Climate assignments
LINK school, Sept 2012

1. **Energy balance:** Write explicitly and then solve (analytically or numerically) for the steady states $\bar{T}_i$ of the simple 0d energy balance model discussed in class, which may be qualitatively represented by,

$$C\frac{\partial T}{\partial t} = \text{insolation} \times (1 - \text{albedo}(T)) - \text{longwave}. \tag{1}$$

Perform linearized stability analysis of the three different steady state solutions: write $T = \bar{T}_i + T'$, $i = 1, 2, 3$, derive the equation for the perturbation T' assuming that it is small and solve it. Is the perturbation growing or decaying with time for each of the three solutions? Show that the results are consistent with those of the graphical method for stability analysis in this case.

2. **Multiple THC equilibria:** find the two solutions for the dimensional two box Stommel-Taylor box model discussed in class at some specified value of the fresh water forcing for which there are two solutions. In each of the solutions, examine the different terms in the salinity equation for each of the boxes and describe what the physical balance is. I.e. advection of high salinity water from the low latitudes to the high latitudes (specify number and units), balanced by precipitation (again, number and units). The answer should be four simple sentences describing the balances for both boxes for both solutions, with numbers. Briefly discuss the differences between the physical balances of the two solutions.

3. **Rossby waves, superrotation:** (i) Draw the dispersion relation for Rossby waves; (ii) derive and plot the phase and group velocities in the longitudinal (x) direction as function of the meridional wave number k. In which direction are these velocities (east or west?) (Iii) Write down the meridional flux of (y direction) zonal momentum, $u'v'$ for these waves, explain why this is the right expression for this flux. Write down the meridional group velocity which is also the velocity of energy propagation for these waves. Show that the group velocity and momentum fluxes are in opposite directions.

4. **Convective cloud feedback:** Read section 2a of Abbot and Tziperman (2009) which is available on the course web page. Write down and explain the equations of this simple radiative-convective model. Solve for the nonconvecting solution using equations (5-6). (Optional: solve for the convecting solution numerically).

References

Abbot, D. S. and Tziperman, E. (2009). Controls on the activation and strength of a high latitude convective-cloud feedback. *J. Atmos. Sci.*, 66:519–529.