



FINAL EXAMINATIONS: DECEMBER 2019 - INDIVIDUAL EXAM

Course number: **ATSC 201** Section numbers: 101

Course name: Meteorology of Storms

Duration: 90 minutes for the individual exam; then a 10 minute break; then 50 minute group exam in groups of 4.

Candidate name _____

Student number _____ Candidate signature _____

Special instructions: Open books, notes, and calculator. No other electronics (cell phones, iPads, laptops, ear phones). Indicate your name, student ID, Test Form (All exams this term are Test Form **A**), and all your answers on the Bubble sheet. Each question has only one best answer. Don't leave any questions unanswered (if you don't know the answer, then guess). Good luck!

Instructor names: Roland Stull

This examination consists of 6 pages (including this cover sheet & bubble sheet). Check to ensure that it is complete. Students ARE allowed to separate all the exam sheets from each other. Only the bubble sheet will be marked, but students must turn in ALL pages of this exam. Please do NOT re-staple the bubble sheet to the exam packet.

Rules governing formal examinations

1. Each examination candidate must be prepared to produce, upon the request of the invigilator or examiner, his or her UBCcard for identification.
2. Examination candidates are not permitted to ask questions of the examiners or invigilators, except in cases of supposed errors or ambiguities in examination questions, illegible or missing material, or the like.
3. No examination candidate shall be permitted to enter the examination room after the expiration of one-half hour from the scheduled starting time, or to leave during the first half hour of the examination. Should the examination run forty-five (45) minutes or less, no examination candidate shall be permitted to enter the examination room once the examination has begun.
4. Examination candidates must conduct themselves honestly and in accordance with established rules for a given examination, which will be articulated by the examiner or invigilator prior to the examination commencing. Should dishonest behaviour be observed by the examiner(s) or invigilator(s), pleas of accident or forgetfulness shall not be received.
5. Examination candidates suspected of any of the following, or any other similar practices, may be immediately dismissed from the examination by the examiner/invigilator, and may be subject to disciplinary action:
 - i. speaking or communicating with other examination candidates, unless otherwise authorized;
 - ii. purposely exposing written papers to the view of other examination candidates or imaging devices;
 - iii. purposely viewing the written papers of other examination candidates;
 - iv. using or having visible at the place of writing any books, papers or other memory aid devices other than those listed above under Special Instructions or authorized by the examiner(s); and,
 - v. using or operating electronic devices including but not limited to telephones, calculators, computers, or similar devices other than those authorized by the examiner(s)—(electronic devices other than those authorized by the examiner(s) must be completely powered down if present at the place of writing); and
 - vi. copying, scanning, or photographing any parts of the exam to take or transmit outside of the exam room.
6. Examination candidates must not destroy or damage any examination material, must hand in all examination papers, and must not take any examination material from the exam room without permission of the examiner or invigilator.
7. Examination candidates must follow any additional examination rules or directions communicated by the examiner(s) or invigilator(s).

Open books, notes, & calculator. No electronics that connect to the internet.

Student Number: _____

In all 39 questions below, if none of the answer-choices are perfectly accurate, then pick the one answer that is the closest to accurate. You can carefully detach all of the sheets from each other if you want. Only the bubble sheet will be marked. Good luck.

Given a jet stream that is zonal (i.e., moving in a straight line from west to east), at latitude 55°N, over the Pacific Ocean just west of British Columbia. For the next 4 questions, assume the top of the troposphere is fixed at 8 km above mean sea level, and assume that the jet stream winds are fully contained within the troposphere.

At this latitude, the Coriolis parameter = $1.195 \times 10^{-4} \text{ s}^{-1}$.

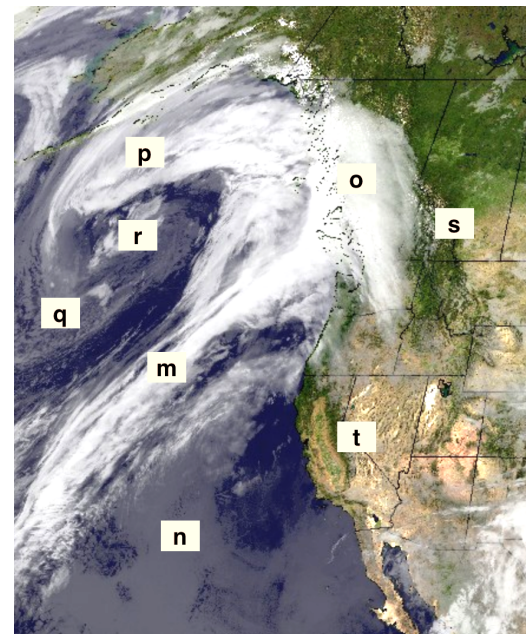
- 1) [1 point] Relative to the wind direction, the Coriolis force in the Northern Hemisphere acts ____ the wind vector.
 - A) to the left of
 - B) in the same direction as
 - C) to the right of
 - D) in the opposite direction as
 - E) independently of
- 2) [2 points] What is the value of the beta parameter (for the "beta plane") in $\text{m}^{-1}\text{s}^{-1}$?
 - A) 1.313×10^{-11}
 - B) 1.47×10^{-11}
 - C) 1.55×10^{-11}
 - D) 1.75×10^{-11}
 - E) 2.0×10^{-11}
- 3) [2 points] What is the value of the relative vorticity in s^{-1} ?
 - A) -1.195×10^{-4}
 - B) -1.14×10^{-4}
 - C) 0
 - D) $+1.14 \times 10^{-4}$
 - E) $+1.195 \times 10^{-4}$
- 4) [2 points] What is the value of the potential vorticity in s^{-1} ?
 - A) 1.195×10^{-4}
 - B) 1.37×10^{-5}
 - C) 1.49×10^{-5}
 - D) 1.37×10^{-7}
 - E) 1.49×10^{-8}

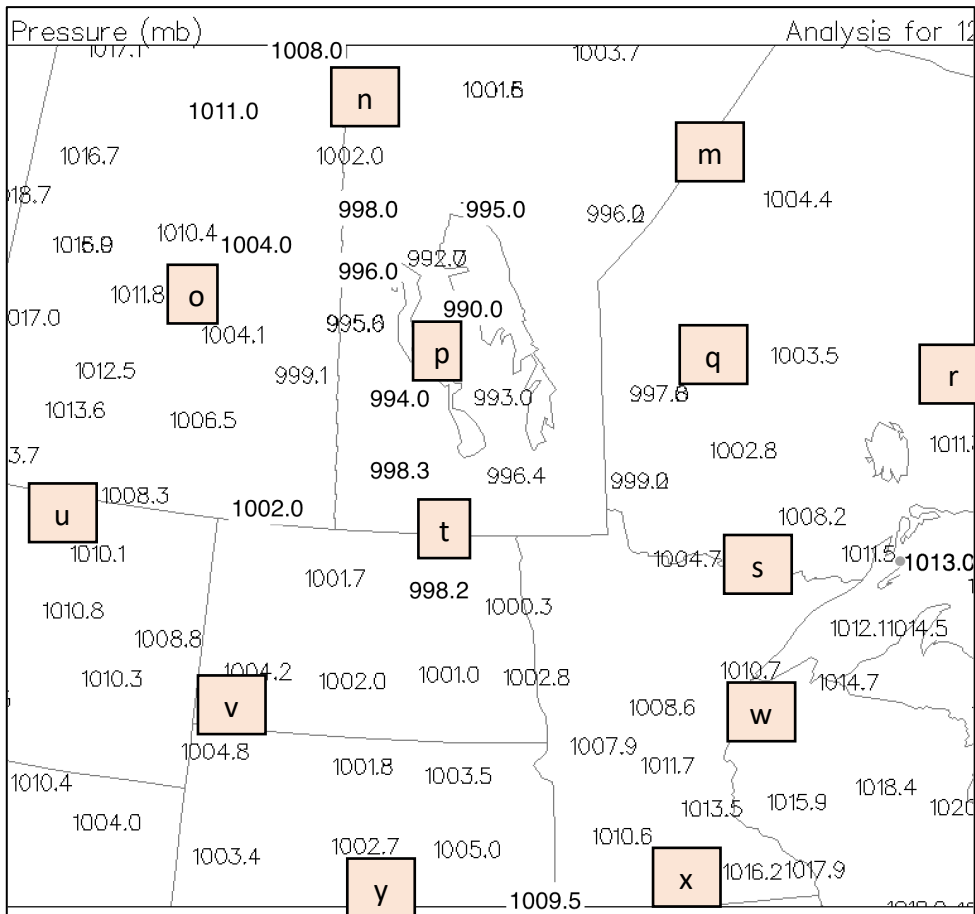
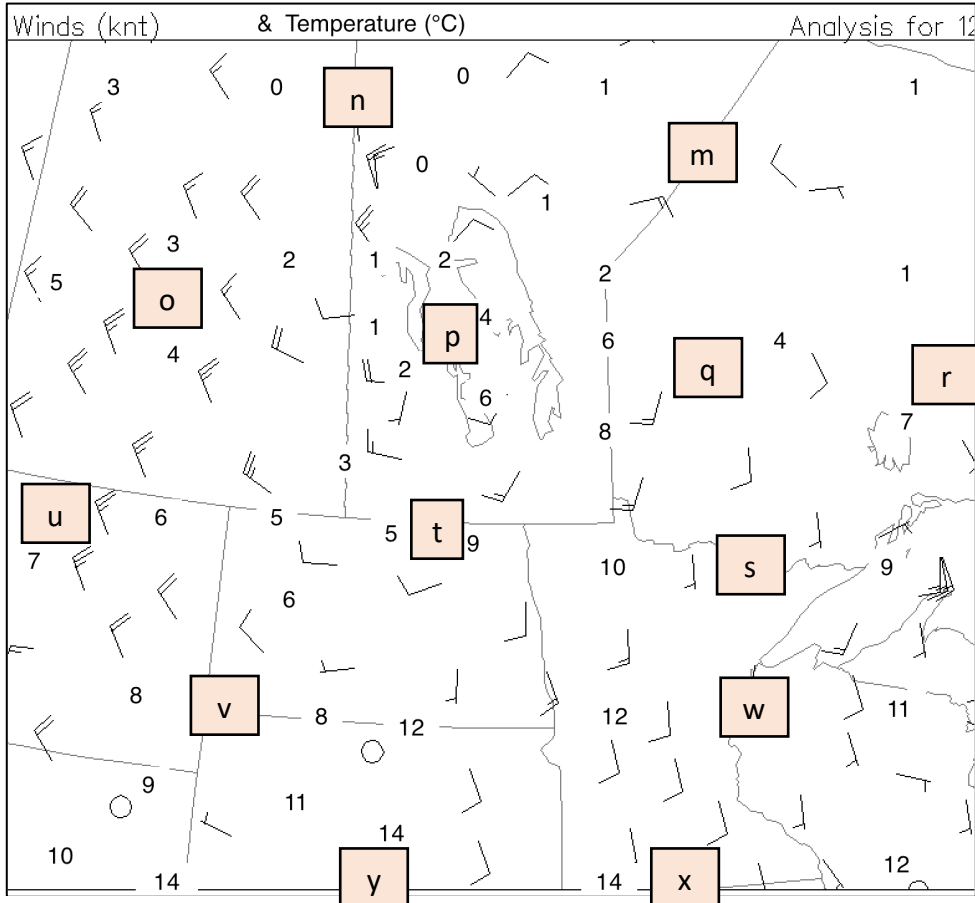
For the next questions, assume that the tropospheric wind from the previous question flows from the Pacific Ocean over a plateau in British Columbia that is 1 km high (above sea level).

- 5) [1 point] What is the new value of potential vorticity over the plateau?
 - A) 1.195×10^{-4}
 - B) 1.37×10^{-5}
 - C) 1.49×10^{-5}
 - D) 1.37×10^{-7}
 - E) 1.49×10^{-8}
- 6) [2 points] What is the new value of relative vorticity over the plateau?
 - A) -1.195×10^{-4}
 - B) -1.493×10^{-5}
 - C) 0
 - D) $+1.493 \times 10^{-5}$
 - E) $+1.195 \times 10^{-4}$
- 7) [1 point] For the portion of the wind that is over the plateau, which way does the wind turn (if at all)?
 - A) upward
 - B) counterclockwise
 - C) (it doesn't turn)
 - D) clockwise
 - E) downward
- 8) [1 point] The resulting north-south meander of the winds is called a/an ____?
 - A) Tropical cyclone
 - B) Extratropical cyclone
 - C) Ekman spiral
 - D) Plateau wave
 - E) Rossby wave
- 9) [1 point] Which is NOT a reason why meanders such as these are important? They ...
 - A) transport heat
 - B) transport momentum
 - C) create lows
 - D) create highs
 - E) are a component of the Hadley cell

Interpret the satellite image at right to answer the following 9 questions. This image is over the eastern North Pacific & western North America.

- 10) [2 points] What spectral name is this image?
 - A) visible
 - B) IR
 - C) water vapour
 - D) microwave
 - E) other
- 11) [2 points] A cold front is likely at:
 - A) m
 - B) n
 - C) o
 - D) p
 - E) both m & p
- 12) [2 points] A warm front is likely at:
 - A) m
 - B) o
 - C) p
 - D) q & n
 - E) r
- 13) [2 points] An occluded front is likely at:
 - A) m
 - B) o
 - C) r
 - D) p & q
 - E) n & r
- 14) [2 points] Low clouds are indicated at:
 - A) m
 - B) o
 - C) p
 - D) n & q
 - E) r & s
- 15) [2 points] A low-pressure center is likely at:
 - A) m
 - B) o
 - C) r
 - D) n
 - E) t
- 16) [2 points] A high-pressure center is likely at:
 - A) m
 - B) o
 - C) p
 - D) r
 - E) t
- 17) [2 points] This GOES-17 image was taken from a _____ satellite?
 - A) low-earth-orbit (LEO)
 - B) sun-synchronous
 - C) polar-orbiting
 - D) geographic-information-system (GIS)
 - E) geostationary
- 18) [1 point] The airmass at location q is likely:
 - A) cP
 - B) mP
 - C) mA
 - D) mT
 - E) cT





The two weather maps on the previous page show observations made at the same location (centered on Canadian-US border in the prairie/plains region) and the same time as each other (i.e., synoptically). To answer the following 9 questions, you will need to first analyze those two maps. (These maps do not correspond to the previous satellite image.)

- On the surface temperature & wind map, draw the following isotherms (0, 2, 4, 6, 8, 10, 12, 14°C) and locate frontal zones (if any). Also identify any relative maxima (warm) or minima (cold) region(s).
- On the mean-sea-level pressure map, draw the following isobars (1012, 1008, 1004, 1000, 996, 992 mb) and locate Low and High pressure centers (if any), and locate trough axes (if any).

Note: we will NOT mark your map analyses, but you will need to do them to answer the following 9 questions. The lower-case letters in the answer options below correspond to the letter boxes on the weather maps on the previous page.

- 19) [3 points] A low-pressure center is at: A) n B) p C) r D) u E) (there are no low-pressure centers)
- 20) [4 points] A trough axis at the Earth's surface is at: A) m B) t C) w D) x E) (there are no surface troughs)
- 21) [3 points] A cold front is at: A) n B) o C) q D) t E) (there are no cold fronts)
- 22) [3 points] An occluded front is at: A) n B) o C) q D) t E) (there are no occluded fronts)
- 23) [3 points] The clouds that are likely at location (m) are:
A) thunderstorms B) cumuliform C) no clouds D) lenticular E) stratiform
- 24) [3 points] The winds at location (u) are roughly:
A) 330° at 25 knots B) 150° at 25 knots C) 10° at 50 knots D) 200° at 50 knots E) 200° at 25 knots
- 25) [5 points] If cyclogenesis is happening at the surface, then over which point would you expect to find a jet-stream trough axis at the tropopause? A) r B) q C) p D) o E) (there is no trough axis)
- 26) [3 points] The most likely location for a cP airmass for this synoptic situation is: A) n B) q C) t D) w E) y
- 27) [3 points] The clouds that are likely at location (u) are: A) cumulonimbus B) cumulus C) altostratus D) nimbostratus E) cirrus

Given a northern hemisphere case with warm air in the west half of a domain and cold air in the east half. There is a surface low-pressure near the center of the domain with surface pressure increasing towards all edges of the domain. (Hint, sketch this on a blank part of the test, to help you visualize the factors that are involved.) Use this scenario for the next 5 questions.

- 28) [3 points] If you were to draw isopleths of the 100 - 50 kPa thickness, these isopleth lines would generally be aligned
A) east-west B) north-south C) northwest-southeast D) northeast-southwest
E) these lines would circle back on themselves to form a closed loop
- 29) [3 points] The thermal wind vector would be from the: A) north B) east C) south D) west E) (the thermal wind is ≈ 0)
- 30) [3 points] Directly north of the low center, halfway to the north edge of the domain, the theoretical gradient winds near the surface (i.e., at 100 kPa) are likely from the: A) north B) east C) south D) west E) nearly calm
- 31) [3 points] At that same location north of the low center, the actual near surface winds would likely be from the
A) southwest B) northwest C) southeast D) northeast E) nearly calm
- 32) [3 points] At that same location north of the low center, the 50 kPa winds would likely be from the
A) southwest B) northwest C) southeast D) northeast E) nearly calm

33) [3 points] Suppose the Earth spun in the opposite direction on its axis. During northern hemisphere winter, which is true regarding a monsoon circulation over a northern-hemisphere continent?

- A) a thermal low would create a near surface counterclockwise circulation.
- B) a thermal low would create a near-surface clockwise circulation.
- C) a thermal high would create a near surface counterclockwise circulation.
- D) a thermal high would create a near-surface clockwise circulation.
- E) monsoon circulations are impossible for an earth that rotates in the opposite direction.

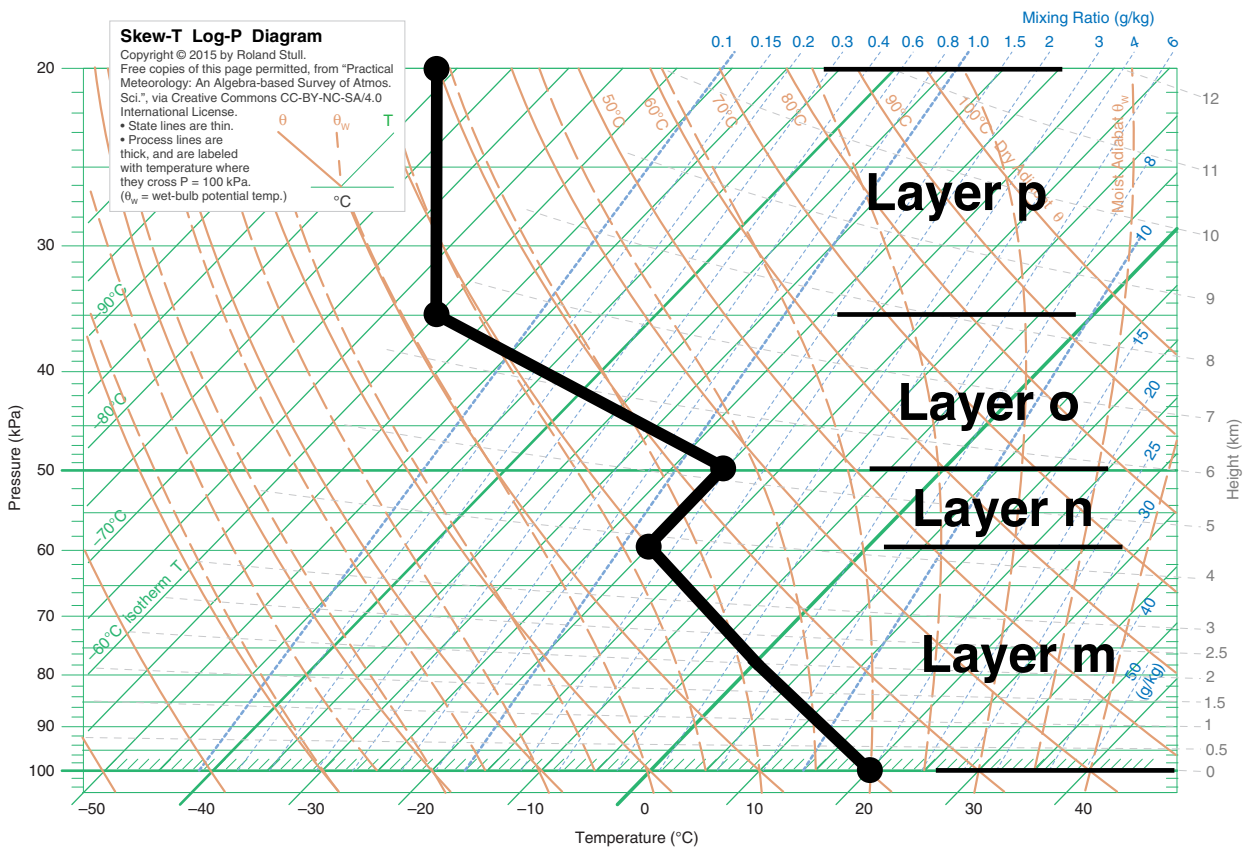
34) [3 points] Thunderstorms in a typhoon eyewall release significant amounts of latent heat due to all the water vapour that condenses and rains out. Why is the hypsometric relationship relevant in this situation to explain why a typhoon's warm core enables the typhoon to exist for a long time?

- A) Pressure decreases more slowly with height in warm air, causing relatively low pressure that drives inflow winds at storm top.
- B) Warmer air is less dense, causing faster decrease of pressure with increasing altitude, creating low pressure at the top of the eye.
- C) (False assumption. The warm core is irrelevant to the longevity of the typhoon. Most important is the sea-surface temperature.)
- D) The symmetry implied by the hypsometric equation ensures that descending air in the eye balances ascending air in the eyewall.
- E) Pressure decreases more slowly with height in warmer air, causing relatively high pressure that drives outflow winds at storm top.

- 35) [5 points] Given a troposphere with average lapse rate of 4°C/km. Assume dry air of average temperature 270K. If this air flows at speed 20 m/s over a mountain, what is the wavelength (km) of the resulting mountain wave?
 A) 5.6 B) 8.7 C) 250.9 D) 596.9
 E) (no mountain wave, because that lapse rate implies a statically UNstable atmosphere)

To answer the next 3 questions, use the environmental sounding plotted on the thermo diagram below. Assume dry air (no condensation).

- 36) [1 point] Which environmental layer(s) is/are nearly isothermal?
 A) only m B) only n C) only o D) only p E) (no layers are nearly isothermal)
- 37) [1 point] Which environmental layer(s) is/are nearly adiabatic?
 A) only m B) only n C) only o D) only p E) (no layers are nearly adiabatic)
- 38) [1 point] Which environmental layer(s) is/are statically unstable?
 A) only m B) only n C) only o D) only p E) (all layers are unstable)



- 39) [1 point] Assume you are in a valley to the lee of a mountain range. A warm, dry, downslope wind at the earth's surface is called a/an _____ wind.
 A) katabatic B) anabatic C) foehn D) bora E) atmospheric-river

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