The Challenge of Abrupt Earth System Change

Jonathan Overpeck, The University of Arizona

Outline of talk:

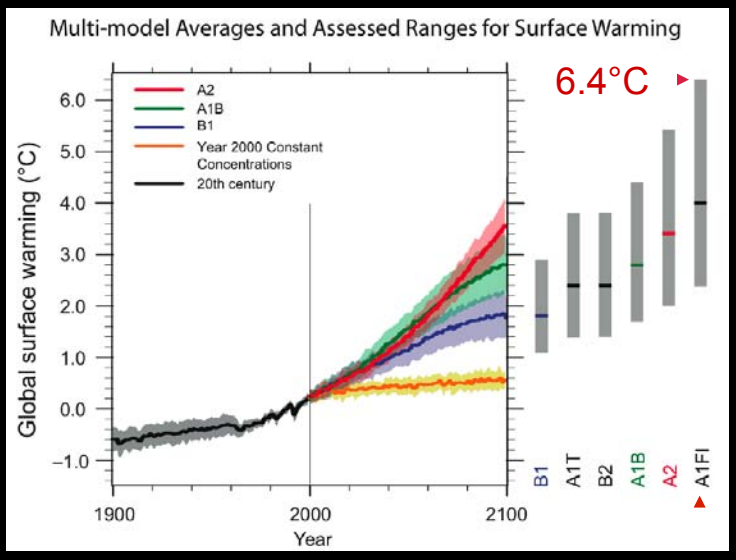
(1) First, the usual view…

(2) Alternative perspectives – gradual change versus abrupt, with examples:

- *Ocean circulation*
- *Sea level change*
- *Future of semi-arid systems*
- *Landscape change, and more…*

(3) And… time for discussion…

Future climate change depends on emissions

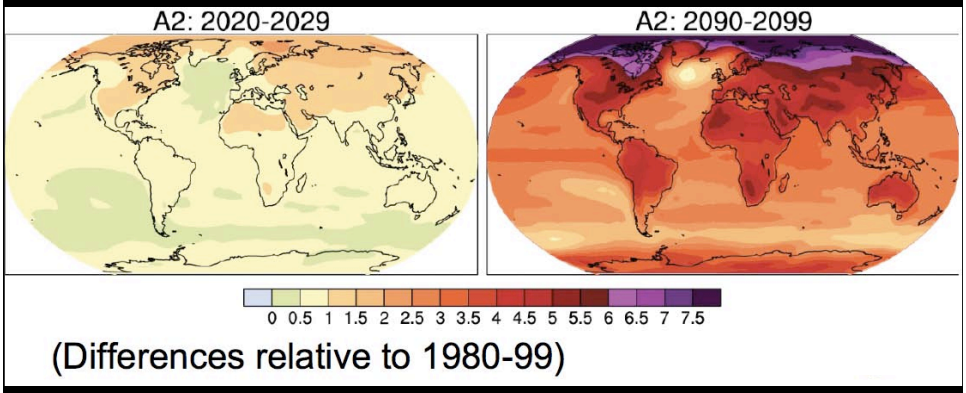


Likely warming depends on emissions scenario

Presently increasing than on the fast-track A2 scenario

IPCC, 2007

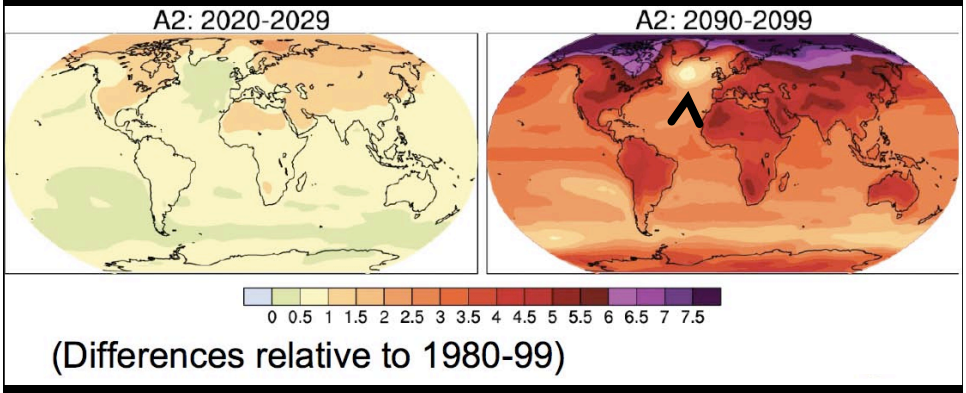
The usual view – gradual warming to a warmer world



*NOTE: A **global** average warming of up to 6°C (or more) is possible if carbon emissions are not curbed*

IPCC, 2007

The usual view – gradual warming to a warmer world



*NOTE: A **global** average warming of up to 6°C (or more) is possible if carbon emissions are not curbed*

IPCC, 2007

An alternative view…

Overpeck and Cole (2006)

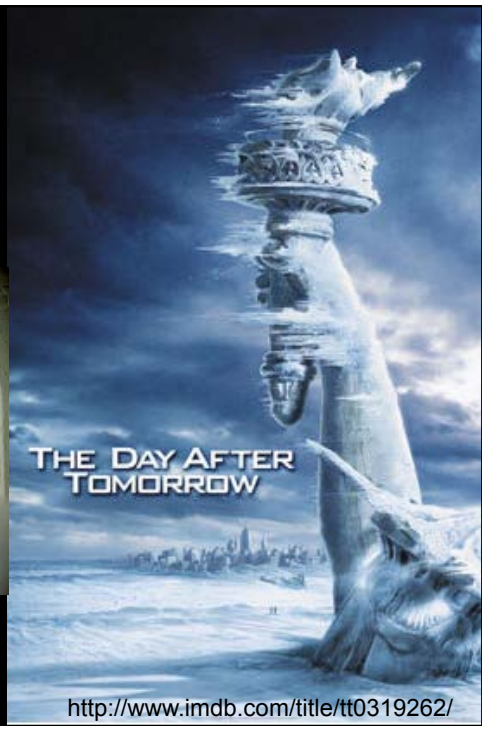
"abrupt climate-related change"

- Shifts in mean state, or **threshold changes**, that occur faster than their observed causes.
- If no cause is apparent, then an abrupt change occurs over a period that is fast relative to the duration of previous mean states (e.g., a multi-decadal drought)
- Abrupt change can also refer to a change in variability, e.g., a sudden increase in the frequency of dry or wet extremes.

AND, models might not simulate abrupt change…

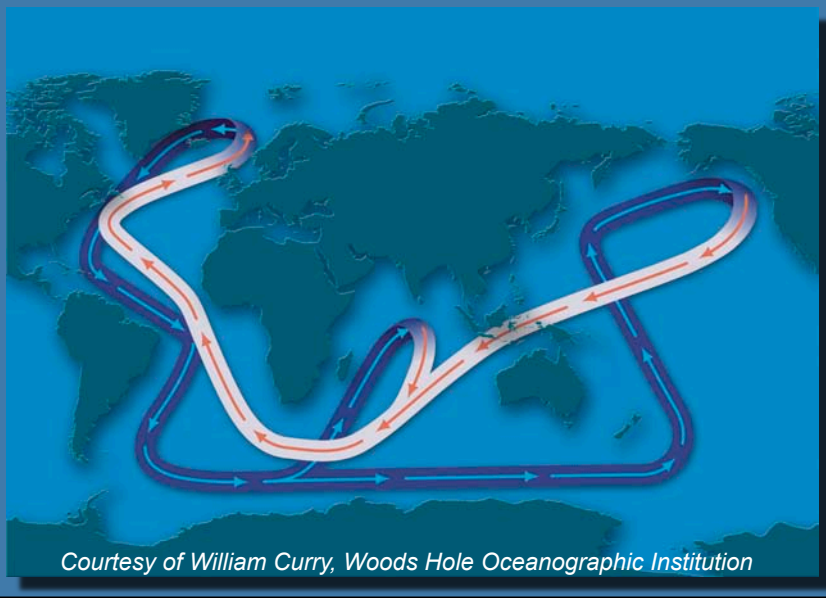
ORIGINS
The Movie…
Fact or Fiction?

Starring, glacier-leaping Paleoclimatologists!



http://www.imdb.com/title/tt0319262/

Potential shutdown (or slowdown) of the "great ocean conveyor"?



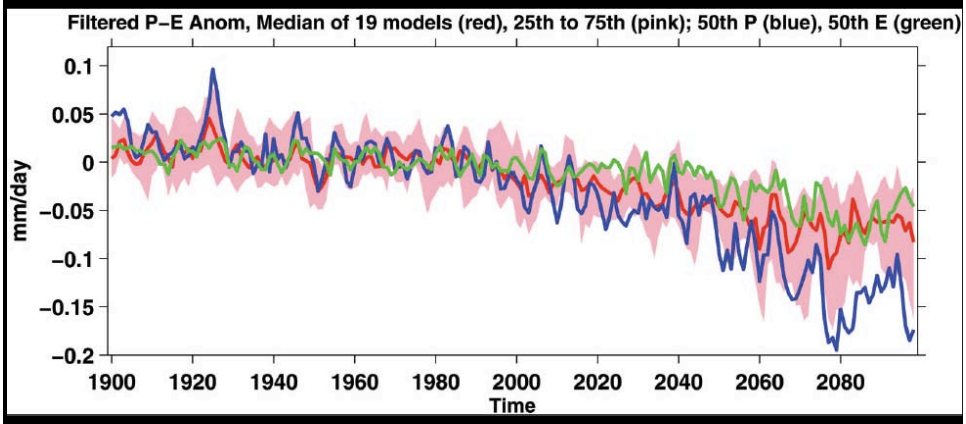
Courtesy of William Curry, Woods Hole Oceanographic Institution

Potential shutdown (or slowdown) of the "great ocean conveyor"?

- it has happened before, and could happen again
- shutdown not likely in next 100 years (but beyond??)
- SLOWdown more possible, but could take decades
- impact would include less warming downstream over Europe; and we know that the North Atlantic can affect precipitation in the West…
- another ice age? No way.

What about water on land?

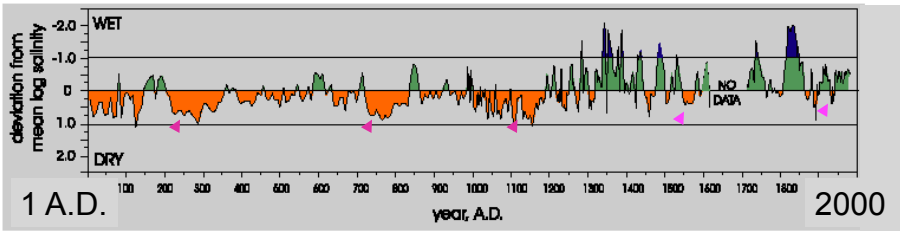
And for the Southwest? What's this?
(hint: what matters most in the SW?)



Gradual or abrupt?

Seager et al., Science 2007

2000 years in the American breadbasket…
drought is relative…



1930's dustbowl

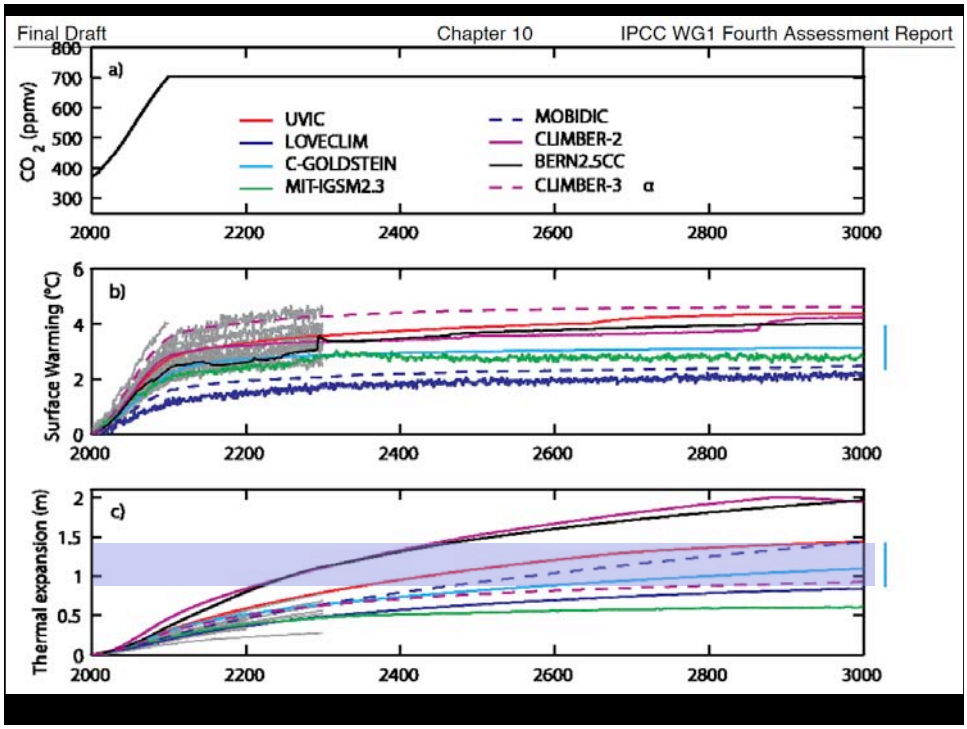
16th century "megadrought"

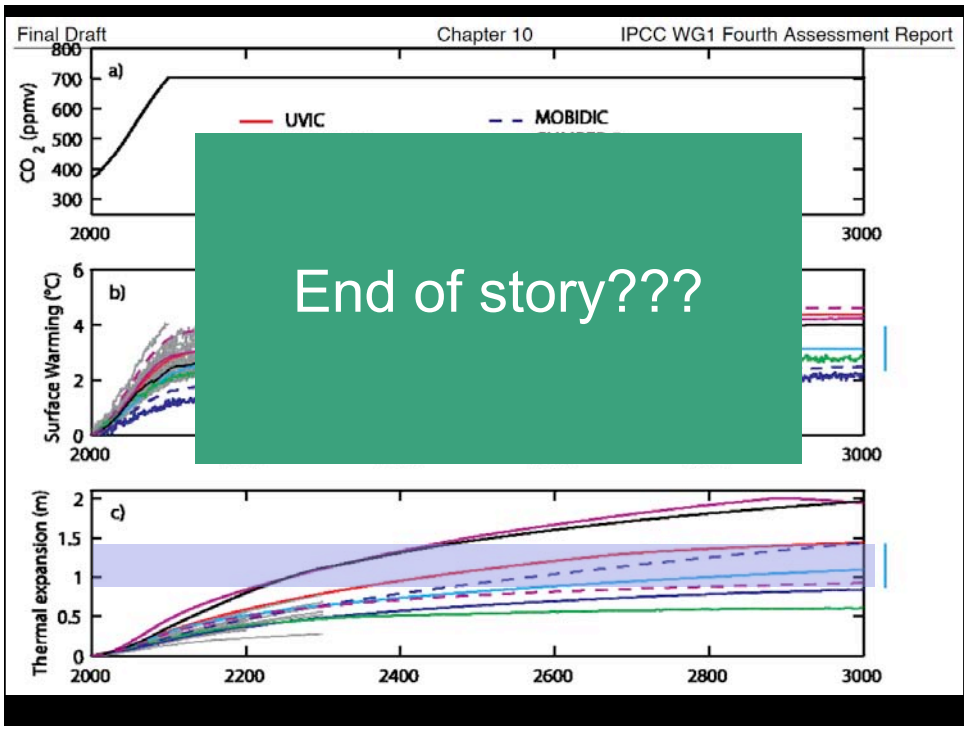
>100 year "megadroughts"

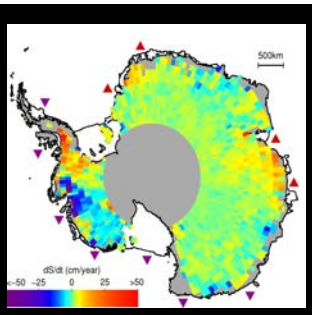
(After Laird et al., 1996, Nature)

Turning to the sea level…

And ice sheets…


Final Draft
Chapter 10
IPCC WG1 Fourth Assessment Report
a)
CO_2 (ppmv)
UVIC
LOVECLIM
C-GOLDSTEIN
MIT-IGSM2.3
MOBIDIC
CLIMBER-2
BERN2.5CC
CLIMBER-3 α
b)
Surface Warming (°C)
c)
Thermal expansion (m)
2000
2200
2400
2600
2800
3000


Final Draft
Chapter 10
IPCC WG1 Fourth Assessment Report
a)
CO_2 (ppmv)
UVIC
MOBIDIC
End of story???
b)
Surface Warming (°C)
c)
Thermal expansion (m)
2000
2200
2400
2600
2800
3000



IPCC 2007 Could not constrain possible upper end sea level rise…
anything abrupt possible?

Image sources: AAAS *Science*
Roger Braithwaite; IPCC, 2007

*What about the last time the Arctic was **3 to 4°C warmer** than today?*

129,000 to 116,000 years ago
(due to changes in the Earth's orbit rather than increases in greenhouse gases)

(Otto-Bliesner et al., and Overpeck et al., 2006, *Science)*

*What about the last time the Arctic was **3 to 4°C warmer** than today?*

129,000 to 116,000 years ago
(due to changes in the Earth's orbit rather than increases in greenhouse gases)

*Sea level was **4 to 9m** above present*

(Otto-Bliesner et al., and Overpeck et al., 2006, *Science)*

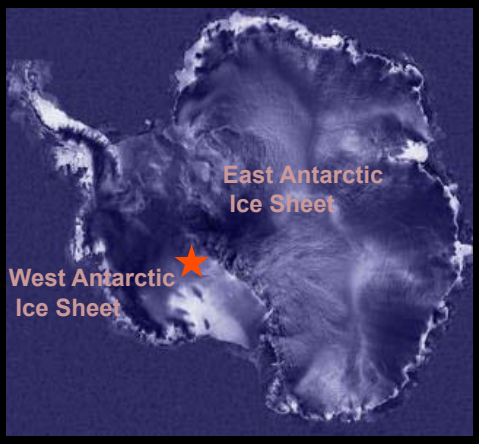
(updated by Hearty et al., 2007, *Quaternary Science Reviews*)

But Greenland can only account for 2 to 3.5 m of the 4-9m of sea level rise…

…where did the rest come from?

Today

Most likely Antarctica…



http://svs.gsfc.nasa.gov

Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise

Science, 2008

W. T. Pfeffer,[1]* J. T. Harper,[2] S. O'Neel[3]

Glacier and ice sheet dynamics: *1 to 2m (>6 feet)* is possible by 2100

0.75 to 1.9m possible by 2100

Global sea level linked to global temperature

Martin Vermeer[a,1] and Stefan Rahmstorf[b] *PNAS*, 2009

Sea level

bottomline…

1 to 2 meters per century for the next 4 to 10 centuries is possible

Pretty abrupt…

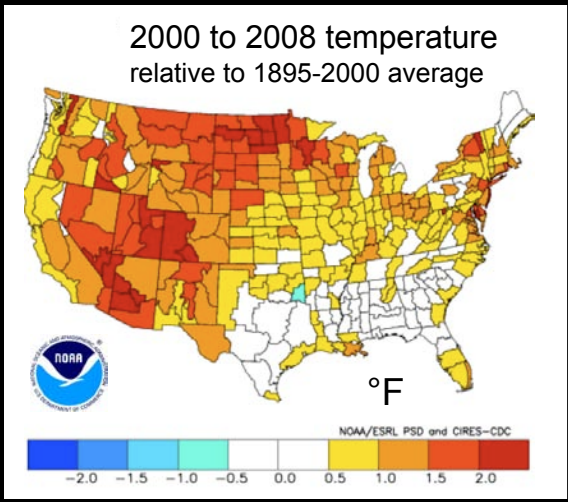
Turning to landscapes…

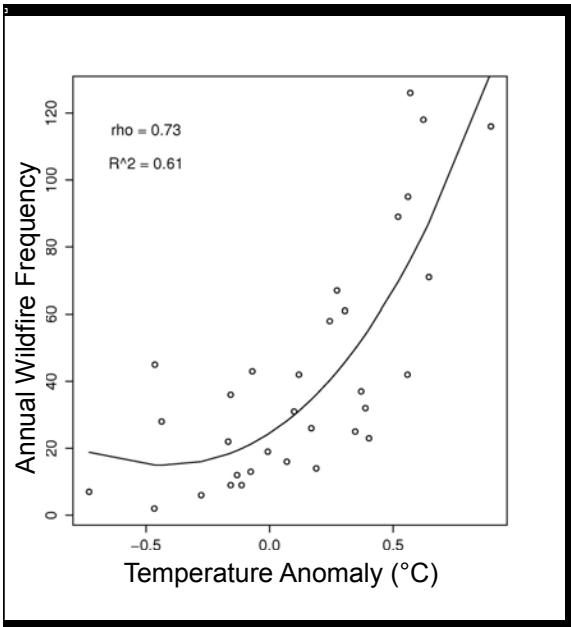
Will change be more abrupt than most think?

A key observation – the West is warming

Parts of the West have **already** warmed more than 2°F relative to average 20th century temperatures…

The U.S. Southwest is among the most rapidly warming regions of the world



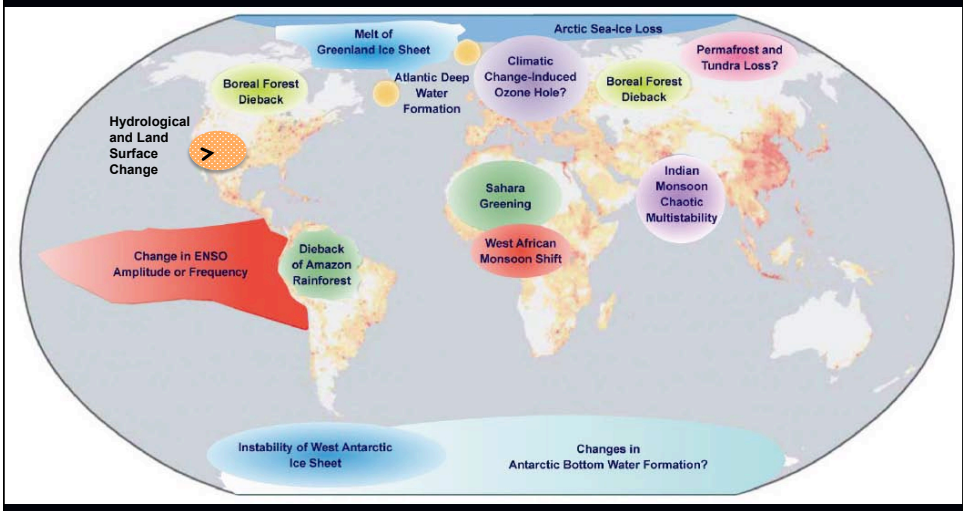


Frequency of forest wildfire (> 200 ha) in the West

Strongly associated with spring and summer *Temperature*

Westerling et al. 2006. Science vol 313, pp 940-943 - Courtesy of T. Swetnam

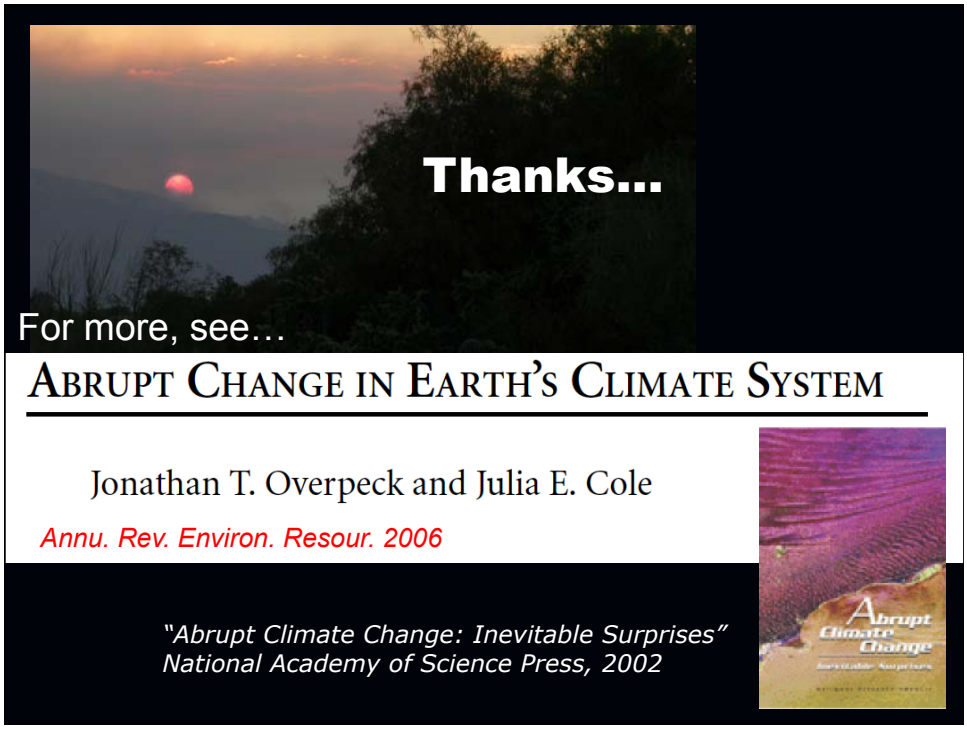
A few more abrupt change issues…



After Lenton et al., 2008, PNAS

The scientific and policy focus on abrupt change is just beginning...

- what about, and where to worry?
- when?
- are abrupt "tipping points" predictable?
- how can we make society less vulnerable to abrupt change? (e.g., we CAN i.d. places/ systems that are likely to change abruptly)
- is there a level beyond which climate change becomes dangerous? What level?


Thanks…
For more, see…
ABRUPT CHANGE IN EARTH'S CLIMATE SYSTEM
Jonathan T. Overpeck and Julia E. Cole
Annu. Rev. Environ. Resour. 2006
"Abrupt Climate Change: Inevitable Surprises"
National Academy of Science Press, 2002
Abrupt Climate Change