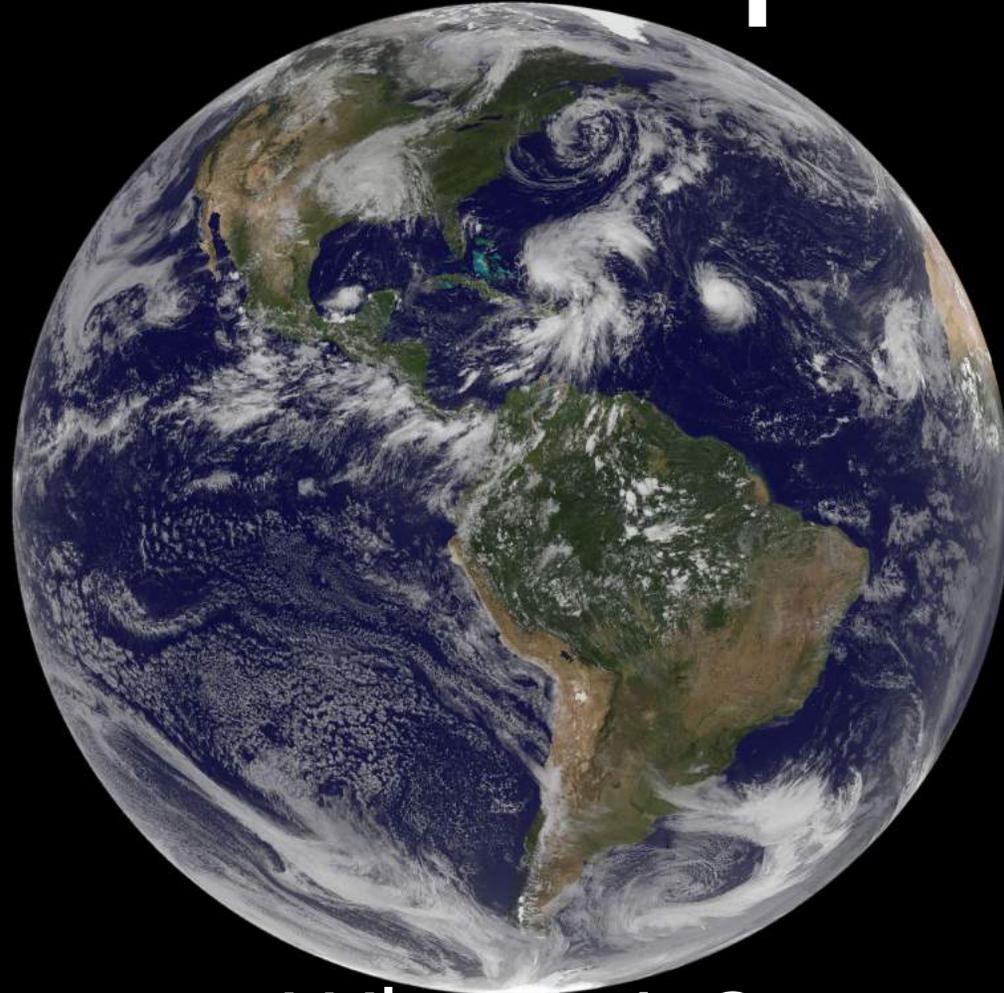
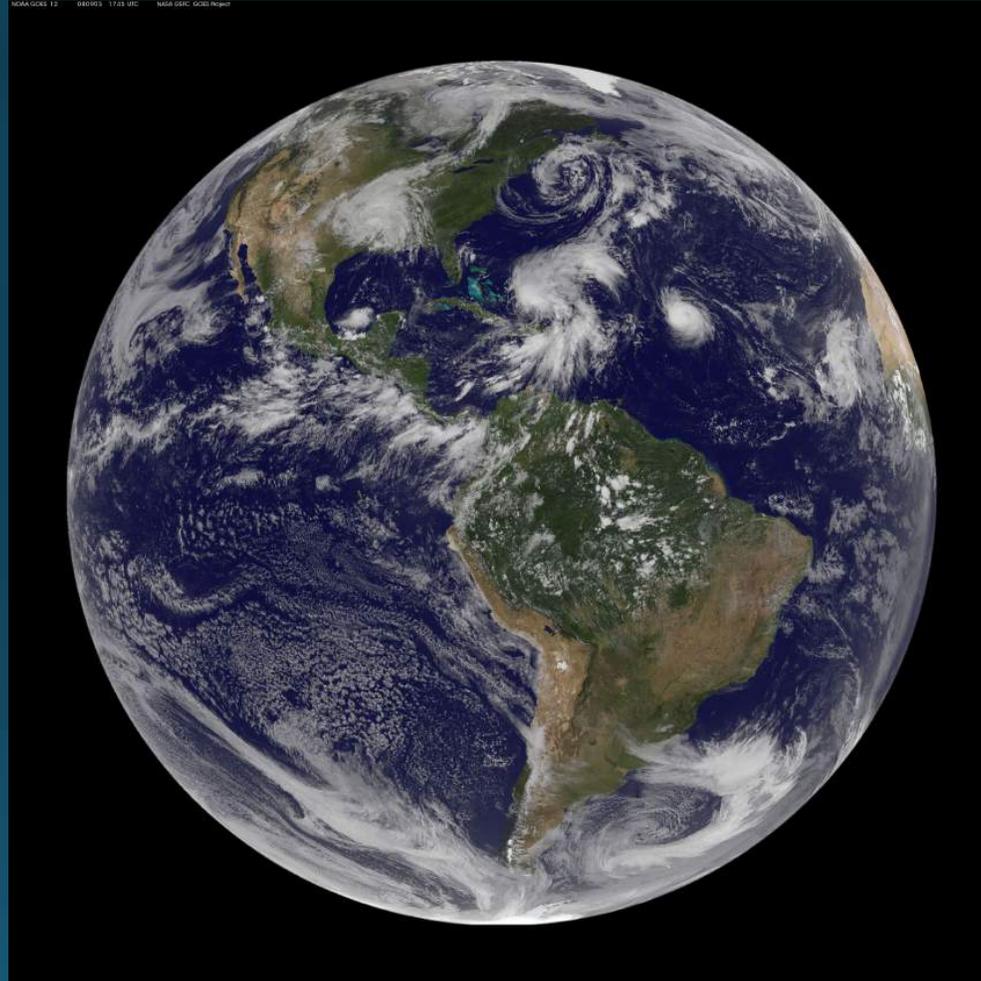


# The Anthropocene



What is it ?  
And Why Should We Care?

# Earth as a “closed” system



Energy moves in and out of the system  
Mass is essentially constant

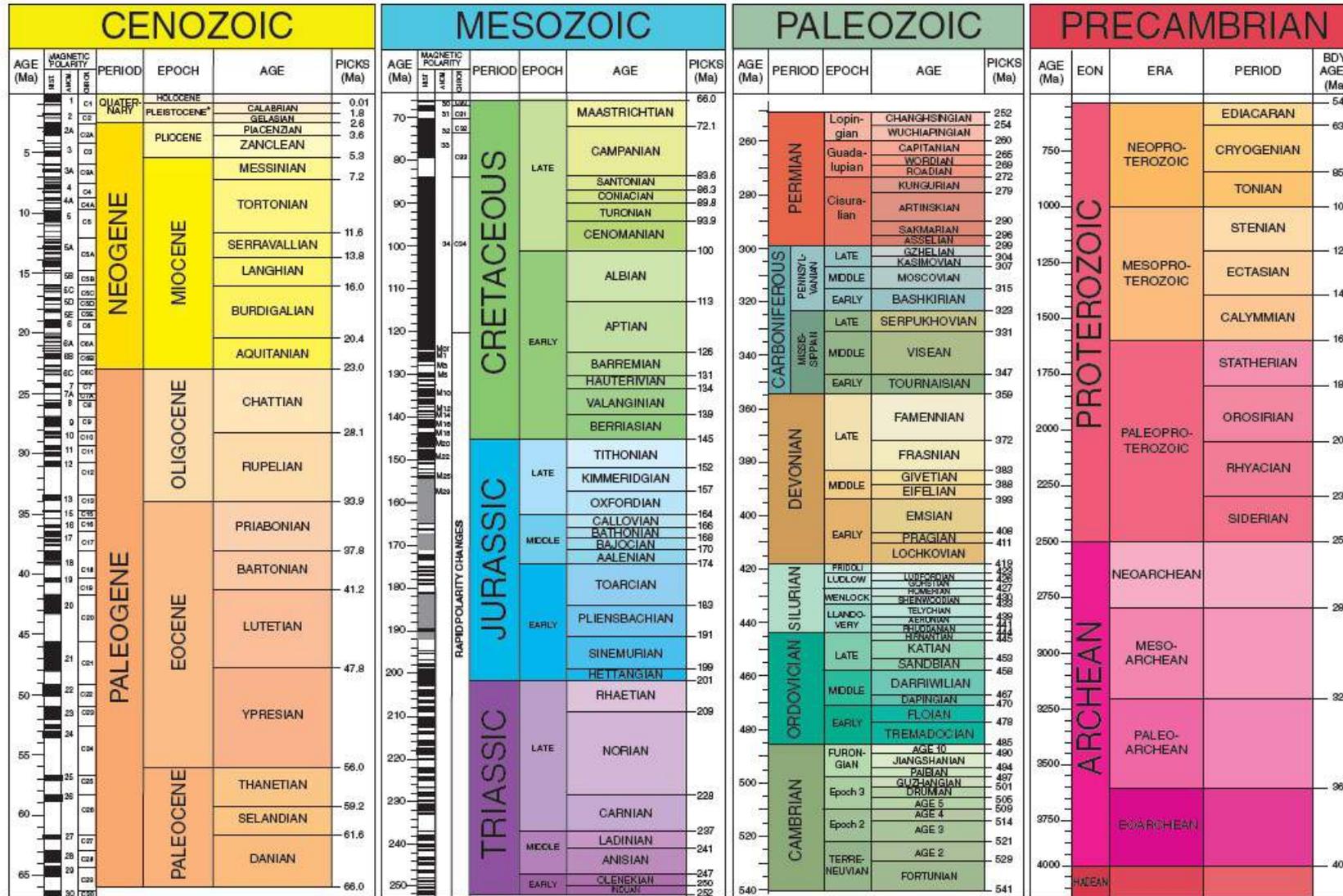
# Nature of Geoscience

- Geosciences encompass the history, materials, and processes of the complex Earth system
- Earth system is open, heterogeneous, dynamic and complex; “deep time” and spatial scales from atomic to planetary
- A central role in contributing to the safety, health, and economic welfare of humanity.
- Geoscientists must make inferences from an incomplete geologic record, deal with ambiguity and uncertainty in their professional work
- Geosciences presents many challenges that confront issues of Geoethics

ENERGY In the Earth System

GEOLOGIC TIME

# GSA GEOLOGIC TIME SCALE v. 4.0



\*The Pleistocene is divided into four ages, but only two are shown here. What is shown as Calabrian is actually three ages—Calabrian from 1.8 to 0.78 Ma, Middle from 0.78 to 0.13 Ma, and Late from 0.13 to 0.01 Ma. Walker, J.D., Geiseman, J.W., Bowring, S.A., and Babcock, L.E., compilers, 2012, Geologic Time Scale v. 4.0: Geological Society of America, doi:10.1130/2012.CT8004R3C. ©2012 The Geological Society of America. The Cenozoic, Mesozoic, and Paleozoic are the Eras of the Phanerozoic Eon. Names of units and age boundaries follow the Gradstein et al. (2012) and Cohen et al. (2012) compilations. Age estimates and picks of boundaries are rounded to the nearest whole number (1 Ma) for the pre-Cenomanian, and rounded to one decimal place (100 ka) for the Cenomanian to Pleistocene interval. The numbered epochs and ages of the Cambrian are provisional. REFERENCES CITED Cohen, K.M., Finney, S., and Gibbard, P.L., 2012, International Chronostratigraphic Chart: International Commission on Stratigraphy, www.stratigraphy.org (last accessed May 2012). (Chart reproduced for the 34th International Geological Congress, Brisbane, Australia, 5–10 August 2012.) Gradstein, F.M., Ogg, J.G., Schmitz, M.D., et al., 2012, The Geologic Time Scale 2012: Boston, USA, Elsevier, DOI: 10.1016/B978-0-444-59425-9.00004-4.

# An Earth System Approach



A heterogeneous, complex and dynamic system



Air



Water



Land

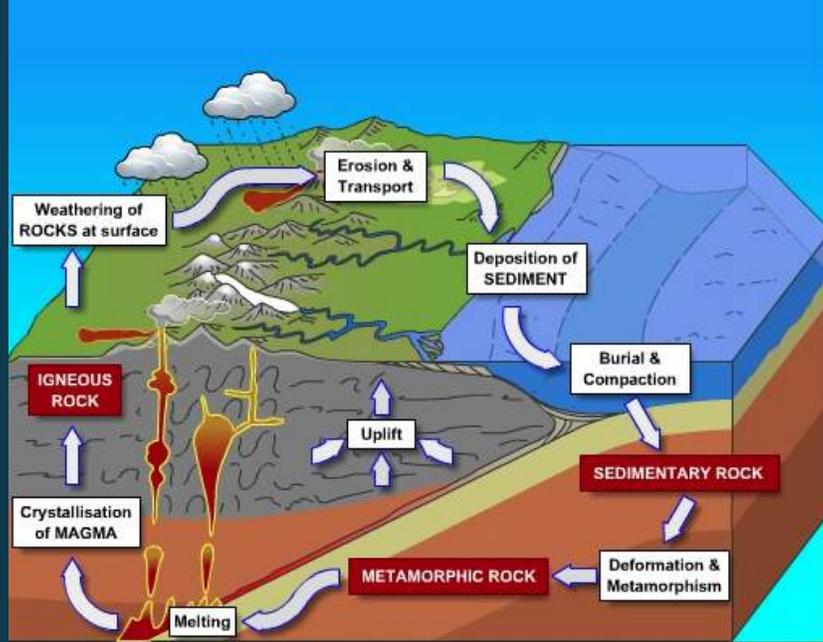


Life

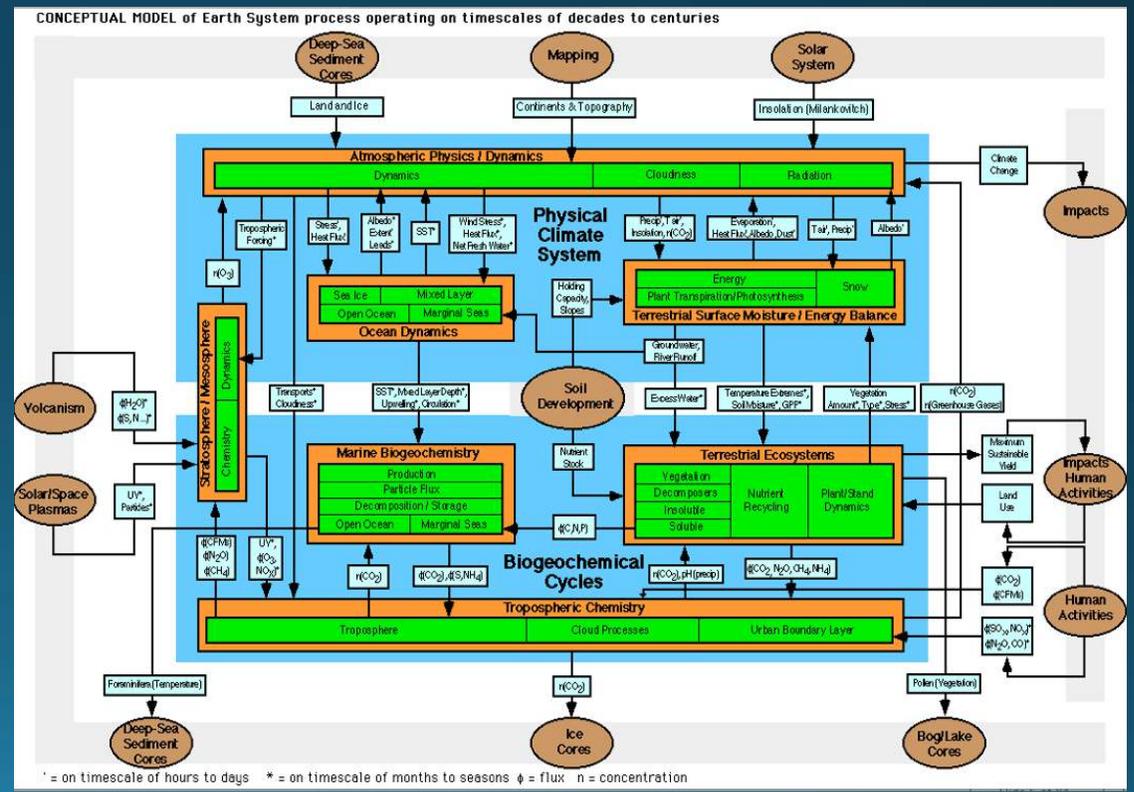
# The Earth System

M. Ruzek, 1999

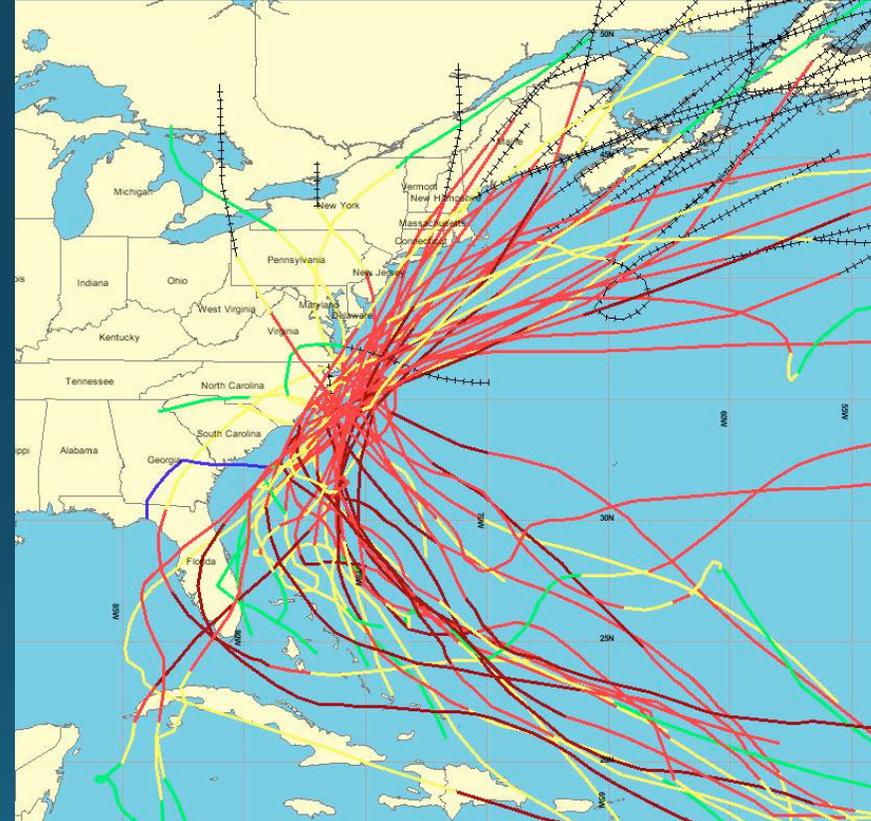
# SHAPING THE FUTURE OF UNDERGRADUATE EARTH SCIENCE EDUCATION INNOVATION AND CHANGE USING AN EARTH SYSTEM APPROACH



- First Law of Ecology: Everything is connected to everything else; Garrett Hardin
- With an emphasis on transfer of mass and energy, process, connections, feedbacks



# Post-diction to enable Pre-diction



# Energy: Some things you can count on!

- Thermodynamics—things blow up
  - Conservation of energy; transformation
  - Disorder of universe increases; (energy not available to do work)
  - Ability to work—convert energy into motion
  - Heat; energy stored or transferred by vibration of molecules; often a waste product
  - Drives chemical work; reactions that consume or liberate energy



# Energy: Some things you can count on!

- Gravity—things fall down!
  - Release of stored potential energy
  - Transfers to kinetic energy
- Radioactivity—unstable atoms will breakdown
  - Drives plate tectonics, volcanoes, earthquakes....
  - Naturally occurring
  - Harnessed by humanity....



# Nature Hates Gradients!

Drives energy flow in the Earth System



# Some General Energy Concepts

- Transformation
- Efficiency
- Rates/Fluxes
  - Time
- Reservoirs
  - storage
- Pathways
  - Processes
- Can we harness energy for productive use?

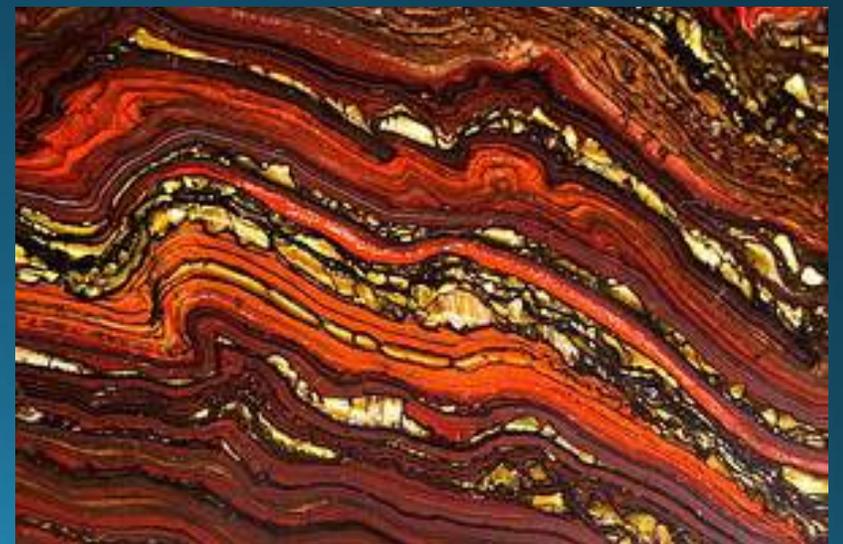
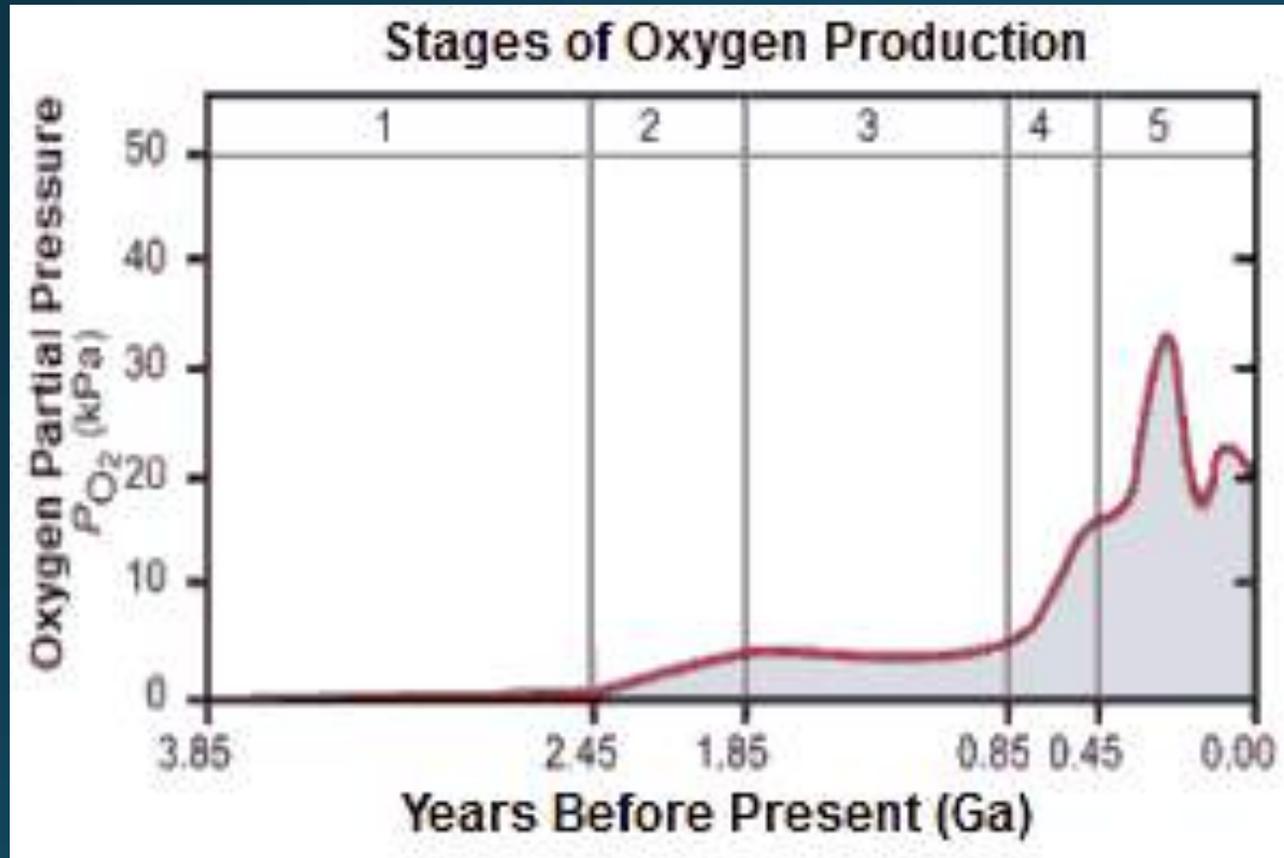


# Don't Forget About Time!

- Rates!
  - Of energy production and transfer
  - Fluxes: Quantity moved/unit time
- Temporal Concepts
  - Frequency/magnitude
  - Recurrence interval
  - Duration
  - Residence time
  - Scale: nano-seconds to eons



# Great Oxygenation Event



# The Anthropocene

- The **Anthropocene** defines Earth's most recent geologic time period as being human-influenced, or anthropogenic, based on overwhelming global evidence that atmospheric, geologic, hydrologic, biospheric and other earth system processes are now altered by humans.
- Proposed by Crutzen and Stormer (2000)
- Widely used in the literature, But
- Controversial whether this “counts” as a geologic time unit.
- What is the age marker?



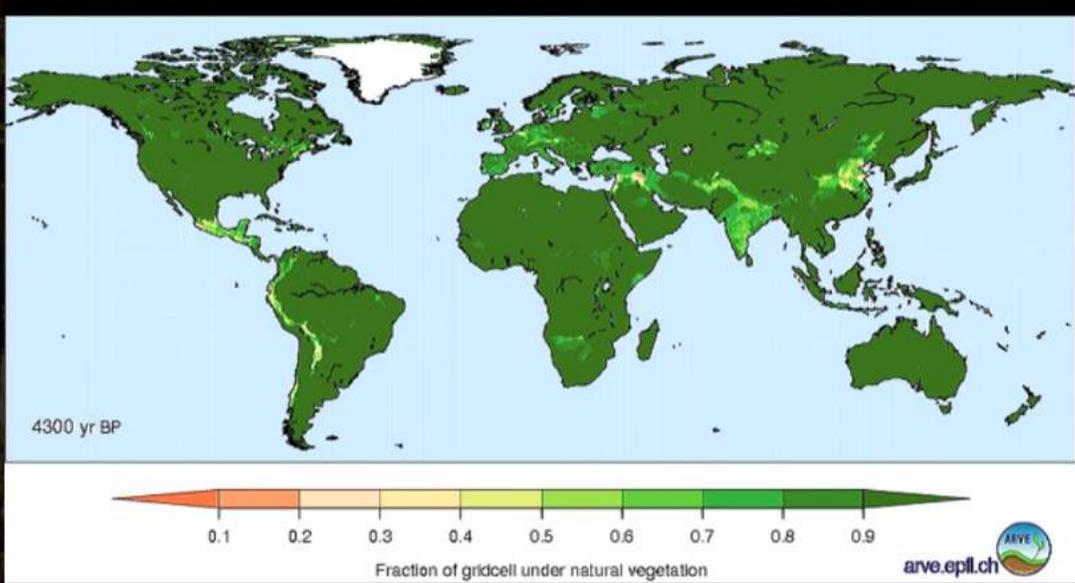
Model at the Royal BC Museum

Mammoth

-50,000 TO -10,000

## Megafauna Extinction

Many periods of Earth's geological history are defined by extinctions, but this time humans had a profound role due to overhunting. North America lost 72 percent of its large mammals, South America 83 percent, and Australia 88 percent by about 11,000 years ago. Source: [rspb.royalsocietypublishing.org...](https://rspb.royalsocietypublishing.org/)

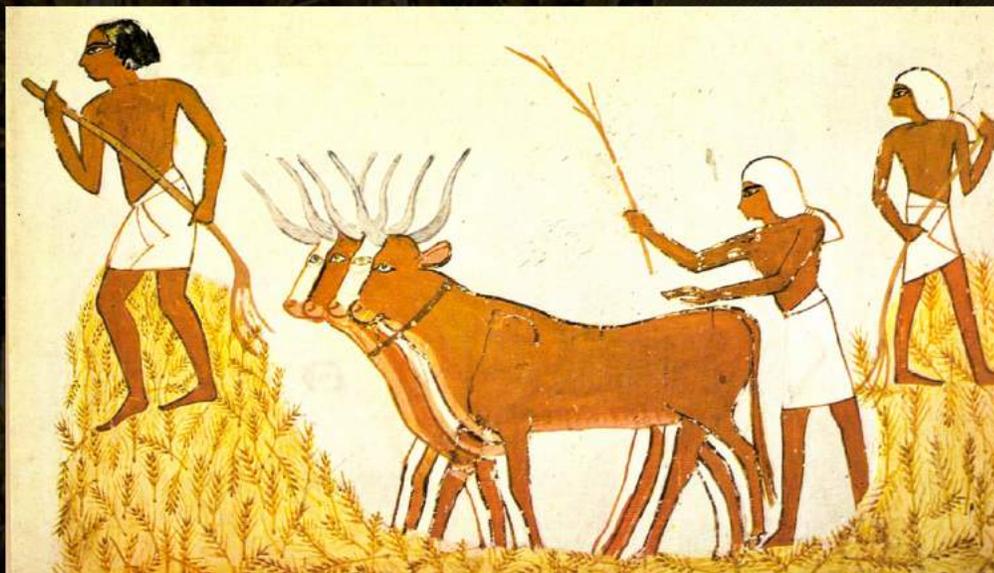


-11,000

## Origin of farming

Humans invented farming more or less simultaneously in Southwest Asia, South America and North China, as long as 11,000 years ago. From this period of time agriculture started to impact ecosystems, biodiversity and the cycles of nature.

Global patte



Carlos E. Soliv rez, Wikipedia

-11,000 TO -9,000

## Domestication of cattle

The tribes that took part in hunting and gathering wild edible plants, started to make attempts to domesticate dogs, goats, and possibly sheep, which was as early as 9000 BC in Southwest Asia. Source: Krebs, Robert E. & Carolyn A. (2003). Groundbreaking Scientific Experiments, Inventions & Discoveries of the Ancient World. Westport, CT: Greenwood Press. ISBN 0-313-31342-3.



-6,500

## Rice production with large scale environmental effects

Rice farming is starting to have considerable effects on the environment through the production of methane, a powerful greenhouse gas once it is airborne. Rice cultivation started already some thousand years earlier. Genetic evidence indicates that all forms of Asian rice, both indica and japonica, spring from a single domestication that occurred 8,200–13,500 years ago in China.



1678

## Coal enters the scene as major source of energy

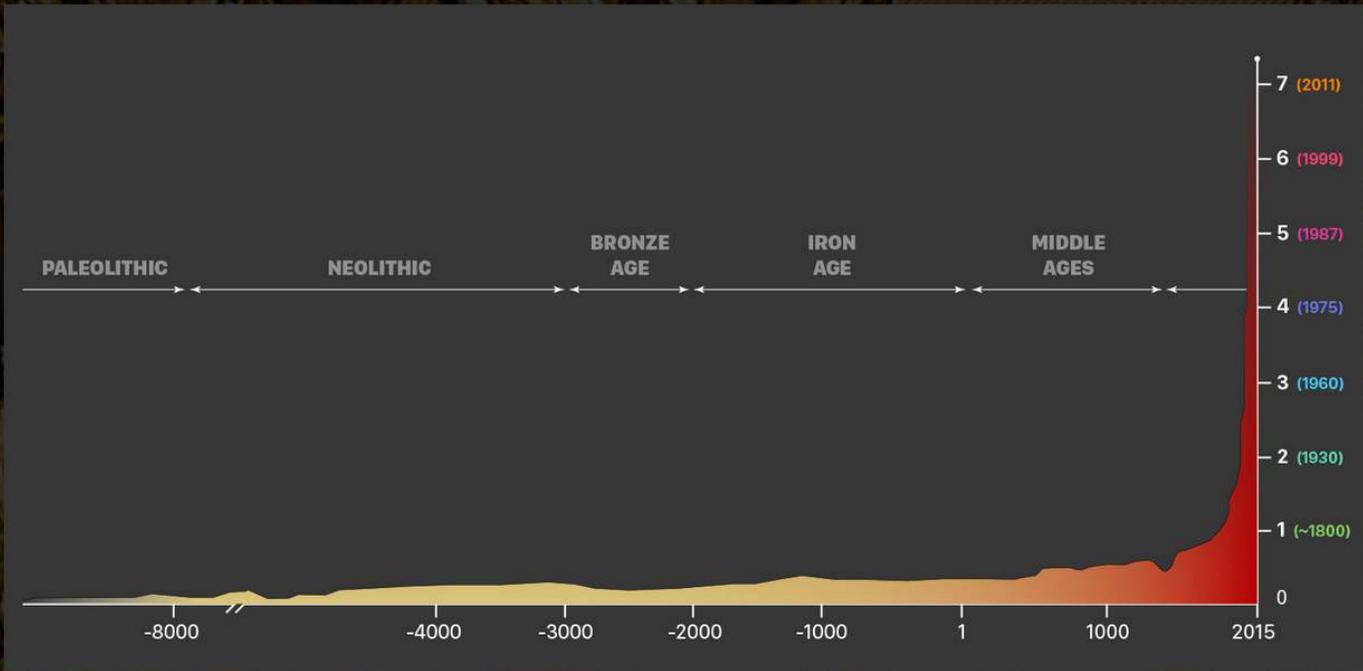
The development of the Industrial Revolution led to the large-scale use of coal, as the steam engine took over from the water wheel. In 1700, five-sixths of the world's coal was mined in Britain. Source: Wrigley, EA (1990). Continuity, Chance and Change: The Character of the Industrial Revolution in England.



1760

## Industrial Revolution

Large-scale combustion of coal, oil, and gas enables the transition to new manufacturing processes, from manual to mechanical.



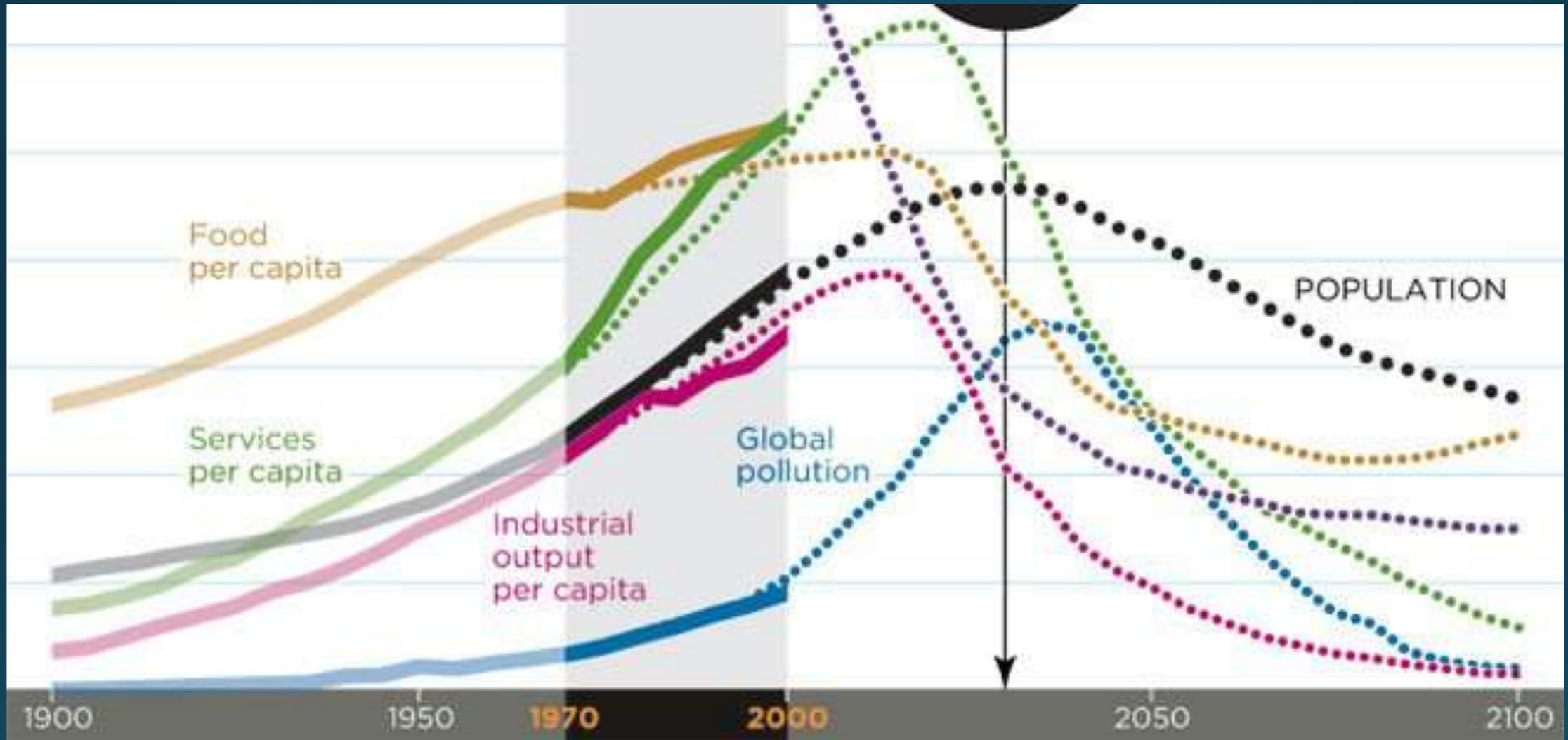
1804  
**World population reaches 1 billion**

Source: [www.census.gov/population/international/](http://www.census.gov/population/international/)

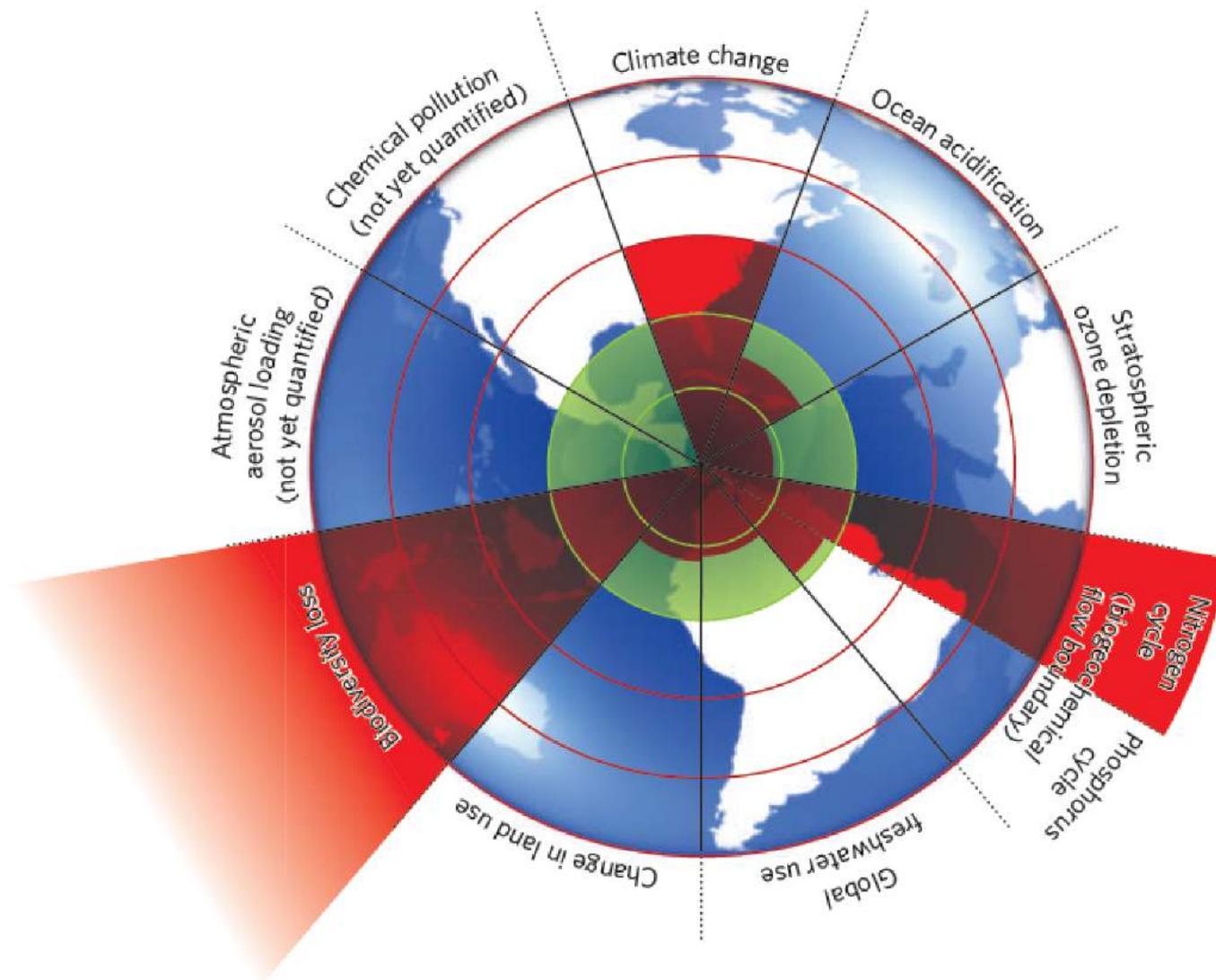
Globaia

World Population over time

# Limits to Growth, Meadows et al 2010



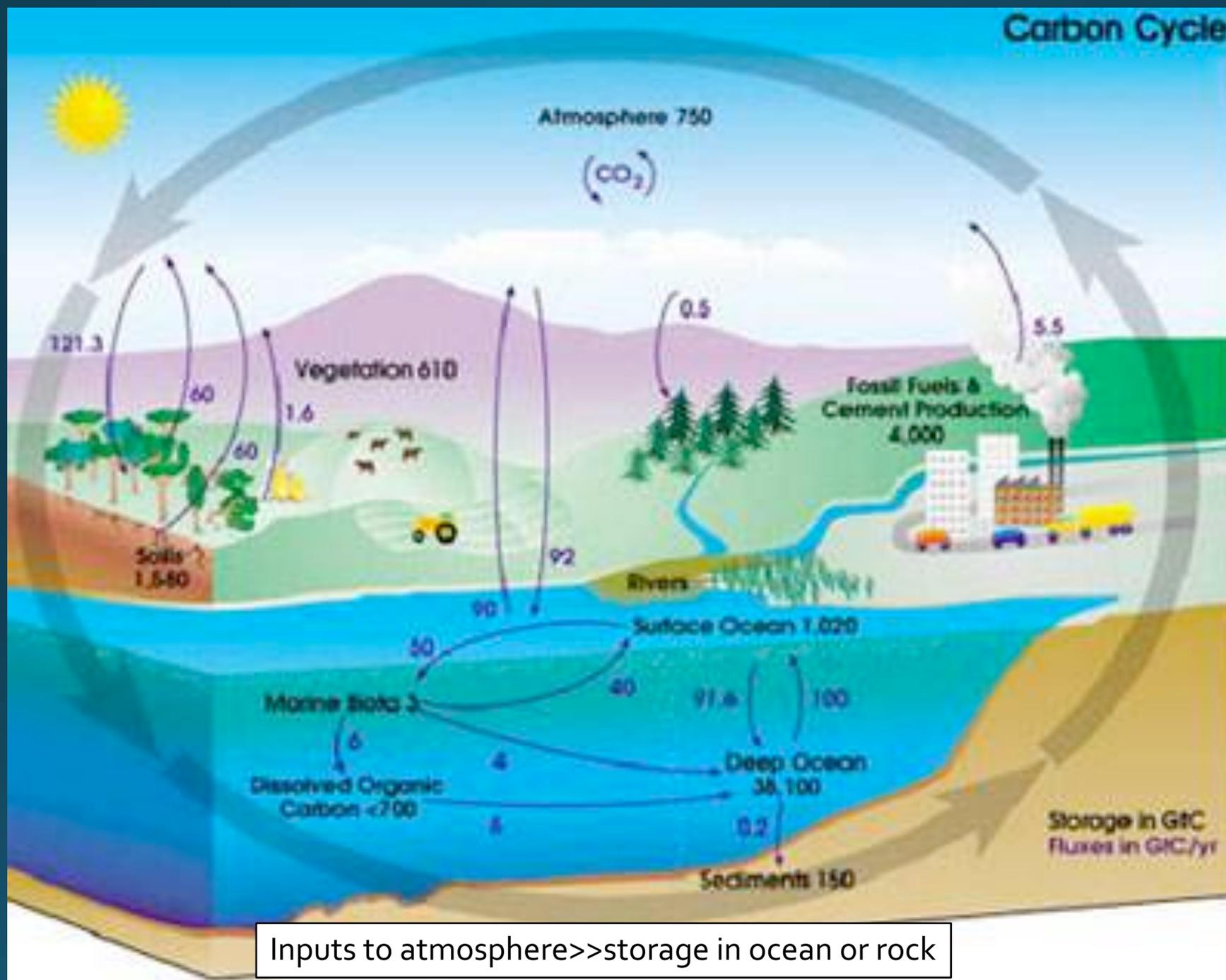
Overshoot and Collapse



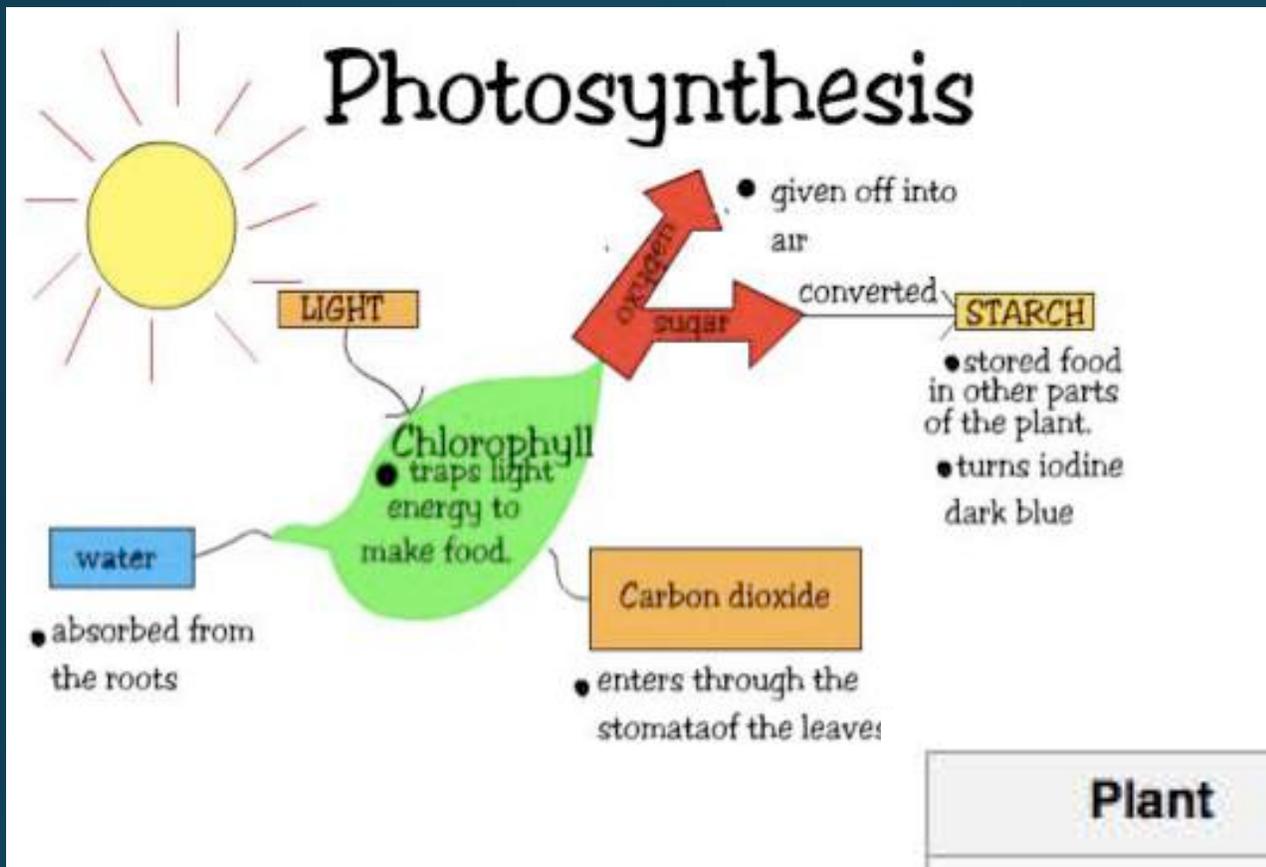
**FIGURE 2.25** Earth-system processes and their proximity to crossing threshold conditions that lead to unacceptable environmental change. Processes are indicated outside each sector. Green colors denote safe operating conditions. The heights of the red-colored wedges represent the status of each process with respect to safe operating conditions. In this figure, climate change, the nitrogen cycle, and biodiversity loss have crossed the threshold of unacceptable environmental change. SOURCE: Rockström et al. (2009). Reprinted by permission from Macmillan Publishers Ltd.



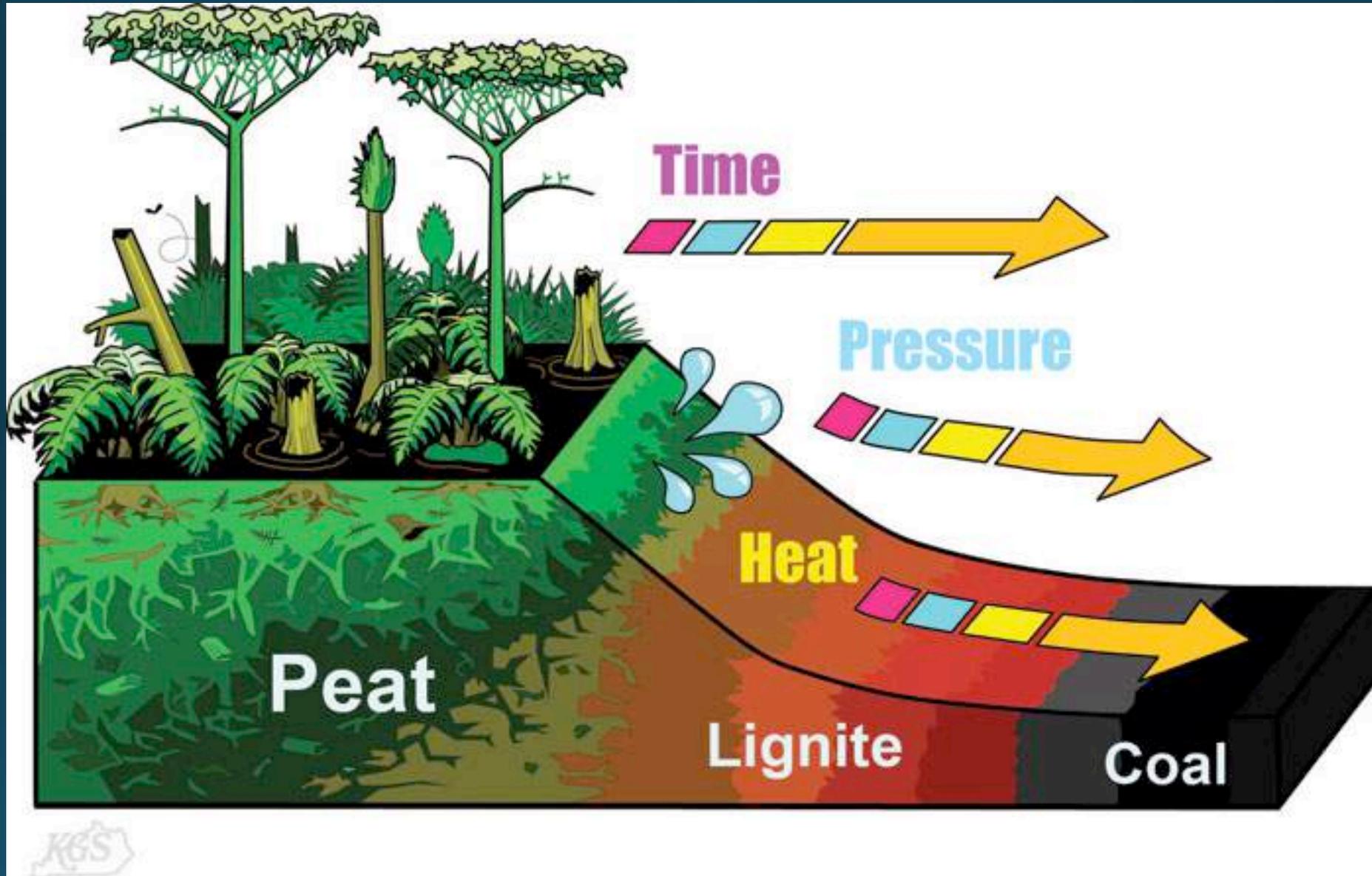
# Carbon Cycle



Inputs to atmosphere >> storage in ocean or rock



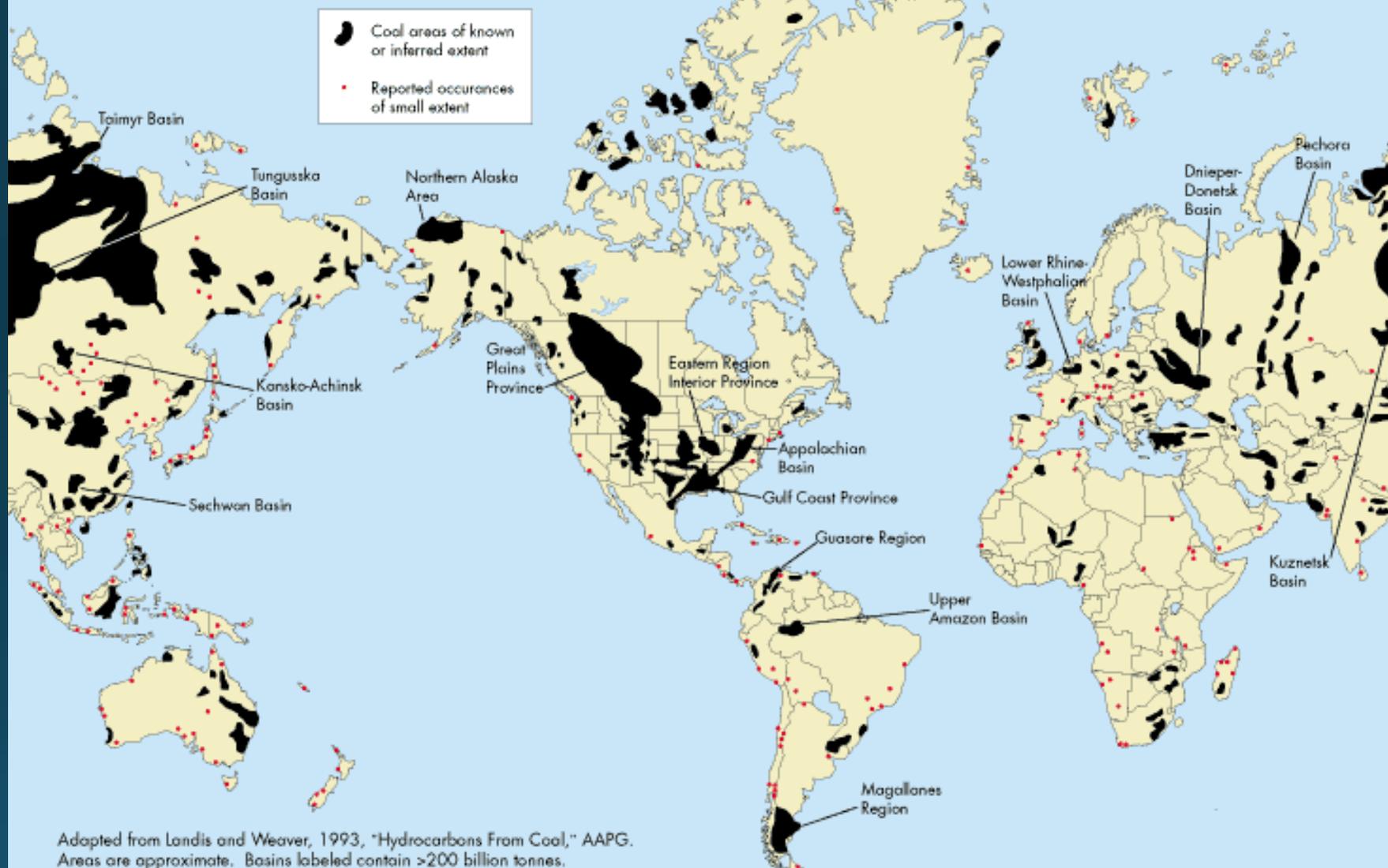
Plant	Efficiency
Plants, typical	0.1% <sup>[2]</sup>
	0.2–2% <sup>[3]</sup>
Typical crop plants	1–2% <sup>[2]</sup>
Sugarcane	7–8% peak <sup>[2][4]</sup>



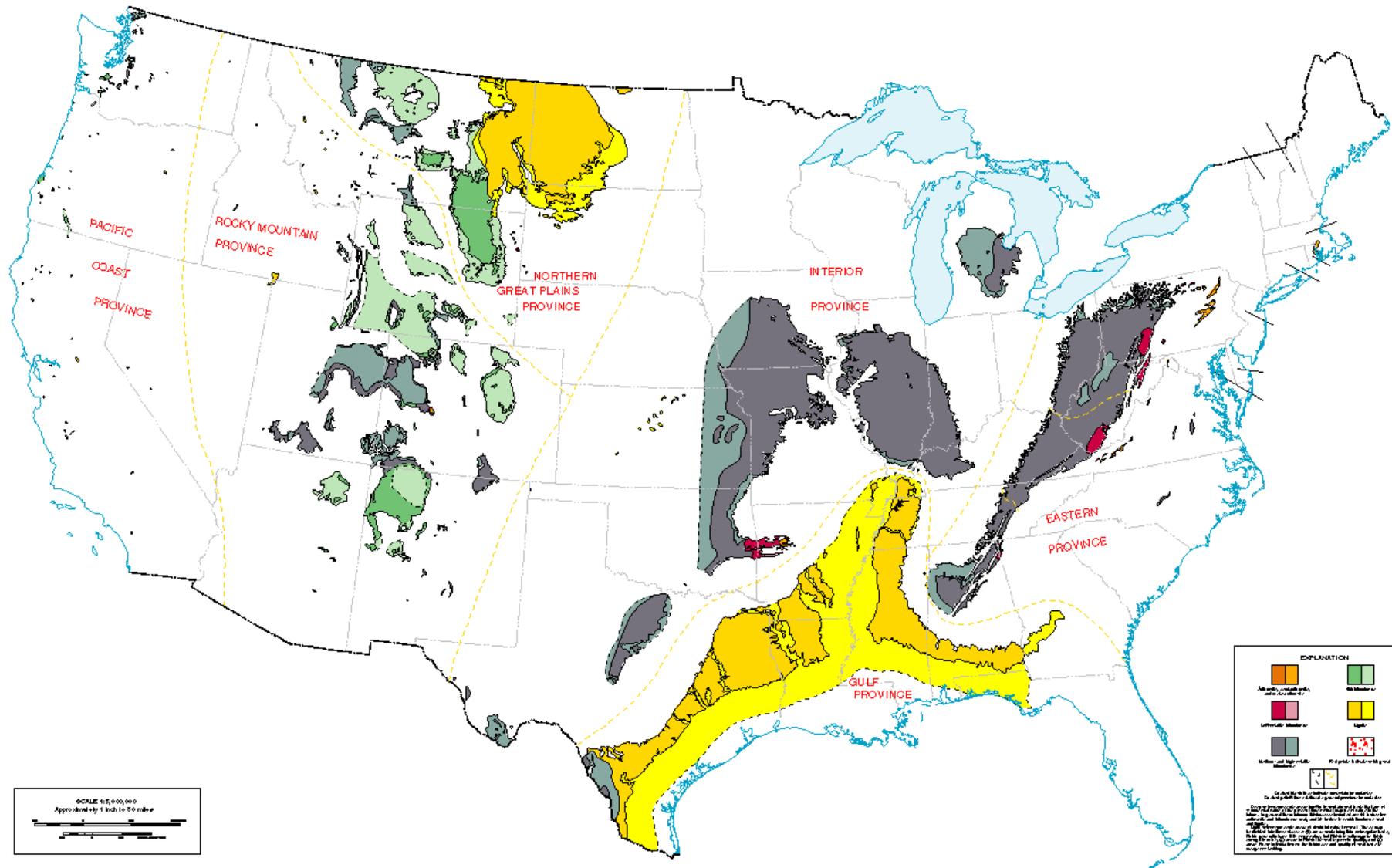
# Montana Coal Production



## GLOBAL COAL DISTRIBUTION



Adapted from Landis and Weaver, 1993, "Hydrocarbons From Coal," AAPG. Areas are approximate. Basins labeled contain >200 billion tonnes.





Bridger Range:  
Limestones as  
"sink" for CO<sub>2</sub>





South Cascade Glacier in  
Washington



# Sea Ice Minimum

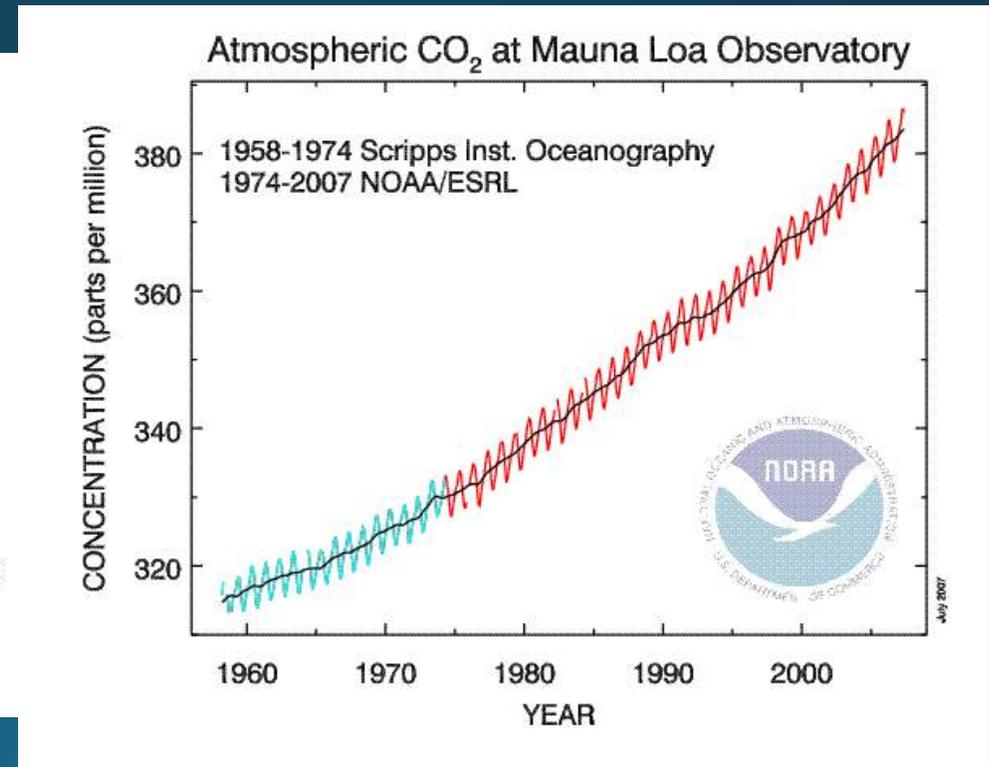
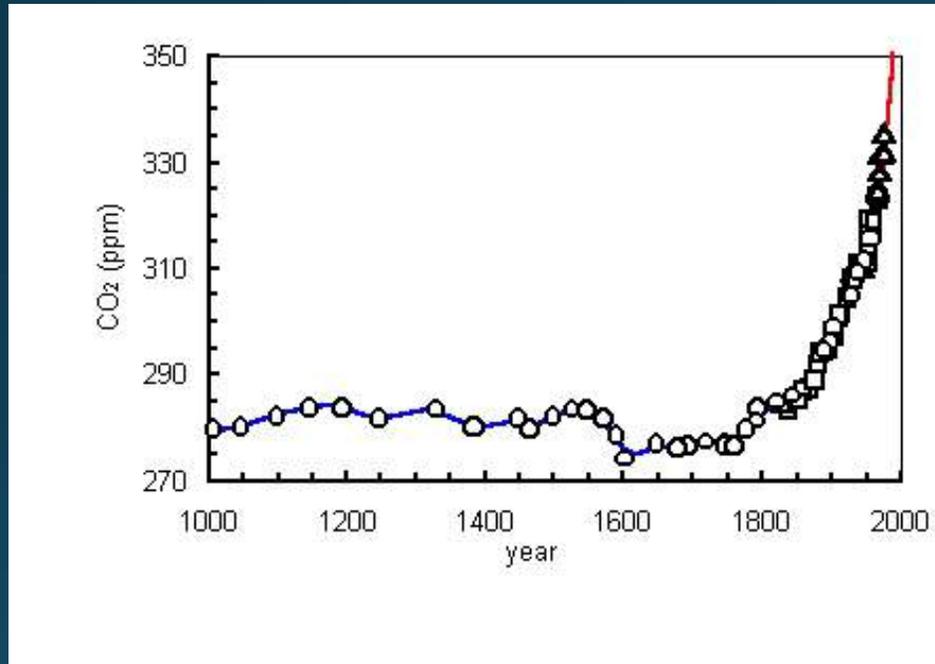
Sea Ice Minimum 1979



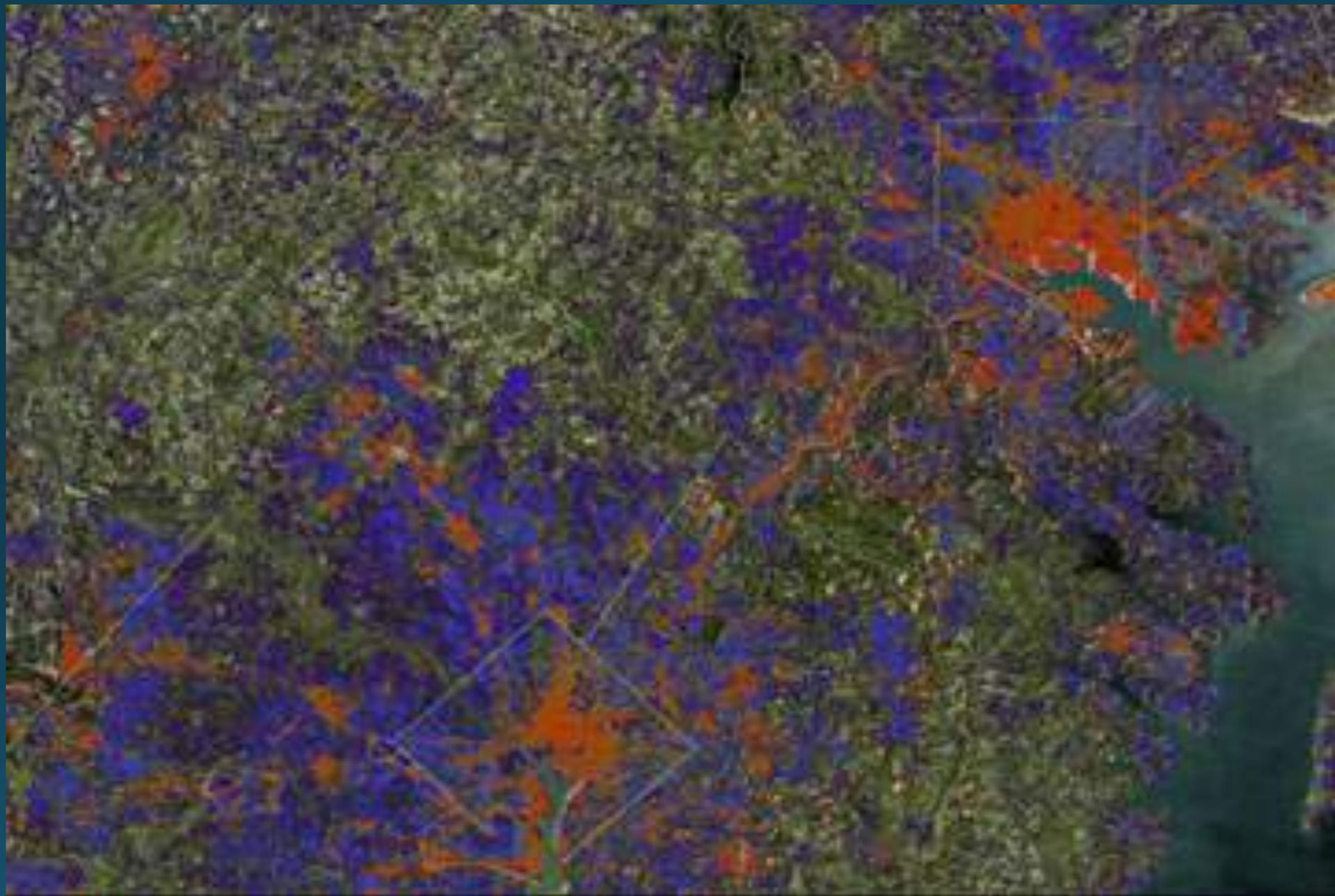
Sea Ice Minimum 2005



# “Keeling Curve” CO<sub>2</sub> Increase in Atmosphere



Visit <http://350.org/>



# 3 Gorges Dam



## Three Gorges Dam on the Yangtze River, China



Landsat Thematic Mapper  
Acquired April 17, 1987



Landsat Enhanced Thematic Mapper Plus  
Acquired May 14, 2000



Landsat Enhanced Thematic Mapper Plus  
Acquired May 9, 2004



# Are we now living in the Anthropocene?

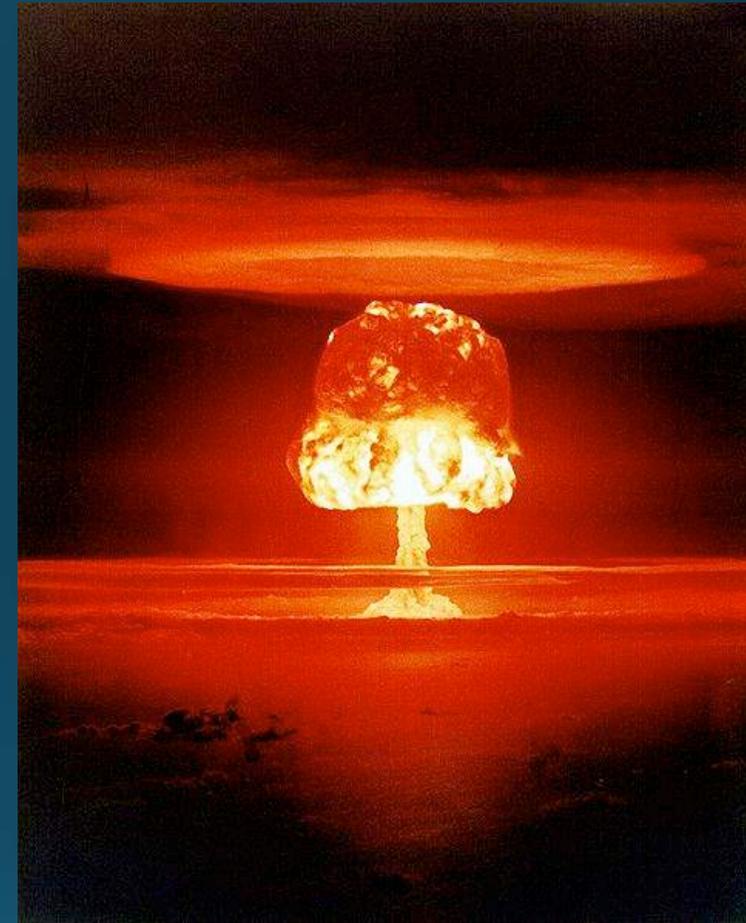
:...since the start of the Industrial Revolution, Earth has endured changes sufficient to leave a global stratigraphic signature distinct from that of the Holocene or of previous Pleistocene interglacial phases, encompassing novel biotic, sedimentary, and geochemical change.

- HUMAN INFLUENCE ON HOLOCENE CLIMATE AND ENVIRONMENT
- BIOTIC CHANGE
  - Extinction, changing habitat, invasive species, increased rate of mutagenesis.



- “Nature is neutral. Man has wrested from nature the power to make the world a desert or make the deserts bloom. There is no evil in the atom; only in men's souls.”
  - --Adlai Stevenson

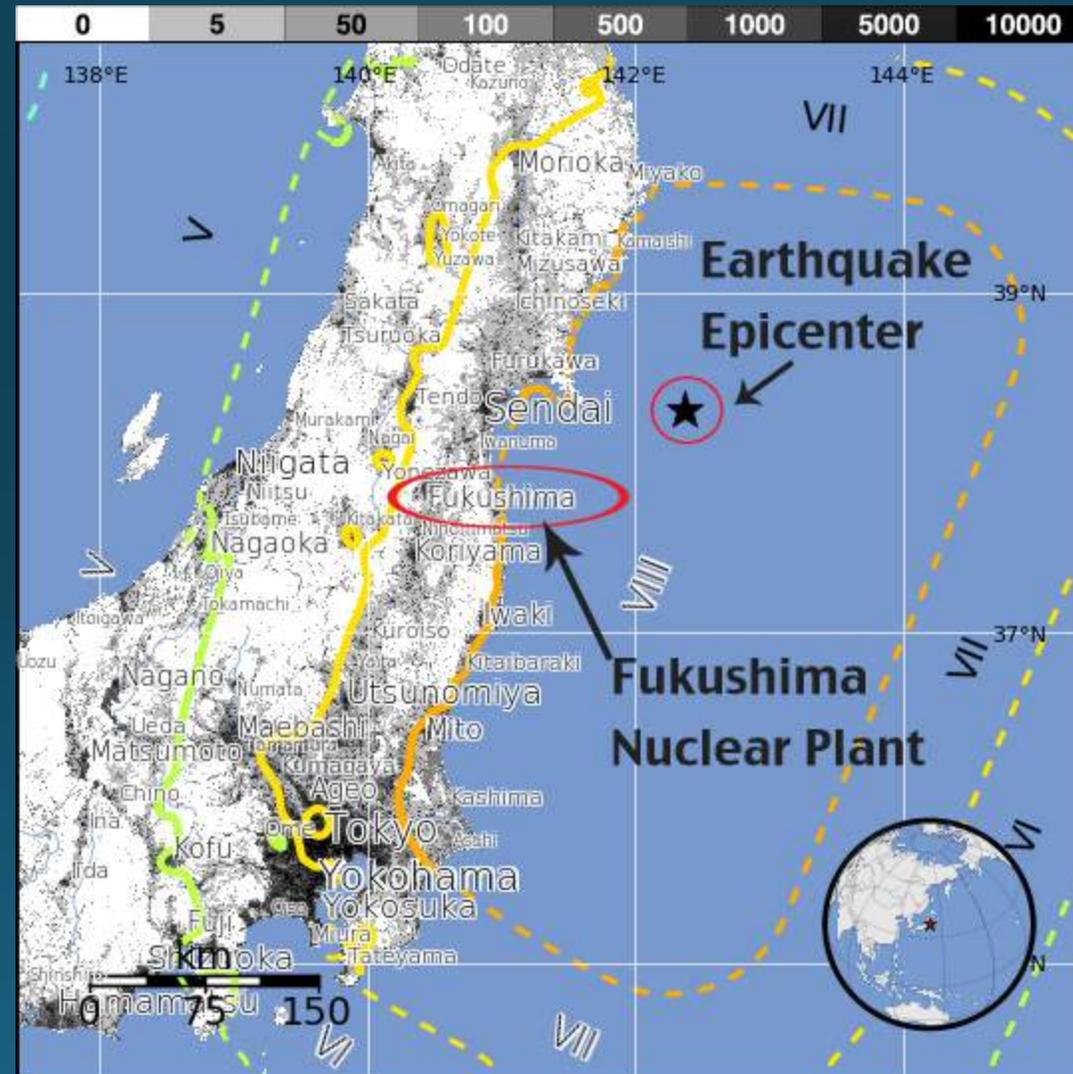
We have the power to change nature.  
Perhaps we should have the wisdom to  
stop and say: “But, should we?”



# Nuclear Accidents



# Nuclear Power after Fukushima

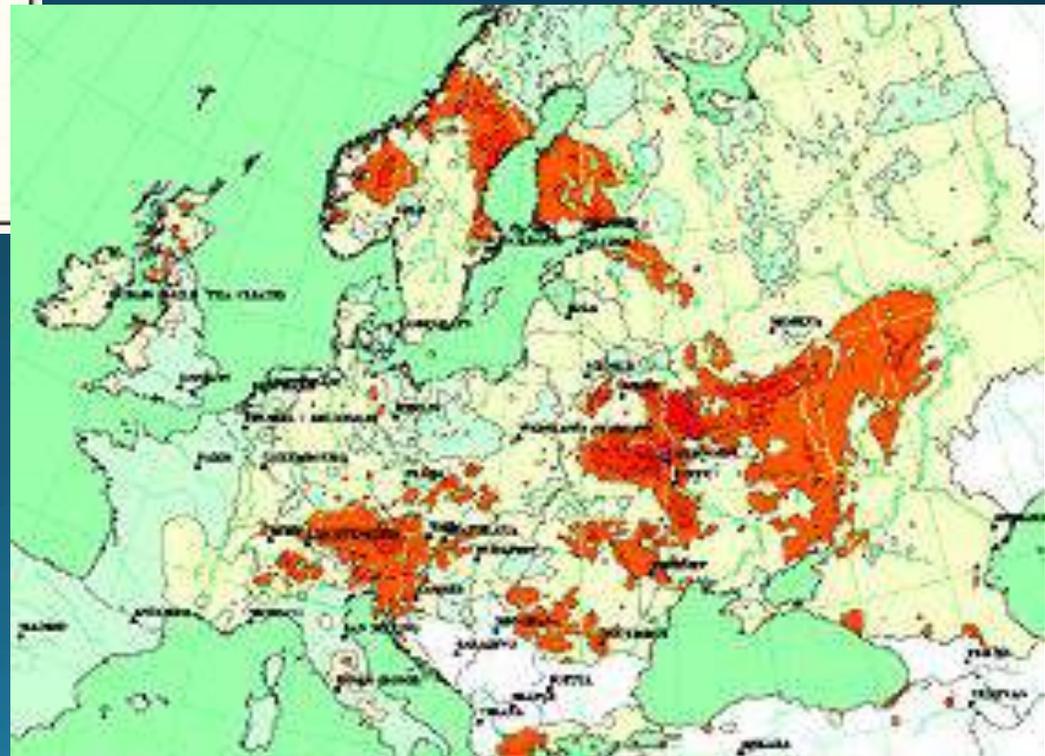


# Japan (2011)





Chernobyl



# Survival: a key driver of Geoethics

- With what temerity do we presume to control natural systems?
- Will human hubris be the destruction of society?
- Rather than Save the Planet , we should rather be rallying to Save Humanity.

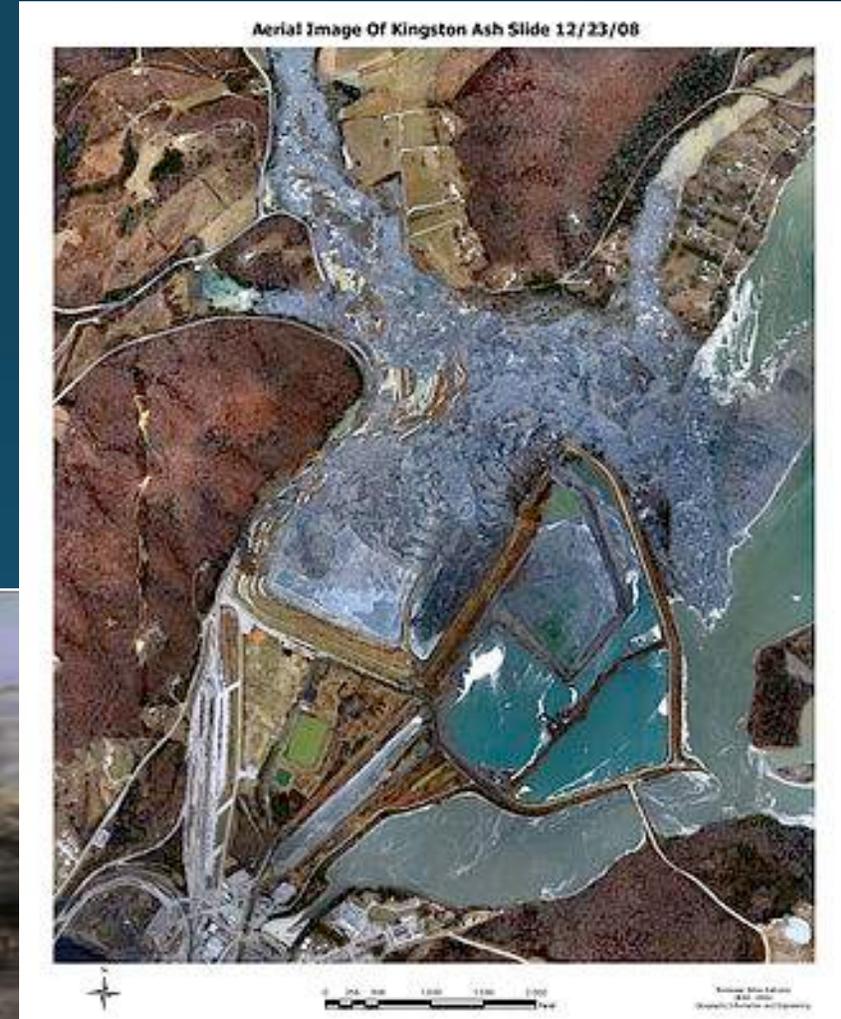
Civilization exists by geologic consent,  
subject to change without notice.

--Will Durant

What's wrong with this picture?



The **TVA Kingston Fossil Plant coal fly ash slurry spill** occurred just before 1 a.m. on Monday December 22, 2008, when an ash dike ruptured at an 84-acre (0.34 km<sup>2</sup>) solid waste containment area at the Tennessee Valley Authority's Kingston Fossil Plant in Roane County, Tennessee, USA. 1.1 billion US gallons (4,200,000 m<sup>3</sup>) of coal fly ash slurry was released.



Or these:



# Hanford Nuclear Reservation



# Social Responsibility

- Responsibility of Science

AAAS believes that, if the U.S. is to respond effectively to the challenges of the 21 st century, we must find ways to reorganize our science and technology enterprise to

- address tomorrow's needs and aspirations:
- maintaining global sustainability,
- improving human health,
- addressing economic disparities,
- understanding our place in the universe,
- promoting peace and security, and
- directing the products of technology toward the betterment of society, nationally and worldwide".

<http://research-ethics.net/topics/social-responsibility/#summary>

**SCIENCE**

# Exxon Mobil Accused of Misleading Public on Climate Change Risks

By **JUSTIN GILLIS** and **JOHN SCHWARTZ** OCT. 30, 2015

More than 40 of the nation's leading environmental and social justice groups demanded a federal investigation of Exxon Mobil on Friday, accusing the huge oil and gas company of deceiving the American public about the risks of climate change to protect its profits.

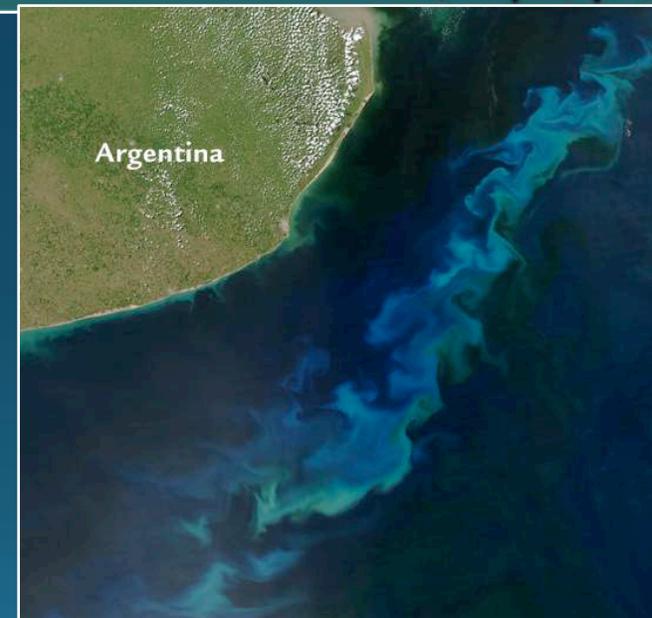
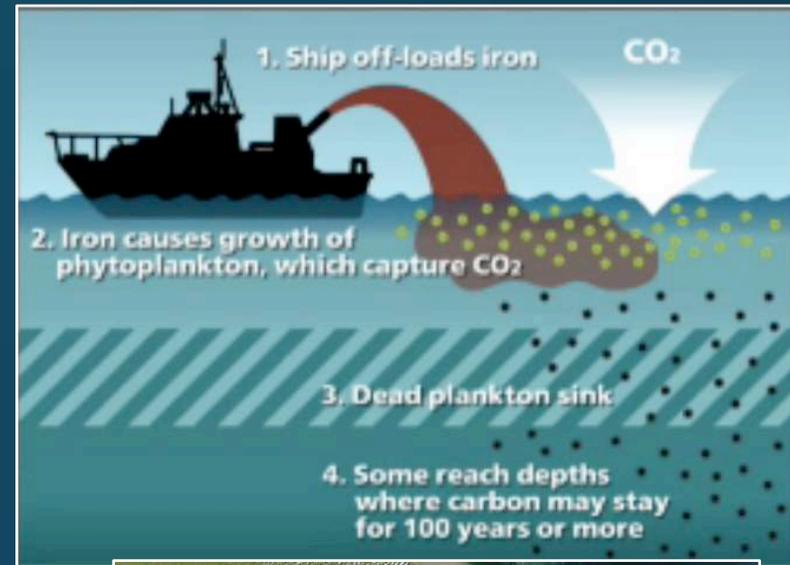
# Scientific Research and the Public Trust

- Society trusts that scientific research results are an honest and accurate reflection of a researcher's work ([Committee on Science, Engineering and Public Policy 2009](#): ix).
- Society trusts that funding is used appropriately and ethically.
- The public must be able to trust the science and scientific process informing public policy decisions ([Obama 2009](#)).
- The mission of the NIH Public Trust Initiative (PTI) is to enable the public to understand and to have full confidence in the research that NIH conducts and supports across the country and throughout the world ([National Institutes of Health 2010](#)).
- Academic medicine is entrusted by society with the responsibility to undertake several important social missions toward improving the health of the public, including education, patient care, and research. This trust is given implicit authority by generous public funding and considerable autonomy ([Schroeder et al 1989](#): 803).

# Geoengineering

Are you prepared:

- To make the decision?
- To accept the consequences?
- Ask: And then what?  
(Garrett Hardin, Filters Against Folly)
  - Chaos: Sensitive dependence on initial conditions



<https://geoengineering2012.wordpress.com/category/geo-engineering/>

<http://www.whoi.edu/oceanus/feature/fertilizing-the-ocean-with-iron>

# Preservation v. Conservation

“...in Wildness is the preservation of the world”.

H.D. Thoreau, “Walking”

“...a man is rich in proportion to the number of things he can afford to let alone.”

H. D. Thoreau

“Where I lived and What I lived for”

# Aldo Leopold—The Land Ethic

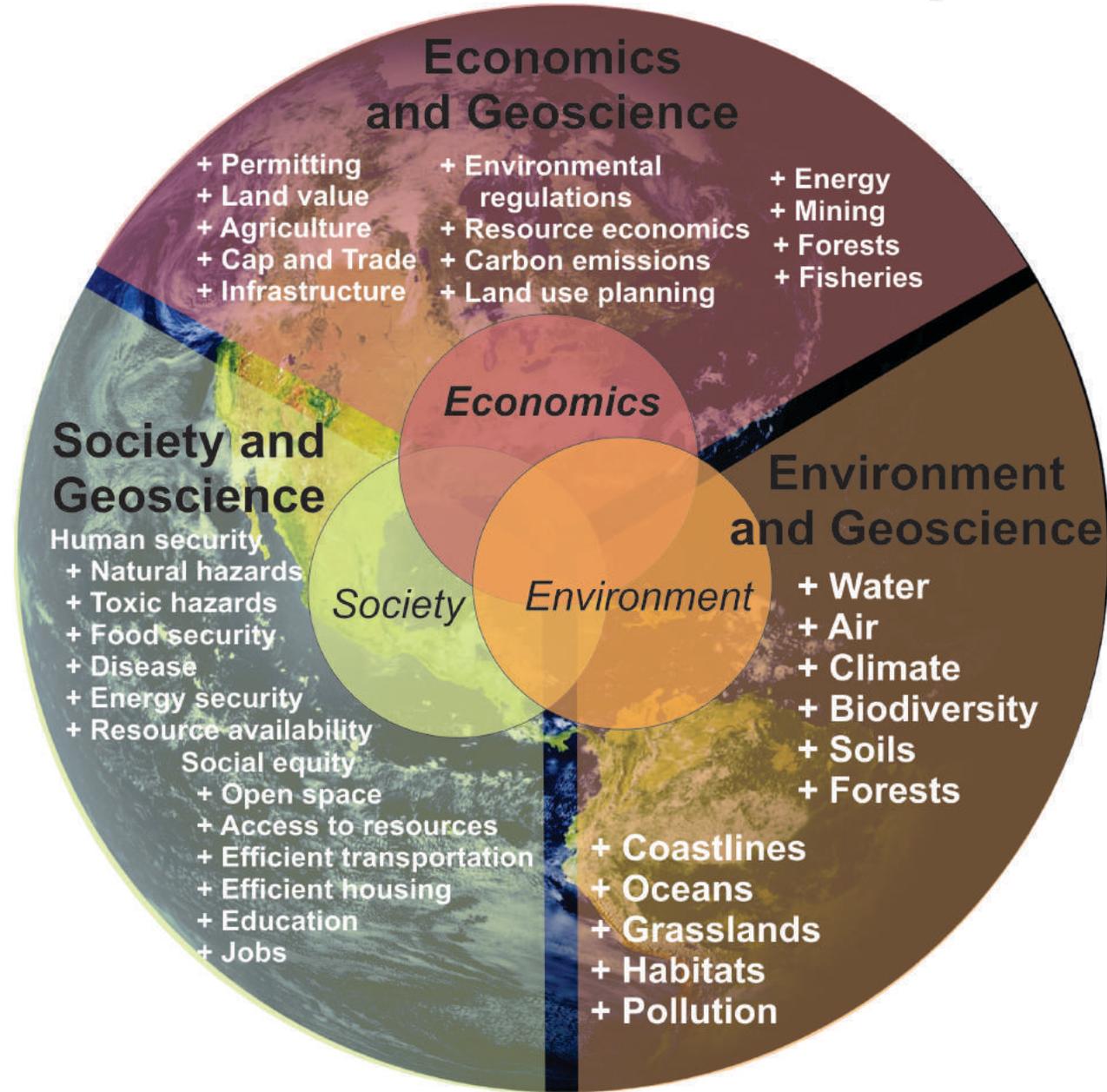
- The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land.”
- “That land is a community is the basic concept of ecology, but that land is to be loved and respected is an extension of ethics.”
- “We can be ethical only in relation to something we can see, feel, understand, love, or otherwise have faith in.”

*"In a sustainable world, human needs would be met without chronic harm to the environment and without sacrificing the ability of future generations to meet their needs. This incorporates four topical themes: environment, energy, materials and resilience."*

Science, Education for  
EOS v. 93, no 1, pg 1-3

Killeen, 2012, A Focus on  
Engineering, and  
Sustainability,

# Intersections of Geoscience and Sustainability



# Geoethics and Justice

- **Environmental Justice:**
  - the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.
- **Generational Justice:**
  - Stewardship and wise use of limited or non-renewable resources
  - Potentially irreversible events
- **Distributional Justice**
  - Equitable distribution of resources among those living today
  - Developed and developing countries
  - Population demographics



Press Releases

- Press Releases
- Media Advisories
- Video
- Photos
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- Archive

Share

# Interior Department Finalizes Stream Protection Rule to Safeguard Communities from Coal Mining Impacts

OFFICE OF THE SECRETARY

Updates 33-year old regulations, provides protections for communities and environment, while setting expectations for responsible mining



# An ethical dilemma from today's news:



The Senate has approved to end a regulation that prevents coal mining debris from being dumped into nearby streams

TIME

CONGRESS

## House Republicans Vote to End Rule Stopping Coal Mining Debris From Being Dumped in Streams

Matthew Daly and Kevin Freking / AP

Feb 01, 2017



Feb 3, 2017 @ 07:30 AM Forbes

# Will Undoing The Stream Protection Rule Really Help Coal?

“All Americans, from Alaska to Appalachia, deserve common sense protections for clean water, and that’s why we just can’t send our nation back in time and let the coal industry do whatever it likes,” says Earthjustice attorney Emma Cheese.

OR

The coal sector, though, has been calling the regulation hugely expensive and a job killer, potentially costing thousands of them.

**Think-Pair-Share**

Use your ethical decision making tools to address these questions

IF NOT YOU, WHO?

LOVE YOUR MOTHER!

