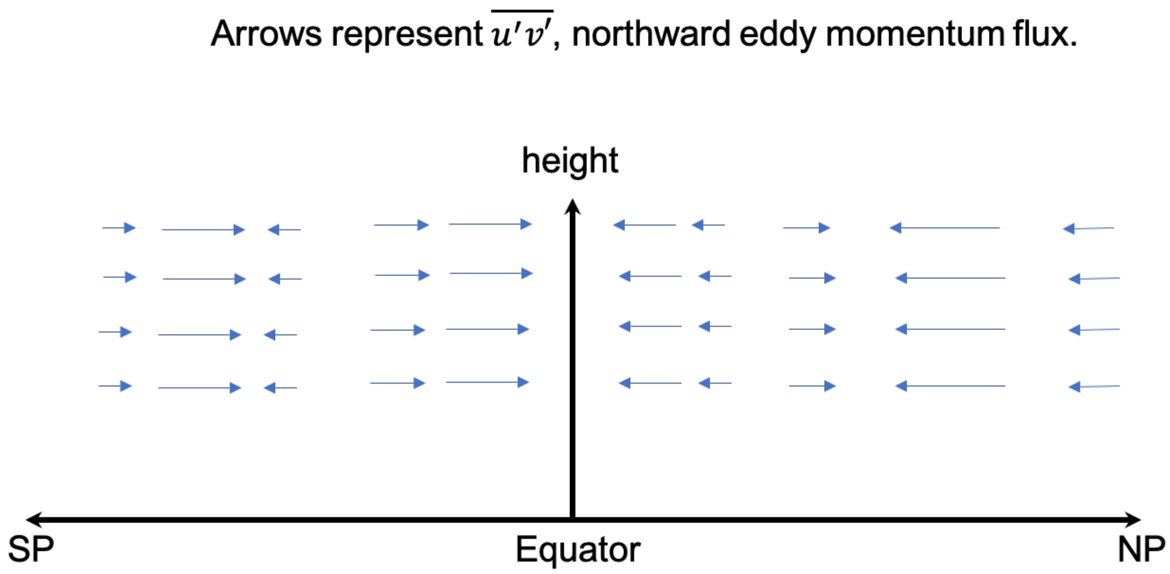
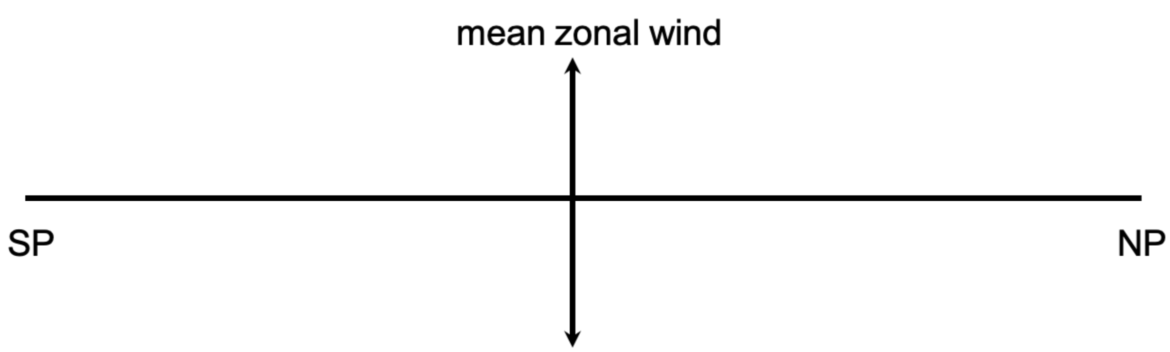
General circulation of the atmosphere

Problem set 3

Problem 1.

The schematic below shows the eddy-momentum fluxes in a hypothetical atmosphere as a function of latitude (x-axis) and height (y-axis). Arrows give the value of the zonal- and time-mean eddy momentum flux at a given latitude and height up to the tropopause (arrows to the right give northward fluxes, arrows to the left give southward fluxes). Assuming quasi-geostrophic scaling is valid (except very close to the equator), sketch the corresponding overturning streamfunction (on the same axis) and the corresponding zonal-mean surface winds (on the axis below).





Problem 3.

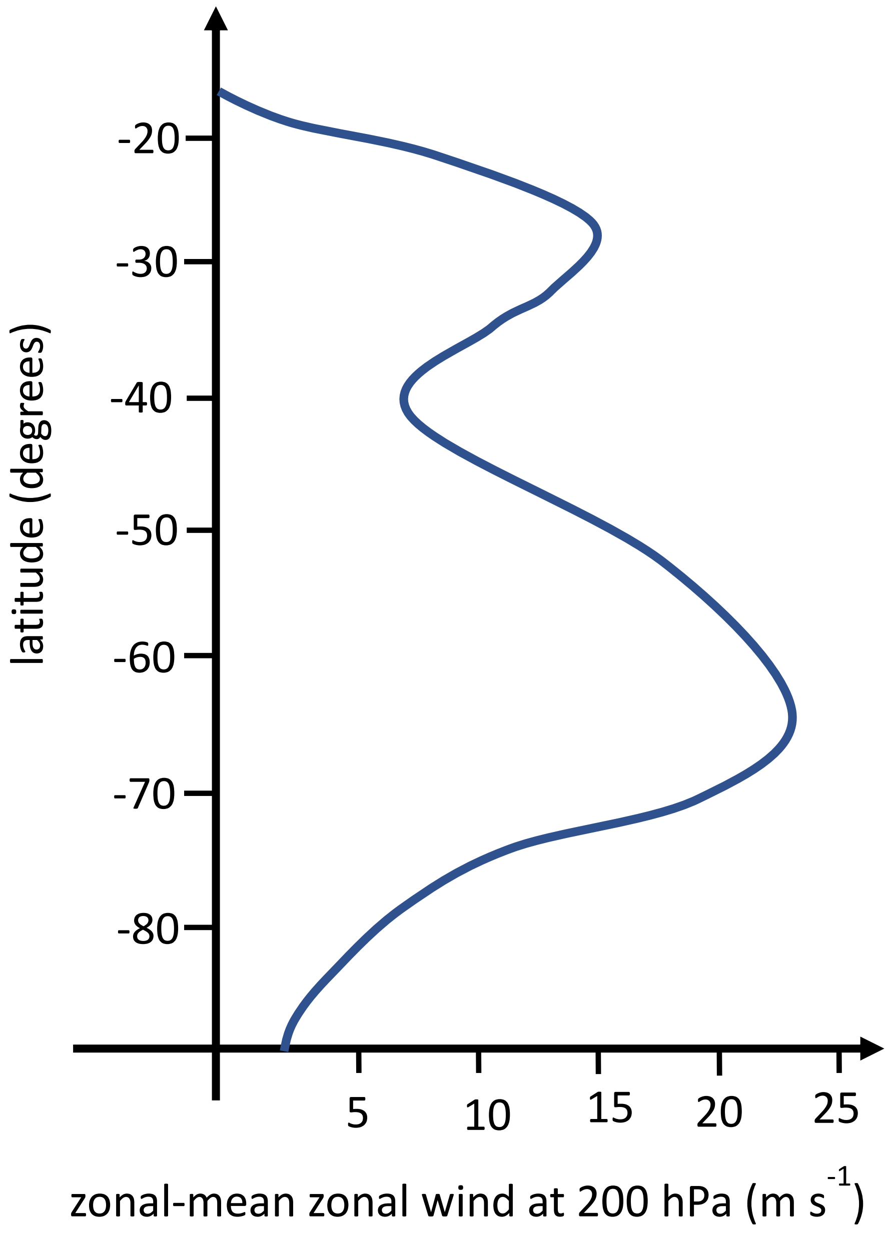
Consider the distribution of zonal-mean zonal wind at 200 hPa in the figure below. Suppose a Rossby wave forms at a latitude of 60°S with a zonal phase speed of 10 m s^{-1}, and a positive meridional phase velocity. In the following, assume that the Rossby wave is barotropic, and that the relevant mean zonal background flow is the wind at 200 hPa.

a) Assuming the zonal wavelength is "long", so that $k \to 0$, estimate the meridional wavelength of the Rossby wave.

b) Use linear theory (in combination with the WKB approximation) to estimate the latitude of the *critical line* at which point the wave can no longer propagate.

c) Based on your answers to (a) and (b) above, comment on the validity of the WKB approximation for this problem.

d) In reality, Rossby waves are not small perturbations on the zonal-mean flow. Describe what happens to a fully non-linear wave-like disturbance as it propagates meridionally from 60°S and approaches its critical line.



latitude (degrees)
-20
-30
-40
-50
-60
-70
-80
5
10
15
20
25
zonal-mean zonal wind at 200 hPa (m s-1)