ESYS10 Final examination
Friday, March 24, 2006
11:30 - 2:30 PM

Answers to review questions and problem sets, case studies allowed. Please pass in your review question answers with your exam paper. No books, no other notes.
220 points total (110 in sections I and II, 110 in the reading sections)

I. Fill in the blank or circle correct choice (3 points each, 30 points total)

1. The Cretaceous-Tertiary extinction resulted in the destruction of approximately

10%

30%

75%

of all species. (circle one)

2. The steady state that a population of a given species reaches is called the _____carrying capacity_____.

3. What is the approximate length of time that it takes for the whole ocean to overturn? (circle one)

20 years 1000 years 100,000 years

4. A geostrophic current is (circle all that apply):

in balance between pressure difference (gradient) force and Coriolis force

in balance between frictional wind stress and Coriolis force

clockwise around a high pressure center in the northern hemisphere

to the right of the wind in the northern hemisphere

5. Destruction of tropical rainforests (with no regrowth) affects the global climate by increasing levels of _____CO2_____.

6. When considering something like the amount of carbon in limestone rocks, the ratio of reservoir size to outflow rate is called the _____residence time____.

7. The international agreement that is in effect to limit greenhouse gas emissions is called the ___Kyoto protocol_____.

8. The reaction $CH_2O + O_2 \rightarrow CO_2 + H_2O$ is called ___respiration_____.

9. Upwelling in the ocean (circle all that apply):

results in higher primary productivity

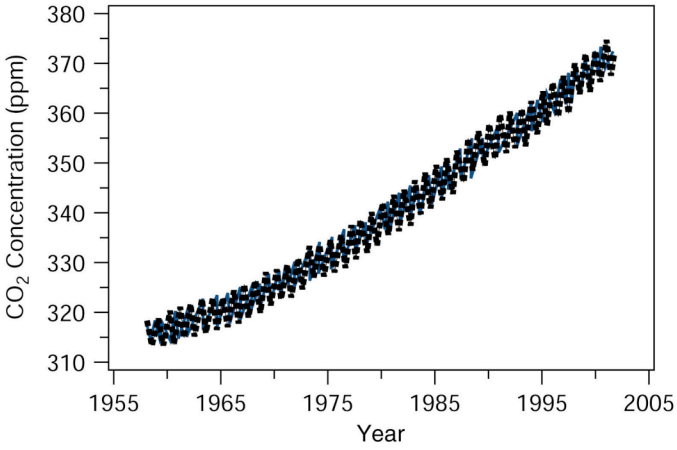
raises bottom water to the ocean surface

is usually caused by Ekman transport

10. The natural climate cycle that takes place over several years in the tropical Pacific is called ____El Nino (or ENSO)_____.

II. Short answer (80 points total)

1. The figure shows CO_2 concentration at Mauna Loa.



(a) Why is there is a general upward trend with time?

Anthropogenic forcing (fossil fuel burning, deforestation, etc) releases CO2 into the atmosphere.

(b) What is the "noise" the superimposed on the general trend? What is it caused by?

Seasonal cycle, caused by photosynthesis and respiration.

(c) The current amount of carbon in the atmosphere is about 760 Gton. (See figure for problem 4.) There are about 4000 to 6000 Gtons of fossil fuel carbon. Of this, about 240 Gton are in oil that is easy to pump. If all of this **easy** oil is burned and if it all remains in the atmosphere, what would the total carbon content of the atmosphere be?

760 Gton + 240 Gton = 1000 Gton

What would the concentration of CO_2 in the atmosphere be? Assume that the starting concentration is 380 ppm. (You do not need to convert Gtons, or know the volume of the atmosphere – assume that it is very well mixed.)

$$\frac{380\text{ppm}}{760\text{Gton}} = \frac{x}{1000\text{Gton}} \quad \text{so} \quad x = 500\text{ ppm}$$

(d) Suppose that the earth's average temperature changes by 2°C for a doubling of the CO_2 concentration. How much would the earth's temperature warm up for the increase in CO_2 that you calculated in part c?

$$\frac{2°\text{C}}{2(380\text{ppm})} = \frac{x°\text{C}}{500\text{ppm}} \quad \text{so} \quad x = 1.32°\text{C}$$

2. (a) Where does the ocean's salt come from? What is the approximate timescale of this process?

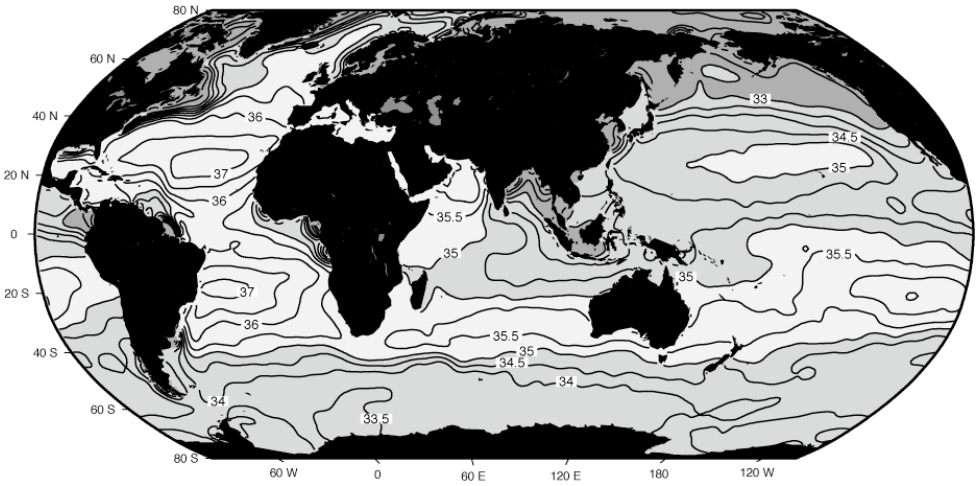
Weathering of rocks. Millions of years.

(b) What is the definition of "salinity"?

proportion of salt to water (by mass, units given in parts per thousand)

(c) "Salinity" varies geographically. It is higher in some regions than others. The map shows the salinity at the sea surface. Most of the variations in salinity are due to precipitation and evaporation.

On the map, mark the regions of highest evaporation. Answer: circle the high salinity regions in every ocean basin (there are 5 of them).



(d) Precipitation and evaporation are due to atmospheric processes. What is the process in the atmosphere that creates large precipitation regions?

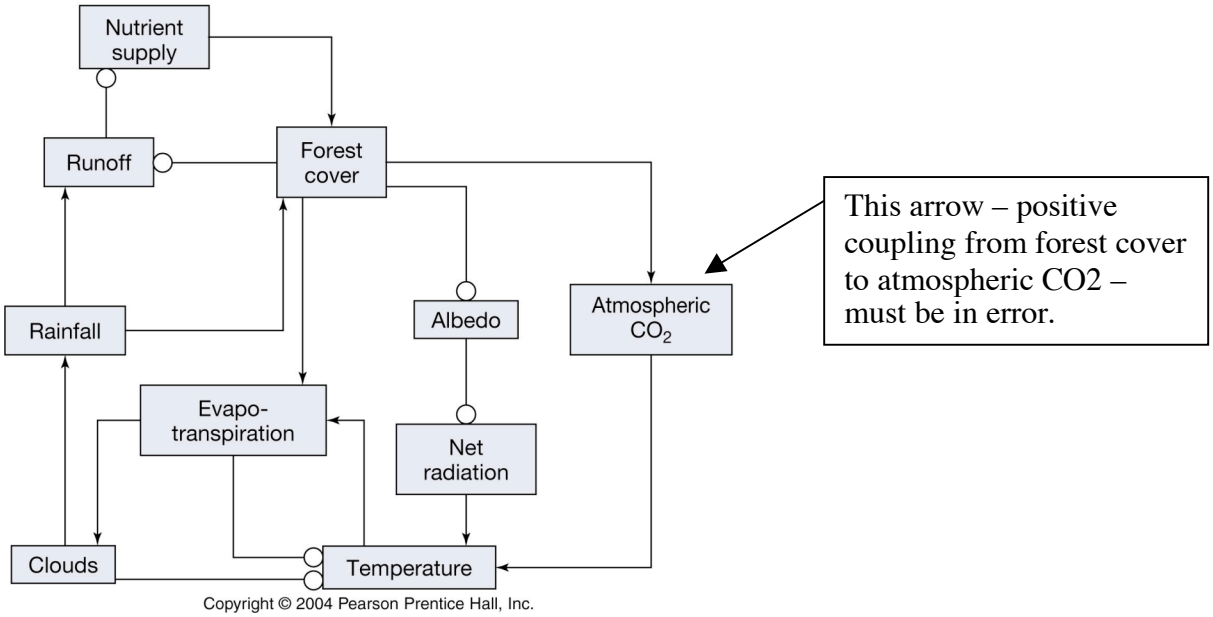
Uplift of air (rising air), due to convection.

(e) Based on the surface salinity distribution and your knowledge, mark on the map the location of the ITCZ in the Pacific Ocean.

Mark the low salinity band at about 5°N in the Pacific Ocean.

(f) Can you think of another process that also changes the surface salinity (on a time scale that is measurable)? Possible answers: melting of formation of sea ice, melting of land ice, runoff (streams, rivers), upwelling, mixing

3. This figure from the textbook shows possible feedbacks between various components of the ecosystem and climate.



(a) Which symbols indicate a positive coupling and which symbols indicate a negative coupling? arrow is positive coupling, line with circle is negative coupling

(b) Look at the simple loop that connects forest cover, runoff and nutrient supply. Describe in words the processes that connect these boxes.

As forest cover goes up, runoff goes down. As runoff goes down, nutrient supply goes up. as nutrient supply goes up, forest cover goes up.

Is the feedback in this simple loop positive or negative? ____positive_____

(c) Now find a loop (with several components) that connects forest cover and temperature. (There might be more than one; please select just one.) **Trace it** on the figure so I know which loop you are considering. There are at least seven possibilities.

(1) forest cover to CO2 to temperature to evapotranspiration to clouds to rainfall to forest

(2) forest cover to albedo to net radiation to temperature to evapotrans to clouds to rainfall to forest

(3) forest cover to evapotranspirtation to clouds to rainfall

(4), (5), (6) these same cycles but going from rainfall to runoff, nutrient supply instead of directly to forest cover

(7) forest cover to evapotranspiration to temperature, back to EVTP, then to clouds, rain, forest – this is a negative feedback loop

(d) In words, describe the couplings between the components of the forest cover/temperature loop that you traced: what is the process that couples them? (You should list one process for every line connecting the boxes in your loop).

forest cover to CO2: there is an error here, should be a negative coupling since plants use CO2 (more plants, less CO2).

CO2 to temperature: greenhouse effect

temperature to evapotranspiration: more evaporation in warmer climate

evapotranspiration to clouds: more water vapor, more clouds

clouds to rainfall: more clouds, more rainfall

rainfall to forest cover: more rainfall, more plants

rainfall to runoff: more rainfall, more runoff

forest cover to albedo: more forest cover, more dark surface, lower albedo

albedo to net radiation: less reflection (darker surface), more radiation

net radiation to temperature: more radiation, more greenhouse effect, higher temperature

forest cover to evapotranspiration: more plants, more ETP from the plants

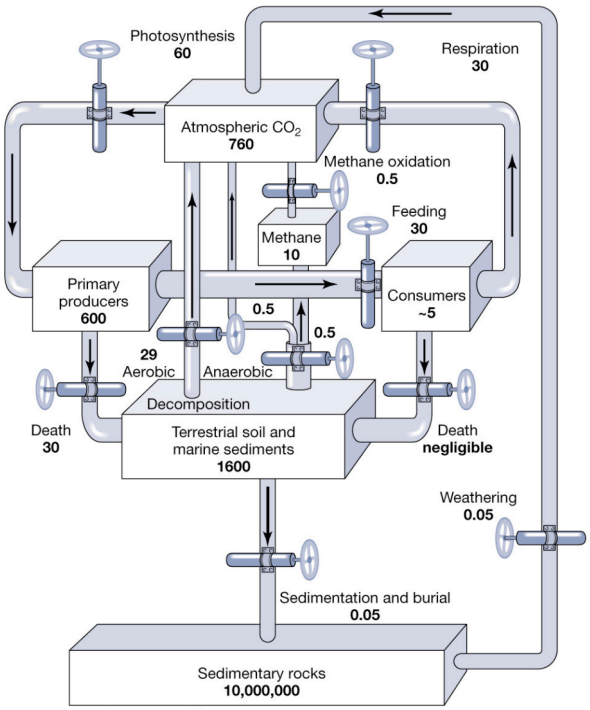
(e) Is there a net positive or negative feedback in the loop that you described? Explain.

Depends on which loop is chosen.

4. The next figure shows elements of the carbon system.

(a) List all of the reservoirs shown in this system.

Atmospheric CO2
Methane
Primary producers
Consumers
Terrestrial soil and ...
Sedimentary rocks



(b) The units of quantities shown are either Gton(carbon) or Gton(carbon)/year. On the figure, circle two of the (many) values that are in Gton(carbon)/year.

Any of the quantities listed beside the pipes and not in the boxes.

(c) Compute the residence time of carbon in the sedimentary rocks using information from the figure and the units from (b). (If you don't have a calculator, give the correct expression for getting the answer and estimate the answer.)

Use number from either sedimentation or weathering (but not both):

10,000,000 Gton / 0.05 Gton/yr = 200,000,000 years

(d) Compute the residence time of carbon in the atmosphere from the figure.

Use the rate leaving the box or sum of all the rates entering the box: both are 60 Gton/yr:

760 Gton/60 Gton/yr = 12.7 yr

(e) Which of the listed reactions below applies to the "pipe" between the atmospheric CO_2 and the primary producers? (circle one)

As noted on the board, the expression was mistakenly not actually given. What you would want to circle is the photosynthesis reaction. I did not count any points from this answer. If you got it right, then I gave you a "+" which could put you a few points higher on the total.

Photosynthesis: $CO_2 + H_2O$ ---> $O_2 + C\ H_2O$

Some possibly useful expressions:

$CO_2 + H_2O$ <---> H_2CO_3

$Ca^{2+} + 2HCO_3^-$ ---> $CaCO_3 + H_2CO_3$

$CaCO_3 + H_2CO_3$ ----> $Ca^{2+} + 2HCO_3^-$

$CaSiO_2 + 2H_2CO_3$ ---> $Ca^{2+} + 2HCO_3^- + SiO_2 + H_2O$

III. Informed science reporting (40 points).

Climate Data Hint at Irreversible Rise in Seas (New York Times)

By ANDREW C. REVKIN

Published: March 24, 2006

Within the next 100 years, the growing human influence on Earth's climate could lead to a long and irreversible rise in sea levels by eroding the planet's vast polar ice sheets, according to new observations and analysis by several teams of scientists.

One team, using computer models of climate and ice, found that by about 2100, average temperatures could be four degrees higher than today and that over the coming centuries, the oceans could rise 13 to 20 feet — conditions last seen 129,000 years ago, between the last two ice ages.

The findings, being reported today in the journal Science, are consistent with other recent studies of melting and erosion at the poles. Many experts say there are still uncertainties about timing, extent and causes.

But Jonathan T. Overpeck of the University of Arizona, a lead author of one of the studies, said the new findings made a strong case for the danger of failing to curb emissions of carbon dioxide and other gases that trap heat in a greenhouselike effect.

"If we don't like the idea of flooding out New Orleans, major portions of South Florida, and many other valued parts of the coastal U.S.," Dr. Overpeck said, "we will have to commit soon to a major effort to stop most emissions of carbon to the atmosphere."

According to the computer simulations, the global nature of the warming from greenhouse gases, which diffuse around the atmosphere, could amplify the melting around Antarctica beyond that of the last warm period, which was driven mainly by extra sunlight reaching the Northern Hemisphere.

The researchers also said that stains from dark soot drifting from power plants and vehicles could hasten melting in the Arctic by increasing the amount of solar energy absorbed by ice. (...some text deleted...)

In a second article in Science, researchers say they have detected a rising frequency of earthquakelike rumblings in the bedrock beneath Greenland's two-mile-thick ice cap in late summer since 1993. They say there is no obvious explanation other than abrupt movements of the overlying ice caused by surface melting.

The jostling of that giant ice-cloaked island is five times more frequent in summer than in winter, and has greatly intensified since 2002, the researchers found. The data mesh with recent satellite readings showing that the ice can lurch toward the sea during the melting season.

(...text deleted...)

"Models are important, but measurements tell the real story," Dr. Zwally said. "During the last 10 years, we have seen only about 10 percent of the greenhouse warming expected during the next 100 years, but already the polar ice sheets are responding in ways we didn't even know about only a few years ago."

(..text deleted...)

Many experts on climate and the poles, citing evidence from past natural warm periods, agreed with the general notion that a world much warmer than today's, regardless of the cause of warming, will have higher sea levels.

But significant disagreements remain over whether recent changes in sea level and ice conditions cited in the new studies could be attributed to rising concentrations of

the greenhouse gases and temperatures linked by most experts to human activities.
(...text deleted...)

Satellites and tide gauges show that seas rose about eight inches over the last century and the pace has picked up markedly since the 1990's.

Dr. Overpeck, the co-author of the paper on rising sea levels, acknowledged the uncertainties about the causes. But he said that in a world in which humans, rich and poor, increasingly clustered on coasts, the risks were great enough to justify prompt action.

"People driving big old S.U.V.'s to their favorite beach or coastal golf course," he said, should "start to think twice about what they might be doing."

(a) List some information in this article which is peer-reviewed science.

computer model results for temperature and sea level change; recent studies of melting/erosion at poles; global nature of warming and amplification of Antarctic melting; stains from dark soot...; rising frequency of earthquakelike rumblings that are more frequent in summer; satellites and tide gauge measurements

(b) List some information in this article which is just opinion.

case for danger of failing to curb emissions; observation of only about 100% of greenhouse warming expected; risks great enough to justify prompt acction; SUV quote

(c) What are two major causes for sea level rise in a warmer world? (draw on information you learned in class) Melting of landfast ice and thermal expansion of the oceans.

(d) In the article, melting of ice in the Arctic is mentioned. The article then goes on to talk about Greenland. What type of ice melt would result in sea level rise?

Melting of land ice. (i.e. Greenland, but not the Arctic sea ice)

(e) If Arctic sea ice is melted away, what is another impact on climate that might occur in addition to sea level rise? This question was too vague. I accepted many answers.

(f) Why is "melting and erosion" at the poles suggestive of anthropogenic climate change, as opposed to some sort of natural warming?

Natural warming would be concentrated in the tropics since water vapor feedbacks are so important. Anthropogenic warming due to CO2 etc would be more global and intensified in the polar regions.

(g) Why might Revkin have chosen to end the article with a statement about cars?

To give people a way to contribute individually to solving the problem, despite uncertainties in the linkage between anthropogenic forcing and the modeled sea level rise.

IV. Biodiversity reporting. (30 points)

Fishing Ban Is Among 3 Options Panel Is Considering to Save Klamath Salmon (Los Angeles Times)

By Eric Bailey, Times Staff Writer
March 9, 2006

SACRAMENTO — Facing a salmon shortage on the ailing Klamath River, a fishing advisory board Wednesday sketched out ways to slash this year's West Coast salmon catch that range from cutting the season by more than half to adopting an outright ban.

The Pacific Fishery Management Council asked its staff to return Friday with a review of three potential options, all of them met with dismay by fishermen already hard-hit by a shortened 2005 season.

"Last season was the most restrictive on record," said Duncan MacLean, president of the Half Moon Bay Fishermen's Marketing Assn. "This year we're hoping we just have some sort of season. But it's not going to be easy pulling a rabbit out of that hat."

During an average year, salmon fishing in California and Oregon is a $150-million industry. The commercial mainstay is the silver-sided Chinook that return each fall from the sea to spawn. Experts say a commercial ban could put struggling coastal fishing fleets financially underwater.

The fishery council, which acts as an advisory board for federal regulators who will decide the fate of this year's salmon season, is meeting in Seattle this week and expects by Friday to complete three options for public review during the coming month.

On Tuesday, an official with the National Marine Fisheries Service — the agency involved in the final decision — told the council there appeared to be few options other than a ban.

Fishermen, however, say they hope a compromise can be reached that will allow a short season.

A ban, the most onerous proposal the council is considering, would cancel the salmon season from near Oregon's northern boundary to Point Sur, just south of Carmel.

A typical season runs about six months, beginning in the spring.

The council also is considering allowing commercial fishing boats to put to sea about as often as they did last year, when the fleets were left at the dock for the late spring and early summer months that are considered best.

In between is a third option, which would likely allow fishermen on the water roughly half as long as they were in 2005.

The trouble lies with the Klamath River, which rises from the snowmelt of the Cascade Range and empties into the ocean north of Eureka, Calif.

During spring 2002 and again the next year, upward of 80% of the juvenile fish returning to sea from the Klamath River succumbed to a parasite scientists blame on a combination of low river flows, pollution and overheated water.

"Simply put," said MacLean, "the river is killing its young."

Environmentalists have blamed the current troubles on the Bush administration, which in recent years has allowed larger irrigation diversions from the Klamath for upriver farmers.

(a) List the stakeholders who appear in this article.

members of Pacific Fishery Management Council; fishermen represented by Fishermen's Marketing Assn.; federal regulators presumably from National Marine Fisheries Service; environmentalists; Bush administration; upriver farmers.

(b) Who is in charge of deciding whether to close a fishery?

federal regulators presumably with the National Marine Fisheries Service, advised by the Pacific Fishery Management Council

(c) What was the ultimate **factual** cause of the problem with this fishery, based on this article? parasites killing juveniles in the Klamath River, possibly because of low river flows, pollution and overheated water.

(d) In the end (after this article), it was decided to actually close the fishery. Who stands to lose the most money in the short term from this decision?

fishermen

(e) What would happen in the long term if the fishery management agency had not made this decision?

fishery might completely collapse

(f) What are some of the factors that have to be considered in projecting the long-term health of this fishery? (I will take into account the fact that some of you worked on salmon for your case study while others didn't.)

Some good choices, based on your answers:

- comparison with past fish populations
- pollution
- possibility of farming salmon here (which brings its own issues of pollutions, disease, etc)
- life cycle of salmon (migration, predators, prey, reproductive behavior and success rates)
- population size necessary to sustain fishery
- where the fish are caught
- size/maturity of fish that are caught
- recreational fishing
- Klamath River – dams and river flow
- potential for cleaning up the river
- improved sanitation in fish farms that might have create the parasite problem (but this wasn't mentioned as a factor in the article)
- global change (affecting ocean and river habitats)
- demand for salmon - size of the salmon industry in this region ($$)
- regulatory factors – options for mediation

V. Final essay (40 points). Read and see questions that follow the article.

Schwarzenegger unveiling global warming plan at U.N. conference

By Terence Chea
ASSOCIATED PRESS
2:25 p.m. June 1, 2005

SAN FRANCISCO – Gov. Arnold Schwarzenegger aimed to steal the show at the United Nations environmental conference Wednesday by unveiling a plan to combat global warming by setting goals for reducing California's emissions of greenhouse gases. The goals, set forth in an executive order, appear on the surface to put the Republican governor on an opposite course from the Bush administration, which has rebuffed international efforts to address climate change.

But because Schwarzenegger – at least for now – isn't offering specifics that will be locked in to state law, the targets won't likely have as much impact as some scientists and state lawmakers want. The California Assembly this week overwhelmingly passed a bill to meet international greenhouse gas reduction standards by 2010.

"The targets are an excellent starting point, and now the heavy lifting of enacting policies to meet them must begin," said Jason Mark, California director of the Union of Concerned Scientists.

Still, Schwarzenegger's announcement was sure to grab headlines as big-city mayors from around the globe arrived Wednesday for the first United Nations World Environmental Day Conference held on American soil.

And while mayors and governors can't do much more than act locally, any such move in such a large state could have major consequences, since California would be the world's eighth largest economy if it were a nation unto itself, according to the latest estimate by the Los Angeles Economic Development Corp.

Many scientists believe that greenhouse gases – which include carbon dioxide, methane and nitrous oxide – are trapping heat in the Earth's atmosphere, altering weather patterns, shrinking wildlife habitats and raising sea levels around the globe.

Schwarzenegger's "Environmental Action Plan" calls for reducing the state's emissions of such gases to 2000 levels by 2010, 1990 levels by 2020 and 80 percent below 1990 levels by 2050, the governor's office said.

The executive order establishes a "Climate Action Team" led by the secretary of California's Environmental Protection Agency that will be responsible for meeting those goals.

"It's a large step but it needs to be accompanied by specific policies to be enacted by the legislature," said Michael Hanemann, director of the California Climate Change Center at the University of California, Berkeley.

Schwarzenegger was unveiling his plan at the opening of the five-day UN World Environment Day Conference. While no major Bush administration official has announced plans to attend, at least 70 mayors from cities such as London, Rio de Janiero and Shanghai are expected, trading ideas on renewable energy, recycling, public transportation, city parks and clean air and water.

Schwarzenegger has made other attempts to rein in greenhouse gases. His "hydrogen highways" program encourages the installation of enough hydrogen fueling stations to enable the use of zero-polluting vehicles across the state, and his "million solar roofs" program would subsidize residential solar power installations, jump-starting that industry as well.

California became the first U.S. state to adopt regulations to curb greenhouse gas emissions from automobiles in September. The Bush administration has joined automakers in challenging those tailpipe emissions standards in court.

The worldwide Kyoto Protocol, adopted in the Japanese city in 1997, requires industrialized nations to cut greenhouse gas emissions by an average of five percent below 1990 levels. The treaty was ratified by more than 140 countries and went into effect in February.

But the United States, the world's largest emitter of greenhouse gases, did not sign because Bush administration officials believed the treaty would result in the loss of five million U.S. jobs and raise energy prices, said Michele St. Martin, a spokeswoman for the White House Council on Environmental Quality.

Frustrated by the U.S. government's stance, many Americans states, cities and corporations are making their own initiatives to reduce emissions of heat-trapping gases from factories, automobiles and power plants.

Last month, Seattle Mayor Greg Nickels announced that more than 130 U.S. mayors have signed an agreement to reduce carbon dioxide emissions by meeting or beating the Kyoto targets.

This week, the mayors in San Francisco will craft a set of international guidelines for sustainable urban living – billed as a municipal version of the Kyoto treaty. The Urban Environmental Accords are to be signed on Sunday – World Environment Day.

"We cannot afford to wait for the state or federal government to do the job. There are too many excuses going around, particularly in this country," said San Francisco Mayor Gavin Newsom. "Increasingly, the world will look at mayors to become the stewards of the environment since the vast majority of the pollution comes from cities."

Write an essay commenting on this article. Include in your essay at least the following.

(1) a discussion of how greenhouse gas increases cause warming;

(2) the evidence that climate is now changing in response to greenhouse gas changes;

(3) a quantitative description of how much the planet is predicted to warm in response to current forcing, if the forcing continues unabated.

(4) The status of the Kyoto protocol as a setting for why European nations are now embarking on emissions trading.

(5) The effect that enforcement of the Kyoto protocol is expected to have on climate.

(6) Possible outcomes for businesses that are forced to comply with the emissions limits.

Set of questions was not exactly pertinent – should have been more tuned to this article rather than last year's, although basic science issues are the same. (Should have changed emphasis from Europe to U.S. cities.)