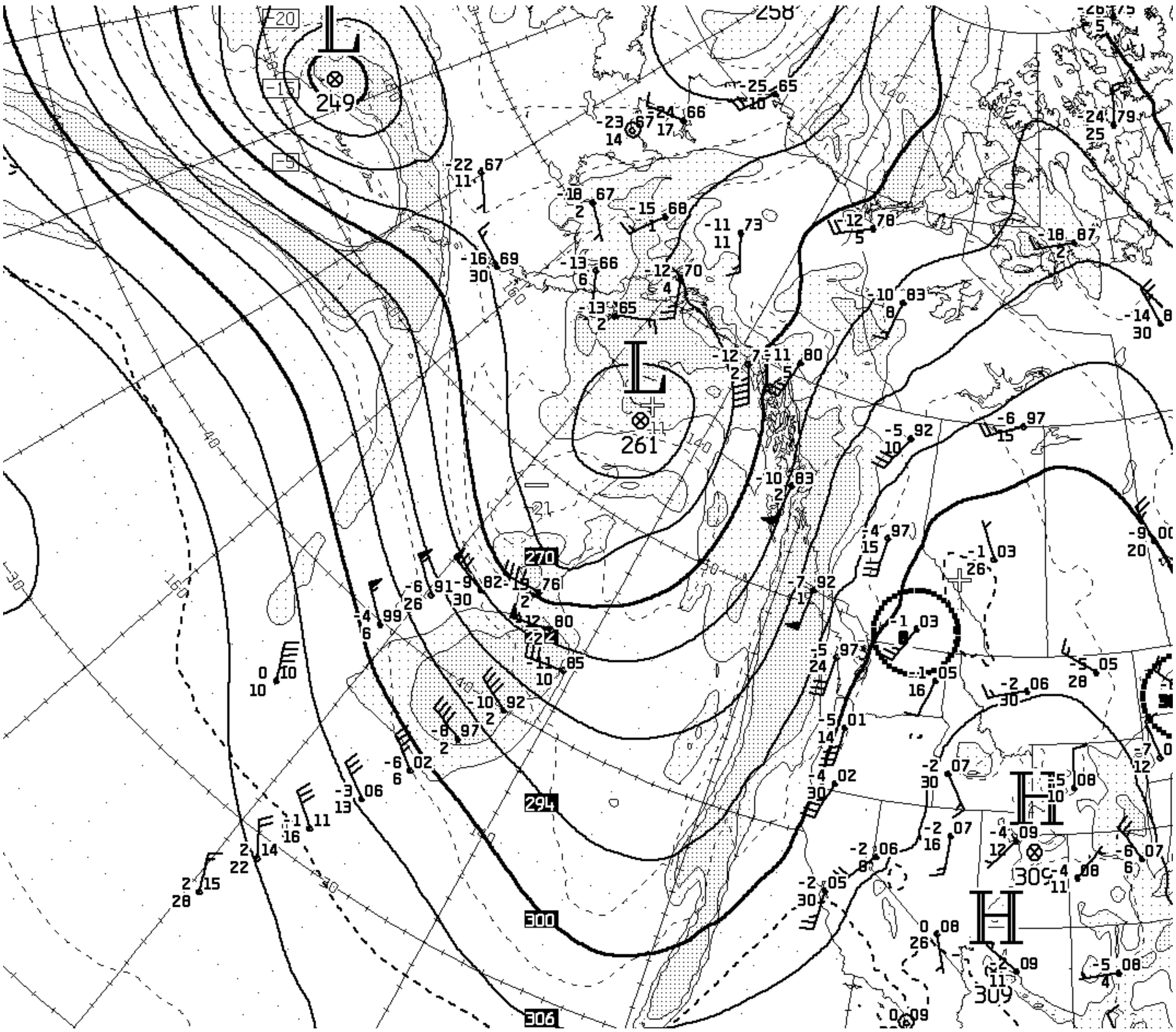

Figure 4: CMC 700 hPa analysis for 00Z on 2 Mar., 2010.