1) Please define GPP, NPP, NEP respectively. (9 pt)

2) Scientists use eddy-covariance tower to measure Net Ecosystem Exchange (NEE), which is a measure of CO_2 fluxes between the ecosystem and its surrounding environments. Does NEE equal to GPP or NPP or NEP? Why? (6 pt)

3) View the latitudinal distribution of the global NPP below. A is global average, B is land average, and C is ocean average. Different lines indicate different seasons as explained in the figure captions. Please describe the latitudinal distribution patterns for NPP for land (5 pt) and ocean (5 pt) respectively. You may have noticed that for both land and ocean NPP, there is a local minimum around 20-30 degree N/S. Do they have similar or different reasons? Please explain. (10 pt)

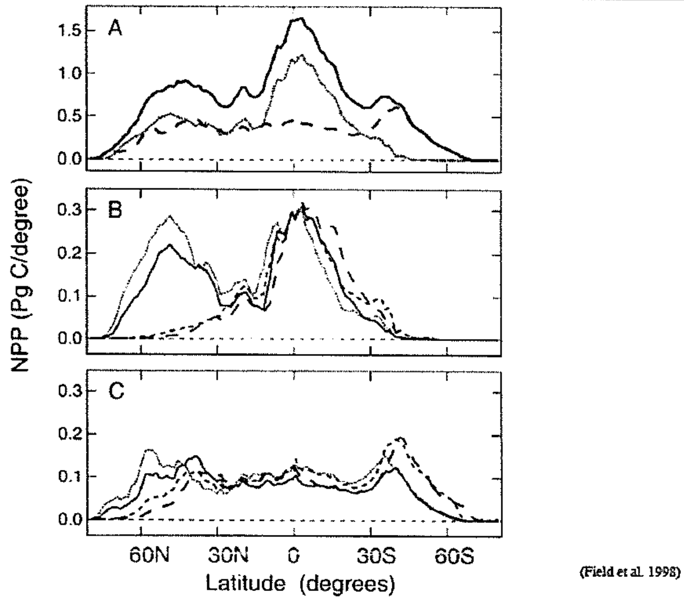
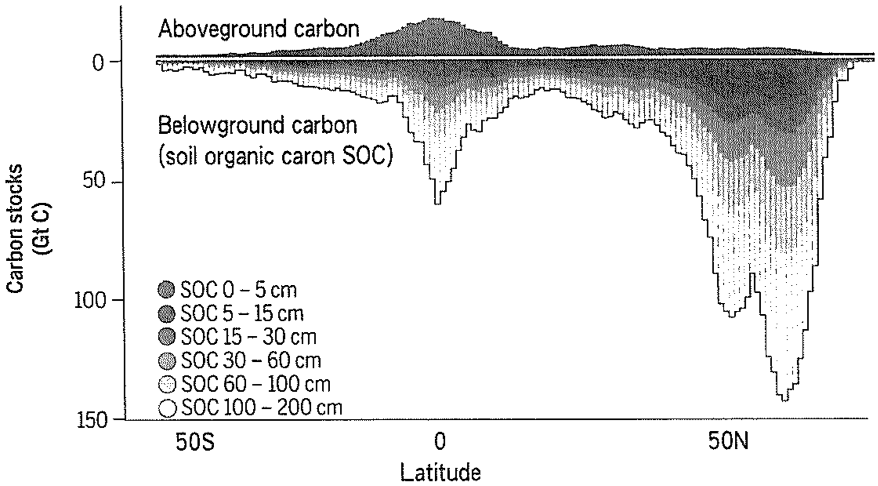


Figure 2. Latitudinal distribution of the global NPP in Fig. 1. (A) The global total (land plus ocean) NPP (solid line), land total NPP (dotted line), and ocean total NPP (dashed line). (B) Land NPP: April to June (solid line), July to September (dotted line), October to December (short dashed line), and January to March (long dashed line). (C) Ocean NPP: The four seasonal periods are as in (B). The seasonal information is available as maps at http://www.sciencemag.org/feature/data/982246.shl

4) Now compare the latitudinal patterns of carbon storage on land in the following figure. The areas above 0 on the y axis is carbon storage above ground, and the areas below 0 on the y axis is carbon storage below ground (or soil organic carbon SOC for different depths shown in the figure caption). Summarize the similarity and differences between the two (5 pt), explain what processes drive the similarities and differences (5 pt). How would we predict future changes in carbon storage under the direct influence of CO2 rise and global warming (5 pt)?



The latitudinal patterns of terrestrial carbon stocks, both aboveground living plant biomass (green) [data from Gibbs *et al.* (*114*)] and soil carbon stocks (brown) [data from Hengl *et al.* (*18*)].

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5) (10 pts) Please describe in detail how the atmospheric composition changed, starting from the Earth formed to now.

6) **Table A** lists the major redox processes occurring in the sediments and their redox potential ($E_h^0(w)$, in volt) at 25 C, 1 atm, unit activity, and pH = 7. In the ecosystem, animals and microbes usually perform respiration through the oxidation of carbohydrates to get energy and release CO_2. Dependent on the environment, different processes will be performed.

(a) (6 pts) Above the ground and near the surface layer, aerobic(有氧) respiration is a major process. Please write the overall reaction for aerobic respiration and calculate $\Delta E^0(w)$ (using CH_2O as the reactant).

(b) (10 pts) Below the surface (anoxic(缺氧) conditions), other respiration processes, such as denitrification, sulfate reduction, and methanogenesis, might become significant. Please write the overall reaction for denitrification and sulfate reduction, and calculate $\Delta E^0(w)$, respectively.

(c) (12 pts) Given your listed reactions above (in a&b), please estimate their Gibbs free energy yield per electron (in the unit of kcal per electron), using $\Delta G^0 = -zF\Delta E^0(w)$ (z is the number of electrons, F is Faraday's constant 23.061 kcal/volt). Compare their Gibbs free energy, and explain how this would control the oxidation/reduction sequence in the sediments with the observed profile shown in **Figure A.**

(d) Nitrification is the biological oxidation of ammonium to nitrite, followed by the oxidation of nitrite to nitrate under aerobic conditions.

(i) (4 pts) Please write the nitrification net reaction with a reactant of ammonium and the final product as nitrate.

(ii) (8 pts) If global net primary productivity on land is 60×10^{15} g C/yr, and the average C/N ratio of plant biomass is 100, what is the upper limit (i.e., maximum estimate) of oxygen used every year in microbial nitrification?

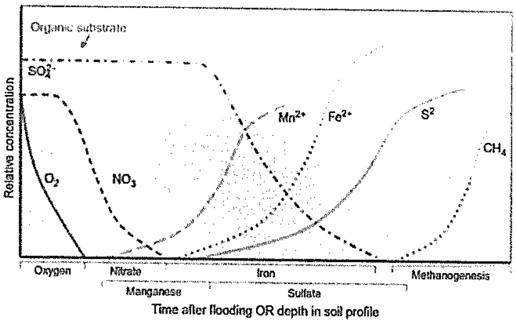

Figure A. the concentrations of reactants and products of terminal decomposition pathways are shown for a wetland sediment over time following flooding. Rotating the figure 90° to the right shows the pattern of substrate concentrations (and the order of metabolic pathways) with depth in a soil profile.

Log K, pe_w^0, and $E_h^0(w)$ of Redox Processes[a]

Reaction	$E_h^0(w)$
(1) $\frac{1}{4}O_2(g) + H^+ + e^- = \frac{1}{2}H_2O$	+0.81
(2) $\frac{1}{5}NO_3^- + \frac{6}{5}H^+ + e^- = \frac{1}{10}N_2(g) + \frac{3}{5}H_2O$	+0.75
(3) $\frac{1}{2}MnO_2(s) + \frac{1}{2}HCO_3^-(10^{-3}M) + \frac{3}{2}H^+ + e^- = \frac{1}{2}MnCO_3(s) + \frac{1}{2}H_2O$	+0.23
(4) $\frac{1}{2}NO_3^- + H^+ + e^- = \frac{1}{2}NO_2^- + \frac{1}{2}H_2O$	+0.42
(5) $\frac{1}{8}NO_3^- + \frac{5}{4}H^+ + e^- = \frac{1}{8}NH_4^+ + \frac{3}{8}H_2O$	+0.36
(6) $\frac{1}{6}NO_2^- + \frac{4}{3}H^+ + e^- = \frac{1}{6}NH_4^+ + \frac{1}{3}H_2O$	+0.34
(7) $\frac{1}{2}CH_3OH + H^+ + e^- = \frac{1}{2}CH_4(g) + \frac{1}{2}H_2O$	+0.17
(8) $\frac{1}{4}CH_2O + H^+ + e^- = \frac{1}{4}CH_4(g) + \frac{1}{4}H_2O$	+0.00
(9) $FeOOH(s) + HCO_3^-(10^{-3}M) + 2H^+ + e^- = FeCO_3(s) + 2H_2O$	−0.05
(10) $\frac{1}{2}CH_2O + H^+ + e^- = \frac{1}{2}CH_3OH$	−0.18
(11) $\frac{1}{6}SO_4^{2-} + \frac{4}{3}H^+ + e^- = \frac{1}{6}S(s) + \frac{2}{3}H_2O$	−0.20
(12) $\frac{1}{8}SO_4^{2-} + \frac{5}{4}H^+ + e^- = \frac{1}{8}H_2S(g) + \frac{1}{2}H_2O$	−0.21
(13) $\frac{1}{8}SO_4^{2-} + \frac{9}{8}H^+ + e^- = \frac{1}{8}HS^- + \frac{1}{2}H_2O$	−0.22
(14) $\frac{1}{2}S(s) + H^+ + e^- = \frac{1}{2}H_2S(g)$	−0.24
(15) $\frac{1}{8}CO_2(g) + H^+ + e^- = \frac{1}{8}CH_4(g) + \frac{1}{4}H_2O$	−0.24
(16) $\frac{1}{6}N_2(g) + \frac{4}{3}H^+ + e^- = \frac{1}{3}NH_4^+$	−0.28
(17) $\frac{1}{2}(NADP^+) + \frac{1}{2}H^+ + e^- = \frac{1}{2}(NADPH)$	−0.33
(18) $H^+ + e^- = \frac{1}{2}H_2(g)$	−0.41
(19) Oxidized ferredoxin + e^- = reduced ferredoxin	−0.42
(20) $\frac{1}{4}CO_2(g) + H^+ + e^- = \frac{1}{24}(glucose) + \frac{1}{4}H_2O$	−0.43
(21) $\frac{1}{2}HCOO^- + \frac{3}{2}H^+ + e^- = \frac{1}{2}CH_2O + \frac{1}{2}H_2O$	−0.45
(22) $\frac{1}{4}CO_2(g) + H^+ + e^- = \frac{1}{4}CH_2O + \frac{1}{4}H_2O$	−0.48
(23) $\frac{1}{2}CO_2(g) + \frac{1}{2}H^+ + e^- = \frac{1}{2}HCOO^-$	−0.49

Table A.

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