Thermal Cloud Model[1] Feb. 23, 2006, MSC 409

Some aspects of Cumulus clouds are successfully captured by a thermal or plume model. These build on the intuition that a cloud, thought of as a bubble, will move up faster if the initial buoyancy is larger, and if the initial bubble size is larger (=less environmental opposition). The bubble buoyancy *B* is equal to $(T_{bubble} - T_{environmental})/T_{environmental}$. With these assumptions and one integration, we find $z^2 = a * (g*V*B)^{0.5} * time$, where *V*=the volume of the bubble, *g* is the gravitational constant 9.8 m/s^2, and *a* is an empirically-derived constant. *Z* is the height of the bubble above the ground. The matlab code given below finds how *z* varies with time for 5 thermal bubbles, each with the same initial buoyancy and size but released separately in one-minute time intervals.

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*****************************************************************************
% runs a one-dimensional thermal/plume cloud model,
% stepping forward in time in 60second increments
% and for one initial value of
%beta, the product of thermal volume*buoyancy*gravity, and
% an empirical constant a, relating time,height, and beta.
% We will examine the evolution of 5 plumes each begun in a
% subsequent time step.
% february 23, 2006, MSC409. based on Rogers&Yau p.54-55

beta=0.1 ;
a=6.6
t=[0,60,120,180,240,300,360,420,480,540,600,660,720,800] ; %time in seconds
newplume=[0,60,120,180,240] ; %one new plume every minute for 4 minutes
for iplume = 1:5;1
    for itime = iplume:14;1     %time step
        z_squared=a*sqrt(beta)*(t(itime)-newplume(iplume)) ;
        z(iplume,itime)=sqrt(z_squared) ; %height of plume
    end
end

% plot height as a function of time for each of the 5 plumes
figure;
plot(t,z(1,:),'-o',t,z(2,:),'-+',t,z(3,:),'-*',t,z(4,:),'-s',t,z(5,:),'-d')
;
xlabel('time (seconds)') ; ylabel('height (meters)')
title('Thermal Cumulus cloud model evolution')
***************************************************************************
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Question: What happens with the successive thermals as time passes? The behavior with time is also observed and explains how if many small clouds are thermally generated in succession, they will tend to merge with each other after a while, which then works to effectively increase the size, buoyancy, and rate of ascent of the composite thermal. This helps explain how afternoon convection can develop into clouds well-developed enough to be able to precipitate.

[1] Foto taken during Rain in Cumulus over Ocean (RICO) experiment.