ATSC 201 Fall 2024
Chapter 11: A11f, A22f, A23f, E1, E2
Chapter 12: A1f, E21
Total marks: 29

Chapter 11

A11f) (5.5 marks)

Find the magnitude of the thermal wind (m/s) for the following thickness gradients: f) ΔTH(km)/Δx(km) = -0.2/400, ΔTH(km)/Δy(km) = -0.1/400.

Given:	ΔTH_x =	-0.2	km	-200	m
	Δx =	400	km	400000	m
	ΔTH_y =	-0.1	km	-100	m
	Δy =	400	km	400000	m

Find: MTH = ? m/s

First, use eqns 11.15a and 11.15b:

$$U_{TH} = U_{G2} - U_{G1} = -\frac{|g|}{f_c}\frac{\Delta TH}{\Delta y}$$

$$V_{TH} = V_{G2} - V_{G1} = +\frac{|g|}{f_c}\frac{\Delta TH}{\Delta x}$$

where |g| = 9.8 m/s^2
assume fc = 1.10E-04 /s

UTH = 22.27 m/s
VTH = -44.55 m/s

Then, use eqn. 11.16: $M_{TH} = \sqrt{U_{TH}^2 + V_{TH}^2}$

MTH = 49.80 m/s

Check: Units ok. Physics ok.

Discussion: The thermal wind speed is the difference in the geostrophic wind speeds at the top and bottom of the layer. Thickness (TH) is analagous to the mean temperature of the layer. From the given thickness gradients, we know that the temperature is colder to the east, and to the north. Thermal wind points parallel to the thickness isolines, with the cold air to its left. This matches with our numerical answers for UTH and VTH.

A22f)
(2.5 marks)

For the latitude given below, what is the value of the beta parameter (1/ms): f) 65°.

Given:	ϕ =	65 °		1.134464014 radians
Find:	β =	?	1/(m*s)	

Use eqn. 11.35:

$$\beta = \frac{\Delta f_c}{\Delta y} = \frac{2 \cdot \Omega}{R_{earth}} \cdot \cos\phi$$

where : 2*Ω/Rearth = 2.29E-11 1/(m*s)

β = 9.68E-12 1/(m*s)

Check: Units ok. Physics ok.

Discussion: When we assume that the Coriolis parameter fc changes linearly with latitude (i.e. beta = constant), we are using the "beta plane". This approximation is valid when we are only looking at a small latitude belt.

A23f)
(6 marks)

Suppose the average wind speed is 60 m/s from the west at the tropopause For a barotropic Rossby wave at 50° latitude, find both the intrinsic phase speed (m/s) and the phase speed (m/s) relative to the ground for wavelength (km) of: f) 3500.

Given:	λ =	3500 km		3500000 m
	ϕ =	50 °		
	Uo =	60 m/s		
Find:	co =	?	m/s	
	c =	?	m/s	

First, find the beta parameter using eqn. 11.35:

$$\beta = \frac{\Delta f_c}{\Delta y} = \frac{2 \cdot \Omega}{R_{earth}} \cdot \cos\phi$$

where : 2*Ω/Rearth = 2.29E-11 1/(m*s)

β =	1.47E-11 1/(m*s)

To find the intrinsic phase speed use eqn. 11.37:

$$c_o = -\beta \cdot \left(\frac{\lambda}{2\pi}\right)^2$$

co =	-4.57 m/s

To find the phase speed use eqn 11.38:

$$c = U_o + c_o$$

c =	55.43 m/s

Check: Units ok. Physics ok.

Discussion: The intrinsic phase speed tells us how fast the wave is moving relative to the mean flow. A negative intrinsic phase speed means that the waves are actually moving westwards if there is no mean flow in the background. The phase speed is the speed of the wave relative to the ground. This wave travels fairly fast (near mean flow wind speed), which is reasonable as it has a fairly short wavelength for a barotropic wave.

E1)
(5 marks)

During months when the major Hadley cell exists, trade winds cross the equator. If there are no forces at the equator, explain why this is possible.

Given: Months when major Hadley cell exists
No forces at the equator

Find: Why trade winds cross the equator

There is an energy surplus where the incoming solar radiation is largest, triggering convection. Since the solar declination angle changes throughout the year, also the location of the ITCZ shifts accordingly. The trade winds are the near-surface winds of the Hadley cell, which converge at the ITCZ.
When the solar declination angle is close to zero and

the ITCZ is near the equator, both Hadley cells are almost symmetric. However, when the ITCZ is shifted off the equator and onto the Northern/Southern hemisphere, a major Hadley cell exists across the equator, hence, the trade winds cross the equator. This process is driven by the incoming solar radiation independent of other forces. However, the effect of the coriolis force in the real world turns the trade winds towards the west.

E2)
(4 marks)

In regions of surface high pressure, descending air in the troposphere is associated with dry (nonrainy) weather. These high-pressure belts are where deserts form. In addition to the belts at ±30° latitude, semi-permanent surface highs also exist at the poles. Are polar regions deserts? Explain.

Given: Semi-permanent surface high at poles

Find: Explain whether polar regions are deserts

Deserts are defined as regions with arid climates, which means that the mean annual precipitation in these regions is relatively small. This is true for both the belts at ±30° latitude and the polar regions, due to the descending air associated with the surface high pressure. Therefore, polar regions are deserts. The subtropical highs cause hot deserts with small amounts of rainfall and high evaporation, whereas the polar highs cause cold deserts of snow and ice with small amounts of snowfall.

Chapter 12

A1f)
(2 marks)

Identify typical characteristics of the following airmass: f) mA.

Given: Airmass = mA = maritime Arctic.

Characteristics: Humid and Very Cold. Formed over ocean.

Discussion:
A maritime arctic airmass is not a common airmass. Forming over the Arctic Ocean, these airmasses would be very cold and humid

E21)
(4 marks)

Background: Recall that a frontal zone separates warmer and cooler airmasses. The warm airmass side of this zone is where the front is drawn on a weather map. This is true for both cold and warm fronts. Issue: AFTER passage of the cold front is when significant temperature decreases are observed. BEFORE passage of a warm front is when significant warming is observed. Question**: Why does this difference exist (ie. AFTER vs BEFORE) for the passage of these two fronts?**

Solution:

Fronts on a weather map are always drawn on the warm side of the surface frontal zone.

For a warm front, the baroclinic zone (the region with the strongest horizontal temperature gradient indicated by the tightest isotherms) is **ahead** of the warm front. For this reason, you will feel the rapid warming before the warm front approaches.

For a cold front the baroclinic zone is **behind** the cold front, so you will feel the rapid cooling after the cold front has passed.