EAS270, "The Atmosphere" Mid-term Exam 27 Oct,2004

Professor: J.D. Wilson Time available: 50 mins Value: 30%

Instructions: For all 45 multi-choice questions (each worth $\frac{2}{3}$ %), choose what you consider to be the best (or most logical) option. Use a pencil to mark that choice on the answer form. ***Equations and data given at back***.

1. Atmospheric ozone (O_3) concentration is normally highest ____ where concentration is ____
   (a) near sea-level; up to about 1 ppm
   (b) near sea-level; up to about 15 ppm
   (c) above 100 km; up to about 1 ppm
   (d) about 25 km; up to about 15 ppm ✓✓
   (e) about 25 km; less than 1 ppm

2. The chloroflourocarbon (CFC) gases whose emission was banned by the Montreal Protocol have an atmospheric residence time of about ____
   (a) 1 year
   (b) 10 years
   (c) 100 years ✓✓
   (d) 1000 years
   (e) 10000 years

3. Plants exert a key role in the hydrologic cycle and in the surface energy balance, because they are able to control the rate of ____ of water through stomata (pores) on their leaves. Through these same pores they ____ carbon dioxide to/from the daytime atmosphere, thus also playing a key role in the greenhouse gas climate mechanism.
   (a) photosynthesis; transpire
   (b) diffusion; absorb ✓✓
   (c) transpiration; release
   (d) convection; absorb
   (e) diffusion; release

4. Although a minor constituent of the atmosphere in terms of their contribution to mass, aerosols are important because ____
   (a) they are an important plant nutrient taken up through the stomata
   (b) as cloud condensation nuclei they play a vital role in cloud formation
   (c) depending on their size, they may reduce incoming solar radiation and/or outgoing (longwave) radiation
   (d) they impact on air quality (eg. visibility)
   (e) (b,c,d) are all true ✓✓

5. Solar elevation above the horizon in Edmonton (latitude 53.5 degrees), at solar noon on the day of the winter solstice, is ____ degrees, and the subsolar point travels along the ____

   (a) 60; tropic of Cancer
   (b) 45; equator
   (c) 23.5; equator
   (d) 13; tropic of Capricorn ✓✓
   (e) none of the above angles; equator

6. The principal factors causing the latitude-dependence of clear-sky, 24-hour total solar insolation measured at a horizontal surface near ground ($K \downarrow$) are ____

   (a) period of daylight, beam spreading, surface albedo
   (b) period of daylight, beam spreading, beam depletion ✓✓
   (c) period of daylight, fractional surface ice-coverage, surface albedo
   (d) beam depletion, surface albedo, surface emissivity
   (e) surface albedo, surface emissivity, relative humidity

7. Let R be the radius of the earth. Earth's shadow cast by sunlight would cover an area of ____ while the surface area of the earth radiating longwave radiation is ____

   (a) $4/3\pi R^3; \pi(2R)^2$
   (b) $\pi R^2; 4\pi R^2$ ✓✓
   (c) $4\pi R^2; \pi R^2$
   (d) $\pi(R/2)^2; 4/3\pi R^3$
   (e) $\pi R^3; \pi R^3$

8. The "atmospheric window" covers a wavelength range of about ____ μm and occurs due to the ____ absorptivity in that waveband of H_2O, CO_2

   (a) 0.4 - 4 low
   (b) 0.4 - 4 high
   (c) 8 - 11 low ✓✓
   (d) 8 - 11 high
   (e) 4 - 100 low

9. Suppose a certain bare, dry soil has emissivity $\epsilon = 0.92$ and its surface temperature is 30 C. It emits longwave radiation energy at a rate $L \uparrow =$ ____ W m^{-2} and the spectrum of that emitted radiation peaks at $\lambda_{max} =$ ____ μm

   (a) 0.04; 97
   (b) 441; 9.6 ✓✓
   (c) 0.04; 9.6
   (d) 441; 97
   (e) Given information is insufficient to permit calculation of these numbers

10. Consider the surface energy balance over a flat, bare, dry field (you may neglect the storage term). Suppose the net radiation $Q^* = 450$ $[W\ m^{-2}]$, that soil heat flux $Q_G = 50[W\ m^{-2}]$, and that the Bowen Ratio $B = 1$. Then the sensible heat flux $Q_H =$ ____ W m^{-2} and the atmosphere is said to be ____ stratified.

(a) 200; topographically
(b) 200; stably
(c) 200; unstably ✓✓
(d) 400; unstably
(e) 400; stably

11. In an inversion layer of the atmosphere, vertical motion is ____ and the direction of sensible heat transfer is ____ the ground.

(a) Enhanced; towards
(b) Suppressed; towards ✓✓
(c) Enhanced; away from
(d) Suppressed; away from
(e) None of the above

12. The "diurnal" (daily) range in near-ground temperature (height 1.5 m) tends to be larger during ____ conditions.

(a) cloudy, windy
(b) cloudy, calm
(c) clear, calm ✓✓
(d) clear, windy
(e) winter-time

13. Local conditions associated with a radiation fog are a strongly ____ temperature profile with a convective flow of heat ____ the atmosphere ____ the ground surface.

(a) adiabatic; to; from
(b) positive; through; at
(c) negative; through; at
(d) stable; to; from
(e) stable; from; to ✓✓

14. A deep layer of fog is more likely to form on a night with a very gentle wind, than during a night which is completely calm, because ____ .

(a) longwave emission rate $L\uparrow$ is increased by wind
(b) eddies carry heat down to the cooling surface from a deeper layer ✓✓
(c) a light wind increases the rate of cooling of the ground
(d) the ELR equals the DALR
(e) none of the above

15. At what time of day is the relative humidity (RH) normally at a minimum?

    (a) just before sunrise
    (b) when the air temperature is highest ✓✓
    (c) about midnight
    (d) when air temperature is lowest
    (e) during the nocturnal inversion

16. A forecaster may take the present dewpoint T_{d0} as an approximate value for his prediction of the overnight low temperature, assuming that as temperature T falls towards T_{d0} ultimately the formation of fog will prevent temperatures falling much below T_{d0}. This could be a poor forecast if ____ .

    (a) strong winds develop
    (b) the spread $T - T_d$ is very large
    (c) the sky is overcast with heavy cloud
    (d) strong temperature advection occurs
    (e) all of the above ✓✓

17. Consider three adjacent depth-layers (1,2,3) of the Planetary Boundary Layer. Mean horizontal windspeeds in the three layers are $U_1 < U_2 < U_3$. Layer 3 is therefore the ____ of the three layers. Parcels of air descending from layer 3 to layer 2 exert an influence that could (if not opposed) cause layer 2 to ____ . This is called ____ .

    (a) lowest; accelerate; turbulent momentum transfer
    (b) lowest; accelerate; viscous drag
    (c) highest; decelerate; forcing
    (d) highest; accelerate; turbulent momentum transfer ✓✓
    (e) highest; accelerate; viscous momentum transfer

18. We expect the wind near ground to diminish overnight because ____ .

    (a) Stable temperature stratification (inversion) suppresses vertical exchange of air parcels, thus decoupling the surface air from the driving winds aloft ✓✓
    (b) Unstable temperature stratification suppresses vertical exchange of air parcels, thus decoupling the surface air from the driving winds aloft
    (c) Stable temperature stratification (inversion) enhances vertical exchange of air parcels, thus decoupling the surface air to the driving winds aloft
    (d) Unstable temperature stratification enhances vertical exchange of air parcels, thus decoupling the surface air to the driving winds aloft
    (e) The air is loaded with dew, thus heavier, and so it slows down

19. If a sample of air is saturated at 20 C its absolute humidity (same as the vapour density, usual symbol ρ_v) is ____ .

    (a) 2337 Pa
    (b) 1.7 x 10^{-2} kg m^{-3} ✓✓
    (c) 0.0172 g kg^{-1}
    (d) 1.7%
    (e) none of the above

20. A parcel of air has temperature $T = 10$ C and vapor pressure $e = 7.05$ mb. Its dewpoint is about ____ C and its relative humidity is about ____ %.

   (a) 10; 100
   (b) 2; 57 ✓✓
   (c) 10.01; 70
   (d) 12.27; 50
   (e) undeterminable from the given data

21. The 'wet-bulb temperature' (T_w) ____

   (a) equals the dewpoint (T_d)
   (b) permits to calculate the relative humidity as $RH = 100\, T_w$
   (c) permits to calculate the relative humidity as $RH = 100\, e/e_s(T_w)$
   (d) is measured by a wet thermometer whose equilibrium temperature (T_w) is the result of a balance between evaporative cooling and input of sensible heat from the warmer air flowing over it ✓✓
   (e) none of the above

22. If a parcel of dry air had a temperature of 20 C when at height $z = 0$, then if it was lifted adiabatically to $z = 700$ m and then sank back down adiabatically to $z = 500$ m, its temperature would be ____ .

   (a) 15 C ✓✓
   (b) 20 C
   (c) 25 C
   (d) 27 C
   (e) 29 C

23. A parcel of dry air ascending 1000 m adiabatically in the atmosphere cools by ____ degrees Celcius. However due to ____ , the cooling experienced by a saturated parcel covering the same path is ____ than this amount.

   (a) one; entrainment of colder environmental air; more
   (b) one; entrainment of warmer environmental air; less
   (c) one; release of latent heat of condensation; less
   (d) ten; release of latent heat of condensation; more
   (e) ten; release of latent heat of condensation; less ✓✓

24. The environmental lapse rate (ELR) in a ground-based layer during exceptionally windy and dry conditions will be ____ .

   (a) Approximately the same as the dry adiabatic lapse rate (DALR) ✓✓
   (b) Approximately the same as the moist adiabatic lapse rate (SALR)
   (c) Zero, ie. the layer will be isothermal
   (d) That of a very strong inversion (temperature increasing with increasing height)
   (e) Strongly unstable, the temperature decreasing with increasing height at a rate far exceeding the dry adiabatic lapse rate

25. Consider the magnitude of the atmospheric pressure decrease ΔP between sea-level ($z = 0$), and a point overhead at a height of 1 kilometre above sea-level ($z = 1000$ m). In the northern hemisphere winter, ΔP is ____ .

(a) larger at the north pole than at the equator ✓✓
(b) smaller at the north pole than at the equator
(c) the same at the north pole as at the equator
(d) negative
(e) zero

26. In a "hydrostatic" weather model, the gravitational and vertical pressure-gradient forces acting on any air parcel are assumed to balance. As a result, according to such a model, ____ .

(a) the parcel's vertical velocity $W = 0$
(b) the parcel's vertical velocity $W < 0$
(c) the parcel's acceleration $\Delta W/\Delta t = 0$ ✓✓
(d) the wind is Geostrophic
(e) the wind is subGeostrophic

27. To roughly estimate effective sea-level pressure from a reading P [mb] made 1000 m above sea-level, one should best ____ .

(a) Add 10 mb
(b) Subtract 10 mb
(c) Add 100 mb ✓✓
(d) Subtract 100 mb
(e) Add 1000 mb

28. Calculate the Geostrophic windspeed at a point at latitude 50^oN, if the height-contours (drawn at intervals $\Delta h = 6$ dam) are spaced at separations $\Delta x = 200$ kilometers.

(a) 0.27 m s^{-1}
(b) 2.7 m s^{-1}
(c) 27 m s^{-1} ✓✓
(d) 2.7 kph
(e) 27 kph

29. Friction near ground turns the wind across the isobars towards lower pressure. In the absence of topographic disturbance, the cross-isobar angle is normally about ____ degrees.

(a) 180
(b) 90
(c) $10 - 40$, depending on surface roughness and other factors ✓✓
(d) $0 - 1$, depending on surface roughness and other factors
(e) < 1

30. At 45^o latitude the Coriolis timescale $(= 1/f)$ has numerical value ____ [s]. Now consider a fluid motion on earth whose lifetime $\tau \sim 1 - 100$ [s]: does the Coriolis force play a role in the dynamics of this phenomenon?

   (a) $1.03\text{x}10^{-4}$; yes
   (b) $1.03\text{x}10^{-4}$; no
   (c) $9.7\text{x}10^{3}$; yes
   (d) $9.7\text{x}10^{3}$; no ✓✓
   (e) 0.707; yes

31. The vapour pressure surrounding a droplet of pure water of radius $R << 1\mu$m and temperature T ____ the benchmark $e_s(T)$ due to the ____ effect.

   (a) is less than; curvature
   (b) is less than; solute
   (c) exceeds; curvature ✓✓
   (d) exceeds; solute
   (e) equals; negligible curvature

For the remaining questions, please refer to the attached charts, valid 12Z 21 Sep/04.

32. Sea-level corrected pressure on the isobar that has been labelled **A** must be ____ mb

   (a) 859
   (b) 921
   (c) 988
   (d) 992 ✓✓
   (e) 1012

33. The wind at the point labeled **A** would likely have been a/an

   (a) northerly
   (b) southerly
   (c) south-easterly
   (d) easterly
   (e) westerly ✓✓

34. Two stations on the BC coastal region reported their present weather as steady rain. One of these stations reported a wind that appears anomalous. The reported pressure at that station was ____ [mb] and the 'abnormal' wind observation is probably a ____ effect

   (a) 992.6; oceanic
   (b) 926; oceanic
   (c) 992.6; topographic ✓✓
   (d) 926; topographic
   (e) 1004.1; island

35. The dashed line that has been added (by the instructor) to the surface analysis represents a/an ____

(a) ridge of low surface pressure
(b) ridge of high surface pressure
(c) trough of low surface pressure ✓✓
(d) trough of high surface pressure
(e) probable track for future motion of the weather system in NE Canada

36. The pressure system defined by the isobars in the region of **C** is a

(a) High or trough
(b) Low or ridge
(c) High or ridge
(d) Low or trough ✓✓
(e) Unable to determine from given data

37. Temperature-dewpoint spread at the station in extreme SE Alberta was ____ C. A feature of the station report that is *consistent* with the reported $T - T_d$ is ____ .

(a) 2; clear skies
(b) 2; intermittent drizzle (past weather)
(c) 0; clear skies
(d) 0; intermittent drizzle (past weather) ✓✓
(e) 4; clear skies

38. At Edmonton (apprx. 700 m above sea-level) the 850 mb surface lay ____ kilometers above ground

(a) $\frac{1}{4}$
(b) $\frac{1}{2}$
(c) $\frac{2}{3}$
(d) $\frac{3}{4}$ ✓✓
(e) $\frac{3}{2}$

39. Comparing the reported Stony Plain 850 mb wind direction with the nearby height contour, one could justifiably suggest

(a) the reported wind direction is anomalous
(b) the reported windspeed, about 10 m s^{-1}, is implausible
(c) the concept of Geostrophic flow does not apply here
(d) at this time the 850 mb surface lay above the friction layer ✓✓
(e) at this time the 850 mb surface lay within the friction layer

40. Referring to the 850 mb analysis, in central Saskatchewan temperature advection is ____ while at the location **B** (east of the Manitoba-Ontario border) strong ____ temperature advection is occurring

(a) weak or non-existent; warm
(b) weak or non-existent; cold ✓✓
(c) dominating weather evolution; warm
(d) dominating weather evolution; cold
(e) seasonal; unseasonal

41. Looking at both the surface and 850 mb analyses, surface air in far N. Manitoba is generally ____ than in far N. Alberta, while the opposite is true of the 850 mb temperature. We may conclude the lower atmosphere over N. Manitoba is ____ stable than over N. Alberta

(a) warmer; more
(b) warmer; less ✓✓
(c) colder; more
(d) colder; less
(e) more anticyclonic; much more

42. The skew T - log P diagram (courtesy U. Wyoming) is for station YQD (The Pas), located in west-central Manitoba near the Saskatchewan-Manitoba border, and identifiable on both the surface and 850 mb analyses. The sounding and the charts are ____ as regards surface properties and ____ as regards 850 mb level properties

(a) inconsistent; consistent
(b) consistent; inconsistent
(c) consistent; consistent ✓✓
(d) inconsistent; inconsistent
(e) none of the above

43. On the YQD sounding we see quite dry air. A significant ground-based feature is ____ while the 400-350 mb layer can be said to ____

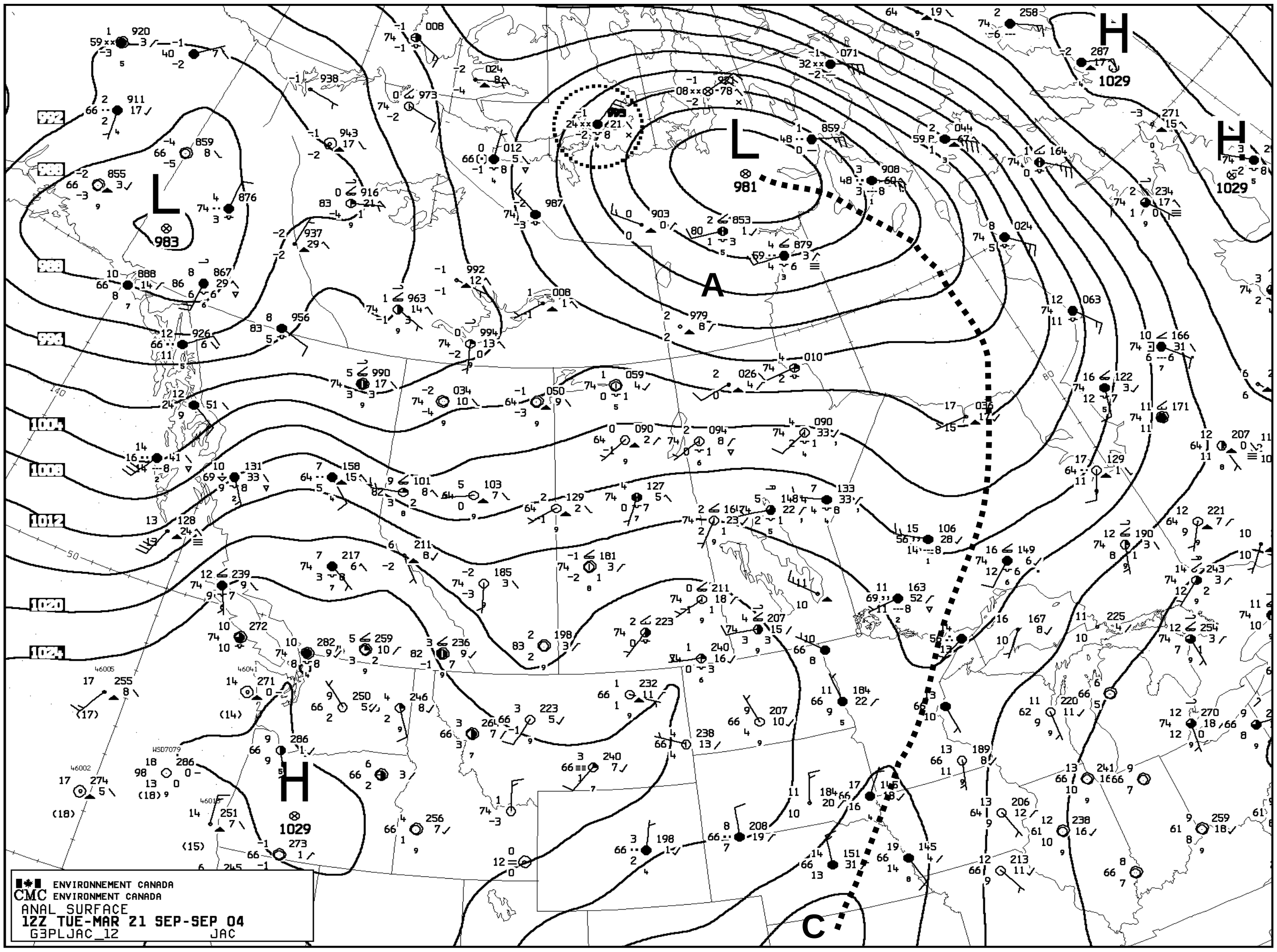
(a) a stable layer; be saturated
(b) the DALR; MALR
(c) the inversion; be well-mixed ✓✓
(d) surface saturation; moist advection aloft
(e) both (c) and (d)

44. Cross-comparing the 850 chart and the skew-T diagram, the radiosonde must have crossed the 850 mb surface at a height of ____ m

(a) 129
(b) 450
(c) 763
(d) 1445 ✓✓
(e) 2977

45. According to the skew-T diagram, at The Pas the tropopause lay at ____ mb.

(a) 100
(b) $\approx$ 130
(c) 200
(d) 350 ✓✓
(e) 850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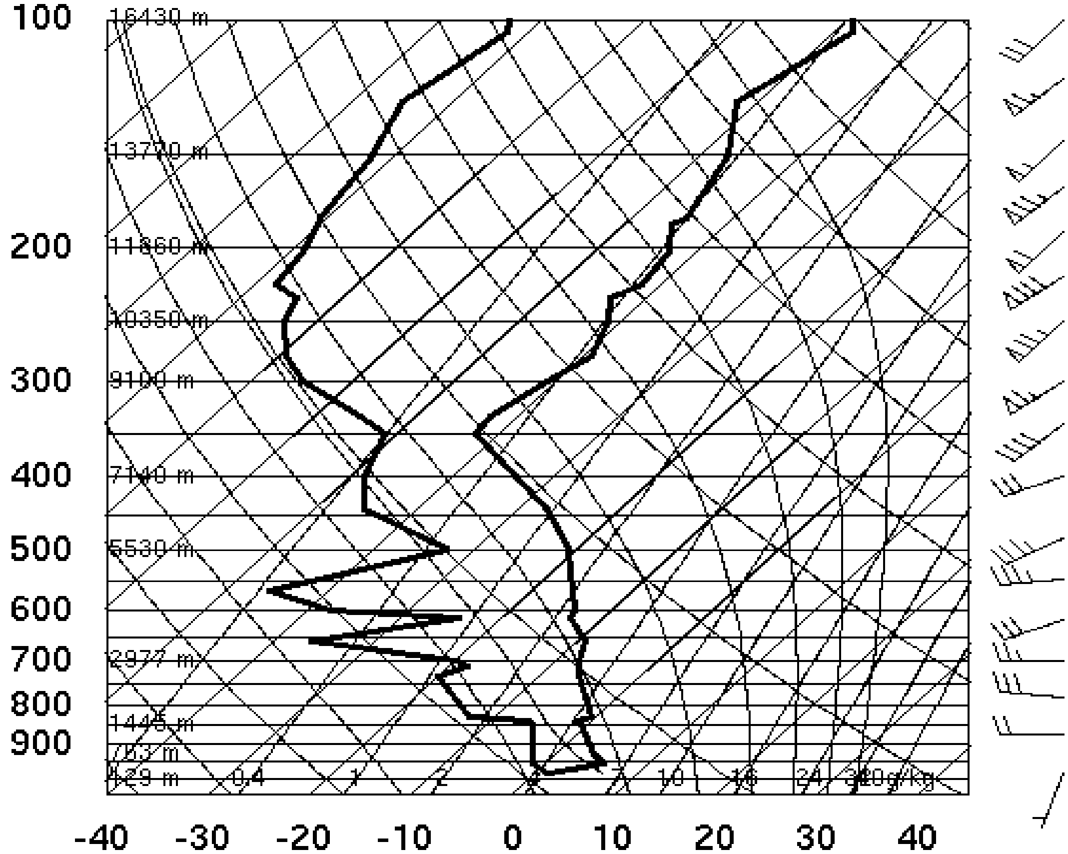
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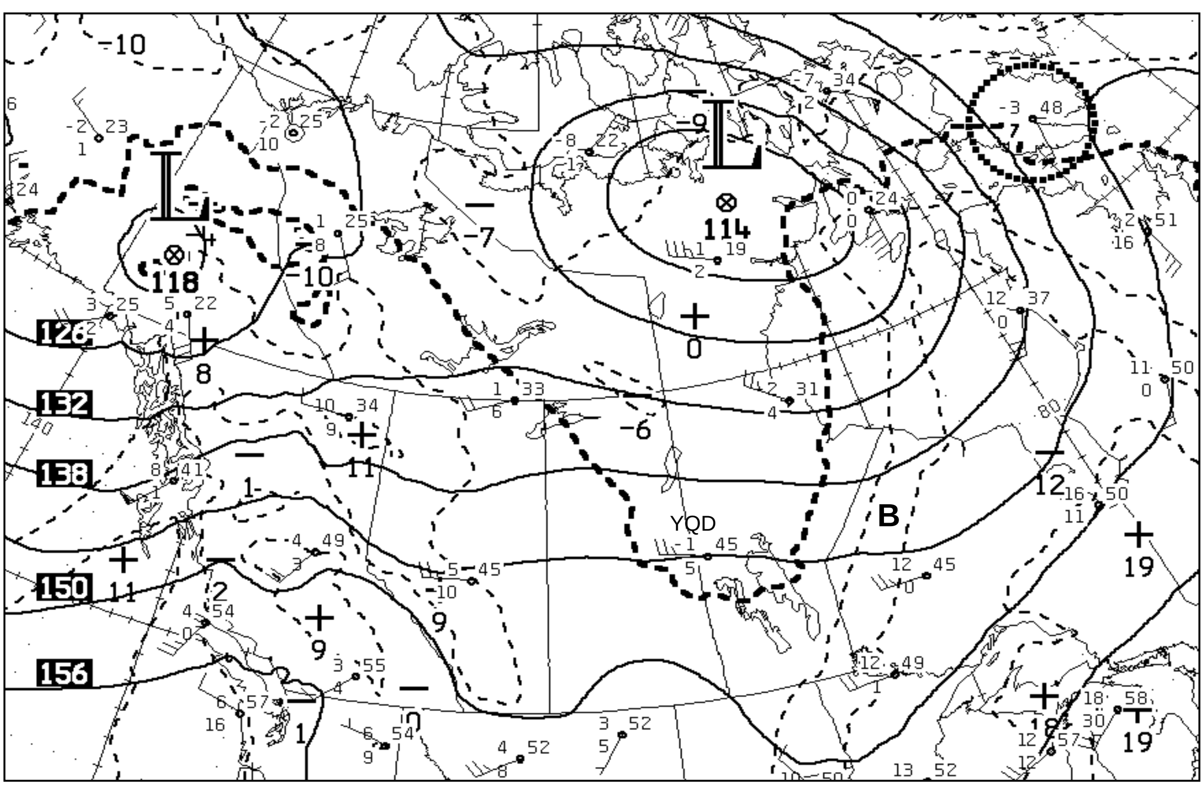
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1

Equations and Data (You may not need to use all given data!)

- $V = \frac{4}{3}\pi R^3$, $A = 4\pi R^2$

  Volume (V) and surface area (A) of a sphere of radius R

- $\frac{\Delta P}{\Delta z} = -\rho g$

  The hydrostatic law. ΔP [Pascals], the change in pressure as one ascends a distance Δz [m]; ρ [$kg\ m^{-3}$] the density; $g \sim 10$ [$m\ s^{-2}$] acceleration due to gravity.

- $P = \rho R T$

  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.

- $e = \rho_v R_v T$

  The ideal gas law for water vapor. e [Pascals], pressure; ρ_v, [$kg\ m^{-3}$] the absolute humidity (ie. vapor density); T [Kelvin], the temperature; and $R_v = 462$ [$J\ kg^{-1}\ K^{-1}$], the specific gas constant for water vapor.

- $L \uparrow = \epsilon \sigma T^4$

  Stefan-Boltzmann law. $L \uparrow$ [W m^{-2}], the emitted longwave energy flux density; ϵ, the emissivity of the surface (dimensionless); $\sigma = 5.67 \text{ x } 10^{-8}$ [W m^{-2} K^{-4}], the Stefan-Boltzmann constant; T [K], the surface temperature.

- $\lambda_{max} = \frac{2900}{T}$

  Wien's displacement law. λ_{max} [μm], the wavelength at which the peak in the emission spectrum occurs; T [K], the temperature of the emitting surface.

- $\theta = 90 - \Phi_{lat} + \phi_{sol.dec}$

  The solar elevation θ at solar noon, at a location with latitude Φ_{lat}, at the time of year when solar declination is $\phi_{sol.dec}$. Latitude is negative in the southern hemisphere; and solar declination is negative during northern hemisphere winter.

- $Q^* = Q_H + Q_E + Q_G + Q_S$

  The surface energy balance. All fluxes are in [$W\ m^{-2}$]. Q^* the net radiation, positive if directed towards the ground surface; Q_H, Q_E the sensible heat flux and the latent heat flux, positive if directed away from the ground surface; Q_G the soil heat flux, positive if directed away from the ground surface; Q_S, the storage term. The Bowen ratio $B = Q_H/Q_E$.

- $Q^* = K^* + L^* = K \downarrow - K \uparrow + L \downarrow - L \uparrow$

  The surface radiation balance. All fluxes are in [$W\ m^{-2}$]. $K \downarrow, K \uparrow$, the incoming and outgoing solar fluxes (net solar, $K^* = K \downarrow - K \uparrow$); and $L \downarrow, L \uparrow$, the incoming and outgoing longwave fluxes (net longwave, $L^* = L \downarrow - L \uparrow$).

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

  The Geostrophic wind equation. Δh [m], the change in height of a constant pressure surface over distance Δx [m] normal 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); $g \sim 10$ [$m\ s^{-2}$] acceleration due to gravity.

- Each full barb on the wind "dart" counts for about 5 m s^{-1}

Table 1: Saturation vapour pressure $e_s(T)$ [mb] versus temperature T [C].

T	$e_s(T)$	T	$e_s(T)$	T	$e_s(T)$	T	$e_s(T)$	T	$e_s(T)$	T	$e_s(T)$
0	6.11	5	8.72	10	12.27	15	17.04	20	23.37	25	31.67
1	6.57	6	9.35	11	13.12	16	18.17	21	24.86	26	33.61
2	7.05	7	10.01	12	14.02	17	19.37	22	26.43	27	35.65
3	7.58	8	10.72	13	14.97	18	20.63	23	28.09	28	37.80
4	8.13	9	11.47	14	15.98	19	21.96	24	29.83	29	40.06