Geosci 232 Problem Set 6

March 17, 2003

1 Exploring thermal inertia

In class we discussed some numerical solutions for the seasonal cycle of a mixed layer ocean, but in these calculations we ignored the greenhouse effect and assumed that the cooling of the surface was given by $\sigma T^4$. In this problem you will re-examine the seasonal cycle with a more realistic model of surface cooling.

It can be shown that the surface cooling is approximately equal to the OLR, since the atmosphere itself comes into equilibrium rather quickly. Further, calculations with realistic radiation models at 280ppm $CO_2$ and incorporating the water vapor feedback show that the OLR has the approximate linear behavior:

$$\text{OLR}(T) = 2 \cdot (T - 285) + 237.$$  \hspace{1cm} (1)

for $260K < T < 310K$. If we allow for a 30% albedo, the equation you need to integrate is now:

$$\frac{dT}{dt} = \frac{1}{\rho c_p H}(0.7L f(\phi, \kappa(t), \delta) - \text{OLR}(T))$$  \hspace{1cm} (2)

where $L$ is the solar constant, $f$ is the solar flux distribution function, $\phi$ is the latitude, $\kappa$ is the season angle and $\delta$ is the obliquity.

Solve this equation numerically, and discuss the seasonal cycle at latitudes $0^\circ, 45^\circ$ and $60^\circ$ for an obliquity of $\pi/8$ radians. First try a mixed layer depth of 50m. Then try a mixed layer depth of 1m, roughly equivalent to the thermal inertia of land. Discuss your results. For the 50m case, discuss how
the seasonal cycle changes if the obliquity is reduced to $\pi/16$ or increased to $\pi/4$.

You will notice, particularly in the 50$m$ mixed layer case, that the mid-latitude temperatures are unrealistically cold and the tropical temperatures are unrealistically hot. This is because our calculation ignores heat export from the tropics to the extratropics. If we call the export $F_{\text{exp}}$, measured as an equivalent flux, the tropical temperature equation becomes

$$\frac{dT}{dt} = \frac{1}{\rho c_p H} (7L_f(\phi, \kappa(t), \delta) - OLR(T) - F_{\text{exp}})$$

(3)

If we approximate $F_{\text{exp}}$ as being time-independant, how large does $F_{\text{exp}}$ have to be to bring the tropical temperature down to 300$K$? If we assume that the same flux is applied as a heating to the midlatitude, how does the seasonal cycle and mean temperature now look at latitude 45$^o$?