

NCAR Mesa Lab – Exhibit Hall



Clouds Field Guide



Clouds Field Guide



iPad & iPhone app
in the works

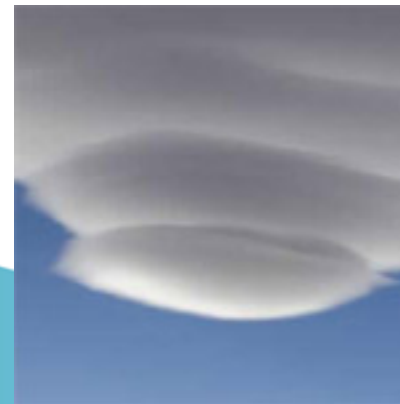
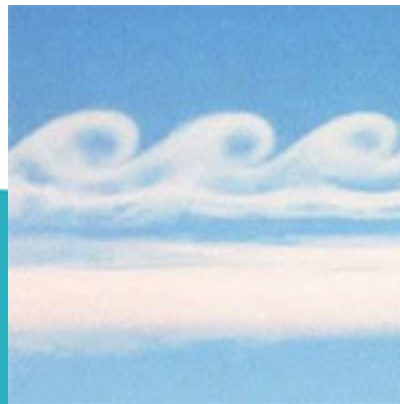
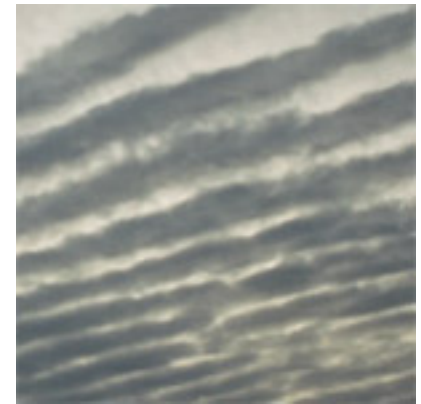
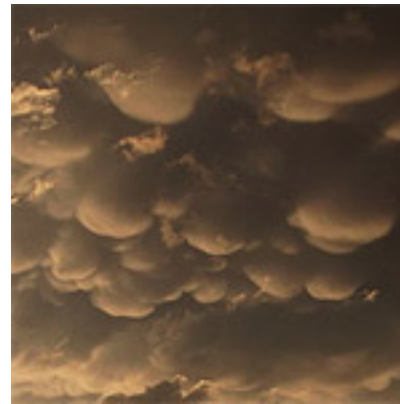
Sort Clouds



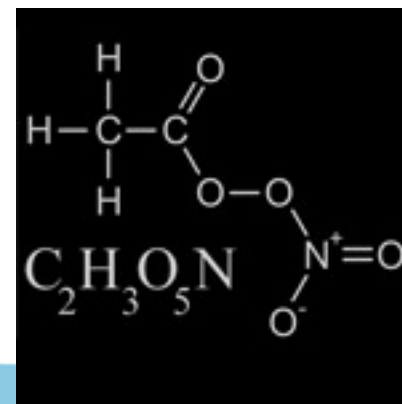
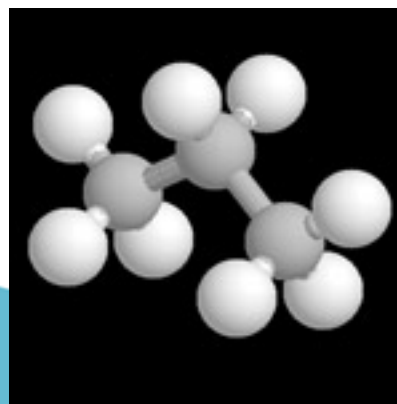
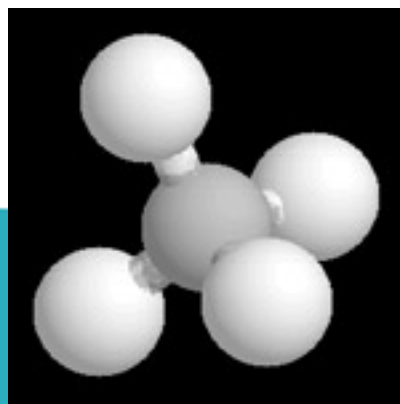
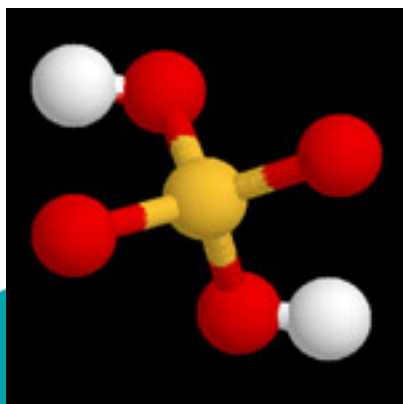
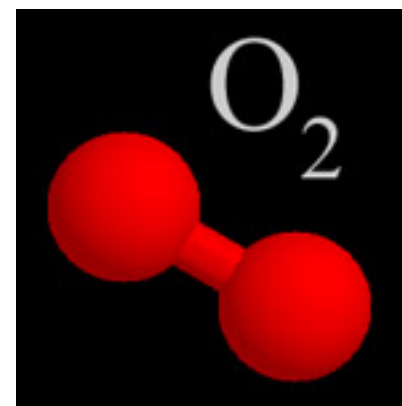
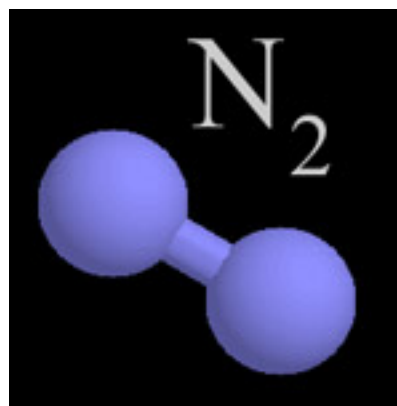
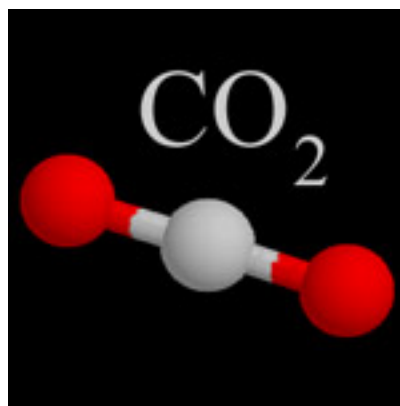
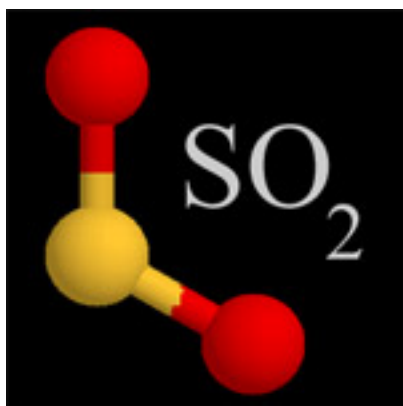
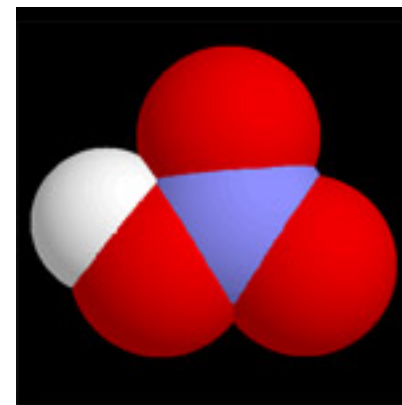
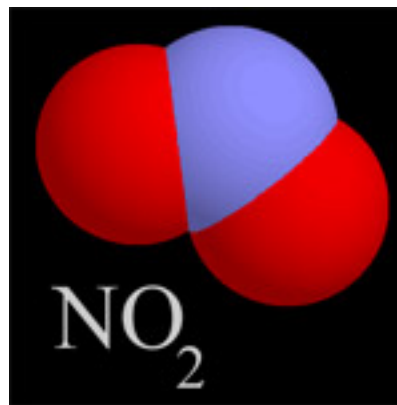
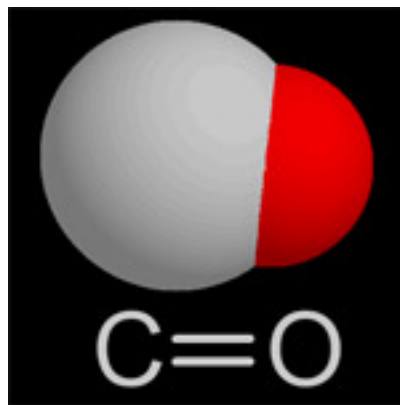
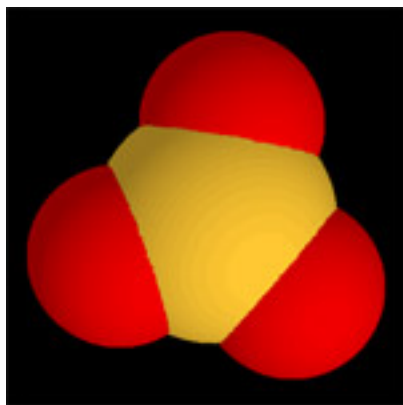
Make Thunderstorm



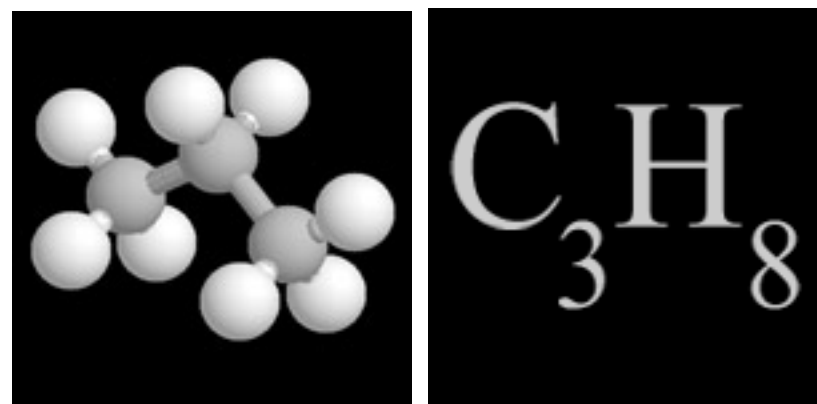
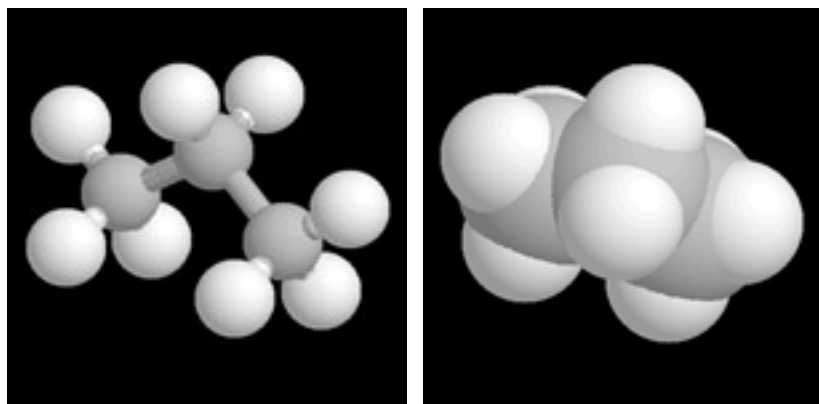
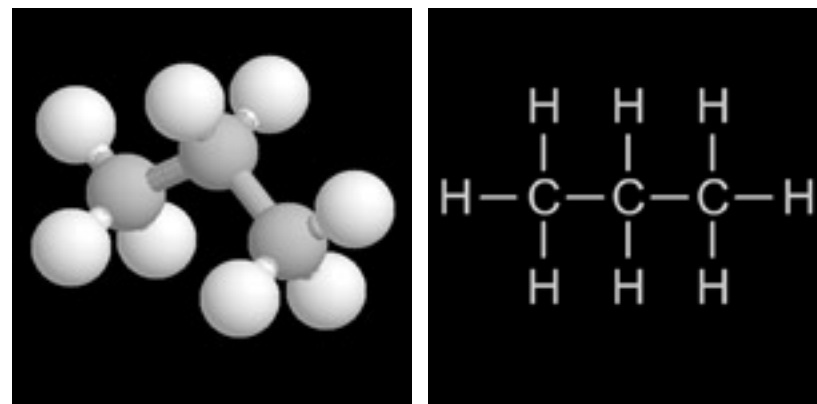
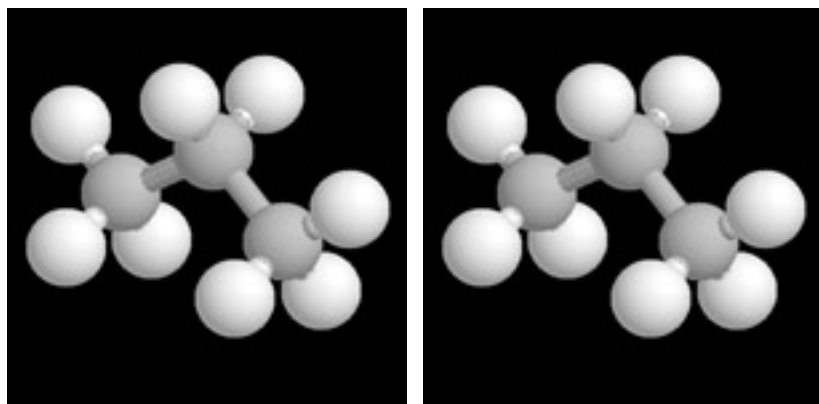
Clouds Memory Game



Molecules – Atmospheric Chemistry



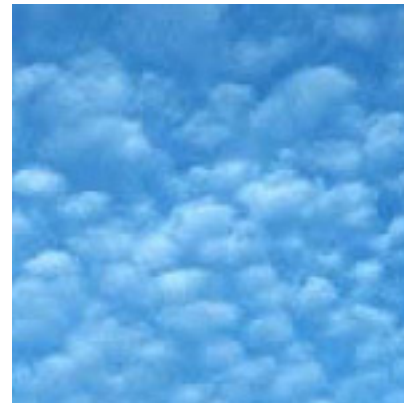
Match – but not identical!



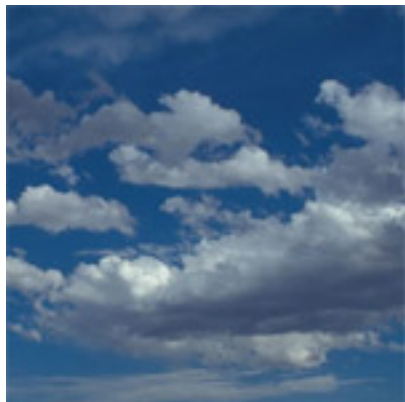
Clouds Game – Match Picture to Name



Cirrus



Cirrocumulus



Cumulus

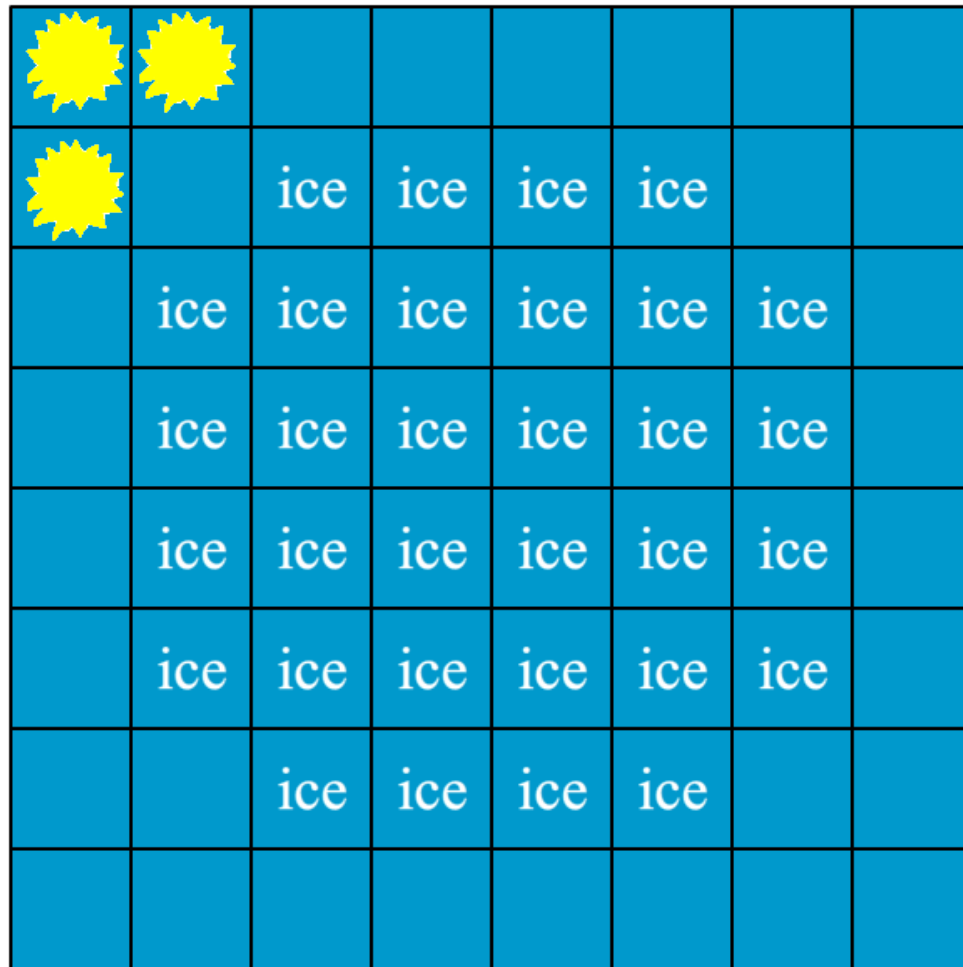


Lenticular

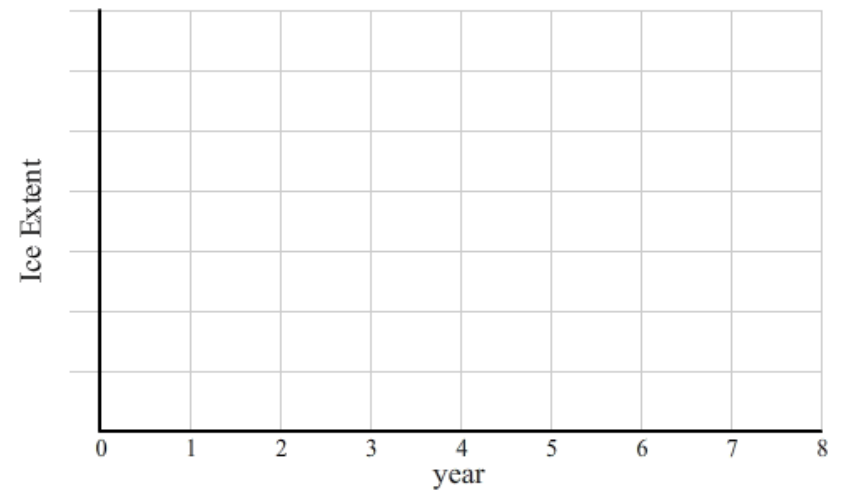
... also, match two different photos of same type of cloud.

Computational Science Activities

Feedback Loops - Arctic Sea Ice



Year	Ice	Sunlight/ Temperature	Ice Change (32° - temperature)
0			
1			
2			
3			
4			
5			
6			
7			
8			



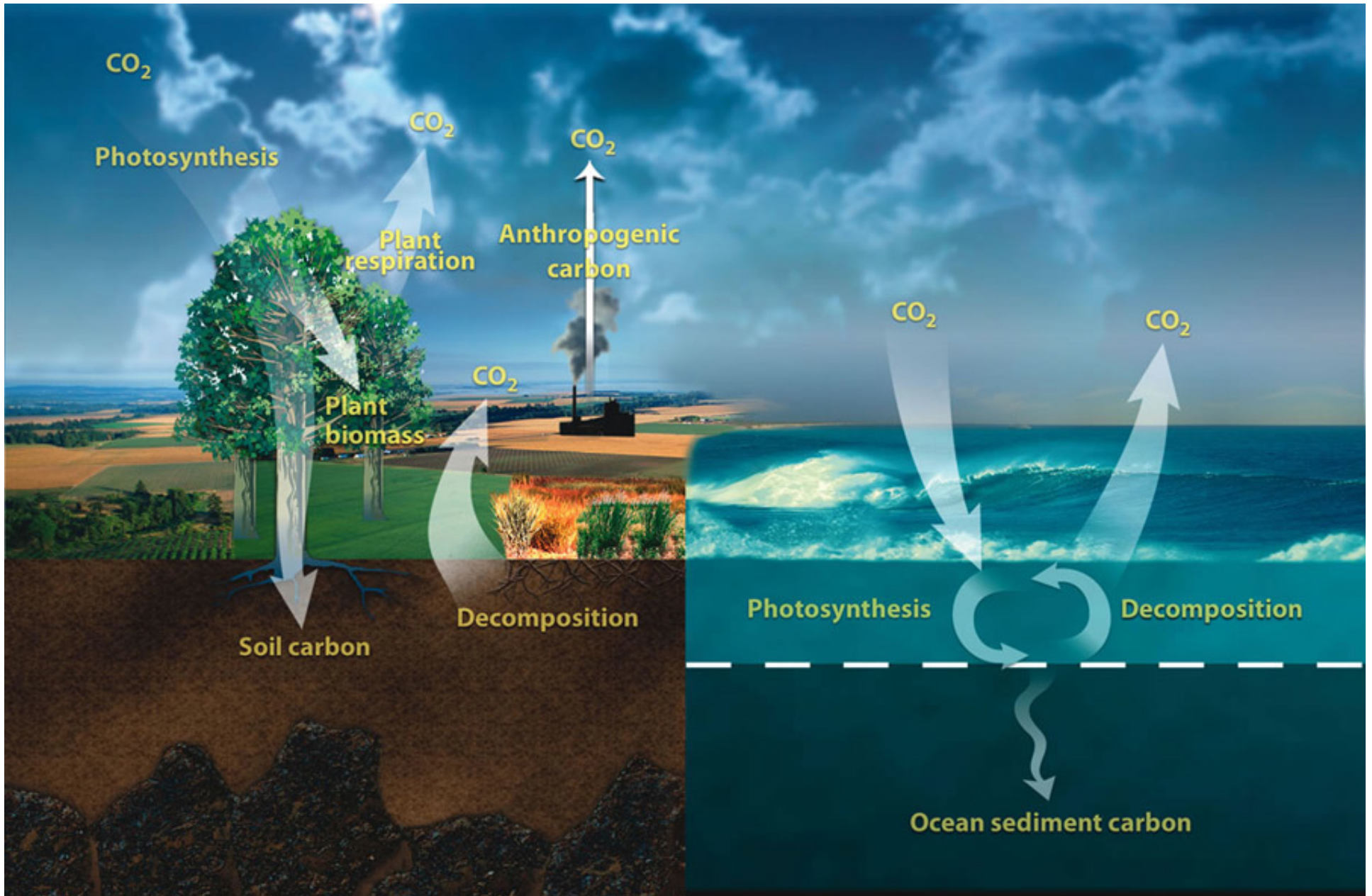
Series of 4 Webinars: Teaching Climate with Models

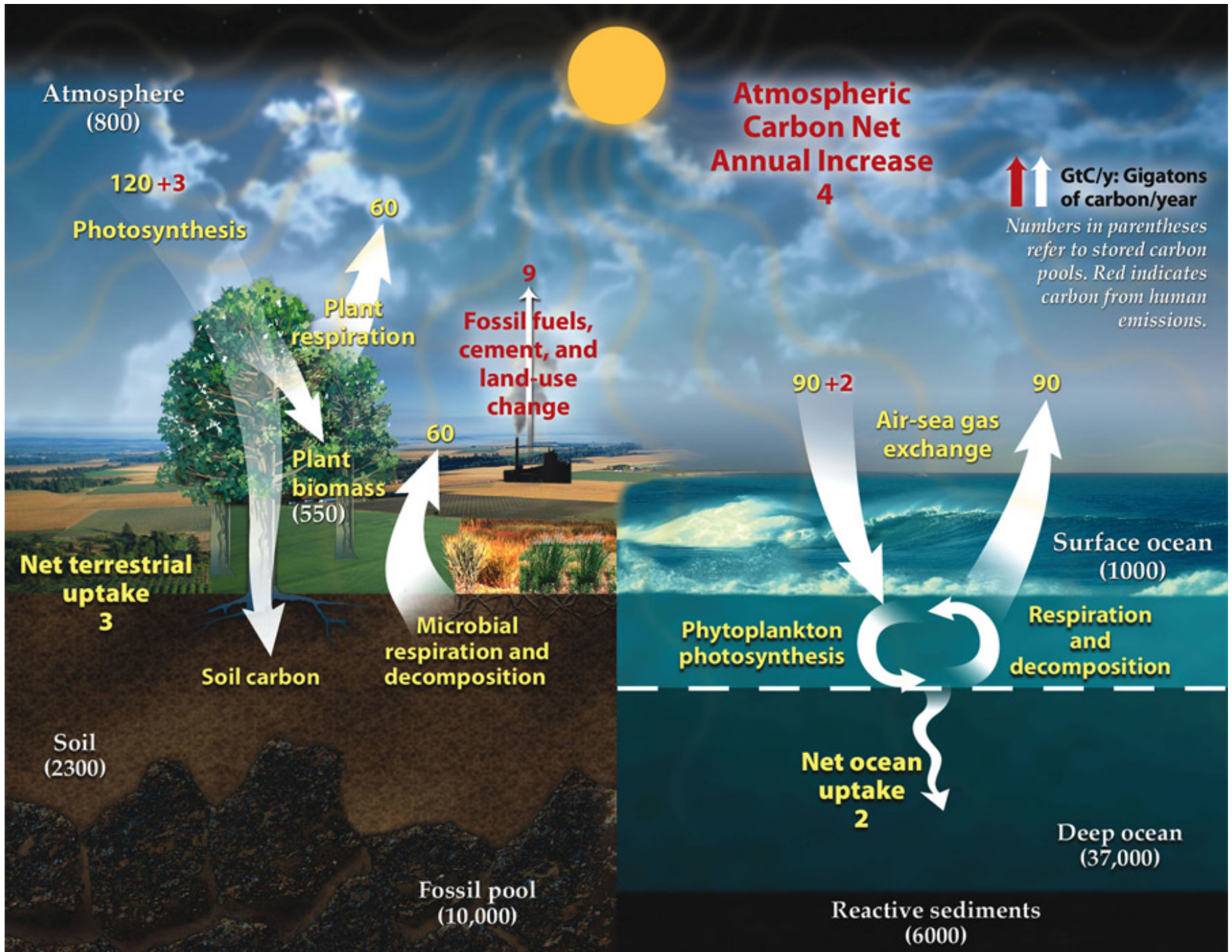


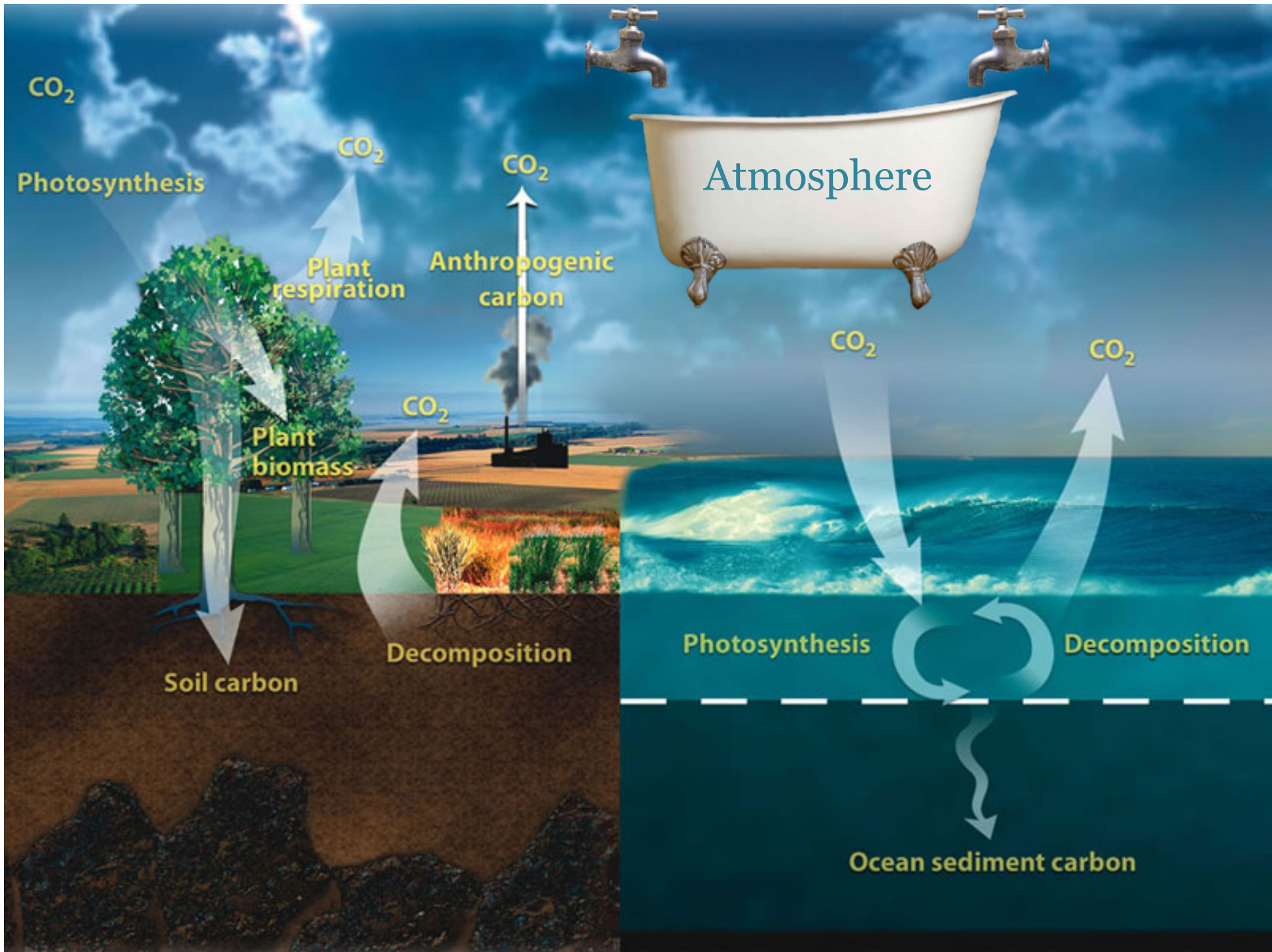
- ❖ Teaching Climate with Models: Breathing of the Earth
 - ❖ June 11, 2012 – archived; 48 attendees
- ❖ Heating and Warming: Sensitivity of Earth's Climate to Atmospheric CO₂
 - ❖ September 24, 2012 – archived; 48 attendees
- ❖ Teaching Climate with Models: Future Climate Projections
 - ❖ scheduled for February 28, 2013
- ❖ Opportunities for Abundance: Solving the problems of energy, carbon, and climate
 - ❖ scheduled for April 25, 2013



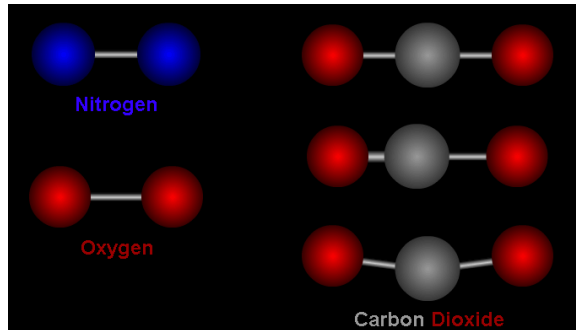
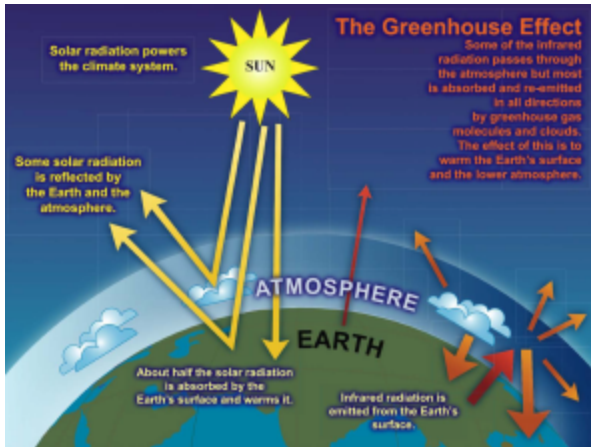
Breathing Earth: Carbon Cycle Diagram from DOE







Heating and Warming: Sensitivity of Earth's Climate to Atmospheric CO₂



Scott Denning



Randy Russell





Heat Budgets



Heat in



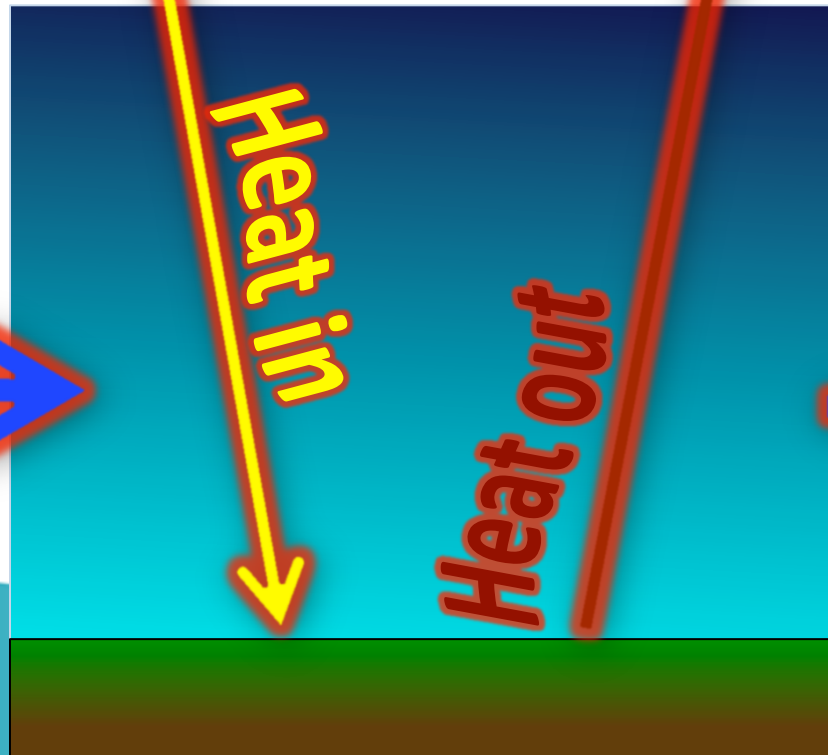
Heat in



Heat out



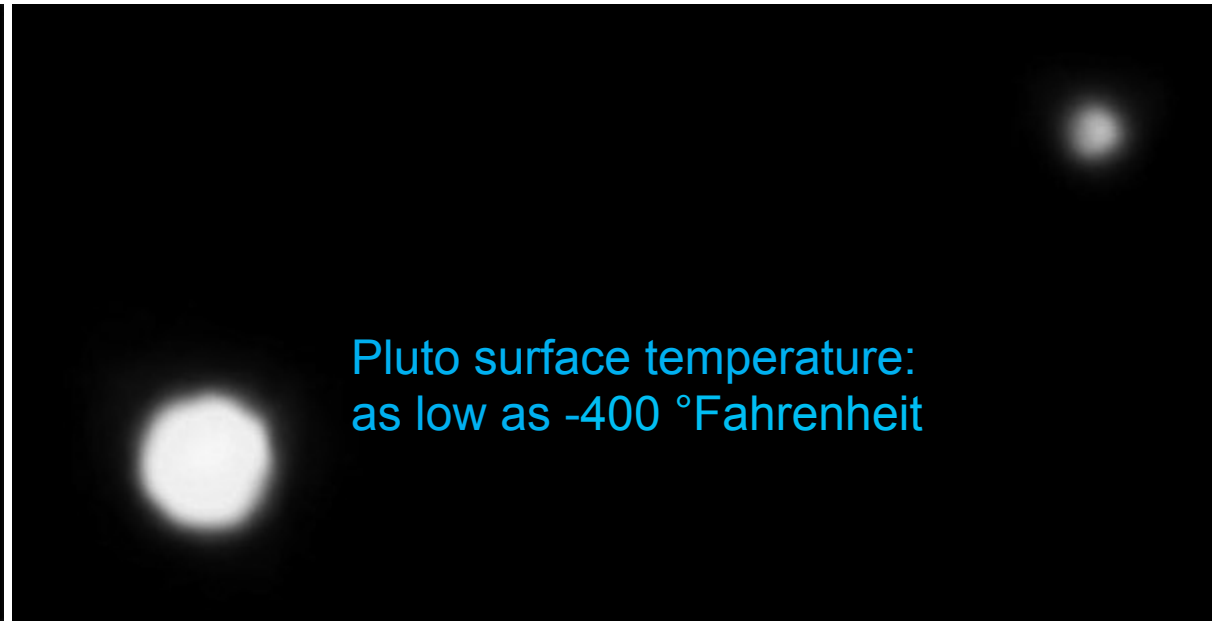
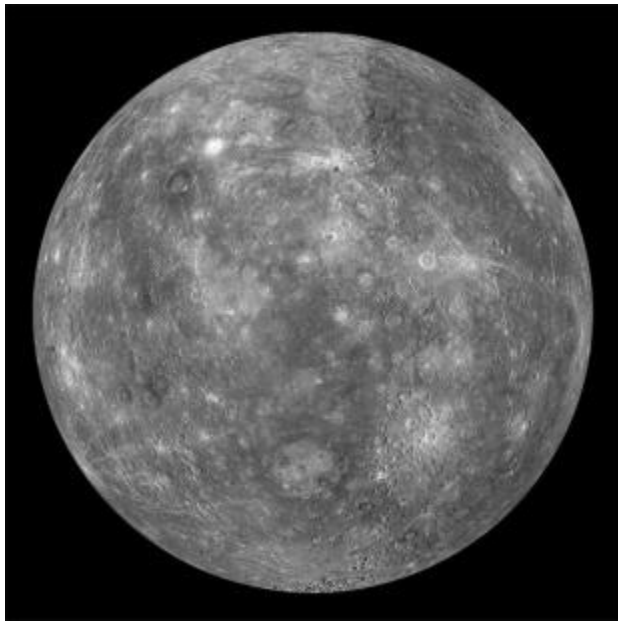
Heat out



Poll: Which gives off longer wavelength infrared radiation:

- A) hot Mercury or
- B) cold Pluto?

Responses: 11% said Mercury,
53% said Pluto,
35% did not respond

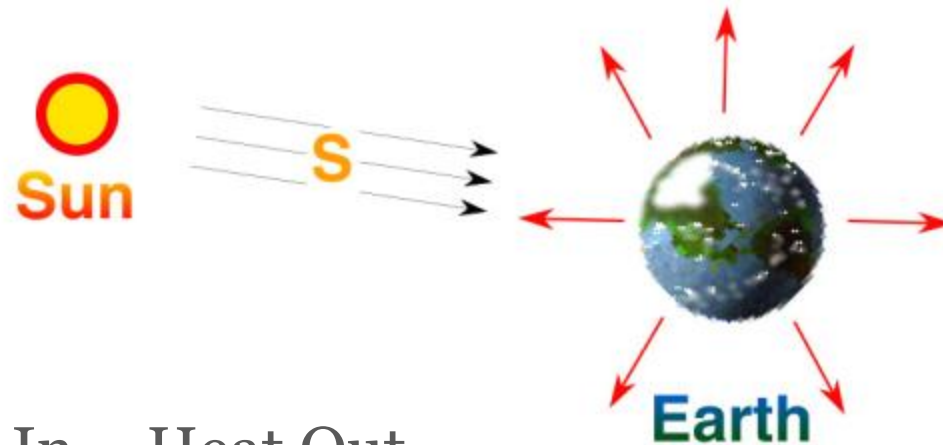


Mercury surface temperature:
up to 800 °Fahrenheit





Planetary Heat Balance

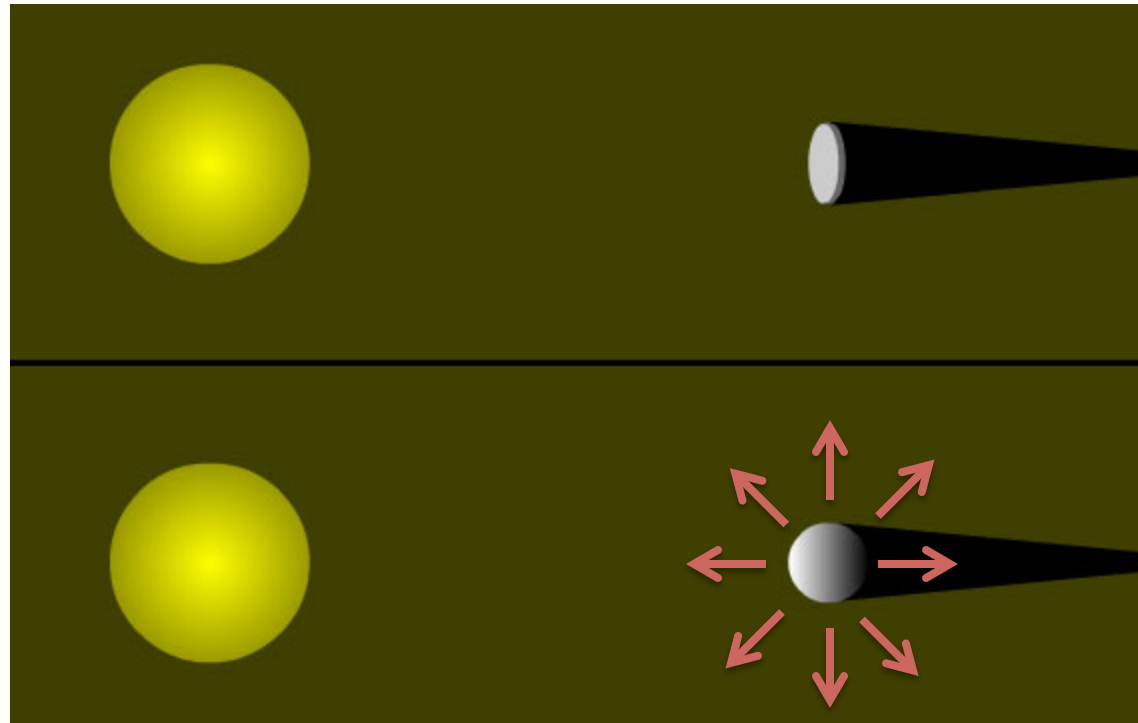


- ❖ Heat In = Heat Out
- ❖ Absorbed solar energy in = emitted thermal energy out
- ❖ HEAT IN: $S * (1-\text{albedo}) * \text{area of Earth's } \textit{shadow}$
= HEAT OUT: Thermal emission * area of Earth's *surface*
- ❖ area of Earth's *surface* = $4\pi R^2$

Energy In vs. Energy Out

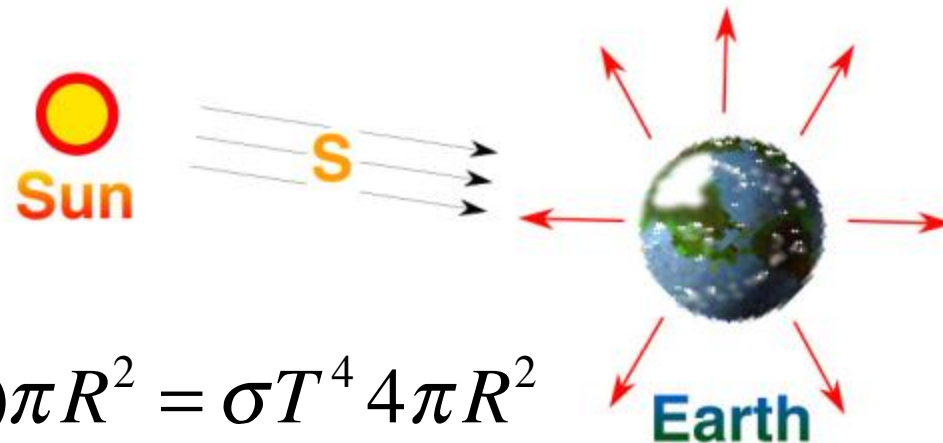


- ❖ We can think of Earth as a circle when calculating sunlight absorbed
- ❖ We must treat Earth as a sphere when calculating energy emitted





Planetary Heat Balance



$$S(1 - \alpha)\pi R^2 = \sigma T^4 4\pi R^2$$

$$S(1 - \alpha) = \sigma T^4 4$$

$$T = \left[\frac{S(1 - \alpha)}{4\sigma} \right]^{1/4}$$

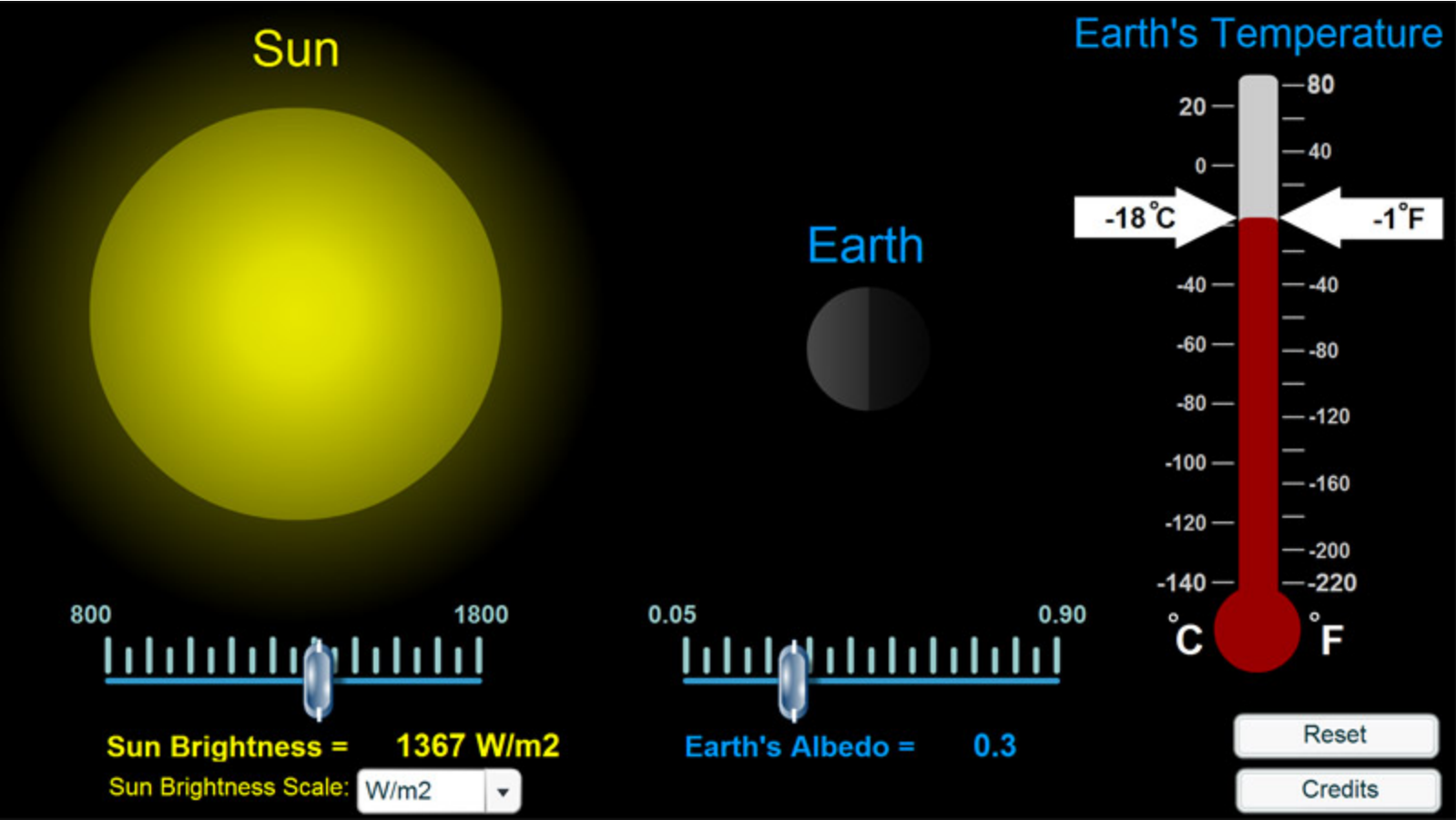
$$\begin{aligned} T &= 255 \quad \text{°Kelvin} \\ &= -18 \quad \text{°Celsius} \\ &= 0 \quad \text{°Fahrenheit} \end{aligned}$$

Brrrrrrr!





Interactive: Earth's Energy Balance





Questions?

- ❖ Is an albedo of 0.9 really bright?
- ❖ Please explain the discrepancy between Earth's theoretical temperature (no atmosphere) of 0°F and what we observe?
- ❖ Temperature calculation seems to be for one wavelength; is there a significant difference when integrating across the whole spectrum?
- ❖ What do you mean Earth's temperature is 0°F ? I thought it was about 59°F .





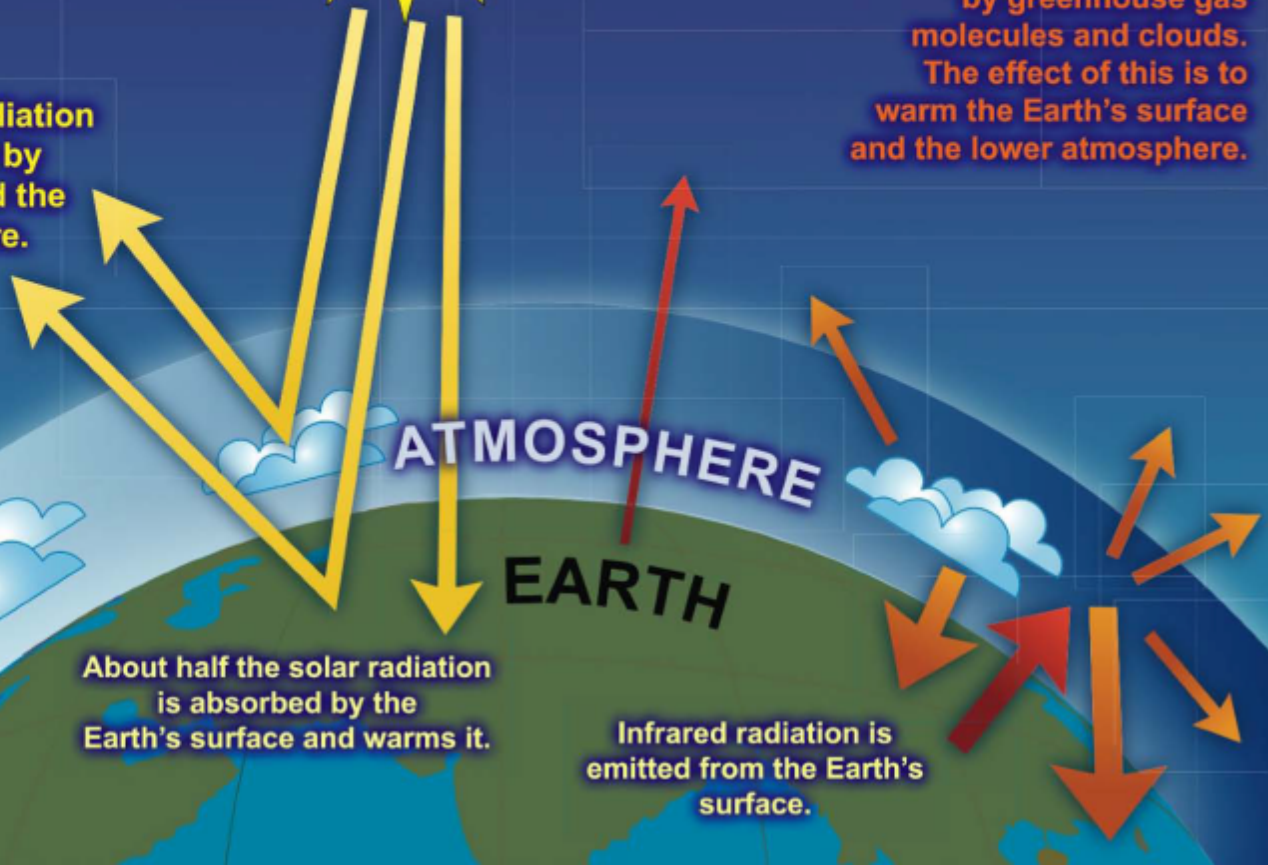
The Greenhouse Effect

Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.

Solar radiation powers the climate system.



Some solar radiation is reflected by the Earth and the atmosphere.



About half the solar radiation is absorbed by the Earth's surface and warms it.

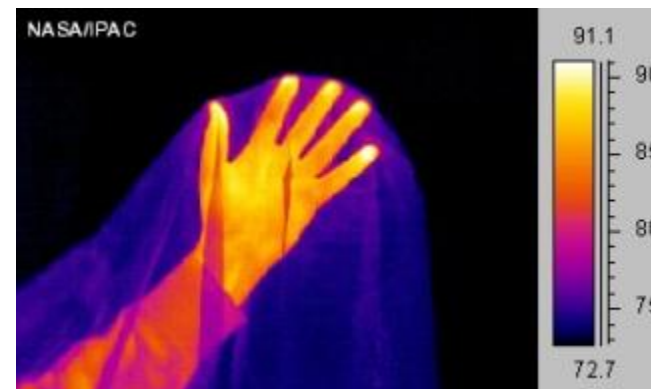
Infrared radiation is emitted from the Earth's surface.



Transparency and Opacity: Infrared vs. Visible Light



Transparency and Opacity: Infrared vs. Visible Light



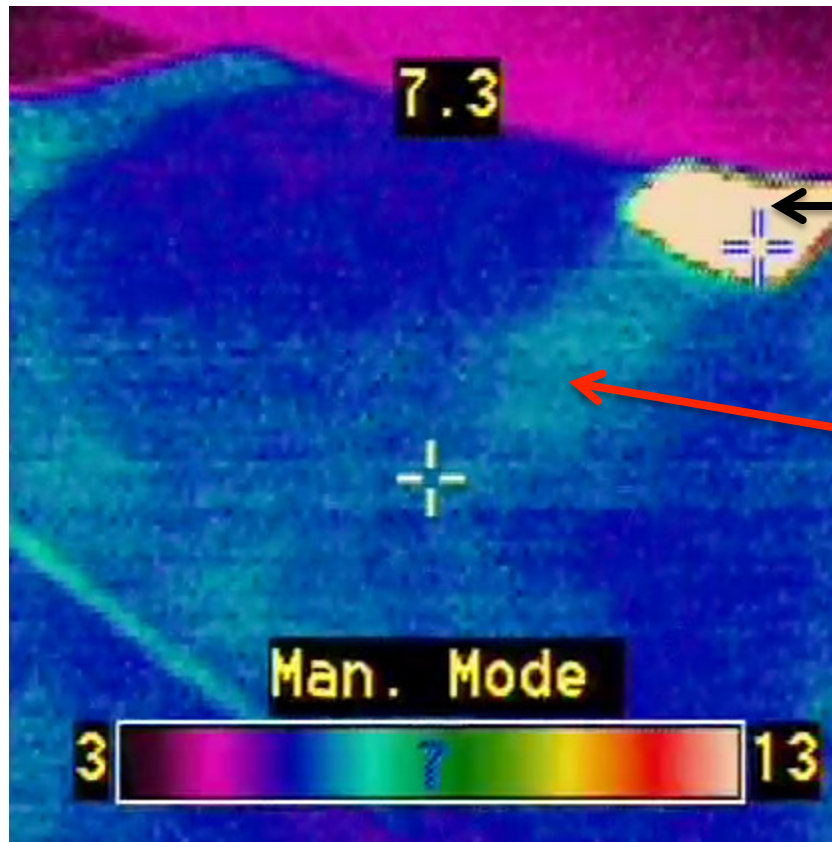
Transparency and Opacity: Infrared vs. Visible Light



Hot (Dry) Air is NOT Visible in the Infrared



Hot Car Exhaust (with lots of CO₂) IS Visible in the Infrared

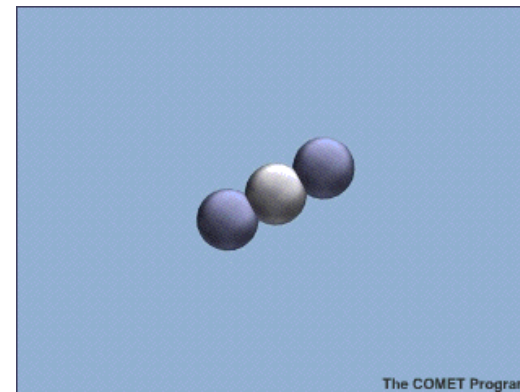
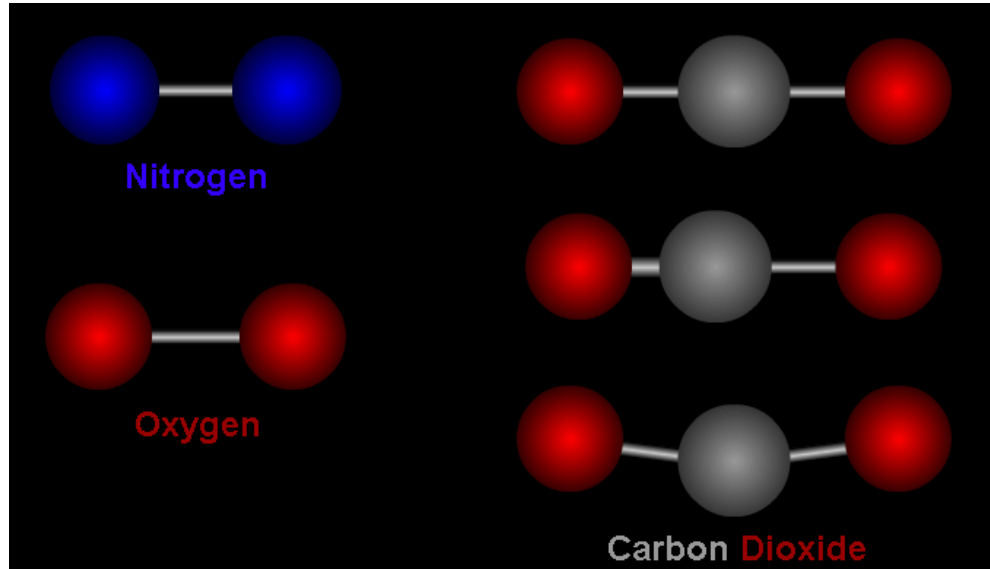
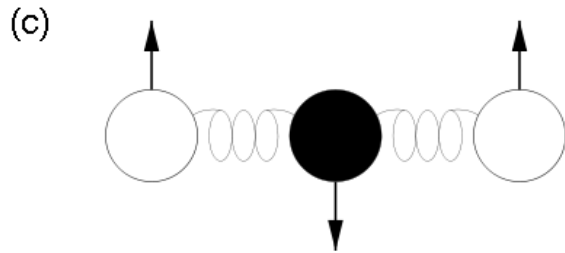
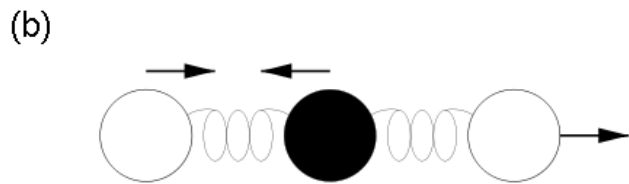
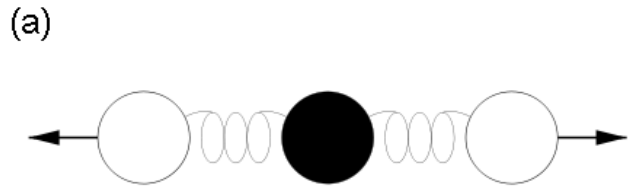


VERY hot
tailpipe

Hot exhaust
with lots
of CO₂



Molecular Vibration Modes and the Greenhouse Effect

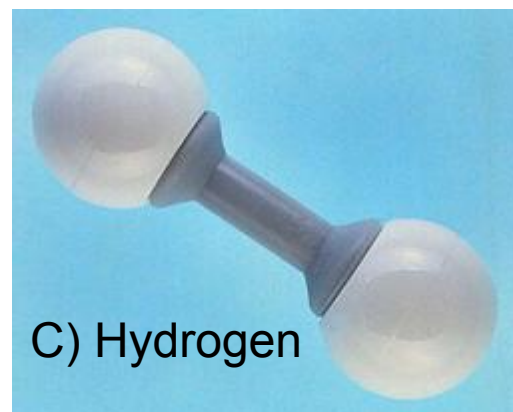
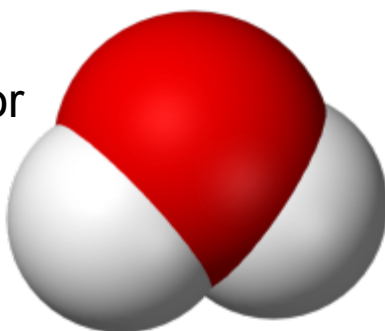




Poll: Which is NOT a GHG molecule?

A) Water vapor

2

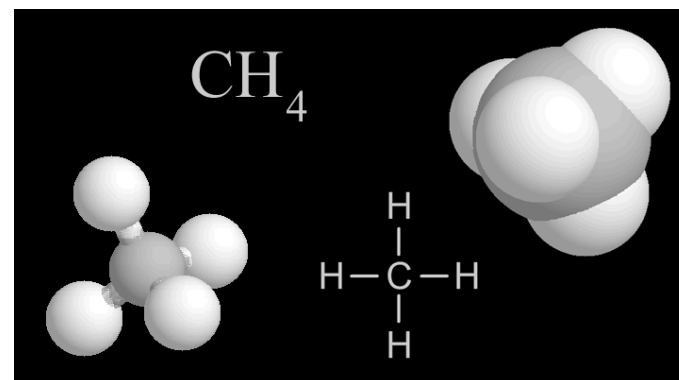
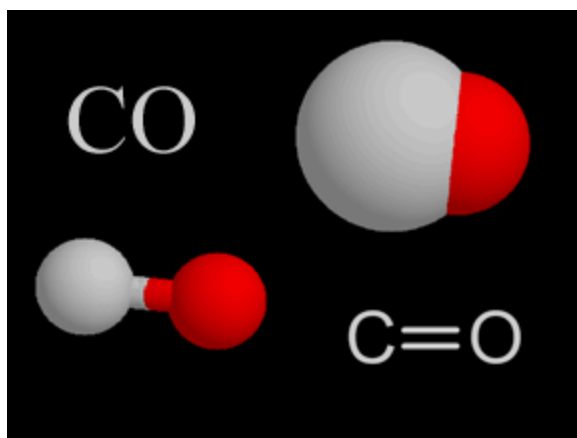


C) Hydrogen

31

B) Carbon monoxide

0



D) Methane

0

14 did not respond

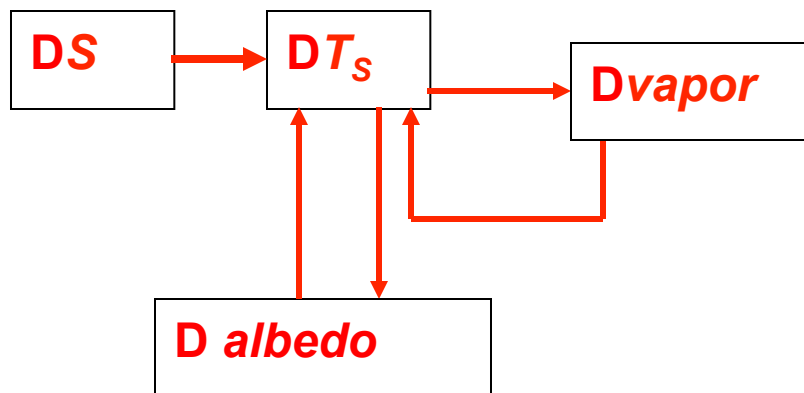




Climate Feedback Processes



- ❖ **Positive feedbacks amplify the changes**
- ❖ Warmer surface has less ice and snow (darker)
- ❖ A darker surface absorbs more incoming sunshine
- ❖ **Darker surface warms**



Ice Albedo Feedback



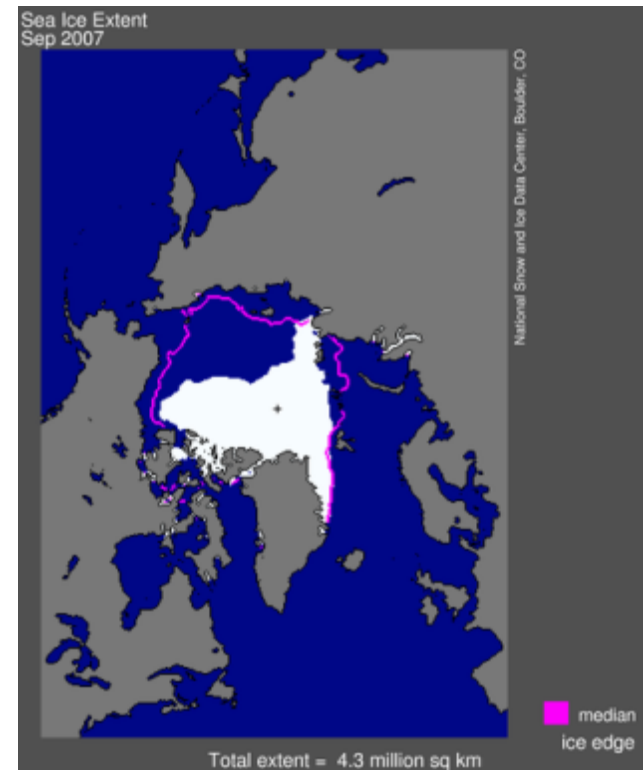
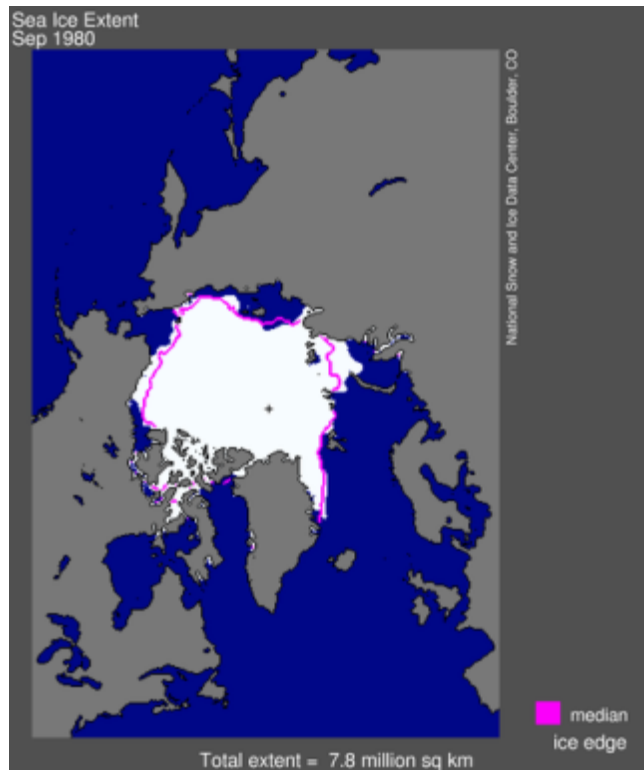
Satellite (LANDSAT) images of the coast of Greenland in August 1985 (left) and September 2002 (right) show how ice reflects much more sunlight than water. Melting ice causes more absorption of energy from sunlight, leading to further warming.



Sea Ice Decline in the Arctic



The amount of sea ice in the Arctic has been declining dramatically in recent decades, as seen here in 1980 (left) and 2007 (right).



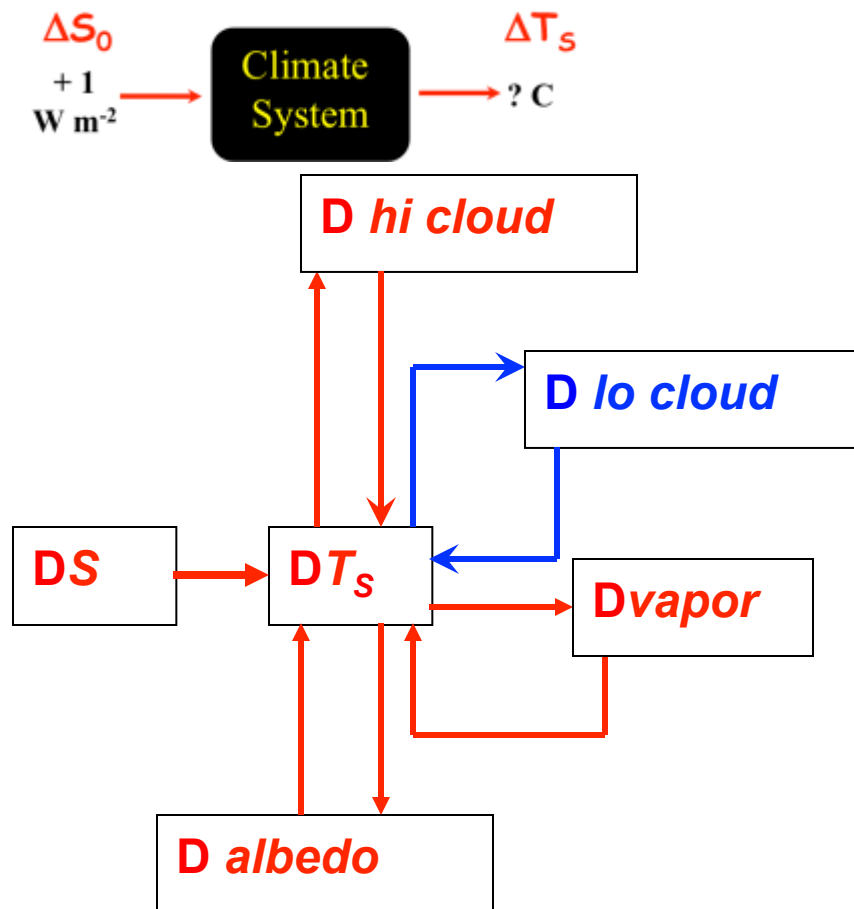
Graphing Sea Ice Extent Activity

... and animations and interactive viewer.





Climate Feedback Processes



- ❖ **Negative feedbacks reduce the changes**
- ❖ Some extra water vapor turns into extra low clouds
- ❖ Low clouds block sunlight, but don't block as much outgoing thermal energy
- ❖ **Extra low clouds cool the surface**

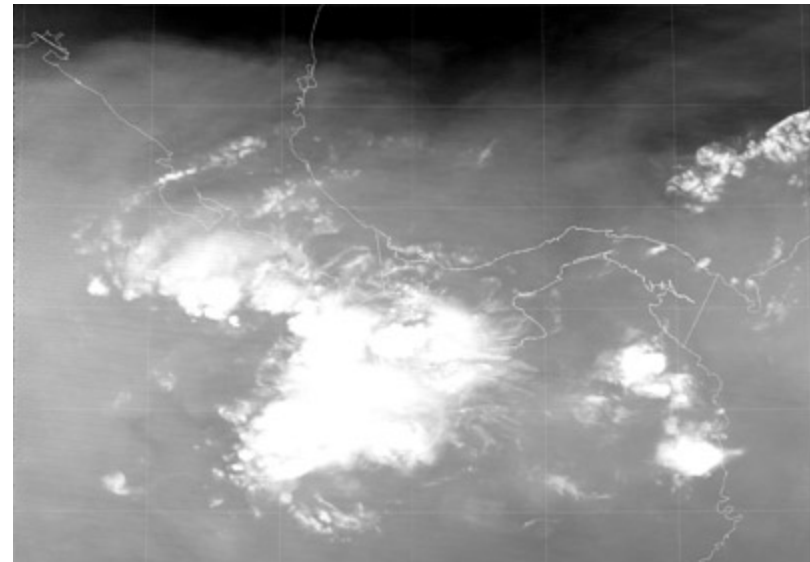
High vs. Low Clouds Different Effect on Climate



Satellite Views of Clouds in Visible Light and Infrared



Satellite views of clouds over Panama in April 2000 show how low and high clouds have different impacts on climate. Image on left is visible light; only shows low clouds. Infrared image on right also shows high cirrus clouds.





Questions on the side

- ❖ Do contrails from airplanes add to this?
 - ❖ Scott responds: yes, contrails are high thin clouds that don't block much sunshine, but they are quite good at blocking outgoing thermal radiation



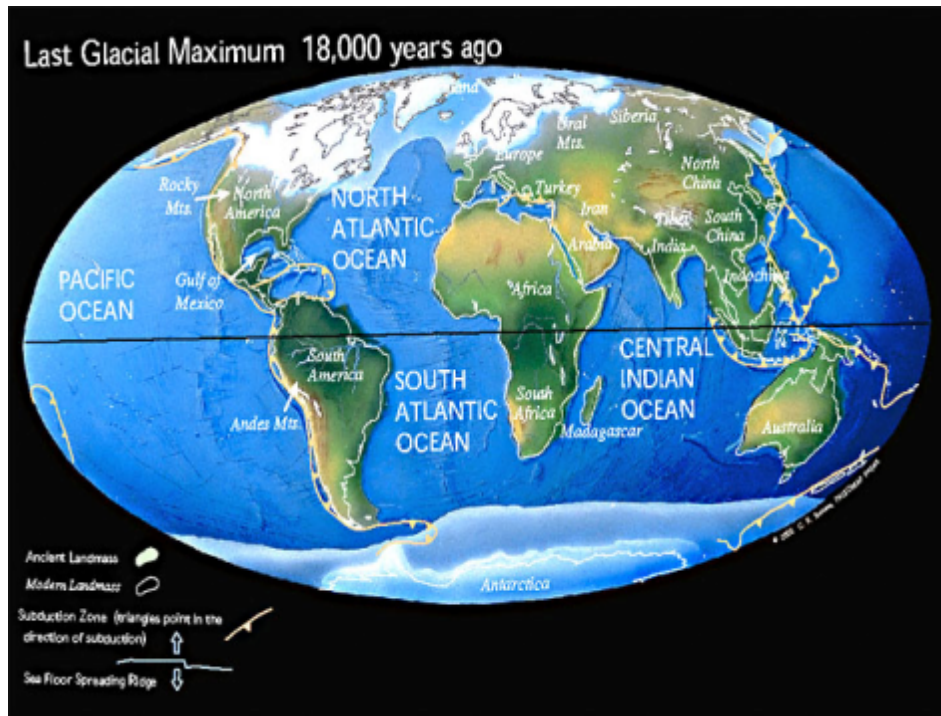


Questions?

- ❖ I've never hear carbon monoxide called a GHG before, only an indirect contributor because it helps form ozone.
- ❖ Are most of the CO₂ normal modes of vibration radiative during photon absorption?



Learning from the Past

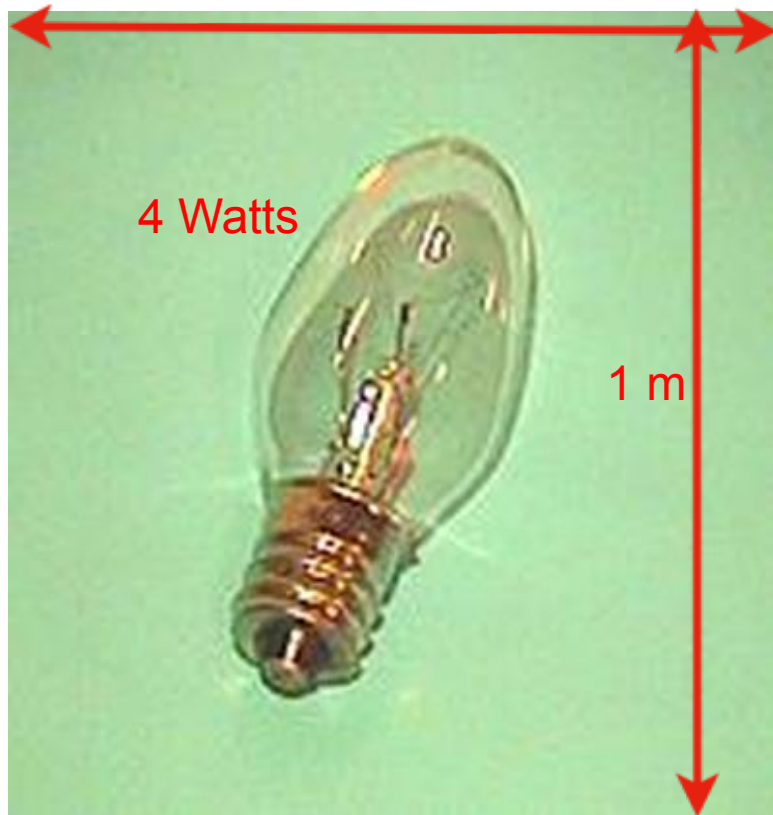


- ❖ Ice Age surface heat balance was about $(3.4 + 3.7) = 7.1 \text{ W m}^{-2}$ less
- ❖ Ice Age surface temperature was about 5°C colder (about 9°F)
- ❖ After Ice Age, extra 7.1 W m^{-2} heat warmed surface by 5°C

Total Climate Sensitivity about 0.7°C per W m^{-2}



Climate Sensitivity to CO₂

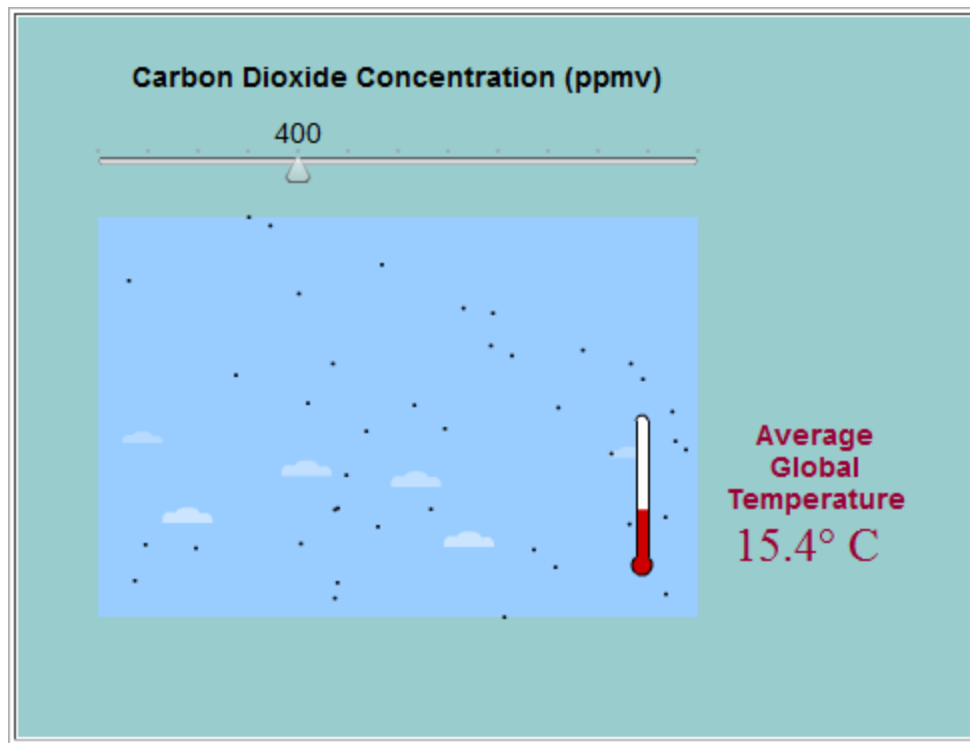


- ❖ Doubling CO₂ in the atmosphere would add 4 Watts of heat to every square meter of Earth
- ❖ Climate sensitivity with all positive and negative feedbacks = 0.7 °C per W m⁻²
- ❖ Climate sensitivity to doubling CO₂ is about
(4 W m⁻²) x (0.7 °C per W m⁻²)

Climate Sensitivity about 3 °C per doubling of CO₂



Climate Sensitivity Calculator



Questions throughout

- ❖ Why does CO₂ radiate more towards the Earth than away from?
- ❖ How are Ice Ages triggered by small changes?
- ❖ Pleistocene - Wisconsin Ice Age
- ❖ More ice, and as it accumulates, more reflection?
- ❖ Lower energy input, lower surface temps, more ice and less albedo?
- ❖ Thanks! Thought so, good to have it confirmed....
- ❖ More on Ice Ages - What are negative feedbacks (limits) on Ice Ages, even one as extensive as the hypothesized Snowball Earth?
- ❖ Doesn't the solar radiation meet the bottom with a small angle at the (melting) pole-regions, so that the energy transfer to the water is not so big ? And aren't those polar regions only radiated (about) half a year ?
- ❖ Yes CO₂ concentration higher but solubility is also effected by temp???



Comments & Discussion

- ❖ I love the bathtub analogy!
 - ❖ Dorothy - check out the archived presentation from June 11, 2012. They go into the bathtub analogy extensively
- ❖ How if at all does temperature effect ocean acidity CO₂ less soluble so less acidic? How is this important
 - ❖ There is more CO₂ in the atmosphere so more CO₂ dissolves into the ocean



Webinar 1 Survey Feedback

- ❖ 42 of the 48 attendees responded to survey
- ❖ Responses to Likert Scale questions
 - ❖ 5 = Excellent, 4 = Good, 3 = Average, 2 = Fair, 1 = Poor
 - ❖ 4.57 - Overall, the Web Seminar was valuable to me
 - ❖ 4.69 - The content of this Web Seminar was relevant to me.
 - ❖ 4.45 - The interactive nature of the Web Seminar was valuable.
- ❖ Would you like to see more Web Seminars like this one offered in the future? Yes 100%, No 0%
- ❖ Evaluation of Presenters
 - ❖ knowledge, clarity, responsiveness, pace
 - ❖ Scott (4.93, 4.83, 4.81, 4.76) Randy (4.88, 4.79, 4.76, 4.67)



Webinar 1 Survey Feedback

- ❖ Very engaging and content rich!! Love the bathtub model - what a great model to use to aid in student understanding! (4)
- ❖ I found the carbon cycling in the oceans fascinating.
- ❖ I really enjoyed the interactive models. The web polls allowed me to see where I stood in respect to the other participants.
- ❖ I learned that climax forests are balanced in terms of their net impact on Carbon amounts in various locations. They take up as much C as they release.
- ❖ I never thought of using a bath tub to model flow. I normally use the flow chart which is still so abstract I think because students have nothing to compare it with. This is why I really enjoyed the use of the bath tub as the model.
- ❖ I liked the tub analogy for modeling; I had always called them "sinks". I would like suggestions for more interactive approach in the classroom. I did like the graphics.



Webinar 1 Survey Feedback

- ❖ I learned more background details of the carbon cycle that I can share with my students.
- ❖ Responses to the audience's questions...and the modifications made to the script towards this particular audience.
- ❖ Great! Loved the easy to use visuals!
- ❖ Very interesting to learn how the deep oceans have yet to absorb fossil fuel carbon emissions
- ❖ I expected more climate discussion, but I'm glad the presenters started at the basics and that this webinar is the first of four.
- ❖ Interesting fact about acidification of ocean affecting the growth of shells on shellfish.
- ❖ Enjoyed the interactive animation the most; learned a lot about the carbon cycle; look forward to the next webinar in the series.



Webinar 1 Survey Feedback

- ❖ Great web seminar! I look forward to using the models in my classes.
- ❖ I would love to see real time data that I could use in the classroom for inquiry added to this presentation. As a middle school teacher I find it difficult to find usable, real time data to use in the classroom.
- ❖ Provide the misconceptions that students have on the topic. How do they get off track in their understanding?
- ❖ Include optional models for ESL learners.
- ❖ I thought there would be more info on how to get students to construct their own models as is suggested in the Next Gen Sci Standards. I would like more seminars that focus on constructing models & engineering design thinking.
- ❖ Less science background, more about using the models in the classroom, pros and cons of using models in teaching, etc.



Webinar 2 Survey Feedback

- ❖ 43 of the 48 attendees responded to survey
- ❖ Responses to Likert Scale questions
 - ❖ 5 = Excellent, 4 = Good, 3 = Average, 2 = Fair, 1 = Poor
 - ❖ 4.51 - Overall, the Web Seminar was valuable to me
 - ❖ 4.49 - The content of this Web Seminar was relevant to me.
 - ❖ 4.88 - The interactive nature of the Web Seminar was valuable.
- ❖ Would you like to see more Web Seminars like this one offered in the future? Yes 100%, No 0%
- ❖ Evaluation of Presenters
 - ❖ knowledge, clarity, responsiveness, pace
 - ❖ Scott (4.77, 4.74, 4.91, 4.81) Randy (4.91, 4.81, 4.79, 4.74)



Webinar 2 Survey Feedback

- ❖ I didn't know why certain gases were greenhouse gases, but Dr. Denning explained it well (the ability of the atoms in a molecule to vibrate in more than one way). Even after my many years of teaching, I know I can still learn more and that is why I attend these webinars :-). Sometimes it's the way someone says something or the way something is illustrated that makes something more clear. I was glad to see some math too. It was explained well.
- ❖ The combination of concept presentation and then augmenting with the web tour interactives helps me incorporate this into my curriculum for my students.
- ❖ There are some great new tools online that can help teach these concepts that so many have trouble comprehending. I liked the tools on molecule vibrations.
- ❖ The polls were good and the question sessions were also. It was great to see the interactive demonstrations that are available now.



Webinar 2 Survey Feedback

- ❖ Positive and negative feedbacks are something I am just beginning to think about/work with. I am trying to put together a short unit on GCC for my preservice teachers, and haven't yet figured out what small slice I can carve out for elementary teachers. This gave me some ideas.
- ❖ I learned that there is a lot more to the global heating and cooling than what I ever knew.
- ❖ Appreciated the explanations of radiation, etc in more detail than I have found previously. Thank you for the visuals.
- ❖ Use of lots of pictures and access to these same pictures for using with my students is useful.
- ❖ nice calculations... and calculator
- ❖ I am anxiously waiting for sessions three and four in this series.
- ❖ I really loved the discussion of positive and negative feedback loops and wish we had spent more time on those.



Webinar 2 Survey Feedback

- ❖ I thought the interactive tools to use with students were among the best content. Overall, I really loved the whole experience.
- ❖ Clear explanations of complex topics. Mathematical, verbal, and graphic representations of information to allow us to use the materials with different kinds of learners.
- ❖ Enjoyed the tag-team approach by Scott and Randy. Loved that we could actually play around with the online animations. Very cool!
- ❖ One of the best I've attended in a while: content rich, good resources, and the presenters were not denigrating to the audience.
- ❖ More interactive components for attendees. Keeps us more engaged. (2)
- ❖ A little more time to play with the interactives during the web tours and then a little more question/reflection time to go after each interactive on line exercise.
- ❖ conceptual animations are always good



Webinar 2 Survey Feedback

- ❖ Less time on basic definitions such as wavelength and energy. The audience is science teachers with college course background. Thereby, more topical information can be covered.
- ❖ I appreciated the double explanations -- ie., Scott first and then another way of thinking about it with Randy.
- ❖ The topic was much too in depth for my students. I was expecting a web seminar on how to teach this to my students, not for it to explain the concept to me in such detail. However, it was good information.

- ❖ Subjects taught: Biology 14, Earth Science 13, General Science 11, Chemistry 10, Physical Science 9, Life Science 9, Physics 9, Environmental 8, Science and Technology 6, Informal Educator 5, Mathematics 3, Other 7

