

Professor: J.D. WilsonTime available: 120 minsValue: 40%

You may keep the exam.

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

1. The “vault” observed on a radar image of a supercell thunderstorm corresponds to ____
 - (a) the region of heaviest hailstones
 - (b) the entry region of the warm inflow ✓✓
 - (c) the region of heaviest raindrops
 - (d) the cold downdraft region
 - (e) the dome where the cloud protrudes into the stratosphere
2. If the pressure on the axis of a tornado $P_0 = 940$ hPa and the pressure outside the tornado is $P = 980$ hPa, a reasonable guess for the peak windspeed associated with the tornado would be about ____
 - (a) 20 kph
 - (b) 20 m s^{-1}
 - (c) 60 m s^{-1} ✓✓
 - (d) 60 kph
 - (e) 120 m s^{-1}
3. In cloud-ground lightning the stepped leader travels ____ and the return stroke travels
 - (a) downward, upward ✓✓
 - (b) upward, downward
 - (c) upward, upward
 - (d) downward, downward
 - (e) laterally, vertically
4. If lightning struck the ground 5 kilometers from where you were standing, you would hear thunder about ____ seconds later
 - (a) 1/3
 - (b) 3
 - (c) 5
 - (d) 15 ✓✓
 - (e) 50
5. Which of the following conditions is **not** conducive to the occurrence of severe thunderstorms?
 - (a) variation of wind direction with increasing height (wind shear)
 - (b) high temperature and small temperature-dewpoint spread ($T - T_d$) in the friction layer
 - (c) absence of any “capping inversion” aloft ✓✓
 - (d) sounding exhibits a large value for CAPE (convectively available potential energy)
 - (e) presence of a front or dryline (i.e. strong horizontal gradient in temperature and/or dewpoint)

6. A “shelf cloud” is formed when a thunderstorm’s _____ is displaced aloft by the _____ associated with the cold outflow
- (a) warm and moist surface inflow; mesocyclone
 - (b) warm and moist surface inflow; gust front ✓✓
 - (c) mesocyclone; outflow boundary
 - (d) mesocyclone; squall line
 - (e) downdraft; wind shear
7. Air mass thunderstorms _____
- (a) occur on a front (airmass boundary)
 - (b) do not produce lightning
 - (c) can occur without need of supporting environmental wind shear ✓✓
 - (d) do not produce hail
 - (e) have a lifetime of the order of 12 hours
8. Which statement is **untrue** or **unrealistic**? In order to provide best possible advance warning of severe weather (including possible tornadoes) the Meteorological Service of Canada should _____
- (a) make 12 hour advanced forecasts of each tornado’s path, to within an accuracy of several tens of metres, using a very high resolution numerical model ✓✓
 - (b) use weather radar to monitor existing thunderstorms for signs of rotation
 - (c) use weather radar to monitor existing thunderstorms for a hook echo
 - (d) use all available tools (eg. thermodynamic charts, surface and upper analyses) to forecast in advance the possible locations of severe storms
 - (e) monitor lightning strikes on the automatic lightning detection network
9. Major airports located in regions prone to severe weather may be equipped with _____ to detect dangerous wind shear prevailing over short distances (order 5 km) due to _____
- (a) conventional (electromagnetic) weather radar; thunderstorms
 - (b) doppler acoustic radar; microbursts (thunderstorm downdrafts) ✓✓
 - (c) conventional (electromagnetic) weather radar; hook echoes
 - (d) doppler acoustic radar; tornadoes
 - (e) rawinsondes; subsidence inversions
10. A hurricane may evolve from a _____ when ocean surface temperature exceeds about _____ °C
- (a) hot tower; 20
 - (b) supercell thunderstorm; 17
 - (c) waterspout; 27
 - (d) mid-latitude storm; 17
 - (e) tropical storm; 27 ✓✓
11. At the central axis of a hurricane there is a/an _____. This core is _____ than air at the same level outside the hurricane.
- (a) updraft; colder
 - (b) updraft; warmer
 - (c) downdraft; colder
 - (d) downdraft; warmer ✓✓
 - (e) thunderstorm; colder

12. The inner ring of thunderstorms closest to the eye of a hurricane is named the _____ and is co-located with _____ wind speeds
- (a) pinwheel; maximum
 - (b) eyewall; maximum ✓✓
 - (c) hot tower; maximum
 - (d) eyewall; minimum
 - (e) tropical squall line; maximum
13. 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; equal frequencies of cyclonic and anticyclonic surface winds ✓✓
 - (e) updraft at core; downdraft at core
14. The eye of a hurricane averages about _____ km in diameter.
- (a) 3
 - (b) 30 ✓✓
 - (c) 300
 - (d) 3000
 - (e) 5000
15. Short and medium range forecasts produced by Numerical Weather Prediction are _____ to errors in the initial fields. This is one rationale for _____ using a set of _____ that differ by small adjustments reflecting the statistics of data error.
- (a) insensitive; not; gridpoints
 - (b) insensitive; adjustments made by the analysis phase; initial states
 - (c) extremely sensitive; adjustments made by the analysis phase; initialization times
 - (d) extremely sensitive; climatological forecasts; initial states
 - (e) extremely sensitive; ensemble forecasts; initial states ✓✓
16. The “domain” of a numerical weather prediction model _____
- (a) encompasses the region (laterally and vertically) of the atmosphere to be represented ✓✓
 - (b) is the distance between model grid points
 - (c) excludes sub-scale phenomena
 - (d) is the interval between the initialization time (“ t_0 ”) and the valid time (e.g. $t_0 + 48$ hr)
 - (e) is the lead time out to which it has forecast skill
17. The “skill” of a numerical weather prediction (NWP) scheme measures _____. Numerical weather forecasts have skill out to about _____
- (a) the percentage of its forecasts that are correct; one month
 - (b) its superiority (measured statistically) relative to the best of all alternative scientific forecast methods; two weeks ✓✓
 - (c) the percentage of its forecasts that are correct; one week
 - (d) its superiority (measured statistically) relative to the best of all alternative scientific forecast methods; one month
 - (e) the mean difference between a forecast (valid at time t_F) and the analysis at t_F ; one week

18. Canada's NWP (Numerical Weather Prediction) model is referred to as "GEM," which stands for _____. GEM runs out to 6 days of lead time are run from initializations _____ daily
- Government's Environmental Model; once
 - General Environmental Model; four times
 - Global Environmental Model; twice
 - Global Environmental Multiscale; twice ✓✓
 - Global Ecosystem Model; twelve times
19. Like most NWP models having comparable resolution, GEM is a "hydrostatic" model. This is an aspect of the model _____ and entails neglecting all terms in the vertical momentum equation except _____
- physics; acceleration and pressure gradient
 - physics; pressure gradient and gravity
 - physics; reduced gravity
 - dynamics; acceleration, pressure gradient and gravity
 - dynamics; pressure gradient and gravity ✓✓
20. The horizontal gridlength of Canada's NWP model exceeds 10 km. Cumulus clouds represent an important scale of motion, and are _____ by the model _____
- parameterized; physics package ✓✓
 - resolved; physics package
 - parameterized; dynamics
 - resolved; dynamics
 - neglected; physics package
21. Most NWP models represent the state of the atmosphere on a lattice of nodes (gridpoints), e.g. the pressure field is represented by the set of values $p_{I,J,K}^n$ at the gridpoints indexed (I, J, K) and times indexed n . Some (but not all) of the equations that express the science of meteorology interrelate (or "couple" or "link") the values of neighbouring variables. Two meteorological equations encountered in this course are the ideal gas law and the hydrostatic equation,

$$p = \rho R T, \quad [A]$$

$$\frac{\Delta p}{\Delta z} = -\rho g. \quad [B]$$

Pressures at neighbouring gridpoints of the vertical column (say $K, K + 1$) are coupled by _____

- neither of these equations
 - both of these equations
 - eqn. A
 - eqn. B ✓✓
22. The "dynamics" of a numerical weather prediction model refers to its treatment of _____. The "physics package" includes _____
- the grid; representation of the effects of clouds
 - the vertical spacing of pressure nodes; interpolation of data onto the grid
 - unresolved (sub-grid-scale) processes; interpolation of data onto the grid
 - unresolved (sub-grid-scale) processes; transport by air motions resolved by the grid
 - motion and transport resolved by the grid; parametrization of effects of unresolved (sub-grid-scale) processes ✓✓

23. Which of the following statements about modern NWP models is **not** true?
- (a) gridpoint spacing is fine enough to resolve the largest tornadoes ✓✓
 - (b) in some regions sparsity of observations reduces accuracy of the initial state
 - (c) treatment of interactions with the surface (land, lake or ocean) is imperfect
 - (d) they solve detailed (though not 100% complete or perfect) mathematical statements of the relevant laws of physics
 - (e) after several weeks the initial conditions are “forgotten,” meaning long range weather forecasts from almost-identical initial states may be entirely different.
24. Sometimes in ensemble forecasting the ensemble includes more than one global forecast model, or the same global model with differing choices for one or more of the parameterization schemes. Which of the following statements is **not** a plausible rationale for this?
- (a) there is no unequivocally best model across all regions, seasons and meteorological situations
 - (b) depending on the regime of flow, different models differ in their fidelity (skill)
 - (c) it may take years to develop confidence in a (putatively) improved parameterization scheme
 - (d) one global model provides lateral boundary conditions for another ✓✓
 - (e) if the models’ forecasts diverge over some region, one will place less confidence in the ensemble mean forecast there
25. In the context of Numerical Weather Prediction and the production of public forecasts, a “Model Output Statistics” method may be used in the _____ phase(s)
- (a) analysis
 - (b) prediction
 - (c) post-processing ✓✓
 - (d) data acquisition
 - (e) data acquisition & analysis
26. Which of the listed activities is **not** a function of the analysis phase in Numerical Weather Prediction in defining the initial state (at time “ t_0 ”) for a forecast?
- (a) eliminate features that cannot be represented by the model
 - (b) ensure the gridded wind field satisfies mass conservation
 - (c) inject ideal circular vortices better representing the identified midlatitude storms ✓✓
 - (d) blend the observations (which have been interpolated onto the grid) with a forecast initialized at $t_0 - 6$ hr
 - (e) eliminate observations that (from the perspective of climatology) are unrealistic
27. In simulations using a Global Climate Model “the early part of the simulation is discarded so that arbitrary starting values do not taint the climate statistics.” However Numerical *Weather* Predictions are _____ to the initial state, and NWP skill at lead times beyond about _____ is poor (in part) because of initialization errors
- (a) extremely sensitive; two months
 - (b) extremely sensitive; two weeks ✓✓
 - (c) extremely sensitive; two days
 - (d) insensitive; two weeks
 - (e) insensitive; two days

28. In Numerical Weather Prediction the resolved fields are represented as gridded data on a lattice of nodes. Suppose $U_{I,J,K}^n$ and $Q_{I,J,K}^n$ represent respectively the east-west component of the windspeed ($U > 0$ for westerly winds) and the humidity, at node (I, J, K) and time n ; and let $\Delta x = x_{I+1,J,K} - x_{I-1,J,K}$ where index I increases with increasing x (distance along lines of constant latitude, increasing towards the east). The product

$$- U_{I,J,K}^n \frac{Q_{I+1,J,K}^n - Q_{I-1,J,K}^n}{\Delta x}$$

represents _____ and if _____ tends to increase the humidity at node (I, J, K)

- (a) humidity advection by velocity component U ; positive ✓✓
 - (b) humidity advection by velocity component U ; negative
 - (c) humidity advection by velocity component U ; zero
 - (d) humidity advection by velocity component V ($V > 0$ for southerlies); negative
 - (e) humidity advection by velocity component V ; positive
29. Society funds the collection of massive volumes of weather data each day, in order to enable accurate “initialization” of Numerical Weather Prediction (NWP) models. This is because short and medium range weather forecasts computed by NWP _____
- (a) “remember” (i.e. are conditioned by) the specified initial state for many months
 - (b) have no skill for a forecast range (lead time) exceeding about two days
 - (c) are controlled by the “boundary conditions”
 - (d) are extremely insensitive to the initial state of the model atmosphere
 - (e) are extremely sensitive to the initial state of the model atmosphere ✓✓
30. Koeppen’s climate classification is broadly based on _____
- (a) growing degree days
 - (b) Penman’s formula for potential evapotranspiration
 - (c) mean monthly temperature and precipitation, classified into regimes that correlate with recognizably distinct plant biomes ✓✓
 - (d) latitude and elevation
 - (e) climate simulations using a modern Global Climate Model
31. Under Koeppen’s classification central Alberta’s climate is classified as “Dfb.” The “D” signifies “severe midlatitude,” the “f” signifies “moist with adequate precipitation in all months and no dry season,” and the “b” signifies “warm summer.” The term “adequate precipitation” on first sight seems subjective, but “adequate” can be taken to imply that actual monthly mean precipitation equals or exceeds “potential evapotranspiration” (also known as “atmospheric demand”) for that month and location. According to Penman’s formula, potential evapotranspiration is determined principally by these variables:
- (a) precipitation, temperature
 - (b) net radiation, temperature
 - (c) precipitation, vapour pressure deficit
 - (d) precipitation, net radiation, vapour pressure deficit
 - (e) net radiation, vapour pressure deficit, wind speed ✓✓

32. In many climates actual evapotranspiration is less than “atmospheric demand,” so that less energy is used to evaporate water than is (theoretically) possible from the perspective of energy available. Measured climate statistics, such as mean monthly temperature and humidity, of course *reflect that fact*. Now suppose one introduced an irrigation scheme over so vast an area that it modified the regional climate, resulting in higher humidity and more frequent cloud cover. Let PE_{dry} and PE_{irr} signify the atmospheric demand before and after introduction of the scheme, and let E_{dry} and E_{irr} represent the *actual* evapotranspiration before and after. The magnitudes of PE_{dry} , PE_{irr} obey _____, and PE_{dry} would _____ E_{irr}
- $PE_{\text{dry}} > PE_{\text{irr}}$; overestimate ✓✓
 - $PE_{\text{dry}} > PE_{\text{irr}}$; equal
 - $PE_{\text{dry}} < PE_{\text{irr}}$; overestimate
 - $PE_{\text{dry}} = PE_{\text{irr}}$; underestimate
 - $PE_{\text{dry}} < PE_{\text{irr}}$; equal
33. “Climate” is by definition concerned with *statistics*, and the computation of climate using an AOGCM (Atmosphere Ocean General Circulation Model) is considered an “equilibrium problem.” Our textbook states (p525): “The early part of a (climate) simulation is discarded so that arbitrary starting values do not taint the (computed) climate statistics.” Those computed statistics are in equilibrium with _____
- the initial conditions imposed at the start of the simulation
 - present day climate observations
 - paleoclimate as inferred from proxy evidence
 - the climate “boundary conditions,” i.e. assumed orbital parameters, solar output, greenhouse gas concentration, etc. ✓✓
 - Koepfen’s designation of regional climates
34. The glacial/interglacial phases of the Quaternary (i.e. present) ice age are believed to be caused by
- an internal (i.e. unforced) oscillation of the earth’s climate system
 - changing parameters of earth’s orbit ✓✓
 - changing solar output
 - Plate Tectonics
 - unstable interactions of animal and plant life altering planetary albedo
35. Sea water contains both ^{16}O and the heavier ^{18}O ; the lighter molecules evaporate preferentially (another way to look at this is that, at given temperature, the equilibrium vapour pressure for the lighter molecules is higher than for the heavier ones). During major expansions of glaciers and icecaps the volume of sea water is decreased, and the calcium carbonate (CaCO_3) skeletons of sea organisms have _____ $^{18}\text{O}/^{16}\text{O}$ ratio. Ocean sediment cores thus provide a proxy record of climate, presently extending back in time to _____ years BP (before present)
- an increased; several million ✓✓
 - a decreased; several million
 - an increased; several thousand
 - a decreased; several thousand
 - a negligible (i.e. very small); several million

36. Earth's history features _____ ice age(s); we are at present in a _____ phase of an ice age
- (a) six or more; warm interglacial ✓✓
 - (b) six or more; glacial
 - (c) only one; warm interglacial
 - (d) only one; glacial
 - (e) seventy or more; warm interglacial
37. 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 the above-mentioned 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
38. The slowest changes in climate (i.e. changes over 100's of millions of years) are believed to have been forced by changing _____ as a consequence of processes related to _____
- (a) solar output; aging of the sun
 - (b) atmospheric constituents (including greenhouse gases); plate tectonics ✓✓
 - (c) sun-earth geometry (Milankovich cycles); tidal forces
 - (d) North Atlantic circulation; the Dansgaard-Oeschger cycles
 - (e) patterns of vegetation; evolution
39. The climatic record as inferred from analysis of air bubbles locked in ice cores stretches back in time over a period of the order of _____ years. The greenhouse gas concentration they record is _____ across both hemispheres
- (a) 1 billion; consistent in phase and amplitude
 - (b) 1 million; opposite in phase but equal in amplitude
 - (c) 1 million; consistent in phase and amplitude ✓✓
 - (d) 100 thousand; lagged in phase by about 1000 years
 - (e) 10 thousand; opposite in phase but equal in amplitude
40. Present day global mean CO₂ concentration is about 386 ppm, whereas before industrial emissions began it was about 260-280 ppm. Changes CO₂ concentration associated with the glacial/interglacial oscillations of the present ice age have been of order _____ ppm, and were associated with (i.e. roughly contemporaneous with) changes in global mean temperature of order _____ °C
- (a) 10; 1
 - (b) 10; 10
 - (c) 100; 1
 - (d) 100; 10 ✓✓
 - (e) 100; 100

41. Relative to the present, throughout most of its 4.5 billion year history earth's climate has been _____. Solar output is believed to have _____ with increasing time since earth was formed
- constant; remained constant
 - warmer; increased ✓✓
 - warmer; decreased
 - cooler; increased
 - cooler; decreased
42. The Dansgaard-Oeschger cycle is a millennial scale climate “flip-flop” (sudden change between two states) in the _____. It is associated with variations in the strength of the “thermohaline ocean circulation” (ocean currents driven by buoyancy forces caused by anomalies in salinity and temperature) possibly associated with ice sheet melting, and considered to be _____
- equatorial Pacific region; an internal oscillation of the climate system
 - north Pacific region; the response to a change in climate boundary conditions
 - north Atlantic region; the response to a change in climate boundary conditions
 - north Atlantic region; an internal oscillation of the climate system ✓✓
 - Antarctic region; the response to a change in climate boundary conditions
43. The largest and most accurately known forcing (i.e. change in “boundary conditions”) for climate simulations of the industrial era is the change in _____
- earth's orbital pattern relative to the sun
 - solar output
 - suspended aerosols from volcanic eruptions
 - proportion of the earth covered by ice and snow
 - concentrations of atmospheric greenhouse gases ✓✓
44. In the context of a *measure* of climatic change, some have argued it would be better to take the (change in) global mean ocean surface temperature than global mean surface air temperature. Suppose the temperature of the lowest metre of atmosphere (density $\rho_a \approx 1.2 \text{ kg m}^{-3}$ and specific heat capacity $c_{pa} \approx 1000 \text{ J kg}^{-1} \text{ K}^{-1}$) were everywhere in equilibrium with (i.e. equal to) the temperature of the uppermost metre of ocean (density $\rho_w = 1000 \text{ kg m}^{-3}$ and specific heat capacity $c_{pw} = 4168 \text{ J kg}^{-1} \text{ K}^{-1}$). Then the ratio of the heat content of the upper oceanic metre to the lowest atmospheric metre is about _____
- $\rho_w c_{pw} / (\rho_a c_{pa}) \sim 3500$ ✓✓
 - $c_{pw} / c_{pa} \sim 4$
 - 1
 - $\rho_a / \rho_w \sim 0.001$
 - $\rho_w / \rho_a \sim 1000$
45. Which climate forcing mechanism is irrelevant for a GCM simulation of climate change over the next few centuries?
- solar output
 - volcanism
 - orbital (Milankovitch) forcing ✓✓
 - atmospheric composition
 - deforestation

46. Numerical climate models, certainly, are imperfect; not all climate mechanisms are represented, and some that are represented are represented in an approximate way. Many coefficients in the parameterizations must be assigned numerical values. Many modelling aspects are arbitrary, such as grid spacing, time step, number of mechanisms to include. According to the IPCC2007, anthropogenic forcing (i.e. enhanced atmospheric greenhouse gas concentration) **must** be included as a driving factor in order that the models reproduce the global climate trend of the instrumental era. It is important to address the possibility that this inference (i.e. that recent climate warming is anthropogenic in origin) is not a spurious consequence of researchers (hypothetically) having “tuned” the models (i.e. having chosen coefficients so as to force their models to fit the observations). In that respect, which of the following arguments is **least relevant**?
- the IPCC conclusions are based on an ensemble of climate models (58 simulations using 14 models)
 - equilibrium climate sensitivity of the climate models has not changed very much since those of the early 1970’s, despite subsequent refinement of the models
 - climate models are exhaustively documented in the scientific literature
 - simulations of paleoclimates *with the same models and same choices of coefficients* constitute an independent test of climate modelling
 - weather models, which contain many of the same parameterizations, demonstrate skill over lead times out to about two weeks ✓✓
47. Select the correct size-ordering (largest \rightarrow smallest) of these four circulation systems
- tornado: hurricane: thunderstorm: midlatitude storm
 - midlatitude storm : hurricane: thunderstorm : tornado ✓✓
 - hurricane: midlatitude storm: thunderstorm: tornado
 - hurricane: midlatitude storm: tornado: thunderstorm
 - midlatitude storm : hurricane: tornado: thunderstorm
48. Three-dimensionality in space is an essential feature of many types of atmospheric circulation. A numerical model that carried only two space coordinates, radius (r) and height (z), i.e. a model that assumed azimuthal symmetry, might represent the essential mechanisms of a/an _____
- severe thunderstorm
 - mid-latitude cyclone
 - individual fair-weather cumulus cloud ✓✓
 - Rossby wave
 - cold front
49. Let W_{FA} , W_{CB} , W_T represent the “order of magnitude” (ie. “scale,” or “typical size”) of the vertical velocity in the free atmosphere (FA), in a cumulonimbus cloud (CB), and in the turbulent friction layer (T). Pick the most reasonable statement concerning the relative sizes of these “scales” (units are m s^{-1} ; the symbol \sim means “approximately equal to”)
- $W_{FA} \ll 1$; $W_T \sim 1$; $W_{CB} \gg 1$ ✓✓
 - $W_{FA} \sim W_T \sim W_{CB} \sim 1$
 - $W_{FA} \sim W_T \sim W_{CB} \sim 10$
 - $W_{FA} \ll W_T \sim W_{CB} \sim 1$
 - none of these statements is plausible

For the remaining questions, please refer to the attached charts.

50. Figure (1) suggests one might be alert for ____
- (a) severe storm
 - (b) extremely high snowfall rate
 - (c) freezing rain ✓✓
 - (d) hail
 - (e) frontal passage
51. Figure (2) suggests one might be alert for ____
- (a) severe storm ✓✓
 - (b) extremely high snowfall rate
 - (c) freezing rain
 - (d) hail
 - (e) frontal passage
52. Heavy short-dashed lines on the skew T-log p diagram (Figure 3) identify several families of reference curves. The family of dry adiabats is represented by line ____
- (a) A
 - (b) B ✓✓
 - (c) C
 - (d) D
 - (e) E
53. Figures (5, 6) contrast two characteristic Alberta winter weather scenarios. Which interpretive statement is **false**?
- (a) Fig. (5) western prairies invaded by cold air washed in by passing storm; Fig. (6) mild air advected over prairies by offshore low
 - (b) Fig. (5) ridge of high surface pressure in Alberta in wake of storm; Fig. (6) lee trough in Alberta due to SW current aloft over Rockies
 - (c) Fig. (5) Edmonton's thickness less than 534 dam; Fig. (6) Edmonton's thickness exceeding 546 dam
 - (d) Fig. (5) lee low forming near the Alberta elbow; Fig. (6) negligible likelihood of a lee low forming in Alberta in this flow configuration ✓✓
 - (e) Fig. (5) intense storm over central Canada with little or no zonal flow over the Rockies; Fig. (6) intense storm moving onshore off the Pacific with strong flow into Alberta over the Rockies

The final seven questions relate to the weather scenario of Figs. (4, 7, 8).

54. The significant feature of the Kelowna sounding (Fig. 4), in terms of it's being causally related to strong low-level winds in mountain passes, is ____
- (a) low temperature-dewpoint spread at the surface
 - (b) nearly saturated at about 480 hPa
 - (c) 900-850 hPa layer is (almost) neutral with respect to dry adiabatic motion
 - (d) unstable lower troposphere
 - (e) stable lower troposphere ✓✓

55. The feature centred over the Alberta Rockies and visible in the configuration of height contours is due to _____. The 700 hPa winds in that region would be _____
- (a) the upper flow regime (offshore trough, ridge over western prairies; eastern low); geostrophic
 - (b) the winds aloft being partially blocked by the mountains; ageostrophic ✓✓
 - (c) the low over Ontario; ageostrophic
 - (d) the low off the coast of B.C.; geostrophic
 - (e) precipitation in flow ascending the mountains; almost saturated
56. An 850 hPa feature over Alberta, delineated by the freezing contour (Fig. 7), signifies relatively _____ air aloft which can be attributed to _____
- (a) warm; adiabatic compression of descending flow in the lee of the Rockies ✓✓
 - (b) warm; adiabatic expansion of descending flow in the lee of the Rockies
 - (c) cold; adiabatic expansion of descending flow in the lee of the Rockies
 - (d) cold; adiabatic compression of descending flow in the lee of the Rockies
 - (e) stable; a subsidence inversion
57. 850 hPa winds around the low in eastern Canada appear to be _____
- (a) anticyclonic
 - (b) clockwise in orientation
 - (c) ageostrophic
 - (d) geostrophic ✓✓
 - (e) increasing
58. The height of the 850 hPa surface at The Pass (in Manitoba, just inside, and about midway along, the Saskatchewan-Manitoba border; $T - T_d$ reported as 4°C) was _____
- (a) 133 m
 - (b) 330 m
 - (c) 133 dam ✓✓
 - (d) 330 dam
 - (e) 930 dam
59. Lloydminster (centrally placed on the Alberta/Saskatchewan border) would be experiencing _____
- (a) weak warm advection ✓✓
 - (b) strong warm advection
 - (c) weak cold advection
 - (d) strong cold advection
60. The band of drier air at 700 hPa in W. Alberta (Fig. 8) can be attributed to
- (a) adiabatic compression of descending air ✓✓
 - (b) adiabatic expansion of descending air
 - (c) adiabatic compression of ascending air
 - (d) adiabatic expansion of ascending air

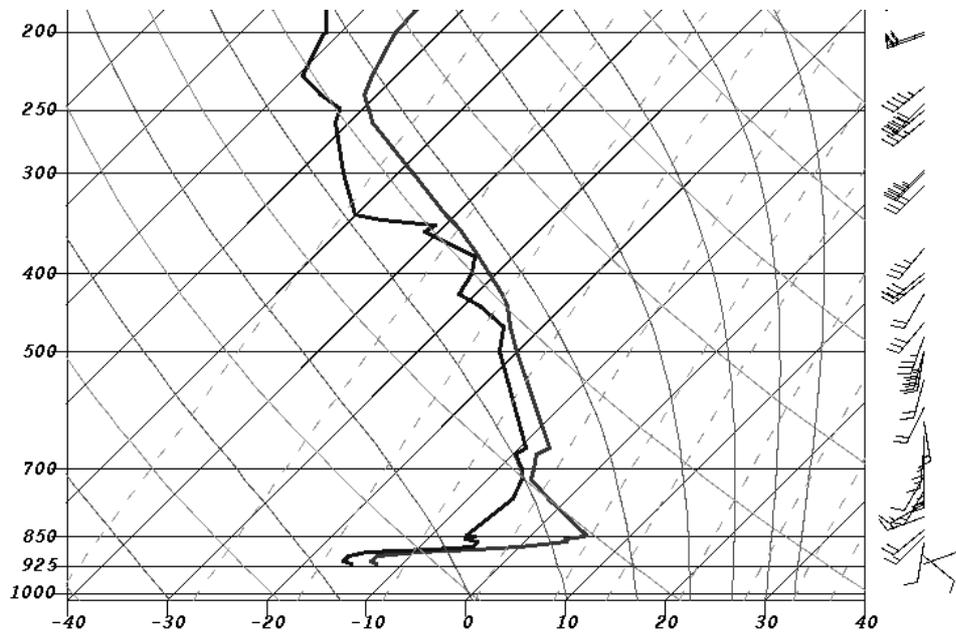


Figure 1: Thermodynamic chart.

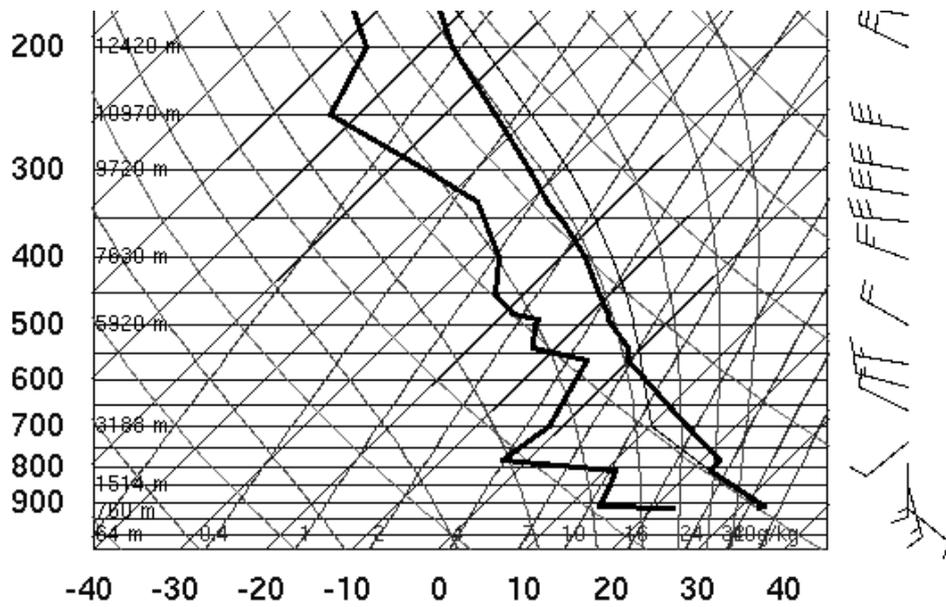


Figure 2: Thermodynamic chart.

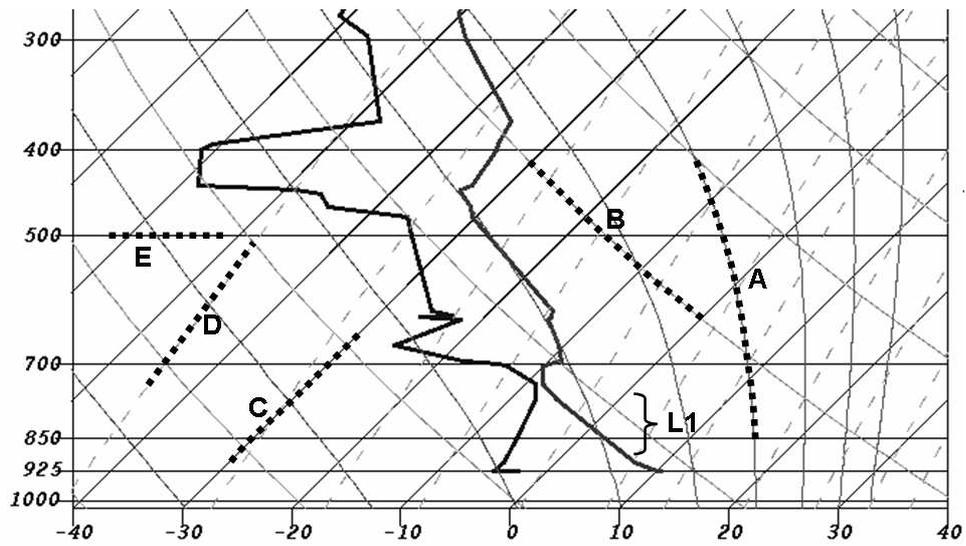


Figure 3: Thermodynamic chart.

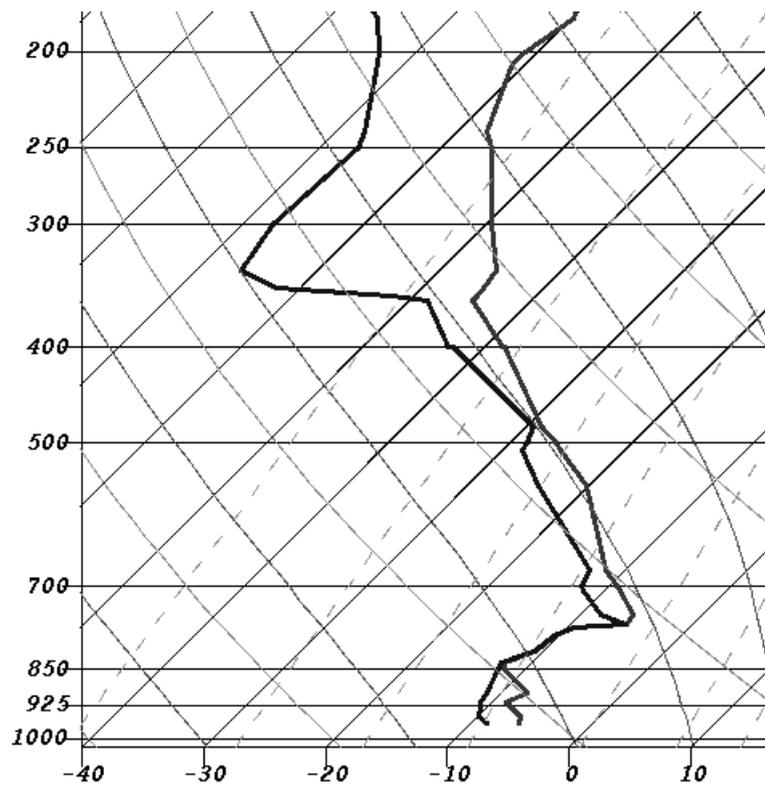


Figure 4: Kelowna (YLW, in SE B.C.) sounding 12Z Nov. 26, 2010 (winds not reported).

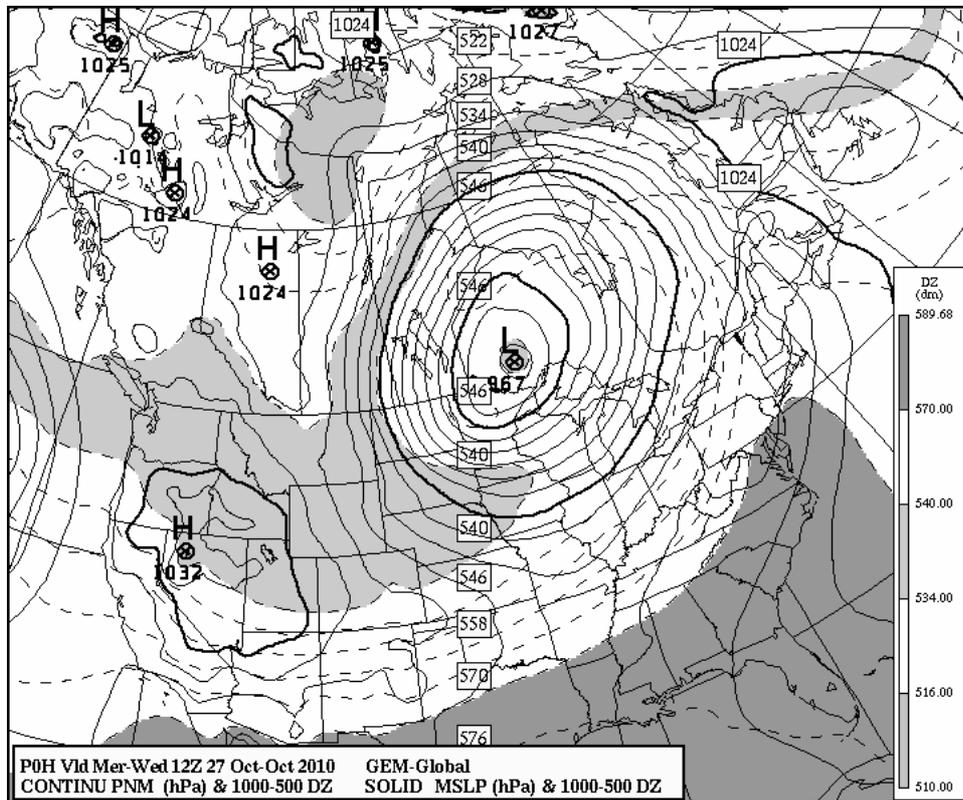


Figure 5: CMC GEM Global 0h prog (i.e. analysis) valid 12Z Oct. 27, 2010. Sea-level pressure and $\Delta z_{1000-500}$ (thickness). The light grey zone marks the 540 – 534 dam thickness band.

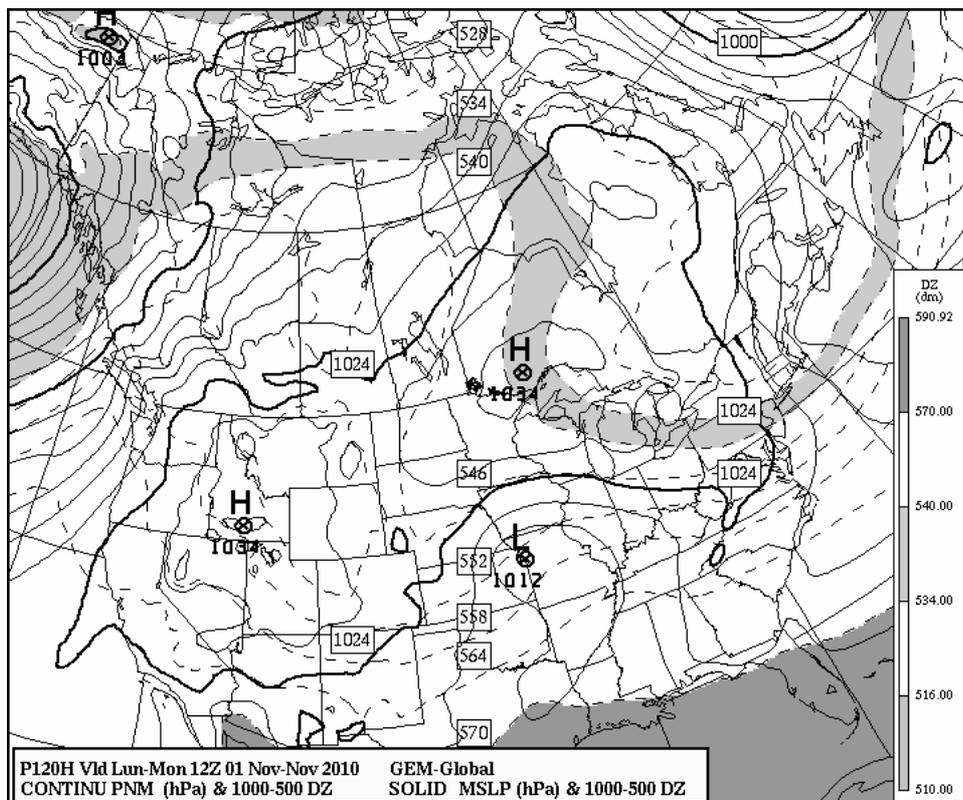


Figure 6: CMC GEM Global 120h prog valid 12Z Mon Nov. 1, 2010. Sea-level pressure and $\Delta z_{1000-500}$ (thickness). The light grey zone marks the 540 – 534 dam thickness band.

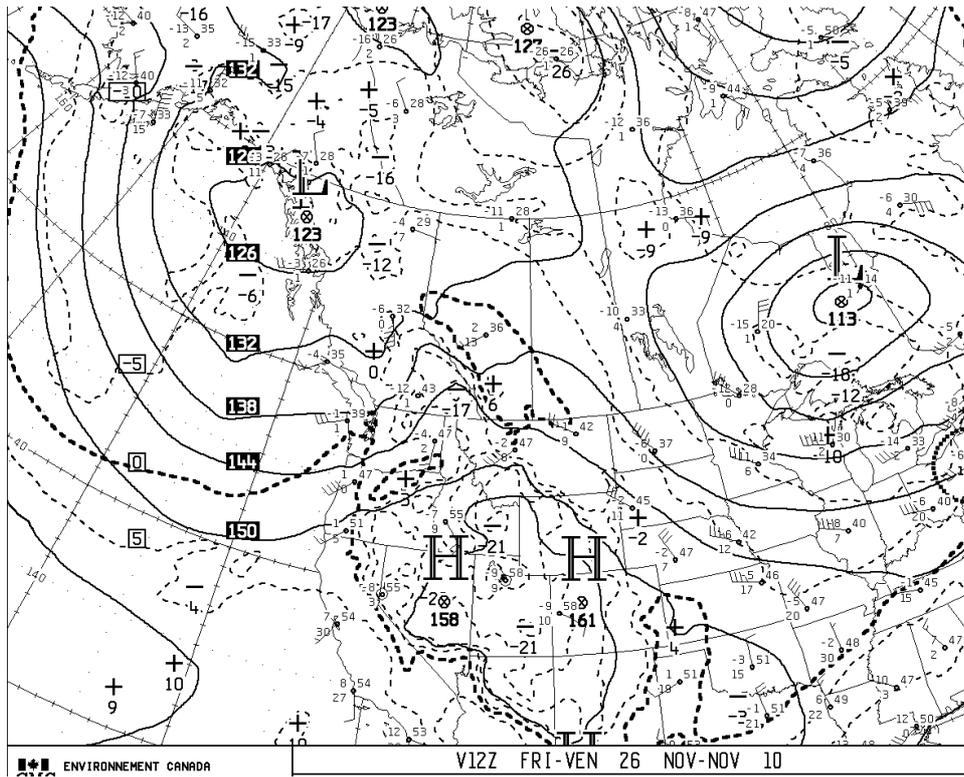


Figure 7: CMC 850 hPa analysis 12Z Nov. 26, 2010.

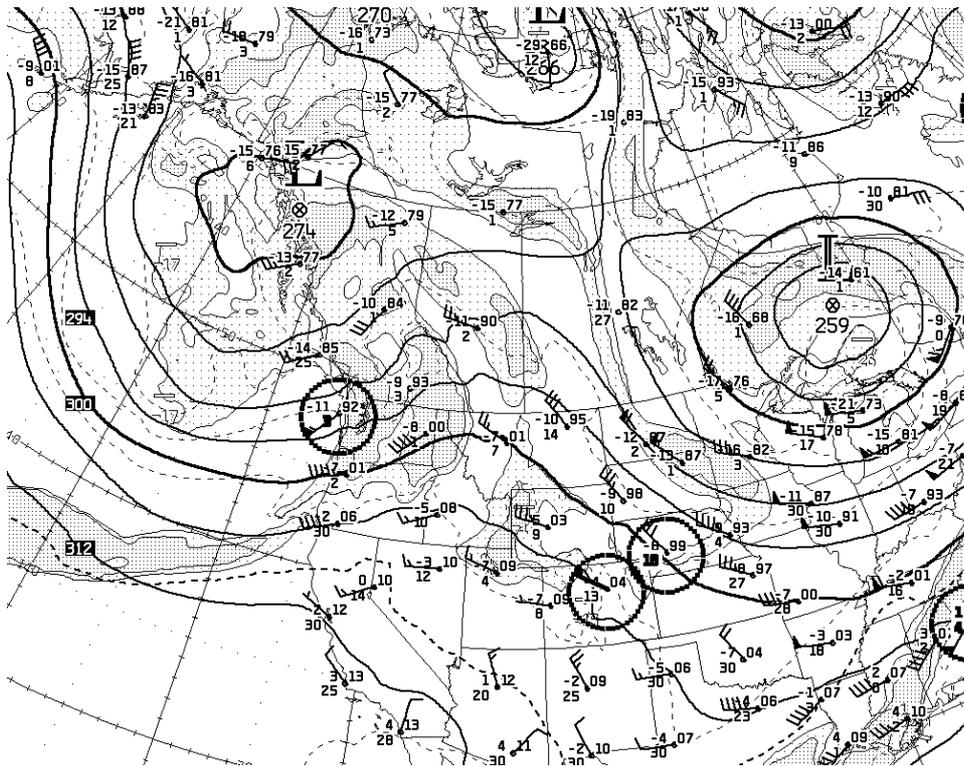


Figure 8: CMC 700 hPa analysis 12Z Nov. 26, 2010. Dense stippling signifies $T - T_d < 2^\circ\text{C}$.