Atmospheric Sciences 6150
Exercise 2: Convection from local sources

1. Emanuel problem 2.1
2. Emanuel problem 2.2
3. Emanuel problem 2.3: Use $\alpha = 0.093$.
4. Emanuel problem 2.4: This is continued on page 45.

EXERCISES

2.1 Using dimensional analysis, derive the functions G and H in (2.3.1) and compare these functions to their equivalents for point sources of heat.

2.2 It is not possible to create true point or line sources of buoyancy in the laboratory, since all real sources will have some nonzero dimension. How would you go about comparing the predictions of dimensional analysis with real laboratory experiments of plumes and thermals?

2.3 A dictator has overrun a small, oil-rich country and threatens to set fire to all the oil wells. Environmental specialists are worried that smoke from the resulting plumes might enter the stratosphere, where it could have long-term effects on climate. Do they have a good reason to worry?

Assume the following in formulating your answer:

(d) The surface air density is about 1.2 kg m^{-3} and its temperature is roughly 300 K. The heat capacity at constant pressure of air is about 10^3 J kg^{-1} K^{-1}.
(e) The troposphere extends upwards to about 10 km and has an average buoyancy frequency (N) of 10^{-2} s^{-1}.

2.4 Estimate the height to which a cloud generated by a bomb will rise through a calm atmosphere, which, to a fair approximation, may be considered to have uniform stratification in the troposphere and a greater but also uniform stratification in the stratosphere. Use similarity theory and a bit of imagination to estimate this altitude, given that

(a) The bomb explodes at the surface.
(b) The bomb may be considered an instantaneous point source of heat.
(c) All the energy of the bomb goes into heat.
(d) Exotic effects such as breakdown of the Boussinesq approximation, plasma behavior, continued heating from radioactivity, and condensation may be neglected.

Calculate the maximum ascent height for (1) a 1-megaton bomb, and (2) a 100-megaton bomb, given the following conditions:

(a) Buoyancy frequency N_t of the troposphere $= 10^{-2}$ s^{-1}
(b) Buoyancy frequency N_s of the stratosphere $= \sqrt{2} \times N_t$
(c) Height of the tropopause $= 10$ km
(d) Surface pressure $= 1020$ millibars

(e) Entrainment parameter = 0.285

(f) 1 megaton = 4×10^{15} J