GEO4960 spring 2020
Obligatory assignment 2

May 24, 2020

1 Thermocline theory

1. Explain why we cannot use the quasi-geostrophic equations to study the main or background vertical structure of the ocean density field.

2. Discuss the motivations for discussing a lower diffusive and an upper advective thermocline (really pycnocline). Give rough scalings for the *thickness* of the diffusive thermocline given a knowledge of the vertical diffusivity. Also give scaling for the *depth* of this thermocline (essentially the depth where the surface Ekman pumping velocity has vanished).

3. Explain the essence of ventilated thermocline theory, i.e. what it tries to explain. What happens in the three regions: a) 'ventilated region', b) 'shadow zone' and c) 'western pool'?

2 The Meridional Overturning Circulation

1. Explain the concept of 'sideways convection' and the apparent problem with this (as formulated by Sandström and others). How does external mechanical forcing 'fix' this problem (there are essentially two ways to drive the ocean circulation).

2. Explain the essentials of the Stommel-Aarons model with a focus on how the model predicts poleward deep flow in the interior of the oceans and equatorward deep flow in western boundary currents. Why can the western boundary currents cross the equator while the interior flow cannot? (Hint: look at the three-term vorticity balance which includes the beta term, the upwelling term and a friction term.)

3. What is some fundamental differences between the 'mixing-driven' model of the MOC (like Stommel-Aarons) and models in which the overturning is driven by winds in the Southern Ocean? Why does an underwater sill in the southern ocean channel seem to be an important ingredient for

a wind-driven overturning to exist? Can a wind-driven overturning still exist without such a sill?

3 Baroclinic instability

1. What does baroclinic instability do in the ocean and the atmosphere? Discuss both energetics (particularly using the concept of Available Potential Energy) and the larger impact on Earth's climate.

2. Explain how b.c. instability of a zonal vertically-sheared jet can be discussed both in terms of meridional transport of mass (volume) that acts to flatten isopycnals and in terms of an eddy form stress that distributes zonal momentum vertically. Can you use the effect of b.c. instability on the thermal wind shear to link the two views?

3. Why do we believe baroclinic instability is central to understand what goes on in the Antarctic Circumpolar Current (ACC)? Explain how eddy fluxes may influence the strength of the ACC, i.e. by setting the thermal wind shear.