Homework 9

```
close all
clear all

% parameters (concentrations are all in mol/L)
A  = 4e14;
Vs = A*100;
Vd = A*3000;
K0 = 0.04;
K1 = 1e-6;
K2 = 1e-9;
Alk= 2300e-6;
pCO2atm0 = 280e-6;
MA = 2.2e6;
Ps = 1.0e-6;
Pd = 2.2e-6;
Vm = 3e8;
G = 2000/3e7;

% (a) At Year 100, atmos pCO2 will be pCO2(0)*e^1
pCO2_100 = pCO2atm0*exp(1);
disp('.....');
disp(['(b) At Year 100, pCO2atm is ',num2str(pCO2_100*1e6,4),' ppm']);

% (b) We can calculate this by solving the quadratic equation
g = K1*K0*pCO2_100/K2;
a = 4;
b = g-4*Alk;
c = Alk*Alk-g*Alk;
Cs = 1/(2*a)*(-b+sqrt(b*b-4*a*c));
disp('.....');
disp(['(b) Equilibrium Cs at Year 100 is ',num2str(Cs*1e6,4),' u molC/L']);

% (c) Numerical solution of the 1% CO2 simulation
Sec2Yr = 1/(60*60*24*365);
dt = 60*60*24; % 1 day timestep
N=365*100;
time(1)=0;
J = Vm*(Pd-Ps)*(106/1);
Cs(1)=2026e-6;
Cd(1)=2153e-6;

for i=1:N-1
    time(i+1)=time(i)+dt; % update time

    % 1% per year CO2 is exponential function
    pCO2atm(i+1) = pCO2atm0*exp(0.01*time(i)*Sec2Yr);

    % ocean pCO2 from carbonate chemistry
    pCO2ocn(i+1) = K2*(2*Cs(i)-Alk)^2/(K0*K1)/(Alk-Cs(i));

    % rate of change for Cs
    dCdt(1)=1/(Vs)*(-G*K0*(pCO2ocn(i+1)-pCO2atm(i+1))*A ...
                    +Vm*(Cd(i)-Cs(i)) -J);

    % rate of change for Cd
    dCdt(2)=1/(Vd)*(-Vm*(Cd(i)-Cs(i)) +J);

    % step forward Cs and Cd
    Cs(i+1)=Cs(i) + dt*dCdt(1);
    Cd(i+1)=Cd(i) + dt*dCdt(2);

end

% diagnostics 1, DIC and pCO2
year = time*Sec2Yr;
figure(1);
subplot(2,1,1);
plot(year,Cs*1e6,'b-');
hold on;
plot(year,Cd*1e6,'m-');
hold off;
legend({'Surface DIC' 'Deep DIC'});
ylabel('DIC concentration, micro M','fontsize',13);
disp('.....');
disp(['(c) Numerical solution for Cs at Year 100 is ',num2str(Cs(end)*1e6,4),' u molC/L']);

subplot(2,1,2);
plot(year,pCO2atm*1e6,'r-');
hold on;
plot(year,pCO2ocn*1e6,'k-');
hold off;
legend({'pCO2atm' 'pCO2ocn'});
ylabel('pco2, ppm','fontsize',13);
xlabel('time, year','fontsize',13);

% diagnostics 2, pH, Buffer factor, Carbon uptake
H=K2*(2*Cs-Alk)./(Alk-Cs);
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pH=-log10(H);
B=H/K2;
Uptake = G*A*(K0*1e3)*(pCO2atm-pCO2ocn); % molC/sec
Uptake = Uptake/Sec2Yr*12e-15; % PgC/yr

figure(2);
subplot(3,1,1);
plot(year,pH,'k-');
ylabel('pH','fontsize',13);
subplot(3,1,2);
plot(year,B,'k-');
ylabel('B','fontsize',13);
subplot(3,1,3);
plot(year,Uptake,'k-');
ylabel('Uptake, PgC/yr','fontsize',13);
disp('.....');
disp(['(d) As ocean absorbs pH drops and the Buffer factor (B) increases, weakening the buffering capacity of the seawater.  ']);
disp(['While atmos pCO2 increases exponentially, the ocean carbon uptake does not increase exponentially. Its rate of increase slows down due to the we
xlabel('time, year','fontsize',13);

% sensitivity experiment with different G and Vm
Gval = [1000:100:3000]*Sec2Yr; %from 1000 to 3000, every 100 m/yr
Vmval= [200:10:410]*1e6;       %from 200 to 400, every 10 Sv
for m=1:length(Gval);
    for n=1:length(Vmval);
        G = Gval(m); % set gas exchange rate
        Vm= Vmval(n);% set vertical exchange

        J = Vm*(Pd-Ps)*(106/1); % set biological pump
        Cs(1)=2026e-6;
        Cd(1)=2153e-6;
        time(1)=0;

        for i=1:N-1
            time(i+1)=time(i)+dt; % update time

            % 1% per year CO2 is exponential function
            pCO2atm(i+1) = pCO2atm0*exp(0.01*time(i)*Sec2Yr);

            % ocean pCO2 from carbonate chemistry
            pCO2ocn(i+1) = K2*(2*Cs(i)-Alk)^2/(K0*K1)/(Alk-Cs(i));

            % rate of change for Cs
            dCdt(1)=1/(Vs)*(-G*K0*(pCO2ocn(i+1)-pCO2atm(i+1))*A ...
                            +Vm*(Cd(i)-Cs(i)) -J);

            % rate of change for Cd
            dCdt(2)=1/(Vd)*(-Vm*(Cd(i)-Cs(i)) +J);

            % step forward Cs and Cd
            Cs(i+1)=Cs(i) + dt*dCdt(1);
            Cd(i+1)=Cd(i) + dt*dCdt(2);

        end
        Uptake = G*A*(K0*1e3)*(pCO2atm-pCO2ocn); % molC/sec
        CUptake(m,n)=sum(Uptake*dt*12e-15); % PgC
    end
end
figure(3);
[c,h]=contourf(Gval/Sec2Yr,Vmval*1e-6,CUptake');
clabel(c,h);
colormap('jet');
xlabel('Gas exchange coefficient, m/yr');
ylabel('Ocean Vertical Exchange, Sv');
title('Cumulative ocean carbon uptake, PgC');
disp('.....');
disp(['(e) As the graph shows, the most important rate-controlling factor for ocean carbon uptake is the vertical exchange rate (Vm). ']);
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.....
(b) At Year 100, pCO2atm is 761.1 ppm
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(b) Equilibrium Cs at Year 100 is 2165 u molC/L
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(c) Numerical solution for Cs at Year 100 is 2161 u molC/L
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(d) As ocean absorbs pH drops and the Buffer factor (B) increases, weakening the buffering capacity of the seawater.
While atmos pCO2 increases exponentially, the ocean carbon uptake does not increase exponentially. Its rate of increase slows down due to the weakened
.....
(e) As the graph shows, the most important rate-controlling factor for ocean carbon uptake is the vertical exchange rate (Vm).
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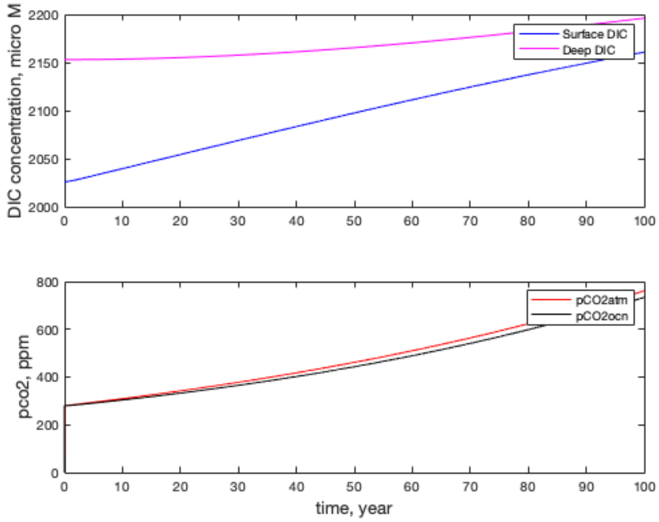

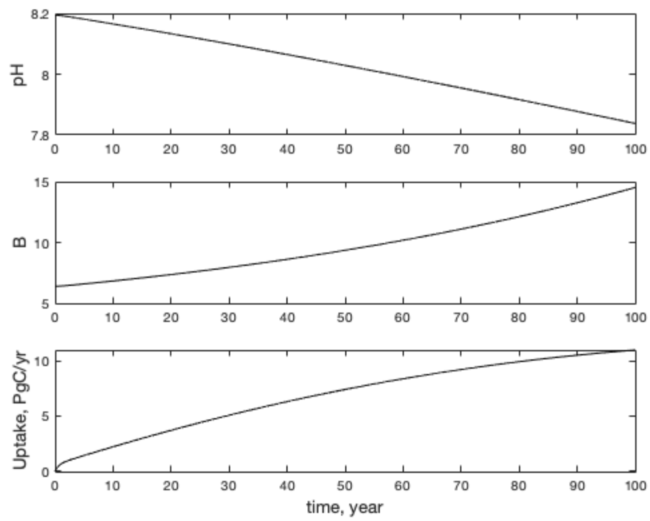

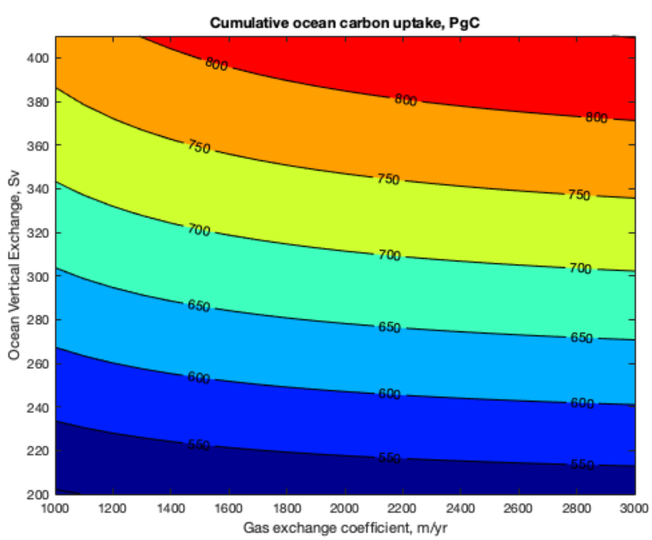

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