EAS372 Open book Mid-term Exam 1 Mar., 2012

Professor: J.D. Wilson Time available: 80 mins Value: 20%

A. Interpretation of weather charts (6%)

In Edmonton late on 24 February 2012 a prolonged period of snow commenced (roughly at 7 pm MST, i.e. 02Z Feb. 25th), with an accumulation exceeding 30 cm after months without significant snowfall. Figs. (1-7) provide a snapshot of the weather situation at 12Z on Saturday Februrary 25th, and Fig. (8) shows the 700 hPa pattern 12 hours later. Responding with (at most) *one tidy, legible, organized page*, identify significant meteorological factors associated with (or explaining) the storm. (You may use point or essay format).

B. "Live" web weather data (2 x 3 → 6%)

1. According to this morning's (12Z) Stony Plain (wse) sounding, what was the height (AGL) of the 500 hPa surface over Edmonton and what was the 1000-500 hPa thickness? Write down a recent METAR for CYEG (Edmonton International Airport). State surface wind speed and direction, and the nature and base height of any reported cloud.

2. Based on the GEM Global prog initialized 00Z Thurs 1 March, give a broad-brush summary of the anticipated meteorological "events" over central Alberta during the interval 12Z Sunday 4 March to 12Z Tuesday 6 March. You need not make specific predictions (e.g. of temperature or precipitation), but rather, focus on the gross trends. (*One page, max – brevity is good – use point format*)

C. Calculations (8 x 1 → 8 %)

1. Compute the quantity

$$Q = \sum_{i=1}^{3} a_i' \, b_i'$$

where the prime indicates the deviation from average, and $a_i = (1, 3, -1)$, $b_i = (-1, 0, 1)$.

2. Evaluate $\nabla \times \vec{a}$, where $\vec{a} = \hat{\imath}\, x^2 y - \hat{\jmath}\, e^{y^2} + \hat{k}\, \ln z$

3. A standardized Gaussian random variate x has probability density function

$$f(x) = \frac{1}{\sqrt{2\pi}} \, \exp\left(\frac{-x^2}{2}\right) \, ,$$

that is, with probability $f(x_1)dx$ a random sample lies in the range $x_1 - dx/2 \le x \le x_1 + dx/2$. Give an approximate value for the probability that single, randomly chosen sample value for x lies in the range $-0.005 \le x \le 0.005$.

4. Referring to Fig. (1), compute the Geostrophic 500 hPa windspeed at The Pas, Manitoba (YQD, the station in west-central Manitoba near the Saskatchwan border; latitude 53.96°N implying $f = 1.18 \times 10^{-4}\,\mathrm{s}^{-1}$) and compare with the reported speed.

5. Referring to Fig. (3), calculate an approximate value for the rate of temperature advection A_T at Glasgow, Montana (GGW, the northern-most station in the U.S. just south of Saskatchewan). Give your answer in $\mathrm{K\,hr^{-1}}$, and state whether your result corresponds to warming or cooling.

6. From the sounding data of Fig. (9), compute the air density ρ at ground level ($p = 915.0$ hPa, $z = 766$ m ASL). Based on the listed value for the potential temperature at ground level ("THTA=268.6 K") deduce what reference pressure p_0 must have been used to define THTA.

7. On the hodograph blank (Fig. 10) plot the sounding data of Fig. (9) at the mandatory levels up to 500 hPa. Add a vector designating the thermal wind between the 850 hPa and 700 hPa levels, and comment on the implied location of colder air.

8. Use the hypsometric equation (given as data) to compute the (p^{-1})-weighted mean temperature of the 850 – 700 hPa layer for the sounding of Fig. (9)

Equations and Data.

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

- $p = \rho\ R\ T$, the ideal gas law. p [Pascals], pressure; ρ, [kg m^{-3}] the density; T [Kelvin], the temperature; and $R = 287$ [J kg^{-1} K^{-1}], the specific gas constant for air.

- $\theta = T \left(\frac{p_0}{p}\right)^{R/c_p}$, 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.

- $A_T \equiv \left(\frac{\partial T}{\partial t}\right)_{adv} = -\ V\ \frac{\partial T}{\partial s}$

  Advective contribution to the rate of change of temperature, expressed in natural coordinates. The unit vector $\hat{s}$ for the s axis points downstream and parallel to the flow contours (eg. height contours), and V is the wind *speed*.

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

  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 $\Omega \approx 2\pi/(24 \times 3600)$ s^{-1} is the angular velocity of the earth, and ϕ is latitude); g acceleration due to gravity.

- $z_2 - z_1 = \frac{R}{g}\ \overline{T}\ \ln\frac{p_1}{p_2}$

  The hypsometric equation (where $z_2 > z_1$). The left hand side is the (z_2 to z_1 hPa) thickness, and $\overline{T}$ is the weighted mean temperature [K] of the layer (weighting factor is p^{-1}).

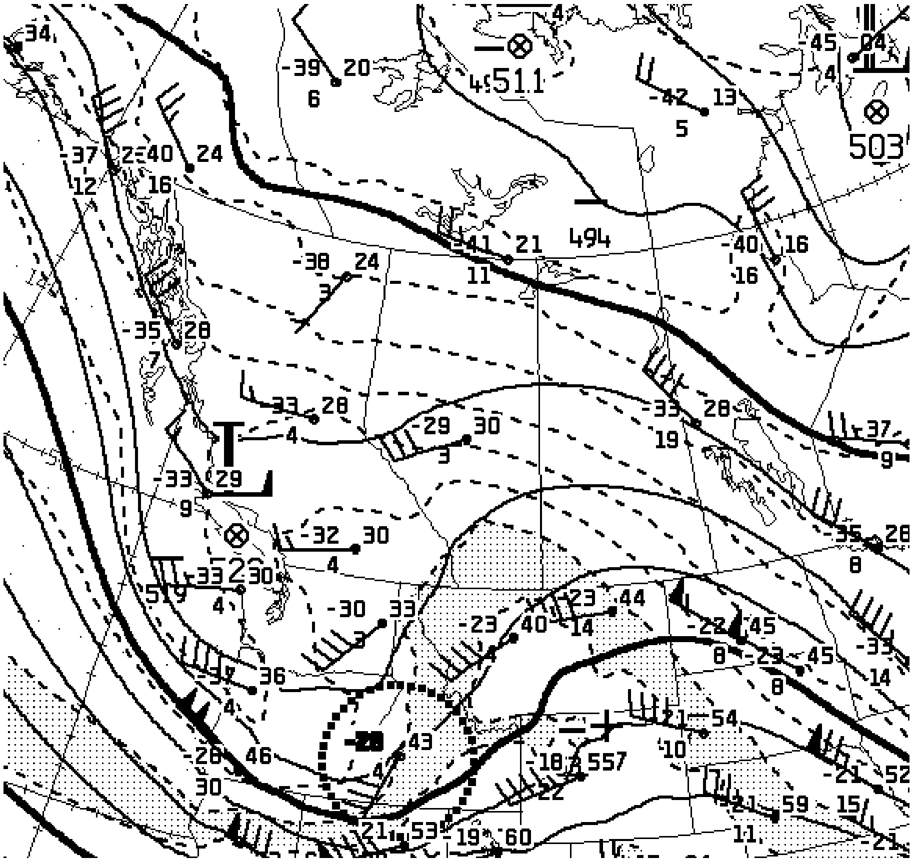

Figure 1: MSC 500 hPa analysis, 12Z 25 Feb., 2012.

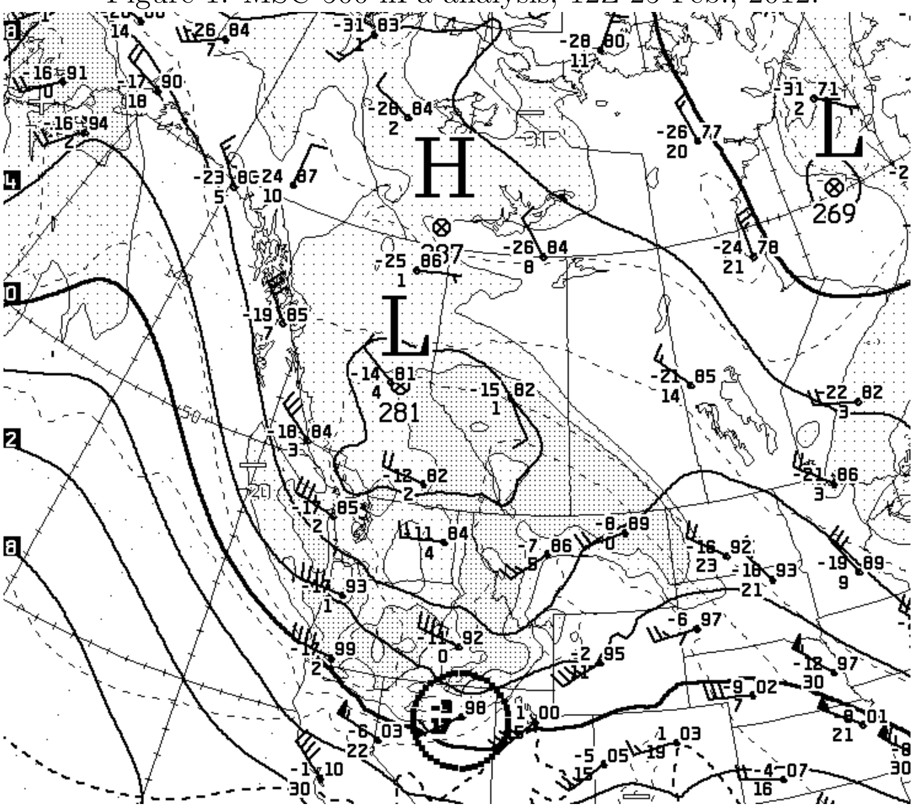

Figure 2: MSC 700 hPa analysis, 12Z 25 Feb., 2012 (see Fig. 8 for the 700 hPa chart 12 hrs later, at 00Z 26 Feb).

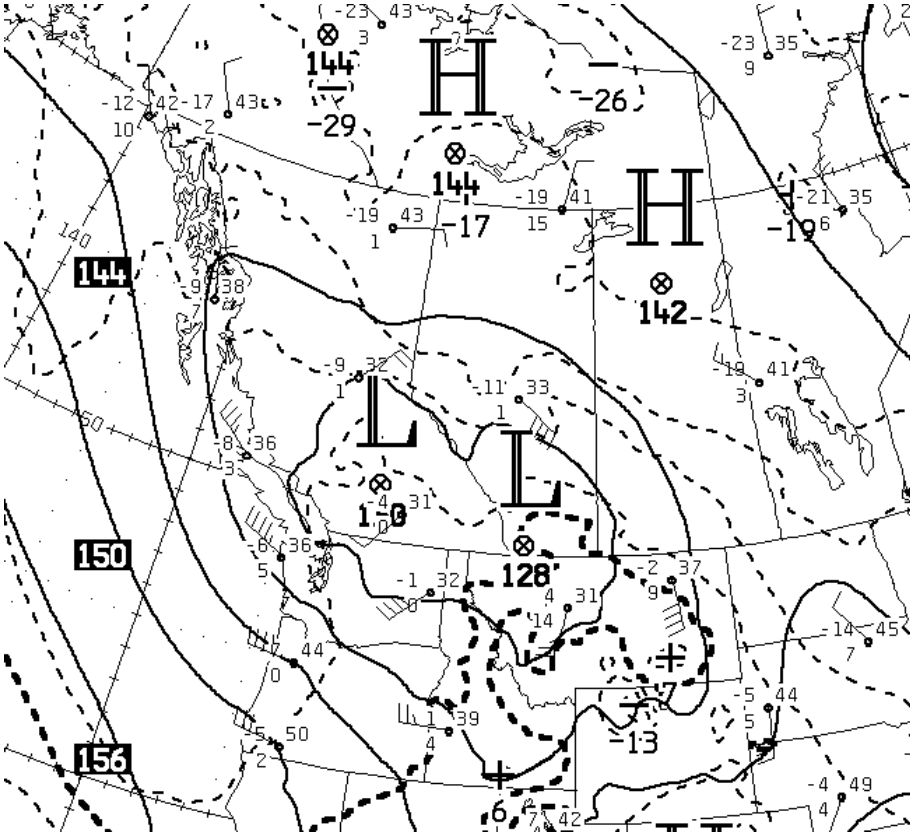

Figure 3: MSC 850 hPa analysis, 12Z 25 Feb., 2012.

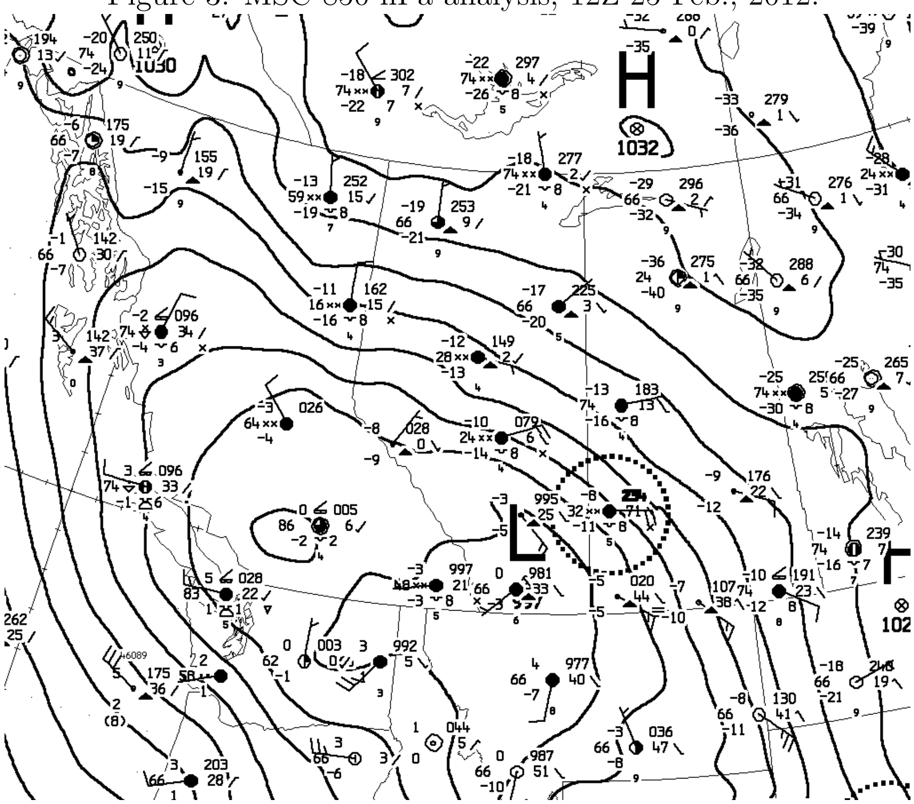

Figure 4: MSC surface analysis, 12Z 25 Feb., 2012.

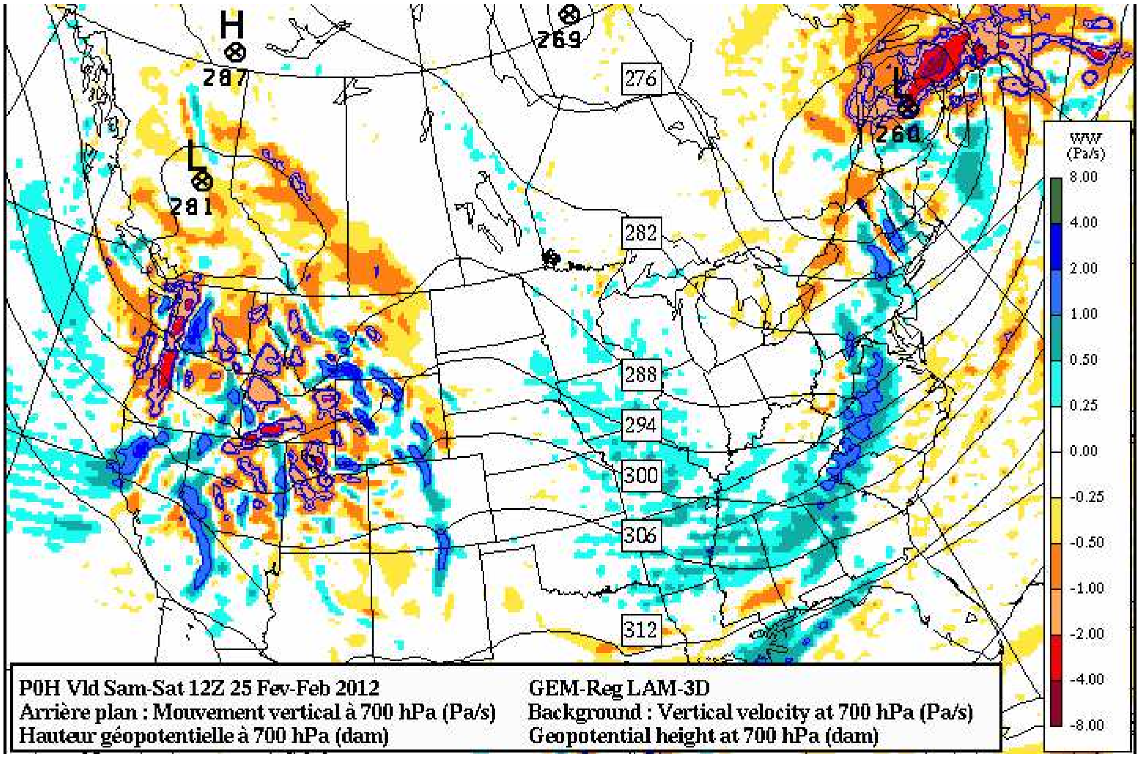

Figure 5: GEM 0h prog vertical velocity at 700 hPa, 12Z 25 Feb., 2012.

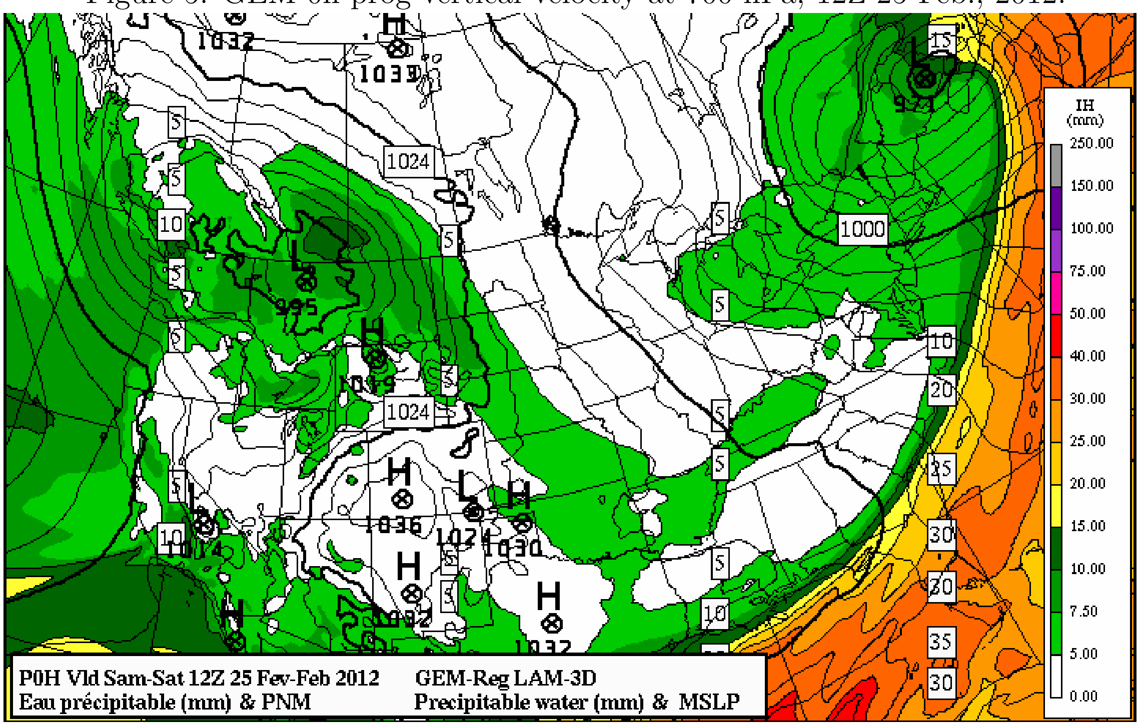

Figure 6: GEM 0h prog precipitable water, valid 12Z 25 Feb., 2012.

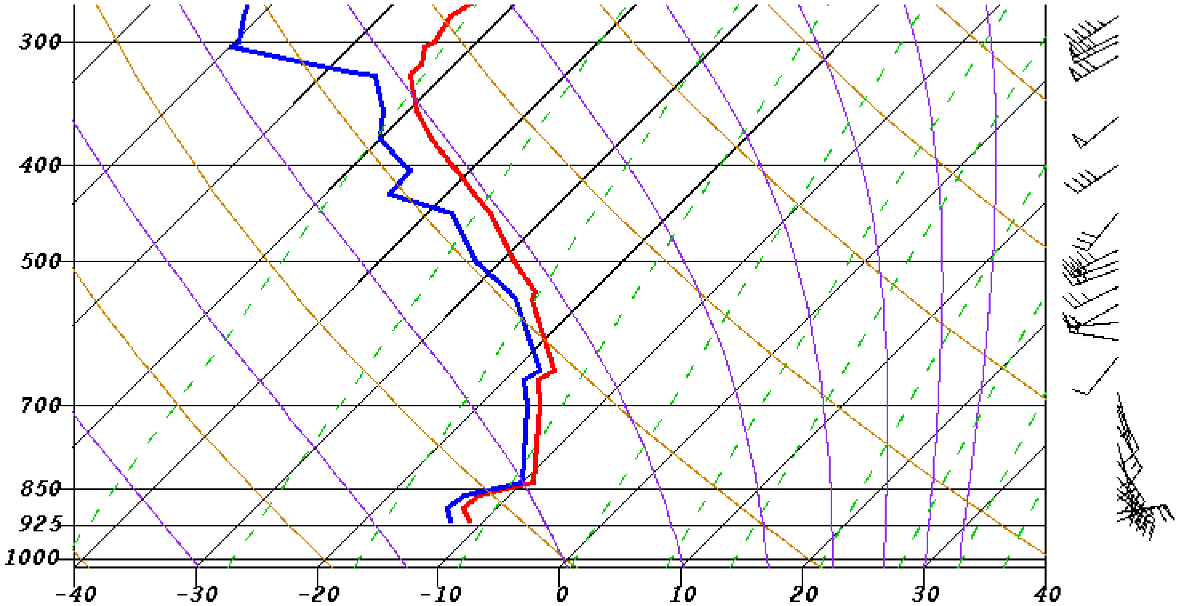

Figure 7: Stony Plain (wse) sounding, 12Z 25 Feb., 2012.

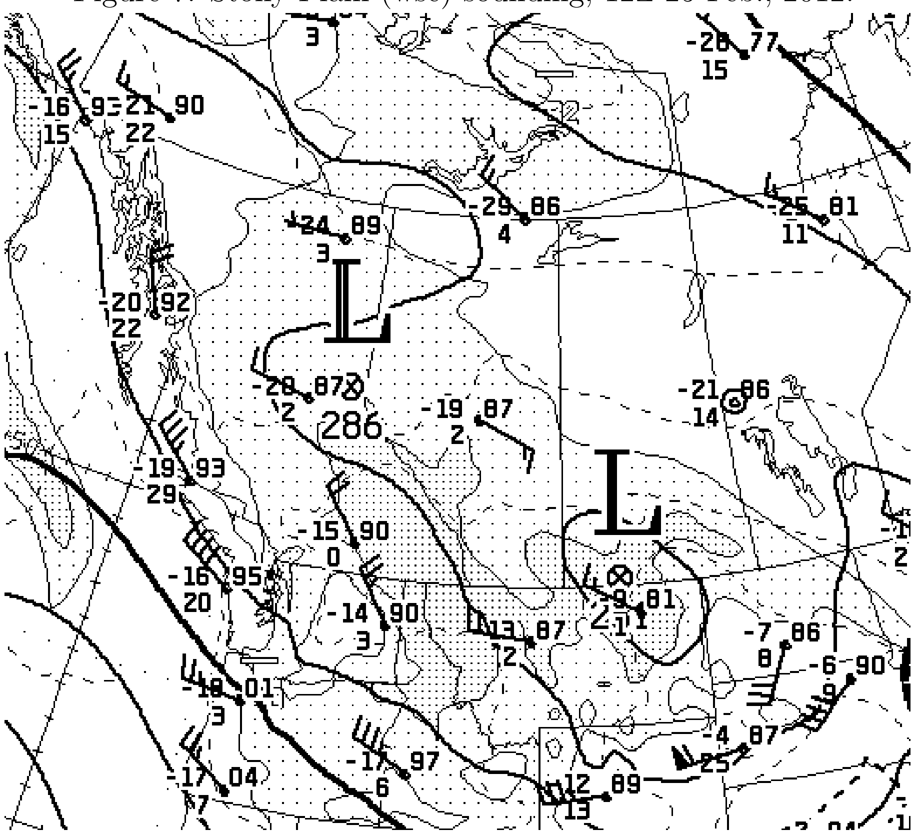

Figure 8: MSC 700 hPa analysis, 00Z 26 Feb., 2012.

71119 WSE Edmonton Stony Plain Observations at 12Z 25 Feb 2012

PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K	THTE K	THTV K
1000.0	69									
925.0	683									
915.0	766	-11.3	-12.8	89	1.57	70	12	268.6	273.0	268.8
897.5	914	-12.3	-13.7	89	1.49	80	23	269.0	273.2	269.2
888.0	995	-12.9	-14.2	90	1.44	93	28	269.2	273.4	269.5
864.0	1205	-12.5	-13.7	91	1.54	128	39	271.8	276.2	272.0
862.4	1219	-12.3	-13.5	91	1.57	130	40	272.1	276.6	272.4
850.0	1330	-10.9	-11.8	93	1.83	130	40	274.7	280.0	275.0
837.0	1449	-9.1	-10.1	92	2.13	136	41	277.8	284.0	278.2
828.8	1524	-9.4	-10.4	92	2.10	140	41	278.3	284.4	278.6
796.5	1829	-10.7	-11.7	92	1.96	145	36	280.1	285.8	280.4
765.3	2134	-12.0	-13.1	92	1.84	165	16	281.9	287.3	282.2
735.5	2438	-13.3	-14.4	92	1.72	150	13	283.7	288.9	284.0
706.8	2743	-14.6	-15.7	91	1.60	160	12	285.5	290.4	285.8
700.0	2817	-14.9	-16.0	91	1.58	155	8	286.0	290.8	286.2
678.8	3048	-16.0	-17.2	90	1.47	165	3	287.2	291.8	287.5
659.0	3271	-17.1	-18.4	90	1.37	185	6	288.4	292.7	288.7
644.0	3444	-16.7	-17.8	91	1.47	201	8	290.8	295.4	291.1
625.6	3658	-18.0	-19.2	91	1.35	220	10	291.7	296.0	291.9
600.4	3962	-19.9	-21.1	90	1.19	280	13	293.0	296.8	293.2
576.2	4267	-21.8	-23.1	90	1.04	265	16	294.2	297.6	294.4
552.9	4572	-23.7	-25.0	89	0.91	240	19	295.4	298.4	295.6
546.0	4665	-24.3	-25.6	89	0.88	242	20	295.8	298.7	296.0
537.0	4785	-24.7	-26.7	83	0.81	243	22	296.8	299.4	296.9
530.2	4877	-25.4	-27.7	82	0.75	245	23	296.9	299.4	297.1
508.2	5182	-27.9	-30.9	76	0.58	250	31	297.5	299.5	297.6
500.0	5300	-28.9	-32.1	74	0.52	250	31	297.7	299.5	297.8
487.0	5486	-30.3	-33.5	74	0.47	245	35	298.3	299.9	298.4
446.9	6096	-34.8	-37.9	73	0.33	220	29	300.0	301.2	300.1
446.0	6110	-34.9	-38.0	73	0.33	220	29	300.1	301.2	300.1
427.0	6412	-37.7	-44.7	48	0.17	226	33	300.3	300.9	300.3
404.0	6792	-41.1	-45.0	66	0.17	234	38	300.6	301.3	300.7
400.0	6860	-41.9	-45.9	65	0.16	235	39	300.4	301.0	300.5

Figure 9: Stony Plain (wse) sounding data, 12Z 25 Feb., 2012.

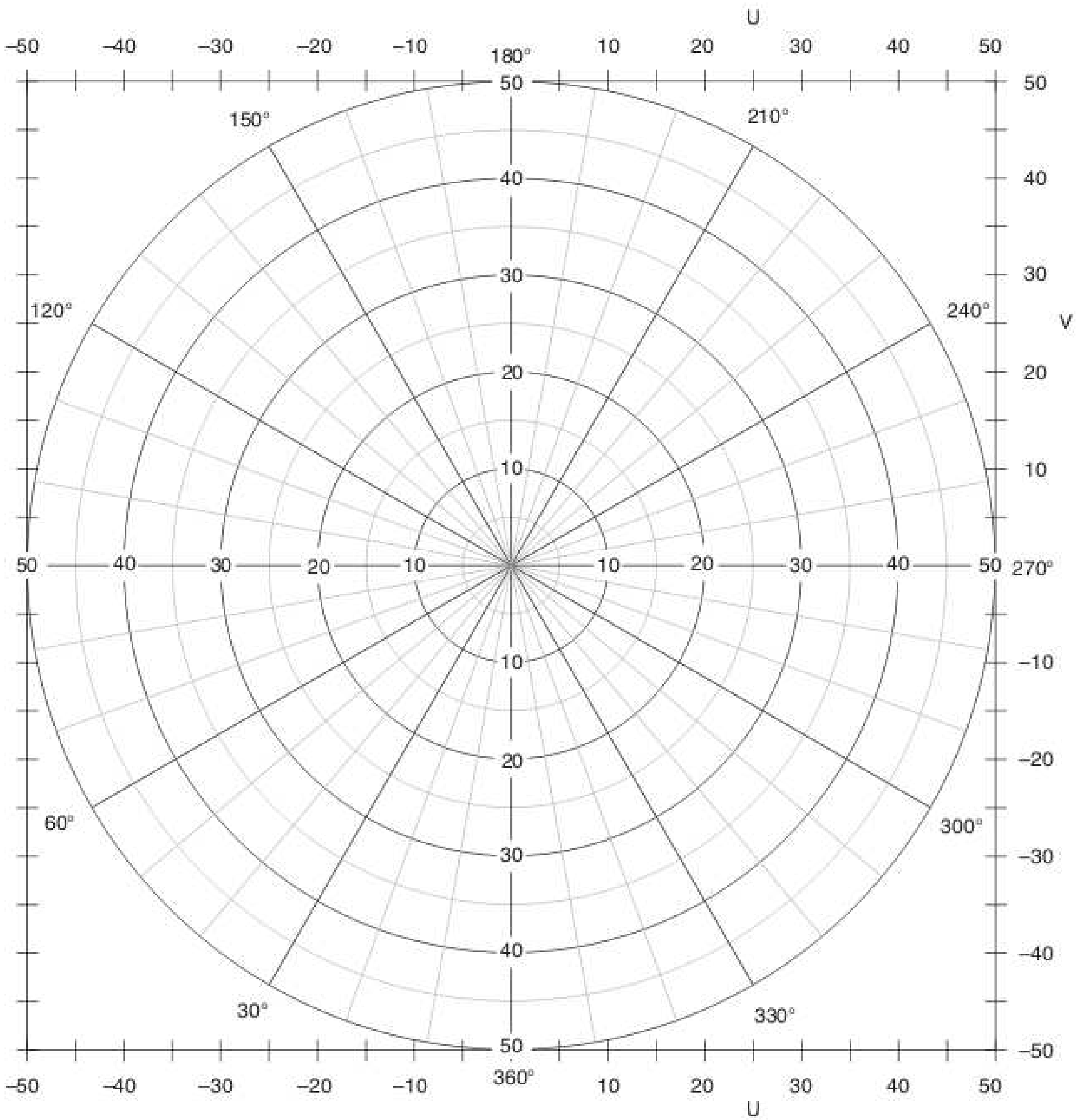

Figure 10: Blank hodograph (courtesy of Prof. R. Stull, 2007).