EAS270 "The Atmosphere" Final Exam 8 Dec., 2009

Professor: J.D. Wilson Time available: 120 mins Value: 40%

See back pages for equations and data you may need. You may keep the exam.

Multi-choice (60 x 2/3 → 40 % | 120 min)

1. Pick the incorrect association:
   (a) shortwave – barotropic atmosphere ✓✓
   (b) temperature advection – baroclinicity
   (c) barotropic – isotherms parallel with height contours
   (d) temperature advection – isotherms not parallel with height contours
   (e) longwave – vorticity maxima and minima

2. A "squall line" most often is located ___
   (a) in the cold air about 100 km behind (i.e. W or NW of) the cold front
   (b) along the cold front
   (c) in the cold air about 100 km in advance of (i.e. NE or N of) the warm front
   (d) along the warm front
   (e) in the warm sector some distance in advance of (i.e. E or SE of) the cold front ✓✓

3. The horizontal force balance in a tornado is dominated by the ___ forces
   (a) Coriolis, pressure-gradient
   (b) centripetal, friction
   (c) friction, pressure-gradient
   (d) centripetal, pressure-gradient ✓✓
   (e) buoyancy, pressure-gradient

4. On the CMC 850 hPa analysis, a feature that can be taken to signify a front is ___
   (a) an occlusion
   (b) a belt (linear region) of very strong winds
   (c) a warm sector
   (d) thunderstorms
   (e) a belt of closely-spaced isotherms ✓✓

5. As a climate diagnostic the daily potential evapotranspiration, also known as "atmospheric demand" (for water vapour), principally reflects the influences of ___
   (a) latitude, longitude, elevation
   (b) latitude, daily mean temperature
   (c) daily mean temperature and daily total precipitation
   (d) daily mean net radiation, vapour pressure deficit and wind speed ✓✓
   (e) solar constant, Coriolis effect, Geostrophic wind speed

6. Upper level divergence ___ ascent, and occurs in a trough ___ region
   (a) induces; exit ✓✓
   (b) induces; entry
   (c) suppresses; entry
   (d) suppresses; exit
   (e) cancels; baroclinic

7. Clouds along the warm front associated with a mid-latitude storm tend to be ___
   (a) orographic
   (b) barotropic
   (c) baroclinic
   (d) cumuliform
   (e) stratiform ✓✓

8. A "baroclinic" region of the atmosphere is a region where ___
   (a) isotherms and height contours are parallel
   (b) isotherms and height contours are not parallel ✓✓
   (c) wind speed and pressure are related by the Geostrophic equation
   (d) the Coriolis force vanishes
   (e) the environmental lapse rate lies between the dry and moist adiabatic lapse rates

9. Consider a vertical cylinder of air extending to the top of the atmosphere. If mass convergence into the column within the friction layer is balanced by mass divergence above the friction layer, surface pressure is ___ in time and the vertical velocity at the top of the friction layer is ___
   (a) steady; zero
   (b) steady; upward ✓✓
   (c) increasing; zero
   (d) increasing; upward
   (e) steady; indeterminate

10. Which statement regarding lightning is false?
    (a) lightning occurs in both warm and cold clouds ✓✓
    (b) negative stroke cloud-to-ground lightning is more common than positive
    (c) the stepped leader is an irregular conductive (ionized) channel that progresses downward from cloud towards ground
    (d) if the delay between a lightning flash and thunder is t [s], then the distance to the lightning stroke is about $300\,t$ [m]
    (e) the top of a thunderstorm is positively charged

11. Which feature of a supercell thunderstorm is particularly significant relative to the possibility of the storm generating a tornado?
    (a) warm, moist, low-level inflow from S or SE
    (b) drier mid-level inflow from SW or W
    (c) rotation on the scale of the storm (mesocyclone) ✓✓
    (d) top penetrates into the stratosphere
    (e) exceptionally cold downdraft

12. Airmass thunderstorms begin to dissipate when ___
    (a) lightning neutralizes all the electric charge in the cloud
    (b) all the precipitation particles in the cloud freeze
    (c) solar heating at the ground decreases in the cloud shadow
    (d) the downdraft spreads throughout the cloud and cuts off the updraft ✓✓
    (e) all cloud water has been precipitated

13. A weather forecast method that compares past weather maps and weather patterns to those of the present moment in order to forecast (anticipate) for tomorrow is called ___ and is probably ___ skillful than today's Numerical Weather Prediction.

    (a) persistence forecasting; more
    (b) an analog method; less ✓✓
    (c) an analog method; more
    (d) qualitative forecasting; more
    (e) quantitative forecasting; more

14. Suppose the central pressure P_c at the axis of a particular tornado is lower than the ambient pressure P_o by an amount given by $P_o - P_c = \rho V^2$, where V is the tangential windspeed. If $P_o = 941$ hPa and $P_c = 860$ hPa, then windspeed V is approximately ___ $\mathrm{m\,s^{-1}}$

    (a) 0.9
    (b) 9
    (c) 90 ✓✓
    (d) 900
    (e) 8100

15. If global warming driven by increasing atmospheric CO_2 concentration results in less ice/snow cover, the planetary albedo will be ___ which is an example of a ___ feedback

    (a) increased; negative
    (b) increased; positive
    (c) decreased; negative
    (d) decreased; positive ✓✓
    (e) unaltered; fictitious

16. The flat, anvil-shaped top sometimes seen on a thunderstorm is a sign that ___

    (a) further deepening is prohibited by the stably-stratified stratosphere ✓✓
    (b) the cloud has penetrated through the top of the friction layer, to the free atmosphere
    (c) above that level, there are insufficient cloud condensation nuclei to permit cloud
    (d) above that level, there are insufficient ice nuclei to permit cloud
    (e) all water vapor has been removed from the rising air by the time it reaches that level

17. Which of the following statements about modern Numerical Weather Prediction models is NOT true?

    (a) NWP is skillful out to a forecast range of up to about two weeks
    (b) they represent the atmosphere by "gridded fields" of the important variables
    (c) they represent an idealized atmosphere, rather than our actual atmosphere
    (d) there remains a useful professional role for a trained interpreter of NWP output
    (e) their continued improvement should eventually render them skillful out to a lead time greatly exceeding two weeks, perhaps even a year ✓✓

18. Variables represented on the grid of a numerical weather prediction model include ___

    (a) daily maximum and minimum temperatures for towns and cities
    (b) airport visibilities
    (c) risk of frost in horticultural regions
    (d) wind speed, temperature and humidity ✓✓
    (e) all of the above

19. If the 1000-500 hPa thickness at Edmonton increases by 2 dam, the mean temperature of the ___ has ___

    (a) troposphere; decreased by 4°C
    (b) friction layer; increased by 4°C
    (c) 1000-500 hPa layer; decreased by 1°C
    (d) 1000-500 hPa layer; increased by 4°C
    (e) 1000-500 hPa layer; increased by 1°C ✓✓

20. Wherever mountain peaks extend up to about 3 or more kilometers above sea-level, regional winds at the 700 hPa level likely ___

    (a) blow parallel to the height contours
    (b) blow parallel to isotherms
    (c) blow perpendicular to isotherms
    (d) obey the Geostrophic equation
    (e) do not obey the Geostrophic equation ✓✓

21. Match forecast type (climatology; numerical model; persistence) with appropriate range (immediate=less than six hours; short/medium= $1/2-15$ days; long= more than 15 days):

    (a) persistence–long, numerical–short/medium, climatology–immediate
    (b) persistence–immediate, numerical–short/medium, climatology–long ✓✓
    (c) persistence–short/medium, numerical–long, climatology–immediate
    (d) persistence–immediate, numerical–long, climatology–short/medium
    (e) persistence–long, numerical–immediate, climatology–long

22. Many numerical weather models diagnose the presence of cumulus cloud on the basis of the gridded fields of humidity and temperature. This approach is called ___ of cloud.

    (a) parameterization ✓✓
    (b) explicit representation
    (c) one-dimensional representation
    (d) a persistence approach to the modelling
    (e) integration

23. Occurrence over a particular region of an "omega block" (or omega high) in the mid-tropospheric flow is considered to flag the possibility of ___

    (a) an rapidly changing weather pattern
    (b) a slowly changing weather pattern ✓✓
    (c) baroclinicity
    (d) warm weather
    (e) zonal flow

24. The "decameter" is a unit used on synoptic maps of the atmosphere, and equals ___

    (a) 10^{-6} m
    (b) 10^{-3} m
    (c) 0.1 m
    (d) 10 m ✓✓
    (e) 100 m

25. Which of the following air properties would normally increase as you travelled upward through the summer, daytime Planetary Boundary Layer (Friction Layer)?
    (a) air density
    (b) air pressure
    (c) air temperature
    (d) wind speed ✓✓
    (e) humidity
26. The vertical pressure gradient ($\Delta p/\Delta z$) on the 850 hPa surface is ___ the temperature T_{850} at that level.
    (a) inversely proportional to ✓✓
    (b) proportional to
    (c) independent of
    (d) proportional to the square of
    (e) unrelated to
27. The skew-T/log-P diagram does **NOT** provide a family of ___
    (a) isobars
    (b) isotherms
    (c) dry adiabats
    (d) moist adiabats
    (e) environmental temperature profiles ✓✓
28. If W is the vertical component of wind velocity and S $(= \sqrt{U^2 + V^2})$ is the horizontal speed, then the relationship $W \ll S$ applies ___
    (a) within the friction layer
    (b) inside deep convective clouds
    (c) inside cumulonimbus
    (d) above the friction layer and away from convective clouds ✓✓
    (e) near steeply sloping ground
29. Atmospheric pressure is of foremost interest in weather forecasting because ___
    (a) it is directly related to mean annual temperature
    (b) it controls humidity and thus cloud formation
    (c) it obeys the hydrostatic law
    (d) it signifies the total mass of air above a pressure-level of 1 hPa
    (e) it controls the horizontal and vertical winds ✓✓
30. When winds are very light, the daily cycle in temperature at a particular location ___
    (a) is dominated by heat advection
    (b) is driven by the daily cycle in the components of the surface energy balance ✓✓
    (c) is very small in amplitude (small diurnal range)
    (d) is slower (i.e. has a longer period)
    (e) is adiabatic
31. Satellite scatterometry measures near surface ___ over the ___
    (a) wind speed and direction; land
    (b) temperature; land
    (c) wind speed and direction; ocean ✓✓
    (d) temperature; ocean
    (e) latent heat flux; ocean

32. Suppose the gridded field $U(I, J, K)$ represents the east-west component of wind velocity and $\rho_v(I, J, K)$ the absolute humidity. Then $U\rho_v$ is a/an ___ quantity representing ___

    (a) explicitly resolved; vertical rate of transport of heat
    (b) unresolved; eastward rate of transport of heat
    (c) explicitly resolved; eastward rate of transport of vapour ✓✓
    (d) unresolved; vertical rate of transport of vapour
    (e) explicitly resolved; baroclinicity

33. In regard to modern NWP models ___

    (a) gridpoint spacing on the "mesh" is now fine enough to represent individual cumulus clouds and even the smallest of the microscale motions
    (b) due to a uniformly dense global network of weather stations the problem of data-sparsity has been overcome, and the accuracy of the initial state is not an issue
    (c) all pertinent processes are adequately represented
    (d) they solve exact mathematical statements of all the relevant laws
    (e) the "prognostic charts" as calculated by NWP estimate the future state of the atmosphere as defined by values of windspeed, temperature (etc.) at all grid points. ✓✓

34. In numerical weather prediction (NWP) the terms "analysis" and "prognosis" are distinguished as follows:

    (a) the analysis concerns present weather conditions, whereas the prognosis is a forecast of future weather conditions ✓✓
    (b) the analysis gives the forecast weather out to 10 days, whereas the prognosis gives the 3-month seasonal forecast
    (c) the prognosis gives the forecast weather out to 10 days, whereas the analysis gives the 3-month seasonal forecast
    (d) the analysis concerns (easily observed) surface conditions whereas the prognosis concerns the upper levels that are observed less often, and at far fewer locations (radiosonde stations)
    (e) the analysis concerns forecast skill, and the prognosis is the expected evolution of forecast skill as NWP models improve

35. The forecasting technique that produces several forecasts for the same "valid at" time, all using the same NWP model, but each beginning with slightly different "present weather" so as to reflect errors in measurements, is called ___

    (a) climatology forecasting
    (b) probability forecasting
    (c) average forecasting
    (d) persistence forecasting
    (e) ensemble forecasting ✓✓

36. Which of the following distinctions (storm; hurricane) between the northern hemisphere midlatitude storm and northern hemisphere hurricane is *false*?

    (a) cold core; warm core
    (b) fastest winds aloft; fastest winds near surface
    (c) frontal structure at surface; relatively uniform low-level temperature
    (d) cyclonic wind pattern; roughly equal frequencies of occurrence of cyclonic and anticyclonic surface winds ✓✓
    (e) updraft at core; downdraft at core

37. Relative to the present, throughout most of its 4.5 billion year history earth's climate has been ___ . Solar output during that time is believed to have ___

 (a) constant; remained constant
 (b) warmer; increased ✓✓
 (c) warmer; decreased
 (d) cooler; increased
 (e) cooler; decreased

38. An "unforced" (or "internal") climate fluctuation is a climate change that ___

 (a) is attributable to changes in the so-called "boundary conditions" of solar intensity, sun-earth orbital configuration and atmospheric composition
 (b) cannot be explained by changes in these boundary conditions ✓✓
 (c) occurs without any observable change in oceanic circulation
 (d) occurs on a timescale comparable with the age of the earth
 (e) is characterized by occurring on a timescale τ far shorter than the averaging period T_{avg} chosen to define climate statistics

39. Millenial scale climate instability in the North Atlantic is characterized by rapid climate "flip-flops" (Dansgaard-Oeschger cycle) between two states. This mode of climate variability is associated with ___

 (a) release of methane hydrates from cold ocean sediments
 (b) orbital (Milankovich) forcing
 (c) the sunspot cycle and associated changes in solar intensity
 (d) variations in the temperature-and-salinity driven 'thermohaline ocean circulation,' perhaps associated with ice sheet melting ✓✓
 (e) continental drift (changing distribution of continents)

40. Which climate forcing mechanism is irrelevant for a GCM simulation of climate change over the next few centuries?

 (a) solar output
 (b) volcanism
 (c) orbital (Milankovitch) forcing ✓✓
 (d) atmospheric composition
 (e) deforestation

41. Which of the following climate forcings or feedback mechanisms is subject to the *least* uncertainty as regards GCM simulations of climate evolution over the coming few centuries?

 (a) solar output
 (b) aerosol feedback
 (c) water vapour feedback
 (d) cloud feedback
 (e) ice albedo feedback ✓✓

42. Spiral rain bands are a characteristic feature of ___

 (a) hurricanes ✓✓
 (b) tornadoes
 (c) midlatitude storms
 (d) anticyclones
 (e) maritime tropical airmasses

43. In simulations using a Global Climate Model (GCM) "the early part of the simulation is discarded so that arbitrary starting values do not taint the climate statistics." However Numerical *Weather* Predictions are extremely ___ to the initial state, and NWP skill at lead times beyond about ___ is poor (in part) because of initialization errors

(a) sensitive; two months
(b) sensitive; two weeks ✓✓
(c) sensitive; two days
(d) insensitive; two weeks
(e) insensitive; two days

44. In Numerical Weather Prediction the state of the atmosphere is represented on a three-dimensional grid by "gridded fields" of wind speed, temperature, etc., and the model computes property exchanges from cell to cell across cell walls. In this respect neighbouring values of air density ρ influence each other (i.e. interact) by the process(es) of ___

(a) persistence
(b) convection ✓✓
(c) radiation
(d) radiation, convection and (to a very small extent) diffusion
(e) integration

45. Signals returned by a radiosonde include ___

(a) temperature, dewpoint, pressure ✓✓
(b) dry adiabatic lase rate, saturated adiabatic lapse rate, pressure
(c) isobars, isotherms, wind direction
(d) wind speed, wind direction, height
(e) wind speed, convergence, vorticity

46. Referring to Figure (1), consider a parcel of dry air at $(p, T) = (1000\,\text{hPa}, 20\,^{\circ}\text{C})$. If this parcel is lifted adiabatically to the 500 hPa level its temperature will be about ___ °C

(a) -33 ✓✓
(b) -20
(c) -10
(d) 0
(e) 15

47. Referring to Figure (1), consider a parcel of saturated air at $(p, T) = (1000\,\text{hPa}, 9\,^{\circ}\text{C})$. If this parcel is lifted adiabatically to the 700 hPa level then descends adiabatically back to 1000 hPa its temperature will be about ___ °C

(a) -20
(b) -10
(c) 0
(d) 15
(e) 21 ✓✓

48. Referring to Figure (2), the feature running through Alberta is a/an ___

(a) arctic hurricane
(b) surface trough ✓✓
(c) thermal trough
(d) Rossby wave
(e) short wave

49. Referring to Figure (2), sea-level corrected pressure at the station near Edmonton was:

    (a) 900.5 Pa
    (b) 900.5 hPa
    (c) 1005 Pa
    (d) 1000.5 Pa
    (e) 1000.5 hPa ✓✓

50. Referring to Figure (2), stations immediately south of the storm in eastern Canada are reporting ___ while those immediately north of the storm report ___

    (a) snow; rain
    (b) rain; snow ✓✓
    (c) overcast sky; clear sky
    (d) clear sky; overcast sky
    (e) SSW to SW winds; SW winds

51. Referring to Figure (2), the innermost isobar surrounding the centre of low pressure in eastern Canada is the ___ contour

    (a) freezing
    (b) cold front
    (c) warm front
    (d) 513 hPa
    (e) 952 hPa ✓✓

52. Referring to Figure (3), the height of the 850 hPa surface over Edmonton is ___ and the dewpoint temperature is ___

    (a) 131 dam; 2°C ✓✓
    (b) 131 dam; 6°C
    (c) 31 dam; 2°C
    (d) 31 dam; 6°C
    (e) 311 dam; 2°C

53. Referring to Figures (2, 3) the storm over eastern Canada is in the ___ phase of the storm life cycle

    (a) cyclogenesis
    (b) mature ✓✓
    (c) occluded
    (d) dissipating
    (e) cumulus

54. Referring to Figure (3), “baroclinicity” is observed at ___

    (a) A
    (b) A and D
    (c) B and C ✓✓
    (d) B and D
    (e) D

55. Referring to Figure (3), warm advection is occurring at ___

   (a) A
   (b) B
   (c) C ✓✓
   (d) C and D
   (e) D

56. Referring to Figure (3), the station immediately east of **D** (Pickle Lake, Ontario, WPL) is in the ___ and reports ___

   (a) warm sector; strong NNW wind
   (b) retreating warm airmass; strong SSE wind
   (c) advancing warm airmass; strong SSE wind
   (d) retreating cold airmass; strong NNW wind
   (e) advancing cold airmass; strong NNW wind ✓✓

57. Referring to Figure (4), the 700 hPa height at The Pass (the station in west-central Manitoba) is ___ . The dense stippling represents ___

   (a) 830 hPa; 534-540 dam thickness band
   (b) 700 hPa; 534-540 dam thickness band
   (c) 830 dam; humidity advection
   (d) 283 dam; temperature-dewpoint spread less than two degrees Celcius ✓✓
   (e) 383 dam; temperature-dewpoint spread less than two degrees Celcius

58. Referring to Figure (5), the stippled band represents ___

   (a) temperature-dewpoint spread less than two degrees Celcius
   (b) temperature-dewpoint spread less than five degrees Celcius
   (c) 534-540 dam band of 1000-500 hPa thickness ✓✓
   (d) 534-540 dam band of 500 hPa heights
   (e) freezing rain

59. Referring to Figure (5), the dashed lines in northern Manitoba represent a ___

   (a) thickness (thermal) trough ✓✓
   (b) thickness (thermal) ridge
   (c) shortwave trough
   (d) longwave trough
   (e) shortwave ridge

60. Referring to Figure (6), the ratio of the lengths L1, L2 as measured by a ruler on the map is about L1/L2 = 37/67 and the true (geographic) distance corresponding to L2 is 11×111 km. According to the Geostrophic wind equation, the wind speed at Edmonton is expected to be about ___ $\mathrm{m\,s^{-1}}$

   (a) 3
   (b) 5
   (c) 10
   (d) 15
   (e) 30 ✓✓

Equations and Data.

- one full barb on the wind vector corresponds to 5 m s^{-1}, and a solid triangle corresponds to 25 m s^{-1}
- $V = \frac{g}{f}\frac{\Delta h}{\Delta n}$

  The Geostrophic wind equation. Δh [m], the change in height of a constant pressure surface over distance Δn [m] normal to (i.e. perpendicular to) the height contours; $f = 2\Omega\ \sin\phi$ [s^{-1}] the Coriolis parameter (where $\Omega = 2\pi/(24\text{x}60\text{x}60) = 7.27\text{x}10^{-5}$ s^{-1} is the angular velocity of the earth, and ϕ is latitude); $g = 9.81$ [m s^{-2}] acceleration due to gravity.

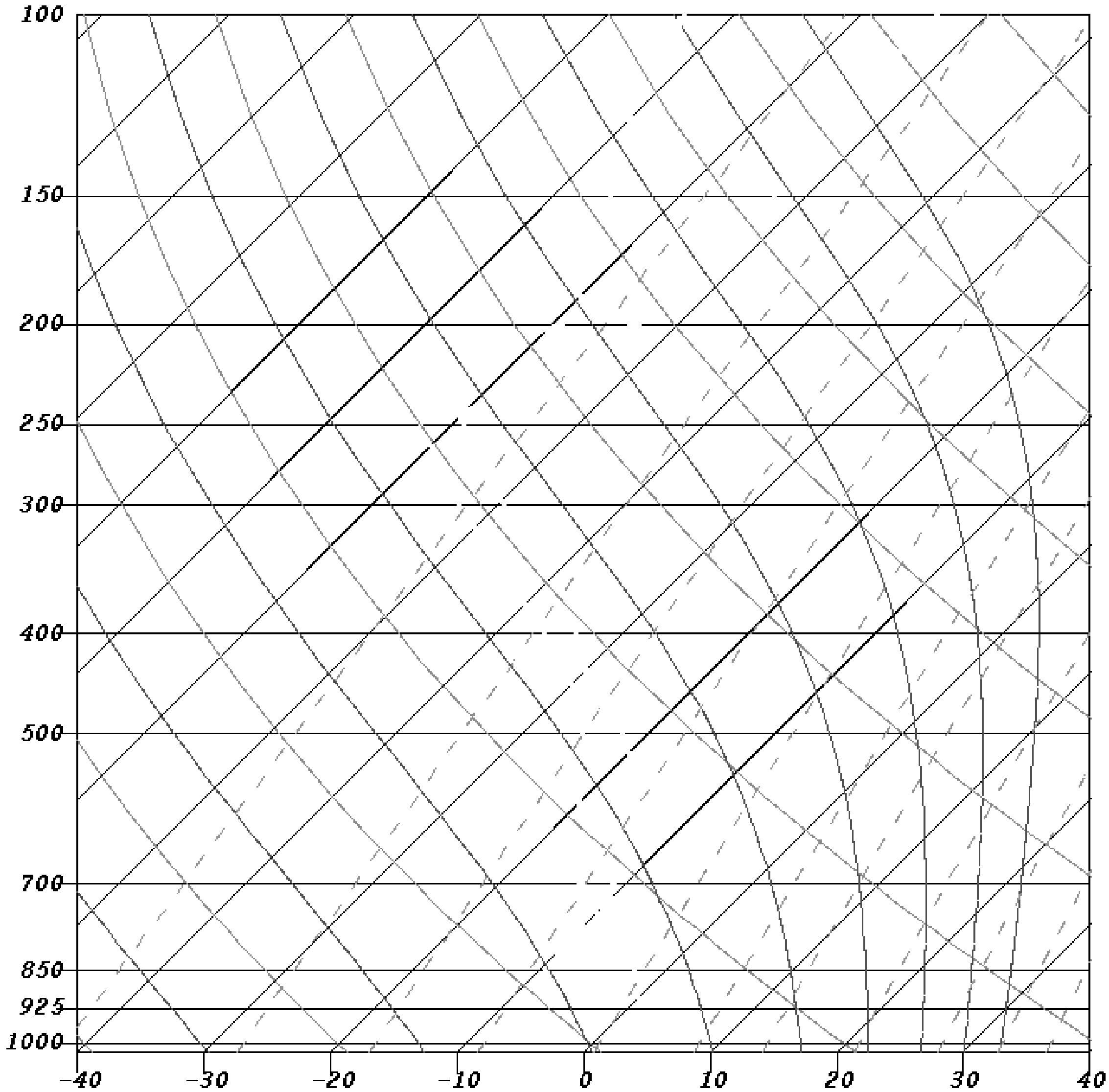

Figure 1: Blank Skew T – log P chart.

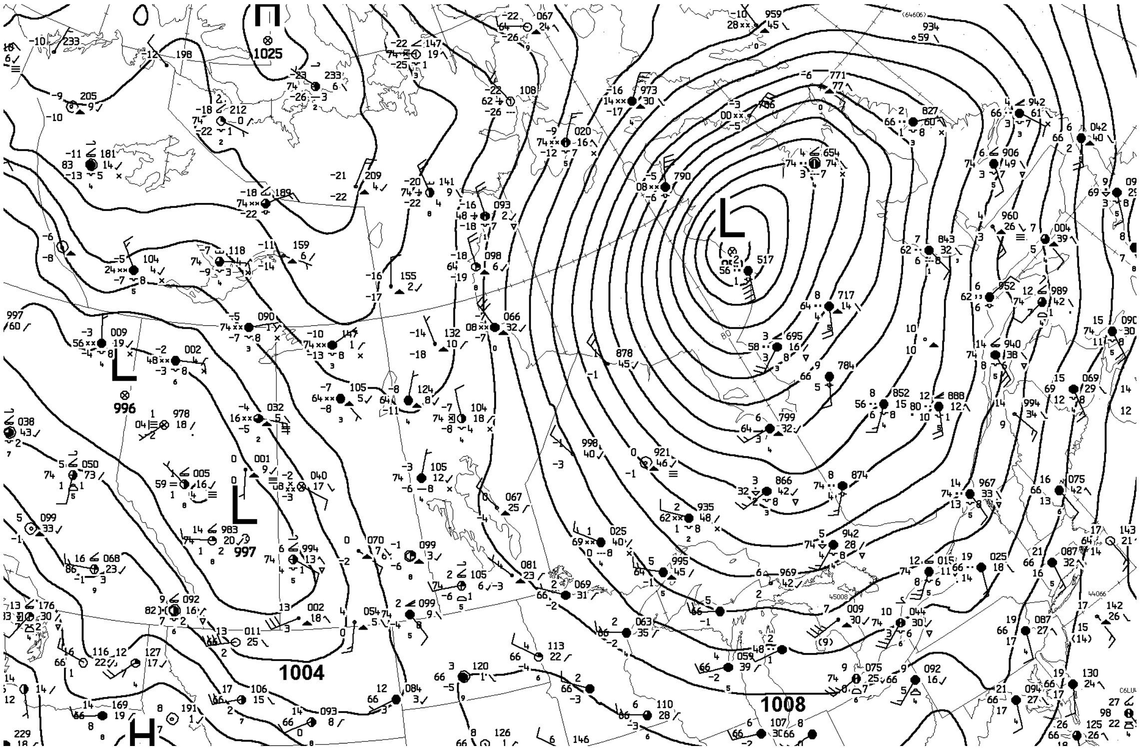

Figure 2: CMC surface analysis, 18Z 31 Oct. 2009.

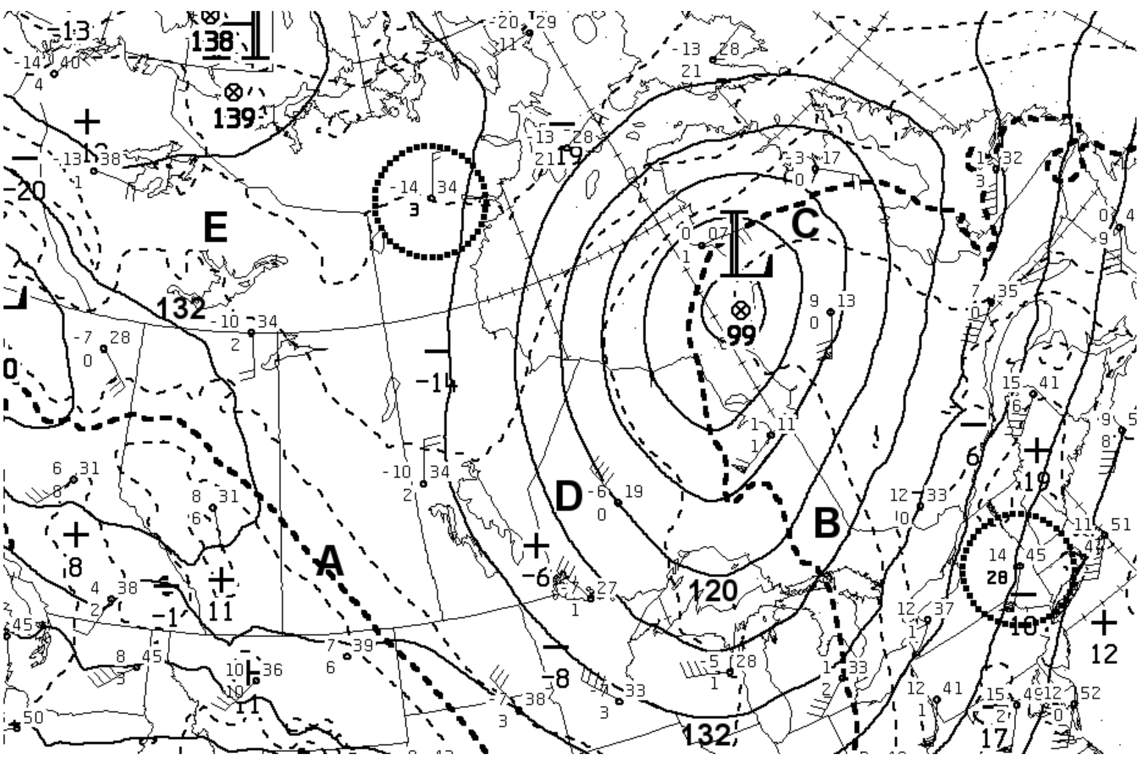

Figure 3: CMC 850 hPa analysis, 12Z 31 Oct. 2009.

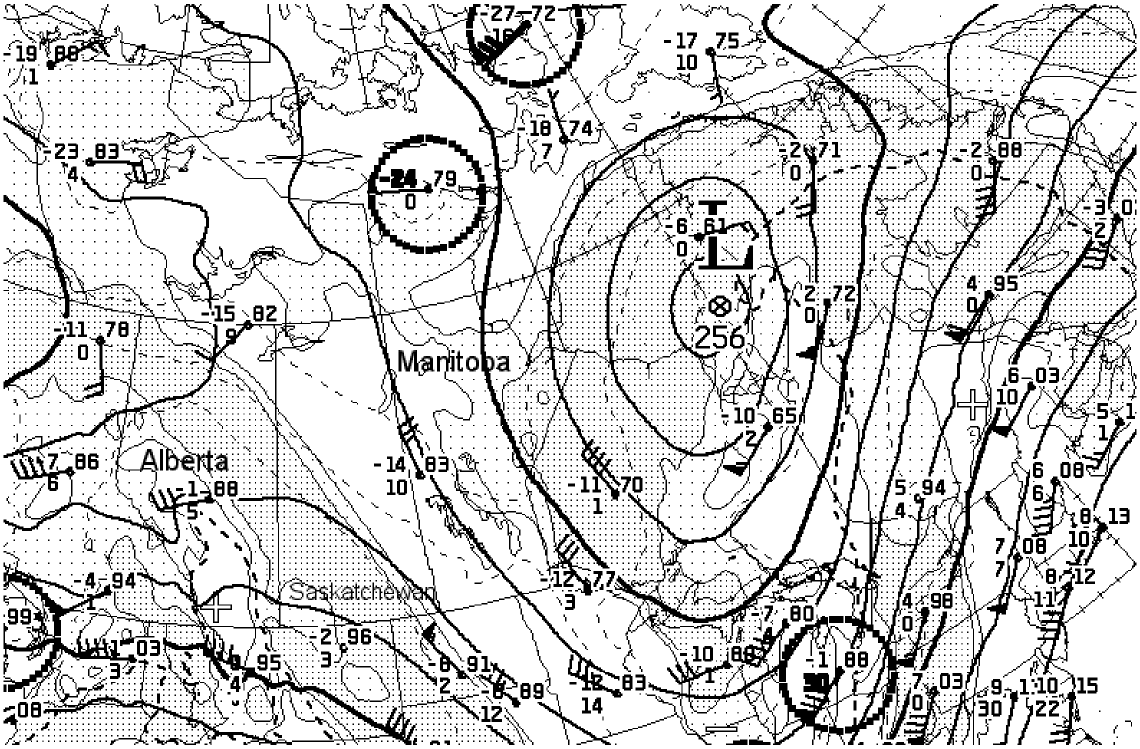

Figure 4: CMC 700 hPa analysis, 12Z 31 Oct. 2009.

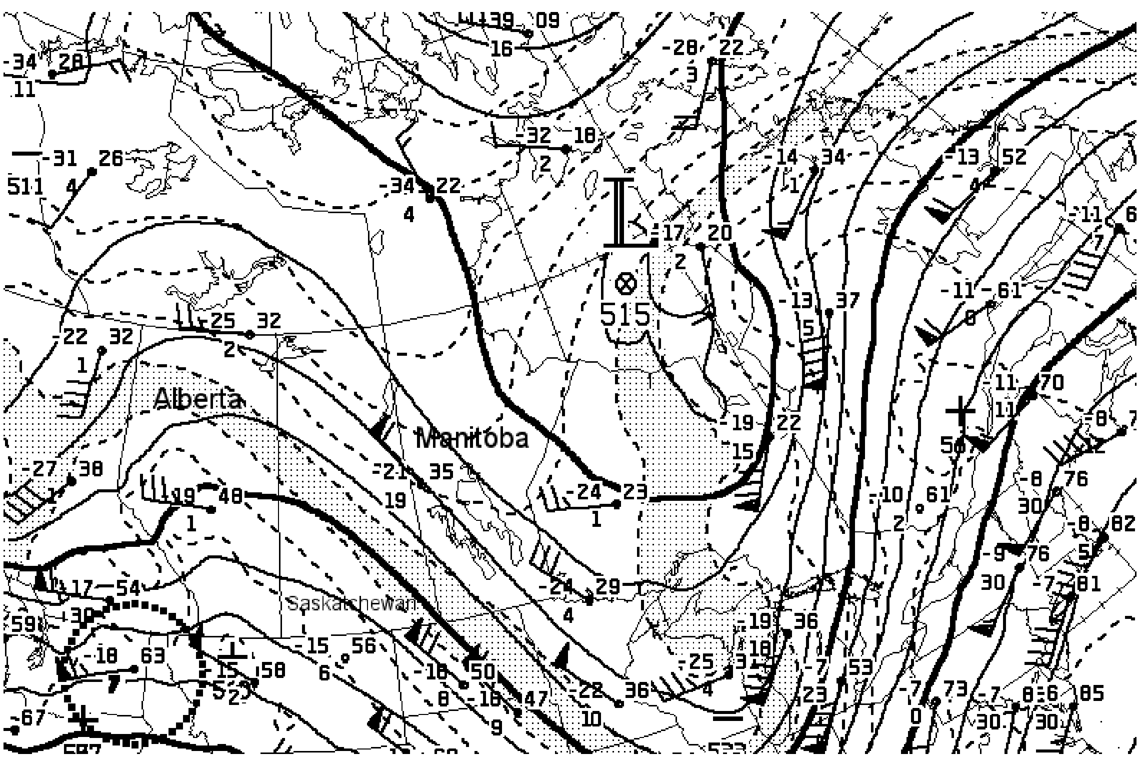

Figure 5: CMC 500 hPa analysis, 12Z 31 Oct. 2009.

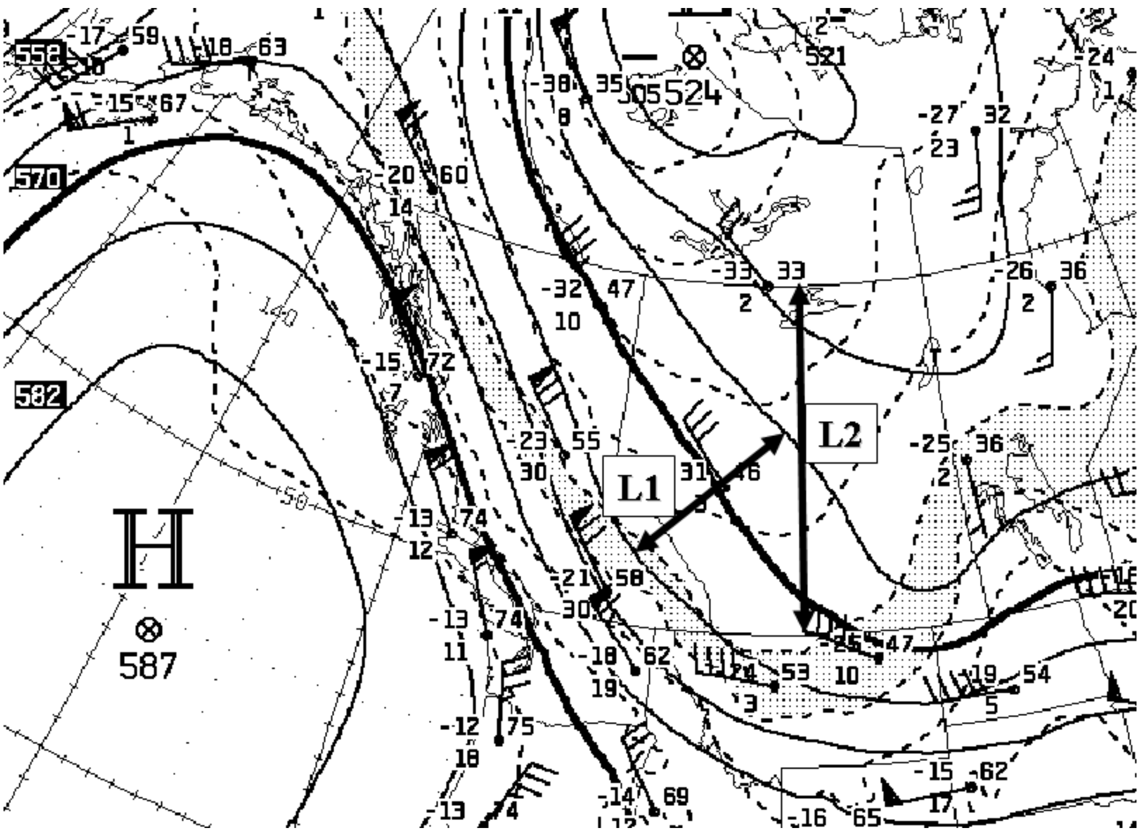

Figure 6: CMC 500 hPa analysis.