WEEK 3:
WINDS IN THE BOUNDARY LAYER and VISCIOUS FLOWS
Homework assignment

Read Chapters 6 and 7 of *Introduction to Micrometeorology*, by Arya, which contains useful example problems.

Problems:

1. The PBL flow is driven by large scale atmospheric motions in response to spatial variations in air pressure. In midlatitudes these large scale flows tend to be in geostrophic balance.

   (i) Use the surface pressure map below to estimate the geostrophic wind vector $[U_g, V_g]$ at the point marked with an $\times$. Assume the surface temperature is $15^\circ C$.

   (ii) Panel (b) shows a close up of the region around the $X$. Mark on this figure the geostrophic wind arrow you found for the previous section. What primary effect would the surface type have on the balance of forces associated with the flow in the PBL? How would this balance differ over land and for ocean? Mark on the panel (b) a schematic representation of the force balance over the land and over the ocean.

   (iii) Draw likely low level wind vectors over the land and over the ocean on panel (b). Be sure to indicate any differences in both the direction and the magnitude of the wind.

   (iv) Using the thermal wind equations, assuming the terms in $dT/dz$ are small, with $dT/dx$ and $dT/dy$ both equal to $2^\circ C$ per 100 km, use your surface geostrophic wind vector estimated in (i) to estimate the geostrophic wind vector at the top of a well-mixed boundary layer that is 1 km deep. What might this imply about forced convection in this area? [Hint: consider what the Richardson number might be for this situation]
2. (i) What key property of a fluid is required in order for Ekman layers to form? For Ekman layers in the upper ocean, we can ignore horizontal pressure gradients so that the Ekman balance is between the Coriolis force and the viscous (friction) force – see Equation 7.19 in Arya. For seawater, the kinematic viscosity $\nu = 1.2 \times 10^{-6}$ m$^2$ s$^{-1}$. Calculate the characteristic parameter of the Ekman flow $a = (f/2\nu)^{1/2}$ at 20°N, where $f$ is the Coriolis parameter. What two aspects of the subsurface currents does $a$ influence?

(ii) Off the coast of California in summer, surface winds flow approximately north to south parallel to the coastline. What does this imply about the direction of the upper oceanic Ekman flow?

Imagine an element of ocean immediately adjacent to the coast. Given the near surface flow you deduced above, use mass continuity to determine the likely source of the water flowing into the element. What does this imply about the temperature of the water in this region?