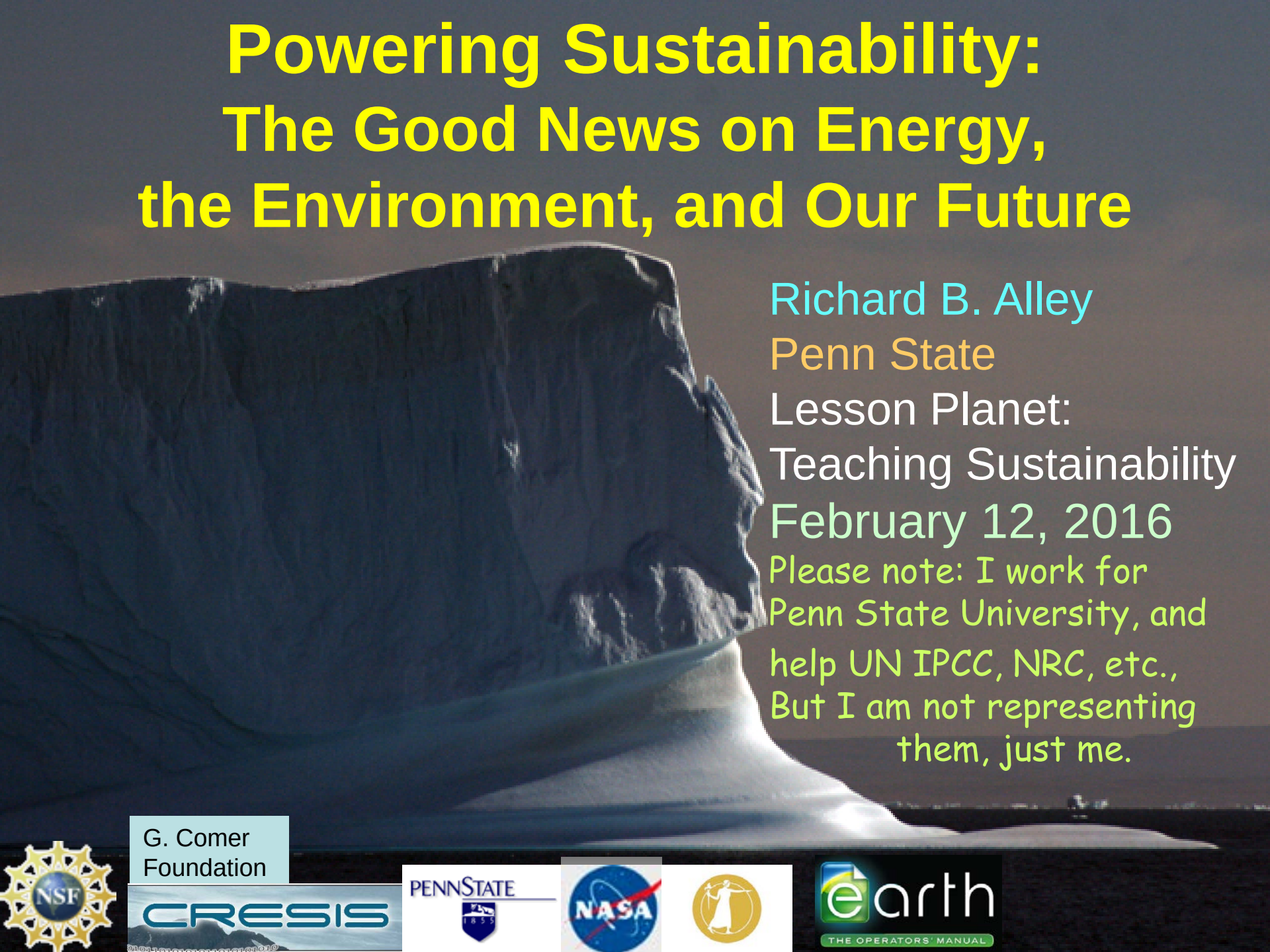
Powering Sustainability:
The Good News on Energy, the Environment, and Our Future



Richard B. Alley
Penn State

Lesson Planet:
Teaching Sustainability
February 12, 2016

Please note: I work for Penn State University, and help UN IPCC, NRC, etc., But I am not representing them, just me.

G. Comer Foundation


earth
THE OPERATORS' MANUAL
G. Comer Foundation
NASA
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Thanks to Sophia McClennen, Sarah Lyall-Combs, Mary Price, The Center for Global Studies, and you for coming today.


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Skinny version:
Using our knowledge on climate and energy wisely can help economy, environment, and ethics

"Stuff", skills, energy do us good

- We love the good we get from fossil fuels
- Can see this by looking at a bit of history
- A few years back, some of us did, on a Penn State national parks trip
- We had a memorable experience…

Bottom of Grand Canyon hiking by moonlight

Left-right, CAUSE students Stephanie Shepherd, Dave Witmer, Sameer Safaya, Sam Ascah, Irene McKenna, Silver Bridge over the Colorado River

Anna Brendle (Geography staff) & Topher Yorks (WPSU videographer)

Raya Guruswami and Sam Ascah

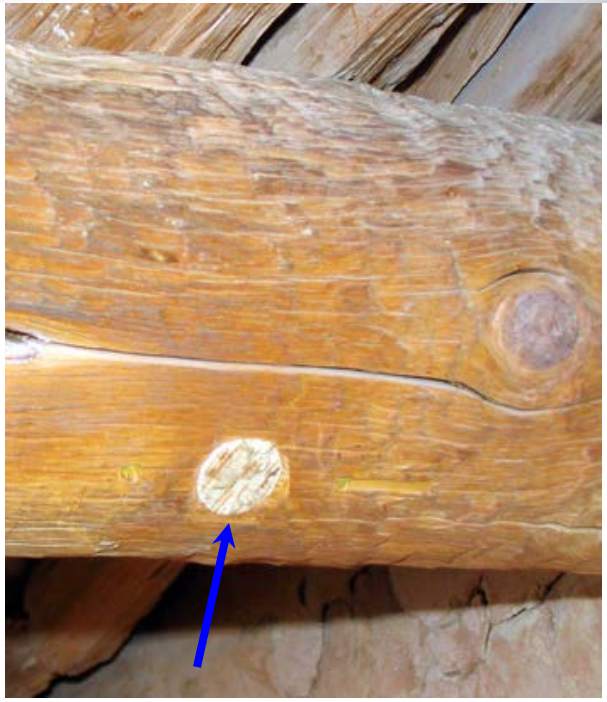
Stephanie Shepherd explains to Topher Yorks why the Colorado River, once “too thick to drink and too thin to plow”, is now clear.

"Stuff", skills, energy do us good

- Mesa Verde was especially striking
- Much more uncertainty in understanding past people than, say, the physics of radiation transfer in the atmosphere
- But much progress learning about people
- The rangers showed us fascinating things…

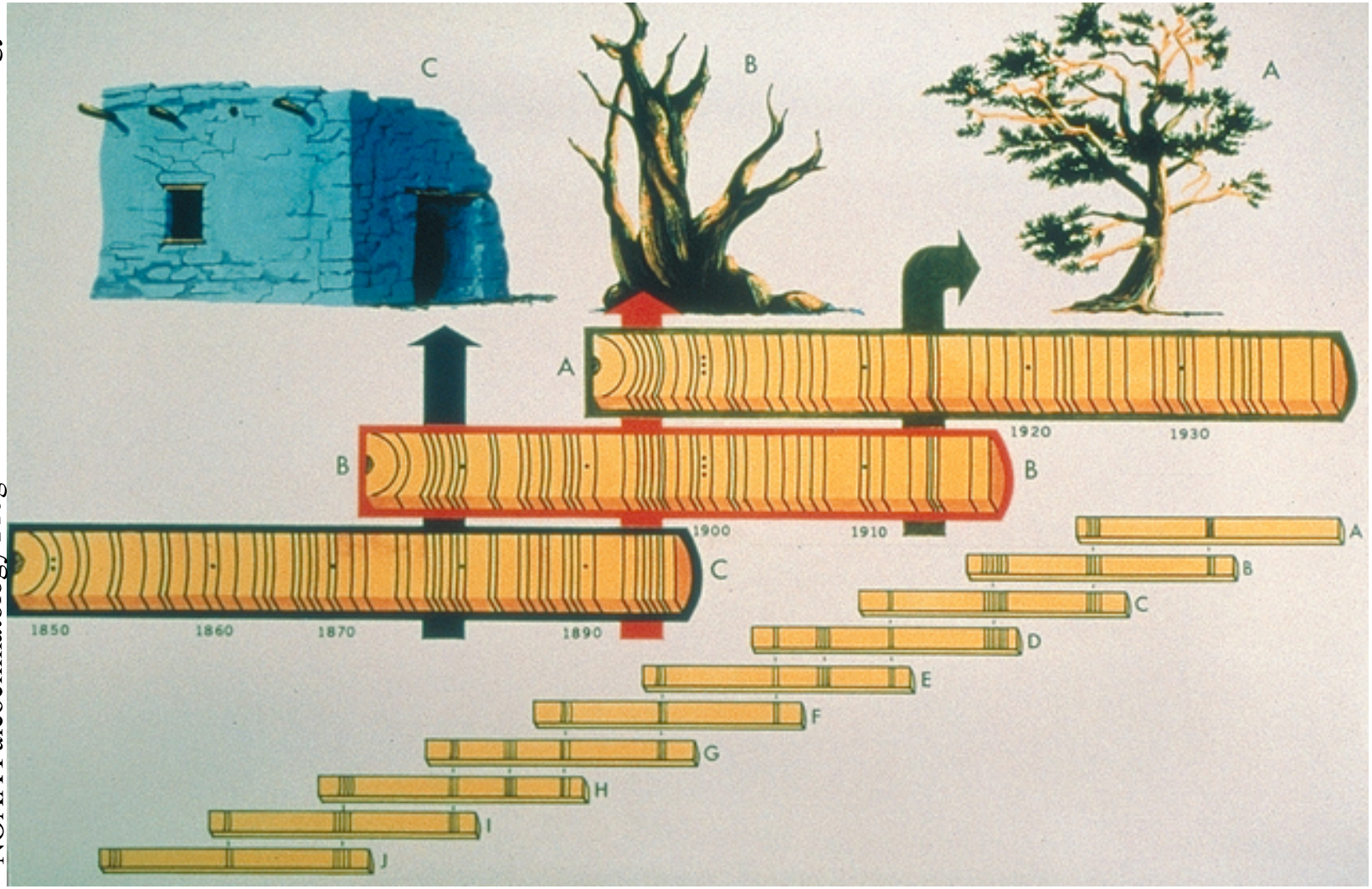
And then they left…

- Hard life in the best of times
- But looks really unpleasant at the end
- Before the site was completely abandoned
- After centuries of habitation



Museum specimen (upper right), and logs from Long House (above and right; arrow on right shows plug removed for tree-ring research and replaced by modern wood), Mesa Verde.

http://www.ncdc.noaa.gov/paleo/slides/slideset/index18.htm
Laboratory of Tree-Ring Research, The University of Arizona,
NOAA Paleoclimatology Program Slide Set on Dendrochronology

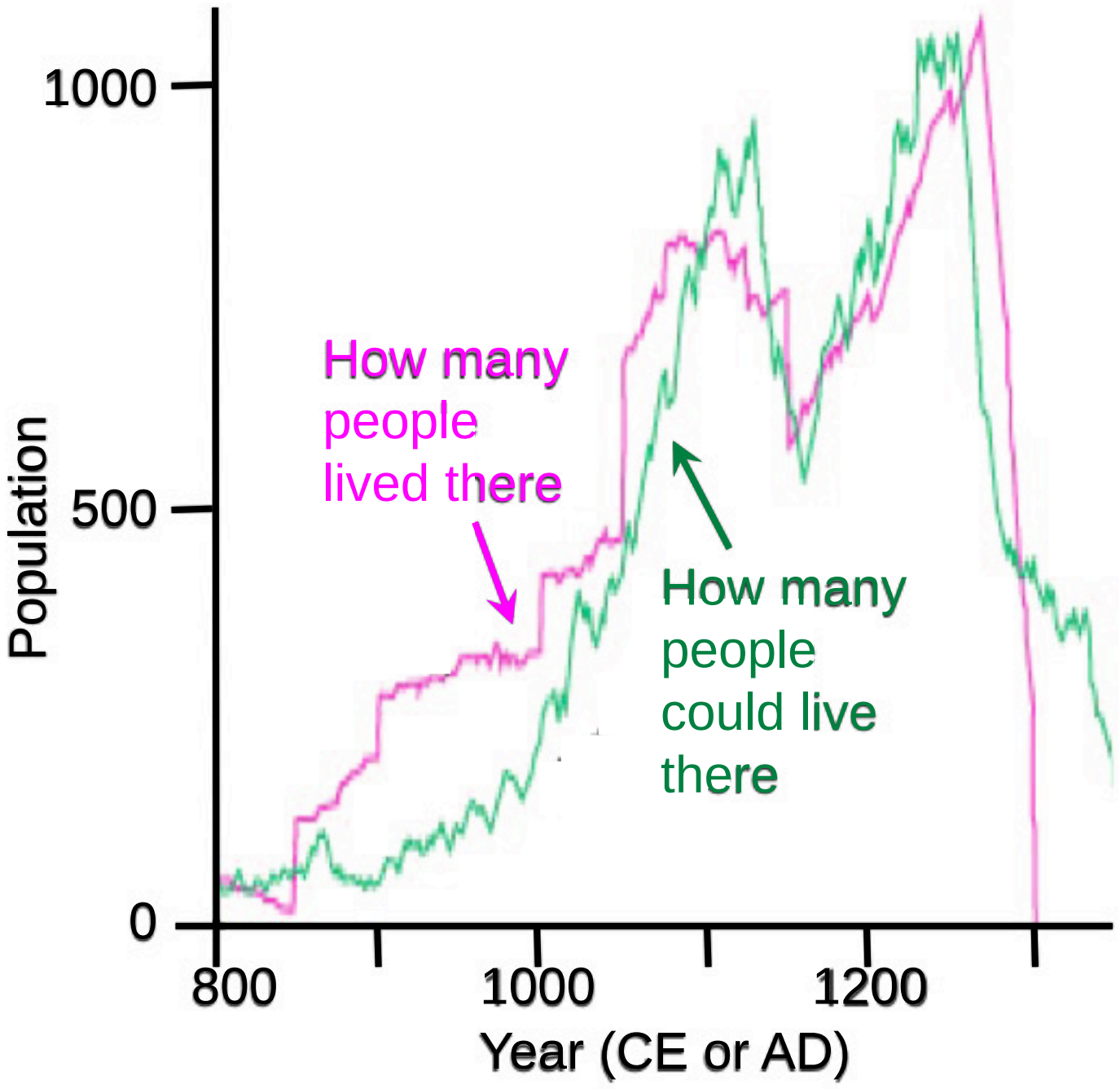


Cross-dating in tree-ring research. In this example, the pattern of thick and thin rings in a core from a living tree (A) is matched to the pattern in a dead tree (B), then to wood in a native-American site, C, and then on to other, older wood samples (D-J).

Can look at influence of climate on people

- Go to "end of the road", Long House Valley, AZ (not a big place with trade like Mesa Verde…)
- Trees grow better when wetter in this dry area
- Use age and ring-width of trees to get history of rainfall, which tells how much corn could grow
- Use corn plus knowledge of Puebloan society to estimate how many people could have lived there
- Use archaeology to estimate how many people actually lived there
- Compare…

Number of ancestral Puebloans living in Long House Valley rose during wet times and fell during droughts.

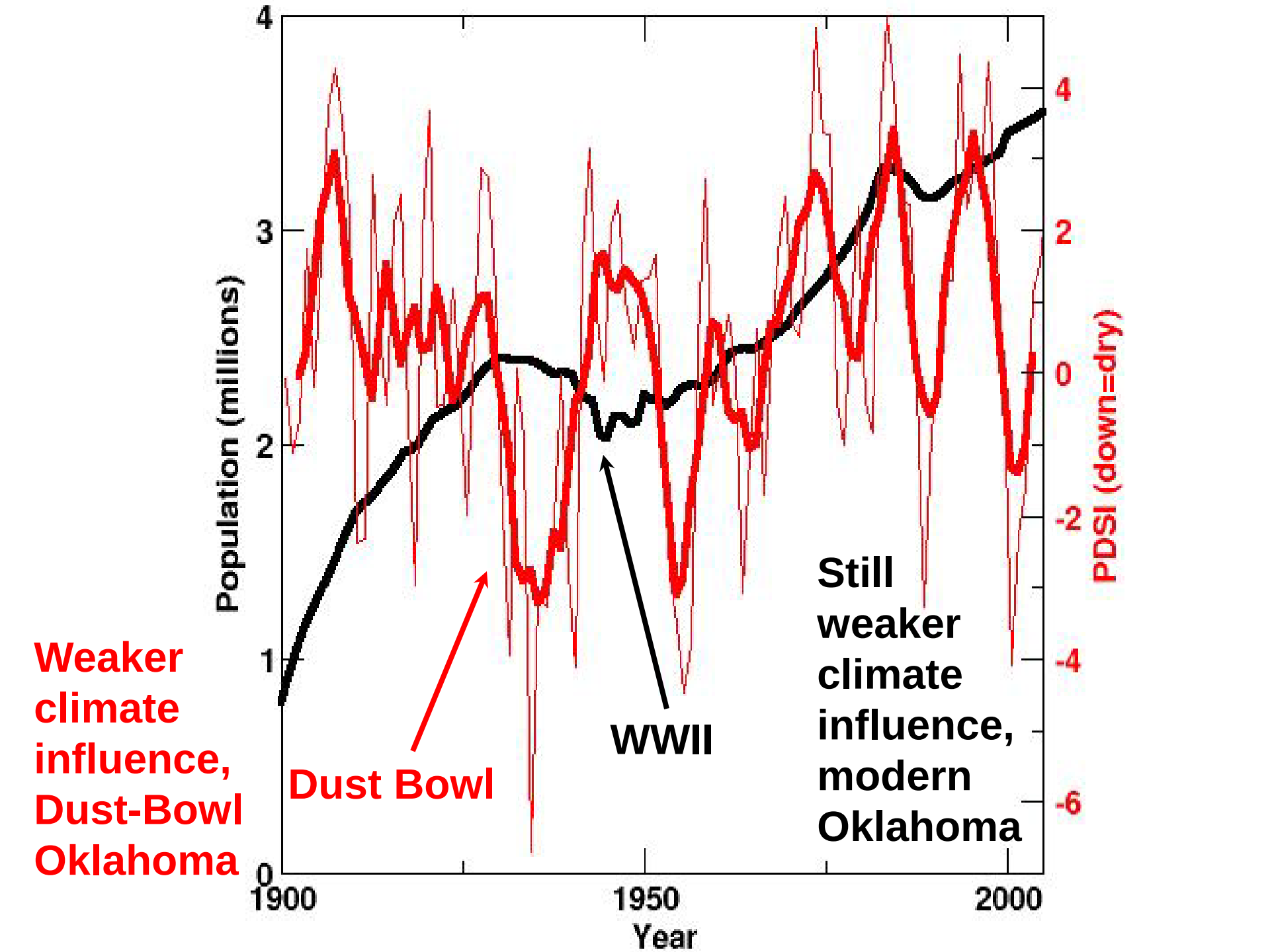


Modified from J.M. Diamond, Nature, 2002, Life with the Artificial Anasazi

More Oklahomans reach Calif. via the cotton fields of Ariz.

http://esp.cr.usgs.gov/projects/sw/dust_inventory/images/dustbowl_truck.gif

http://www.photolib.noaa.gov/bigs/wea01422.jpg


Weaker climate influence, Dust-Bowl Oklahoma
Dust Bowl
WWII
Still weaker climate influence, modern Oklahoma
Population (millions)
PDSI (down=dry)
Year
0
1
2
3
4
-6
-4
-2
0
2
4
1900
1950
2000

Lots of smart, hard-working people in Oklahoma, and at Mesa Verde, too!

- But failed at Mesa Verde, succeeded in OK
- Difference is knowledge, tools and energy—learning and teaching, building and sharing
- Science and engineering work—world was overpopulated with a few million hunter-gatherers, but we are a few billion now
- A cell phone is just a bit of oil, and sand, and the right rocks… plus Einstein and Bohr, science and engineering, design and marketing
- Many issues in moving forward (Water, food, …)

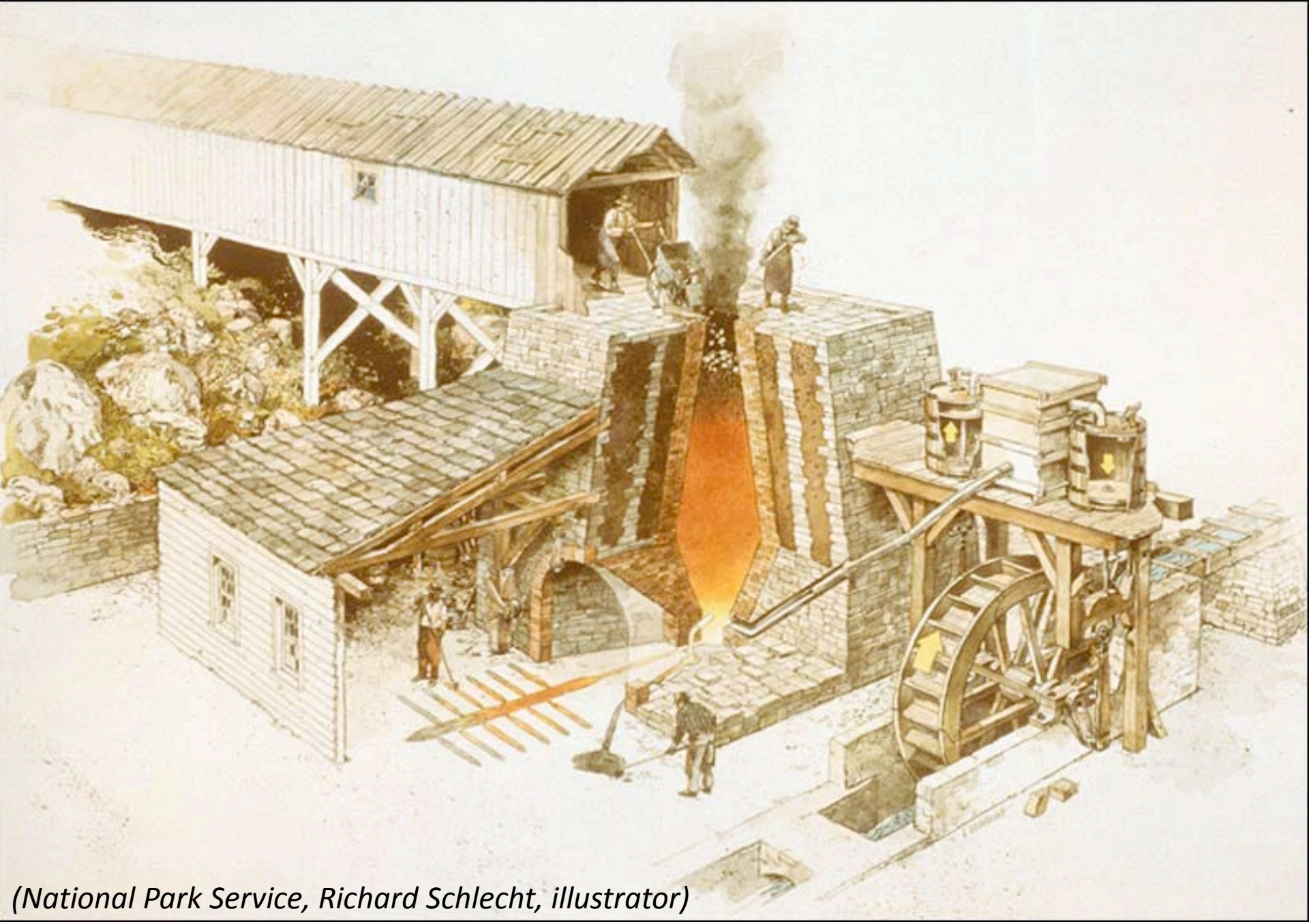
Energy

- You eat about 2000 Calories per day;
- You use over 240,000 Calories per day;
- Like having 100+ serfs to do your bidding;
- Driving, heating, cooling, pumping, plowing, trucking, flying, cooking…
- Most from oil, coal and natural gas (fossil fuels) (~85% in most places)
- And we love this—it gives us much good!

Hunter-Gatherers of Energy

- We have a long history of energy crises
- Burn through a source much faster than nature makes more
- Face shortages (bringing intrusive governments and other problems)
- Find a new source to burn


Penn State
University
EXIT 1/2 MILE
SOUTH
26



(National Park Service, Richard Schlecht, illustrator)

http://www.cr.nps.gov/nr/twhp/wwwlps/lessons/97hopewell/97visual1.htm

Charcoal making, US National Archives

Colliers (also spelled colyers) preparing to make charcoal for use in iron furnaces. This pile would be covered with dirt and then fired for ~2 weeks, with great care to drive off unwanted materials without burning up the wood.

Pennsylvania Historical and Museum Commission

http://www.phmc.state.pa.us/ppet/cornwall/page2.asp?secid=31

Logging for charcoal—about a square mile of trees per furnace per year to smelt the iron and fuel the workers

Photo US National Archives

Maria Furnace	Adams	Iron Springs
Mahoning Furnace	Armstrong	Distant
Buffalo Furnace	Armstrong	Worthington
Furnace Run	Armstrong	Kittanning
Stewardson Furnace	Armstrong	Templeton
McCrea Furnace	Armstrong	Distant
McCreas Furnace	Armstrong	Distant
Pine Furnace	Armstrong	Mosgrove
Pine Creek Furnace	Armstrong	Mosgrove
Old Furnace	Beaver	Zelienople
Oley Furnace	Berks	Fleetwood
Joanna Furnace	Berks	Morgantown
Etna Furnace	Blair	Spruce Creek
Springfield Furnace	Blair	Frankstown
Allegheny Furnace	Blair	Hollidaysburg
Durham Furnace	Bucks	Riegelsville
Durham Furnace	Bucks	Riegelsville
Julia Ann Furnace	Centre	Julian
Julian Furnace	Centre	Julian
Juliana Furnace	Centre	Julian
Hecla Furnace	Centre	Mingoville
Centre Furnace	Centre	State College
Martha Furnace	Centre	Port Matilda
Hanna Furnace	Centre	Port Matilda
Hannah Furnace	Centre	Port Matilda
Manda Furnace	Centre	Port Matilda
Helen Furnace	Clarion	Lucinda
Hieland Furnace	Clarion	Lucinda
Sarah Furnace	Clarion	Rimersburg
Canoe Furnace	Clarion	Knox
Saint Charles Furnace	Clarion	Sligo
Adrian Furnace	Clearfield	Falls Creek
Pine Grove Furnace	Cumberland	Dickinson
Pinegrove Furnace	Cumberland	Dickinson
Victoria Furnace	Dauphin	Halifax
Wharton Furnace	Fayette	Brownfield
Coal Spring Furnace	Fayette	Uniontown
Oliphant Furnace	Fayette	Brownfield
Furnace Hill	Fayette	South Connellsville
Lemont Furnace	Fayette	Uniontown
Franklin Furnace	Franklin	Saint Thomas
Richmond Furnace	Franklin	McConnellsburg
Rockhill Furnace	Huntingdon	Orbisonia
Union Furnace	Huntingdon	Spruce Creek
Pennsylvania Furnace	Huntingdon	Franklinville
Paradise Furnace	Huntingdon	Entriken
Huntingdon Furnace	Huntingdon	Franklinville
Monroe Furnace	Huntingdon	Pine Grove Mills
Cornwall Furnace	Lebanon	Lebanon
Cornwall Iron Furnace	Lebanon	Lebanon
Hampton Furnace	Lehigh	East Greenville
Mary Ann Furnace	Lehigh	East Greenville
Sigmumds Furnace	Lehigh	East Greenville
Sigmunds Furnace	Lehigh	East Greenville
Lehigh Furnace	Lehigh	Slatedale
Balliets Furnace	Lehigh	Slatedale
Balliots Furnace	Lehigh	Slatedale
Reeds Furnace	Mercer	Sandy Lake
Furnace Hill	Mercer	Sharon East
Lucy Furnace	Mifflin	Mount Union
Franklin Furnace	Montour	Riverside
Juniata Furnace	Perry	Newport
Old Shade Furnace	Somerset	Windber
Shade Furnace	Somerset	Windber
Old Furnace	Union	Allenwood
Alliance Furnace	Westmoreland	Dawson

Charming Forge	Berks	Strausstown
Pine Forge	Berks	Boyertown
Tyrone Forge	Blair	Tyrone
Franklin Forge	Blair	Williamsburg
Somerton Forge	Bucks	Hatboro
Moorehall at Valley Forge	Chester	Malvern
Valley Forge Meadows	Chester	Valley Forge
Valley Forge Mountain	Chester	Valley Forge
Valley Forge Mountain North	Chester	Valley Forge
Valley Forge Woods	Chester	Valley Forge
The Commons at Valley Forge	Chester	Valley Forge
Meadows at Valley Forge	Chester	Valley Forge
Valley Forge	Chester	Valley Forge
Ellendale Forge	Dauphin	Enders
Old Forge	Franklin	Iron Springs
Colerain Forge	Huntingdon	Franklinville
Barree Forge	Huntingdon	Alexandria
Old Forge	Lackawanna	Avoca
Martic Forge	Lancaster	Conestoga
Mews at Valley Forge	Montgomery	Collegeville
Forge Spring Village	Montgomery	Norristown
Valley Forge Homes	Montgomery	Norristown
Valley Forge Acres	Montgomery	Norristown
Valley Forge Trailer Park	Montgomery	Valley Forge
Providence Forge	Montgomery	Phoenixville
Valley Forge Estates	Montgomery	Valley Forge
Valley Forge Towers	Montgomery	Valley Forge
The Colony at Valley Forge	Montgomery	Collegeville
Valley Forge	York	York

PA place names “Furnace” and “Forge”—and there were more—Greenwood Furnace not on here, for example. Almost 1 square mile of trees per year for a fully functioning furnace (charcoal for iron making plus wood for workers).

http://pennsylvania.hometownlocator.com/

http://www.smithsonianmagazine.com/multimedia/rich-media/0206-forgotten-forest/index.php

© Lois Barden Collection

http://www.explorepahistory.com/ (Pennsylvania State Education Association)

Settlers cut almost all Pennsylvania trees, often for fuel, losing all (elk, bison, fisher, mountain lion), or almost all (deer, turkey) large wildlife.

Penn's Woods-->Pennsylvania "Desert" (**and not just Pennsylvania!**)

After Bardi, 2004; data from A. Starbuck, History of the American whale fishery, Seacaucus, N.J. 1878

Price

Production

First modern oil well

Whale oil (million gallons)

15

0

Price/gallon (in 2003 $)

20

10

0

1800

1820

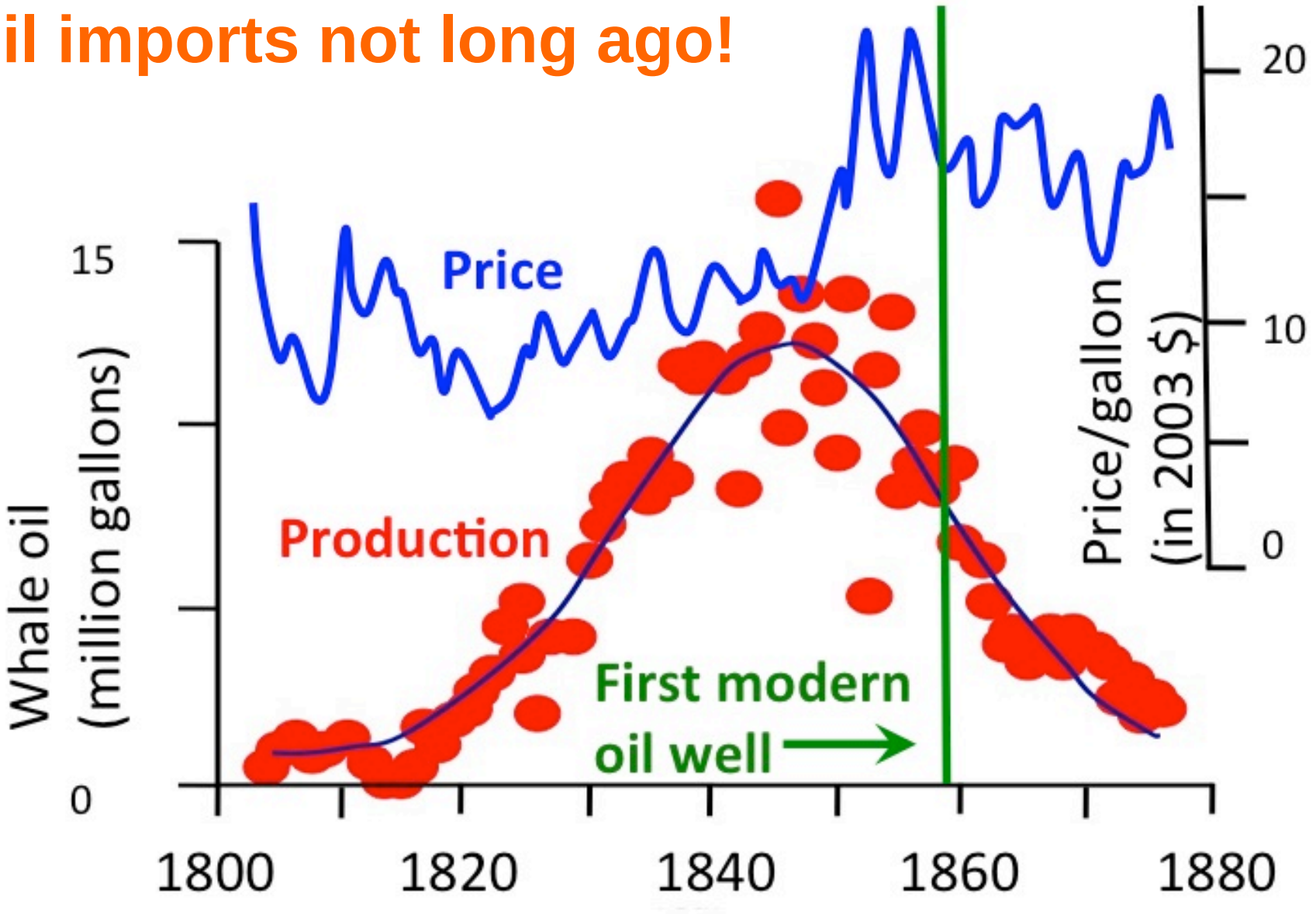
1840

1860

1880

http://www.loc.gov/pictures/item/2002698808/Currier and Ives, Whale Fishery: Attacking a right whale, Library of Congress

We can’t go back—total US whale-oil production in 1800s about 1 week of US oil imports not long ago!



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“GRAND BALL GIVEN BY THE WHALES IN HONOR OF THE DISCOVERY OF THE OIL WELLS IN PENNSYLVANIA”, VANITY FAIR, 1861

Fossil Fuels Will "Run Out":

- Yes, economists hate that term
- But realistically, scarcity is coming
- We are using ~1 million times faster than nature saved them for us
- Per year in US, we each discard ~½ ton household trash, ~20 tons CO_2
- First modern oil well drilled where oil leaking from ground…
- But, a lot left, and they release CO_2

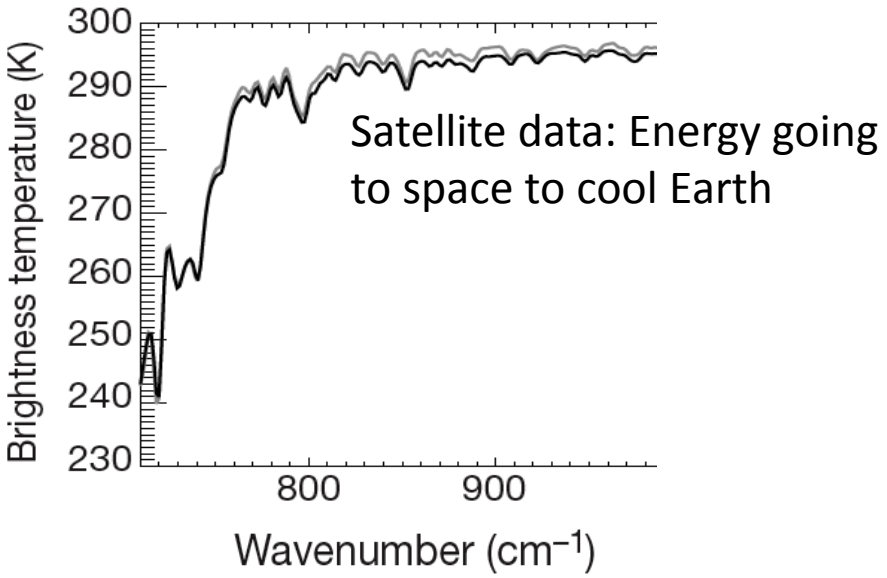
Basis for expecting global warming is PHYSICS

**Known for over a century

**Refined by Air Force after WWII (operations, communications, heat-seeking missiles)

**Observed today by satellites, etc.

**Confirmed by history



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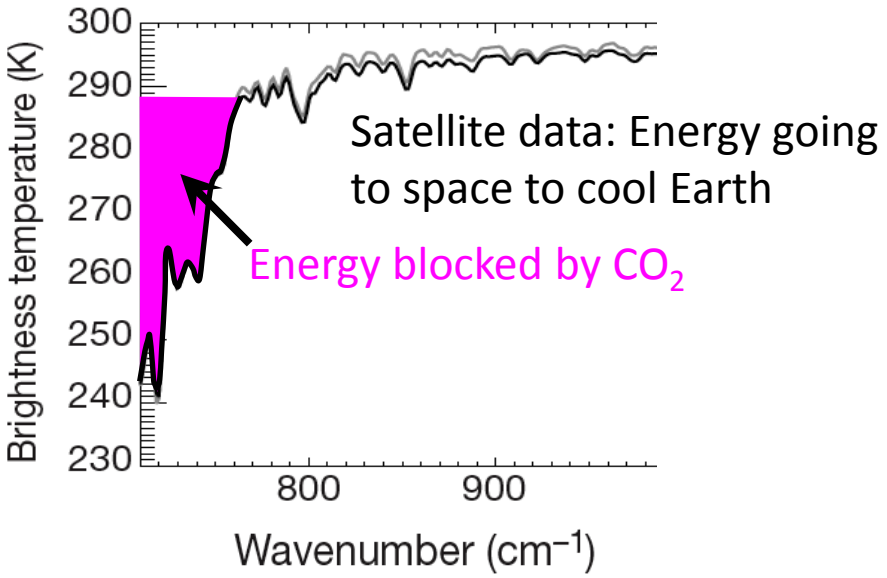

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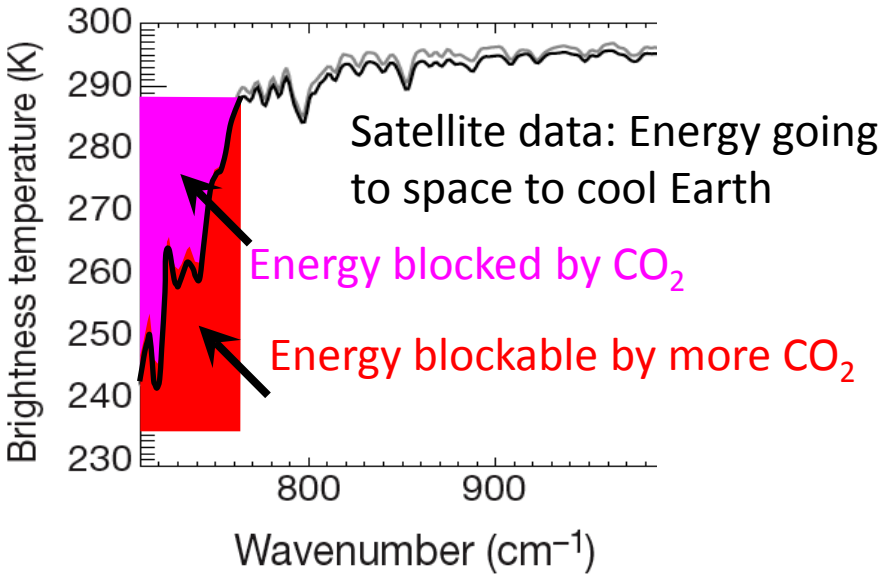

We don't "believe" in global warming

- It arises from unavoidable physics
- It is very well established
- There is no serious scientific controversy
- You can't "hear the other side" because there isn't one—science is the middle, with many groups around
- Scientists knew a long time ago; surprise is 40,000 pounds of CO_2 per person per year, dwarfing 1000 pounds of trash

I have literally HOURS on this:

- Fossil-fuel burning is raising CO_2
- Has warming influence, from physics
- Warming is occurring, despite
- Sun-blocking smokestack particles, dark forest replaced by more-reflective grass, and slight recent dimming of sun
- Warming has size, pattern expected from CO_2 plus other human and natural causes
- Confirms our understanding
- Which shows that future changes can be much larger than those to date

Likely impacts of warming

- →Grain-belt drying and crop heat stress
- →Sea-level rise
- →Tropical diseases no longer frozen
- →Loss of unique ecosystems, especially with humans in way of migration (can your park be an ark if the animals must jump overboard?)
- →Tropical cyclones that form likely to become larger (more energy/fuel)
- →More floods and more droughts (more water in air; faster drying)
- →COSTS RISE FASTER THAN TEMPERATURE!

Significance

There is evidence that the 2007–2010 drought contributed to the conflict in Syria. It was the worst drought in the instrumental record, causing widespread crop failure and a mass migration of farming families to urban centers. Century-long observed trends in precipitation, temperature, and sea-level pressure, supported by dimate model results, strongly suggest that anthropogenic forcing has increased the probability of severe and persistent droughts in this region, and made the occurrence of a 3-year drought as severe as that of 2007–2010 2 to 3 times more likely than by natural variability alone. We conclude that human influences on the climate system are implicated in the current Syrian conflict.

Climate change in the Fertile Crescent and implications of the recent Syrian drought

Colin P. Kelley[a,1], Shahrzad Mohtadi[b], Mark A. Cane[c], Richard Seager[c], and Yochanan Kushnir[c]

2015, Proceedings of the National Academy of Sciences of the USA

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…drought contributed to the conflict in Syria…

…anthropogenic forcing has increased the probability… 2 to 3 times…

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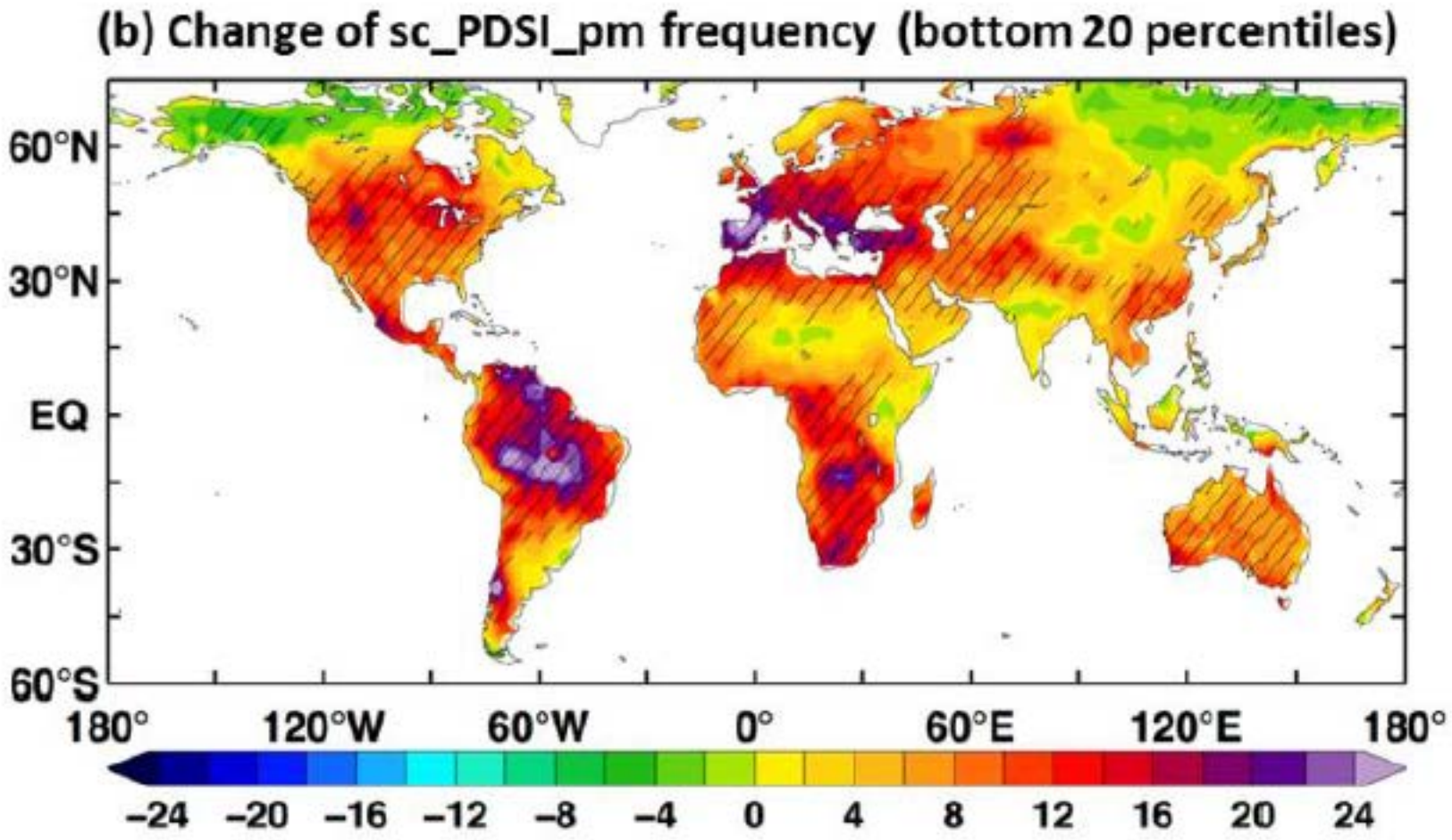
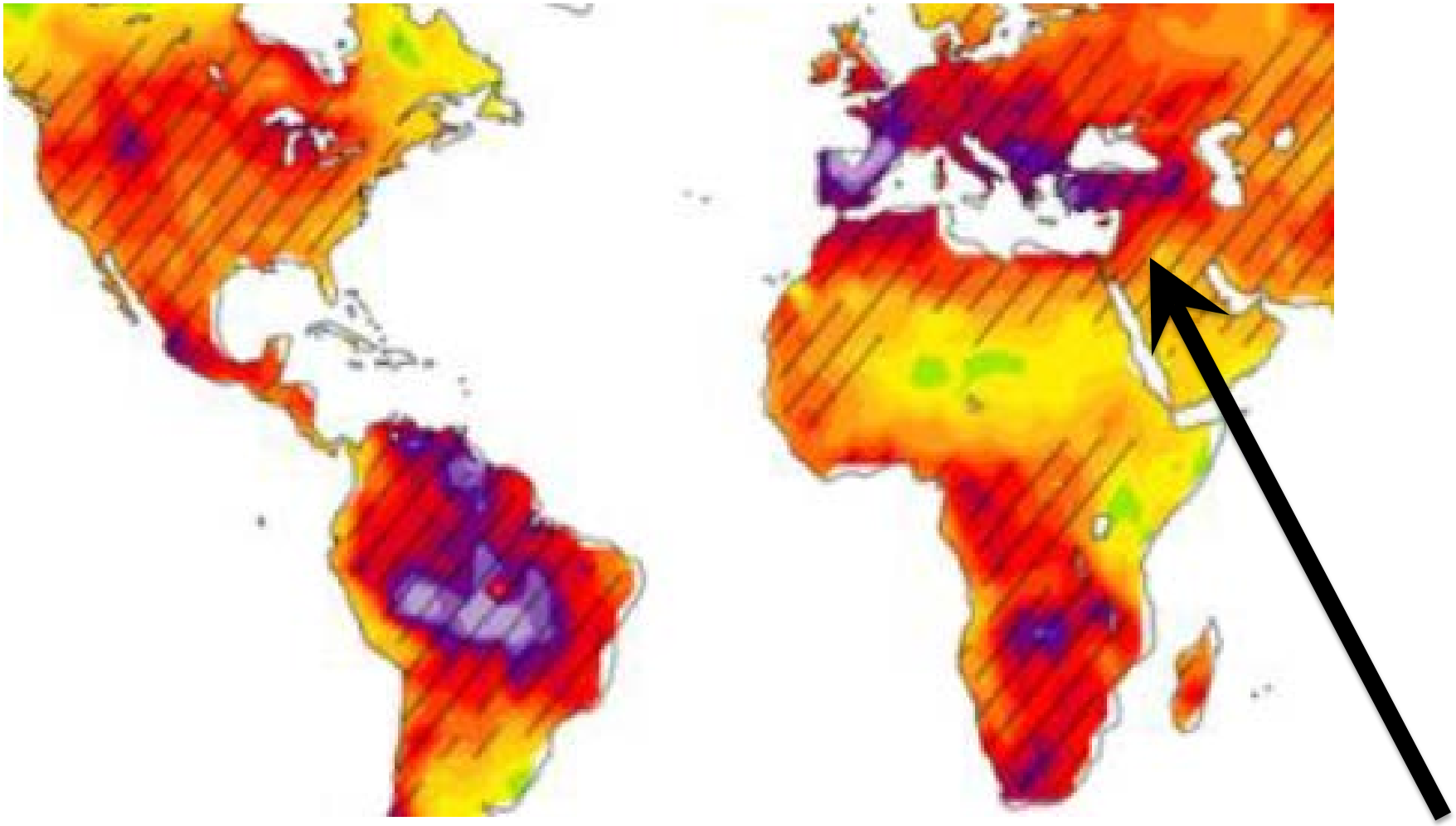


Redder=more time in drought if we keep burning fossil fuels and releasing CO_2, **Greener**/**Bluer**=less

NOT a worst-case scenario (sort of optimistic, actually)

Zhao, T., and A. Dai, 2015: The Magnitude and Causes of Global Drought Changes in the 21st Century under a Low-moderate Emissions Scenario. J. Climate. doi:10.1175/JCLI-D-14-00363.1, in press.



Significant projected increase in drought, where drought already is causing problems

Zhao, T., and A. Dai, 2015: The Magnitude and Causes of Global Drought Changes in the 21st Century under a Low-moderate Emissions Scenario. J. Climate. doi:10.1175/JCLI-D-14-00363.1, in press.

2014 report from distinguished retired US generals and admirals traced the dashed lines from:

→Drought to civil war in Syria

→Heat & drought in Russia & China, to crop failure, to rising bread prices and North Africa uprisings

→We likely contributed to these climate changes already, with much more to come

For Mali (and the others): "While climate change alone did not cause the conflict, it certainly added environmental stressors…"

CNA Military Advisory Board *National Security and the Accelerating Risks of Climate Change* (Alexandria, VA: CNA Corporation, 2014)

SHOCK WAVES

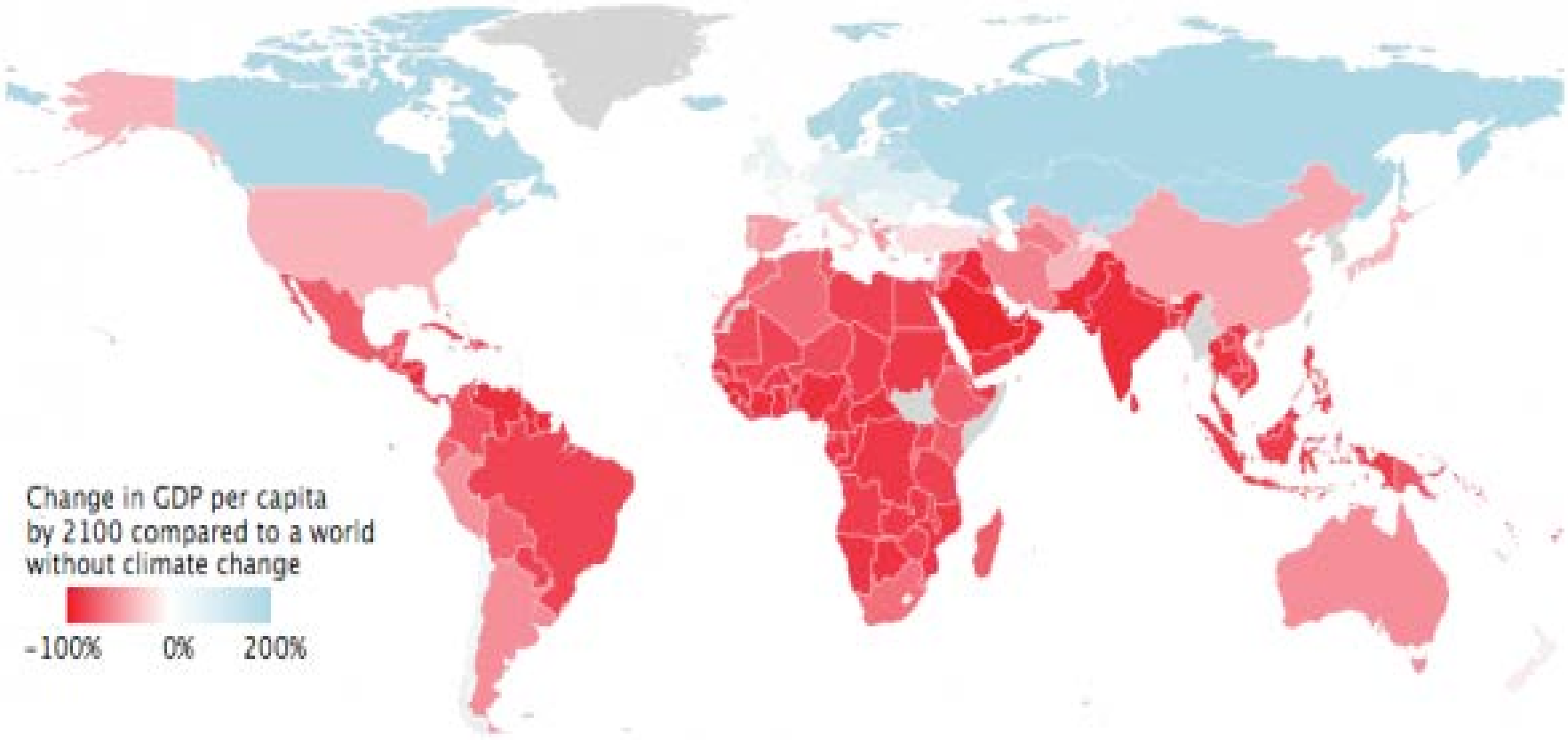
Managing the Impacts of Climate Change on Poverty

This week from the World Bank "…climate change could force more than 100 million people into extreme poverty by 2030…" (Foreword, p. xi)

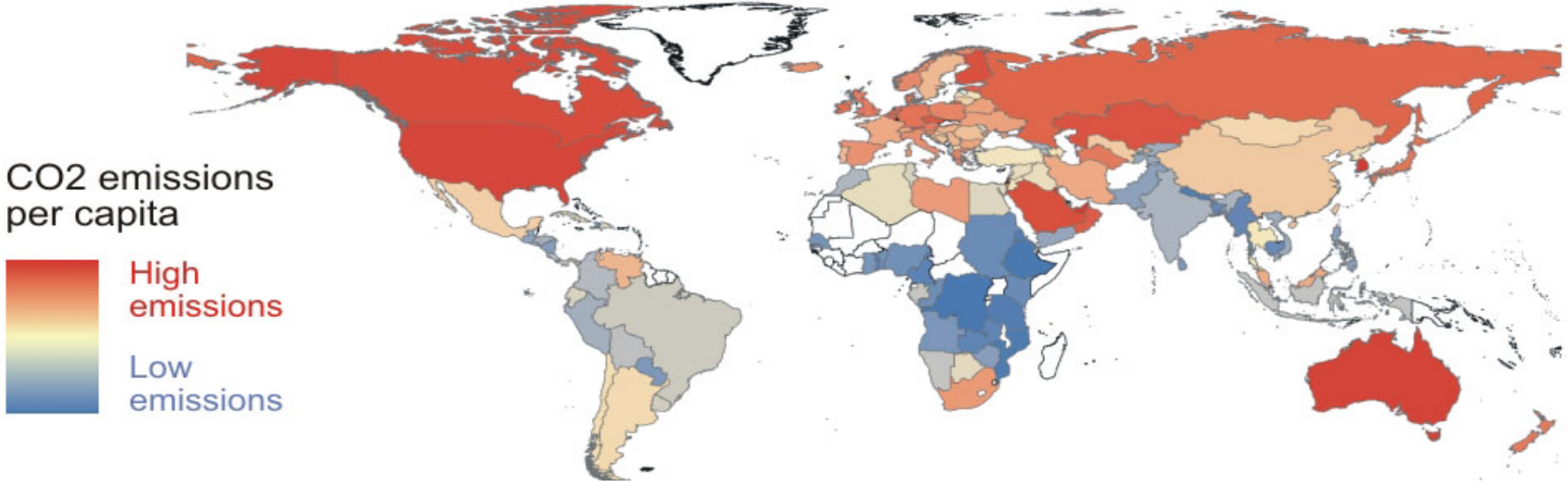
Stephane Hallegatte, Mook Bangalore, Laura Bonzanigo, Marianne Fay, Tamaro Kane, Ulf Narloch, Julie Rozenberg, David Treguer, and Adrien Vogt-Schilb

WORLD BANK GROUP

http://thinkprogress.org/climate/2015/10/22/3714991/climate-change-world-economies-study/



A prediction for how gross domestic product (GDP) will change across the globe by 2100. Colder countries, like Canada, will see an economic boost with climate change, while most tropical nations will witness a drop. This model assumes a “business as usual” global warming scenario, wherein unmitigated climate changes raises temperatures by 4.3 degrees Celsius (8 degrees Fahrenheit) by the end of the century. Photo by Burke M, Hsiang SM and Miguel E., Nature, 2015. http://www.pbs.org/newshour/updates/best-temperature-economic-happiness/

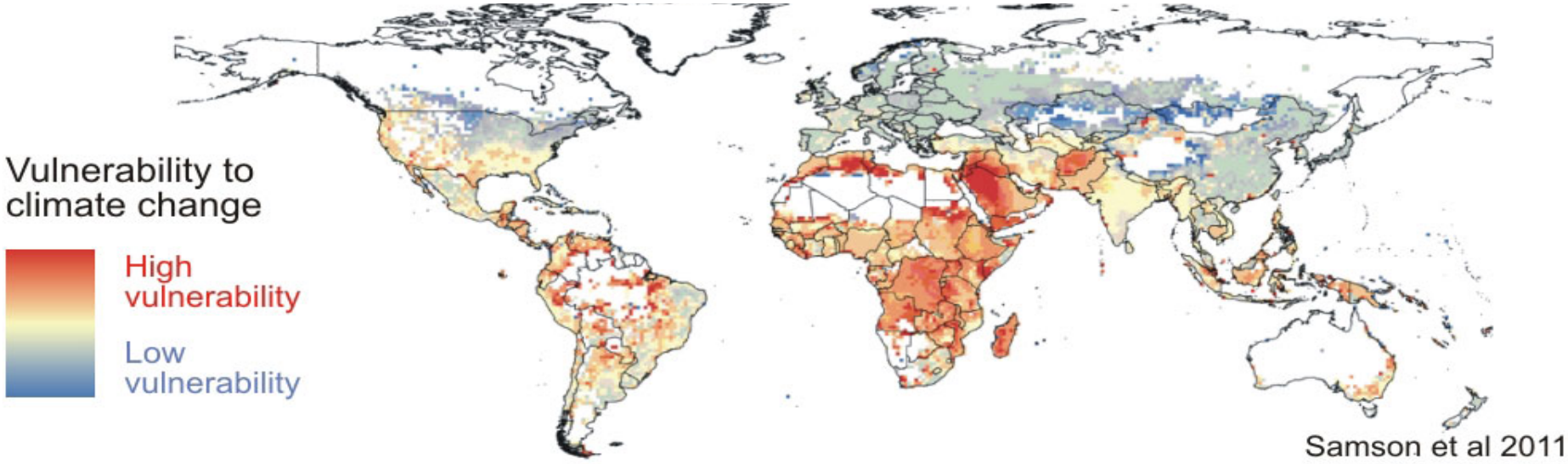


RED=People changing climate the most

Geographic disparities and moral hazards in the predicted impacts of climate change on human populations, *Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2011)* ***20, 532–544*** J. Samson, D. Berteaux, B. J. McGill and M. M. Humphries

http://www.skepticalscience.com/roy-spencers-bad-economics.html Accessed 14mar2012

RED=People most vulnerable to changing climate



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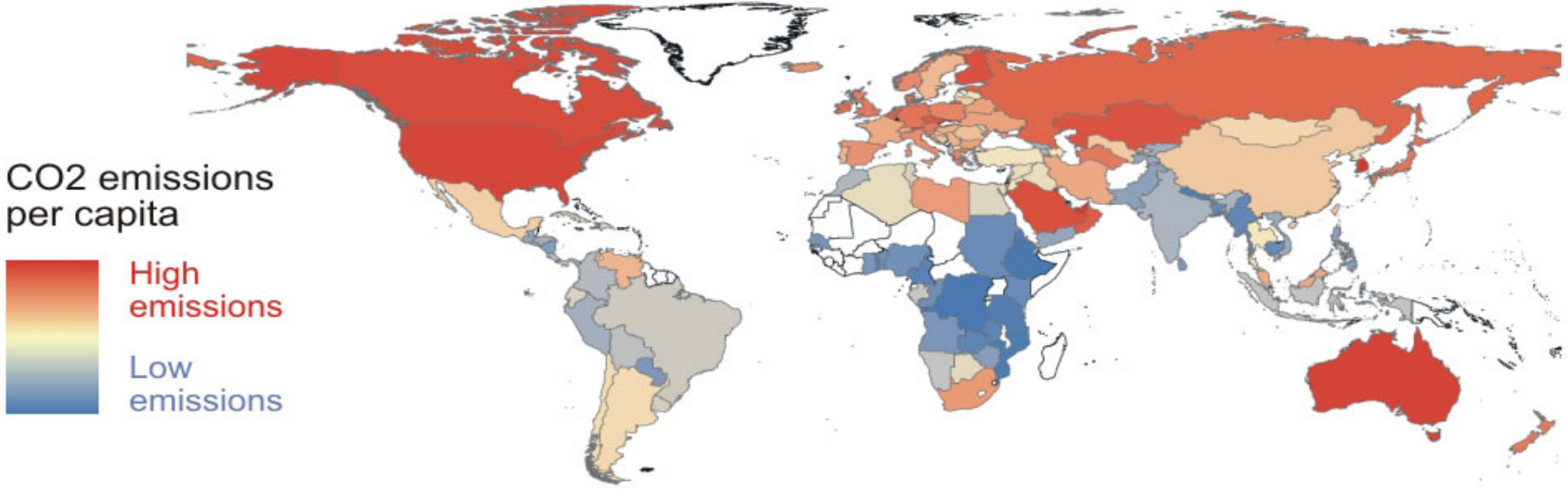
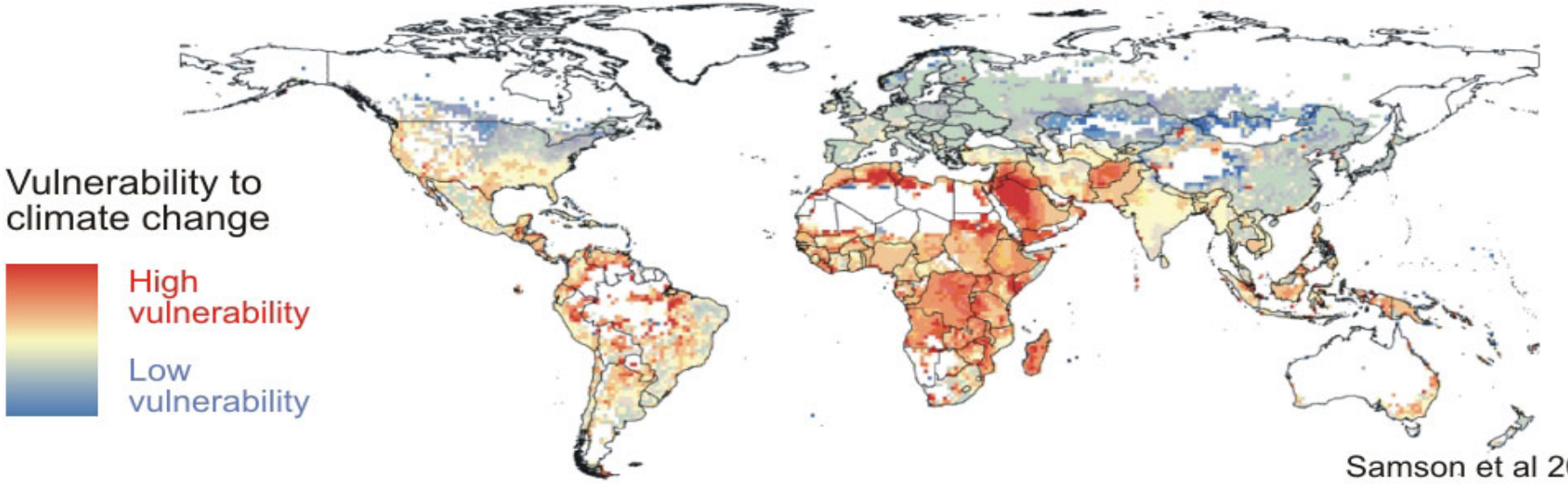


Those who contribute the least greenhouse gases will be most impacted by climate change



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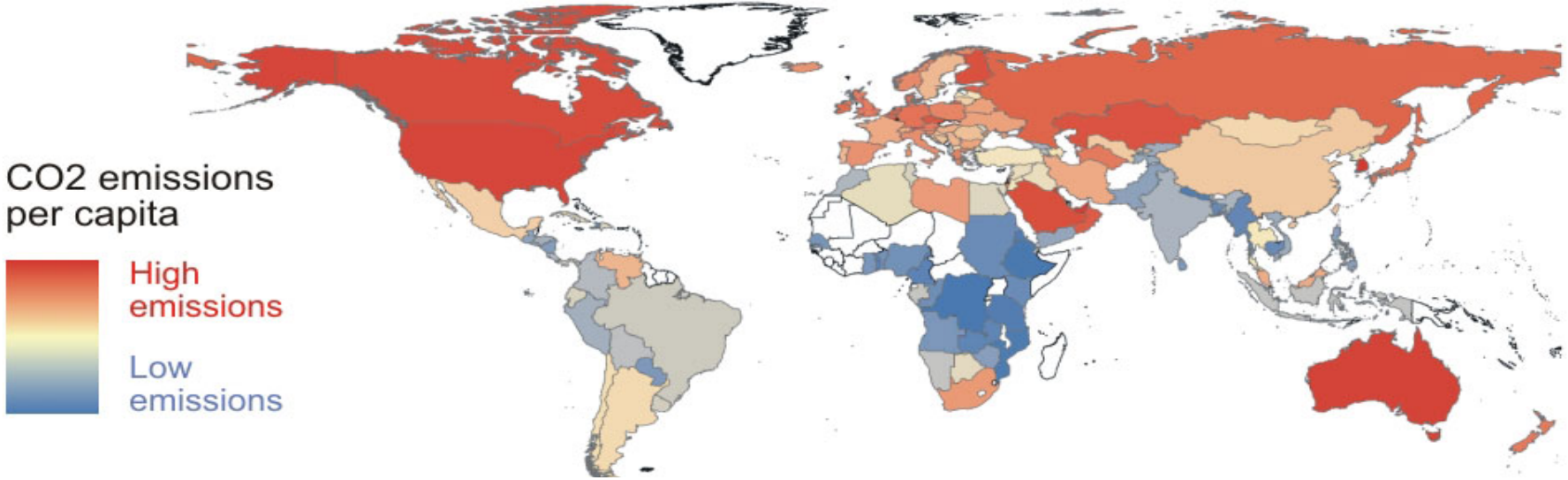
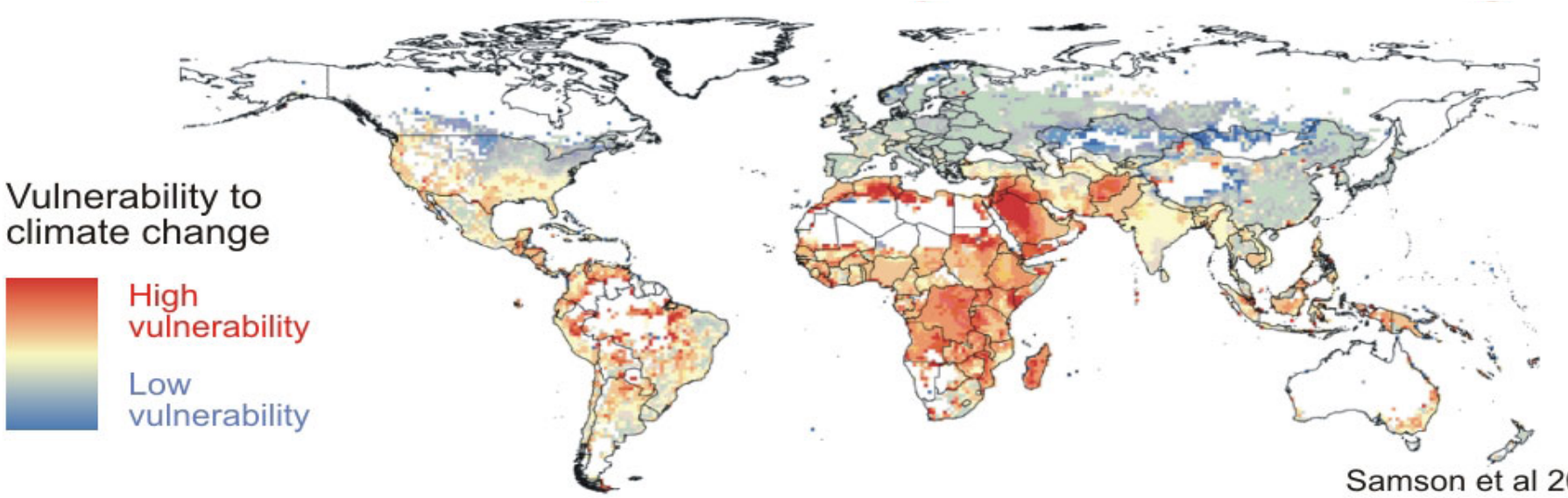


Pope Francis "…it seems clear to me also that climate change is a problem which can no longer be left to a future generation" 9/30/15



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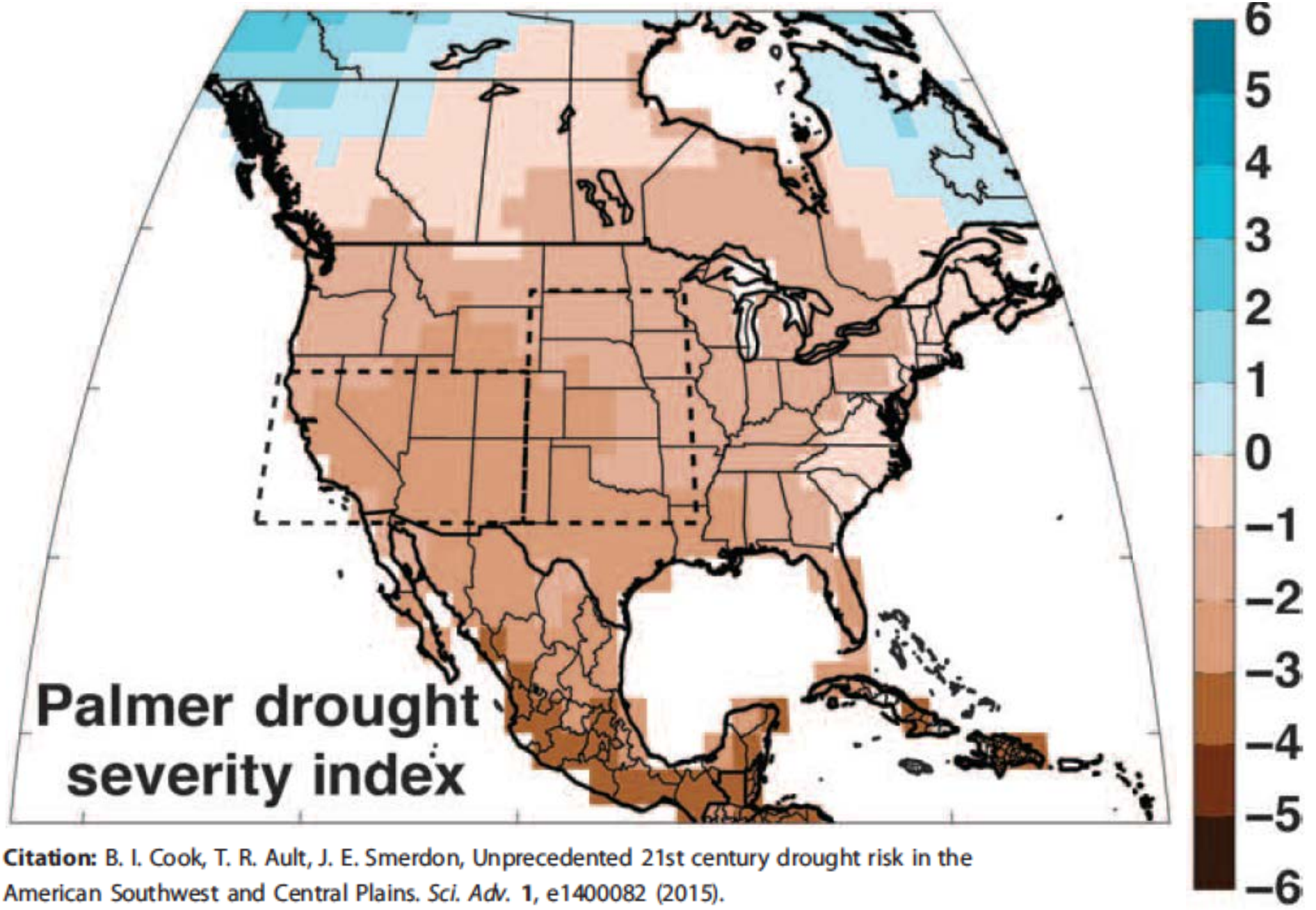
CMIP5 Drought Projections (RCP 8.5, 2050-2099 CE)



Citation: B. I. Cook, T. R. Ault, J. E. Smerdon, Unprecedented 21st century drought risk in the American Southwest and Central Plains. *Sci. Adv.* **1**, e1400082 (2015).

Costs rise faster than temperatures

- First degree of warming cheap, but here
- Second degree fairly cheap, but committed
- We are discussing 3, 4, 5°C… (land warms more, so >10°F possible for most people)
- Each degree costs more than one before
- We've lived with variability; if warming small, learn from people in warmer places
- But if we quickly heat large areas above anything now on Earth, not so easy…

What we don't know can hurt us…

- Building is hard—takes many tools;
- Breaking is easier—just need a big hammer;
- Virtually no chance that CO_2 makes Eden—need to get much more right than just CO_2
- But can break things we value
- The less you trust science, the more you might worry about "hammer" of ~40,000 pounds of CO_2 per person per year in USA
- Tipping points, etc.—some chance of very large, rapid, damaging changes
- Could become too hot to work, live, or grow food in much of large, populous tropics…

Full scholarship shows wisely using knowledge can give:

→ Stronger economy

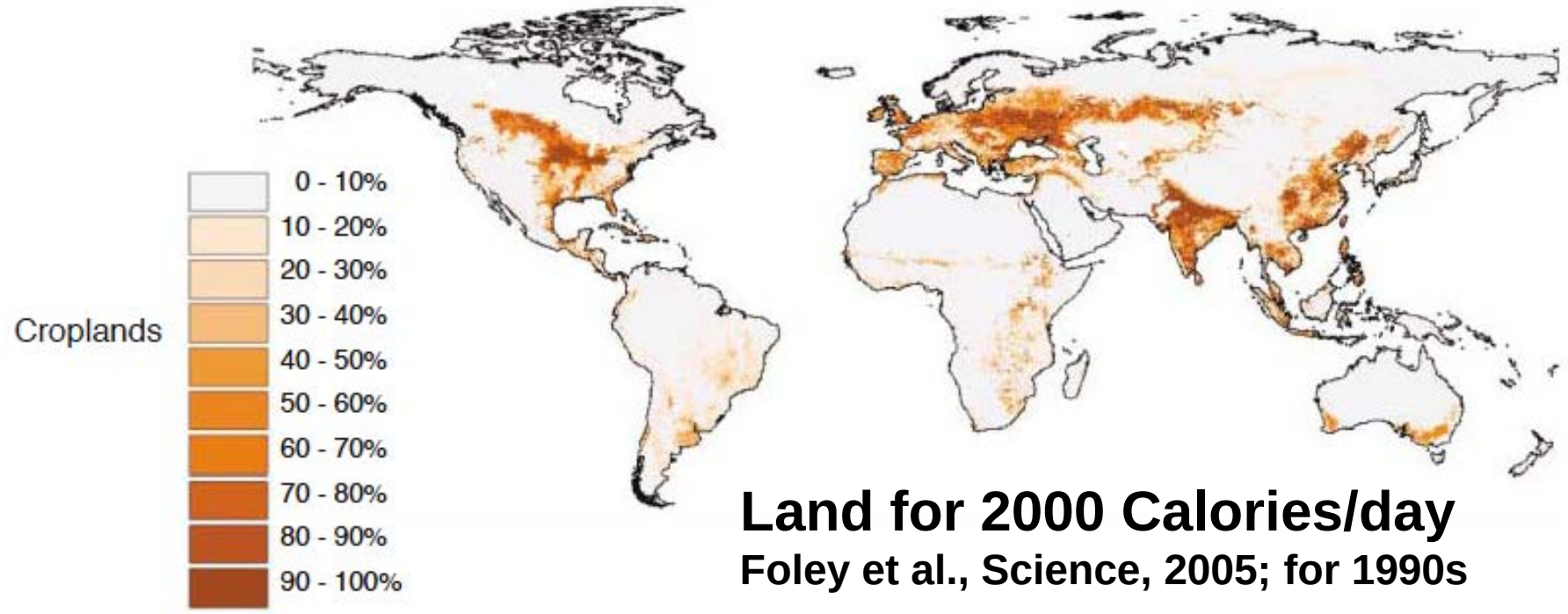
→ More jobs

→ Greater national security

→ Cleaner environment

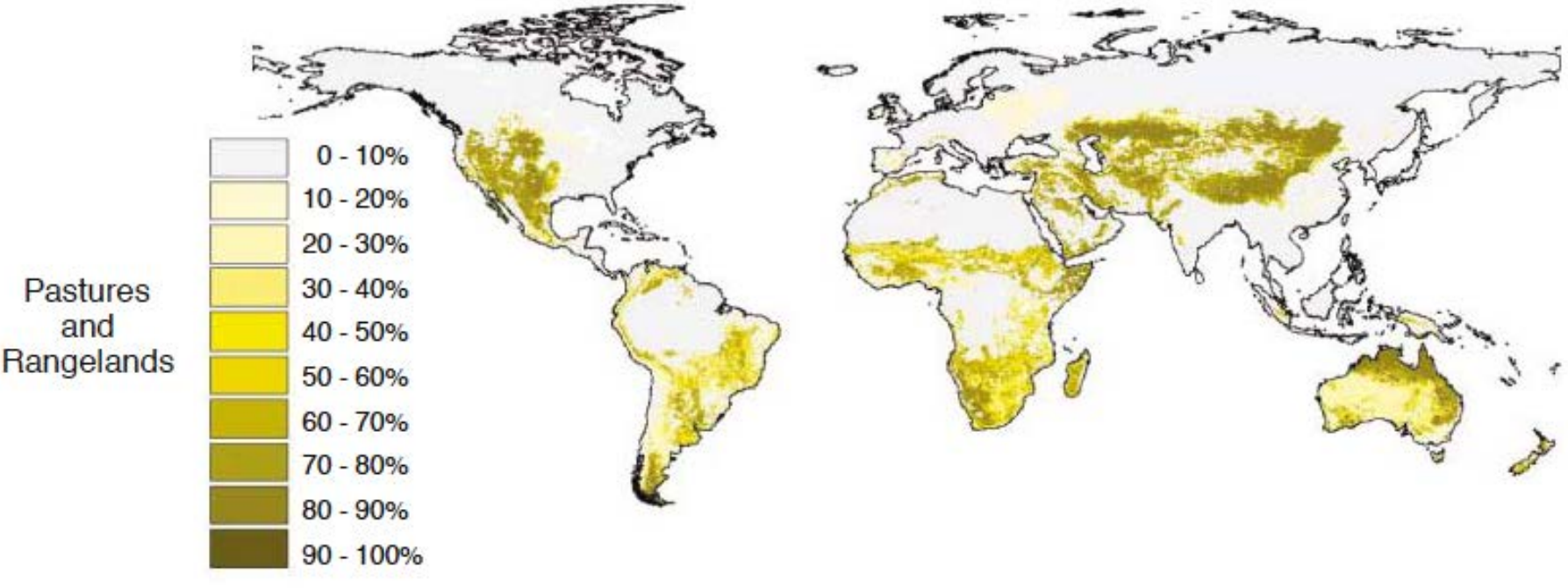
→ More consistent with the Golden Rule

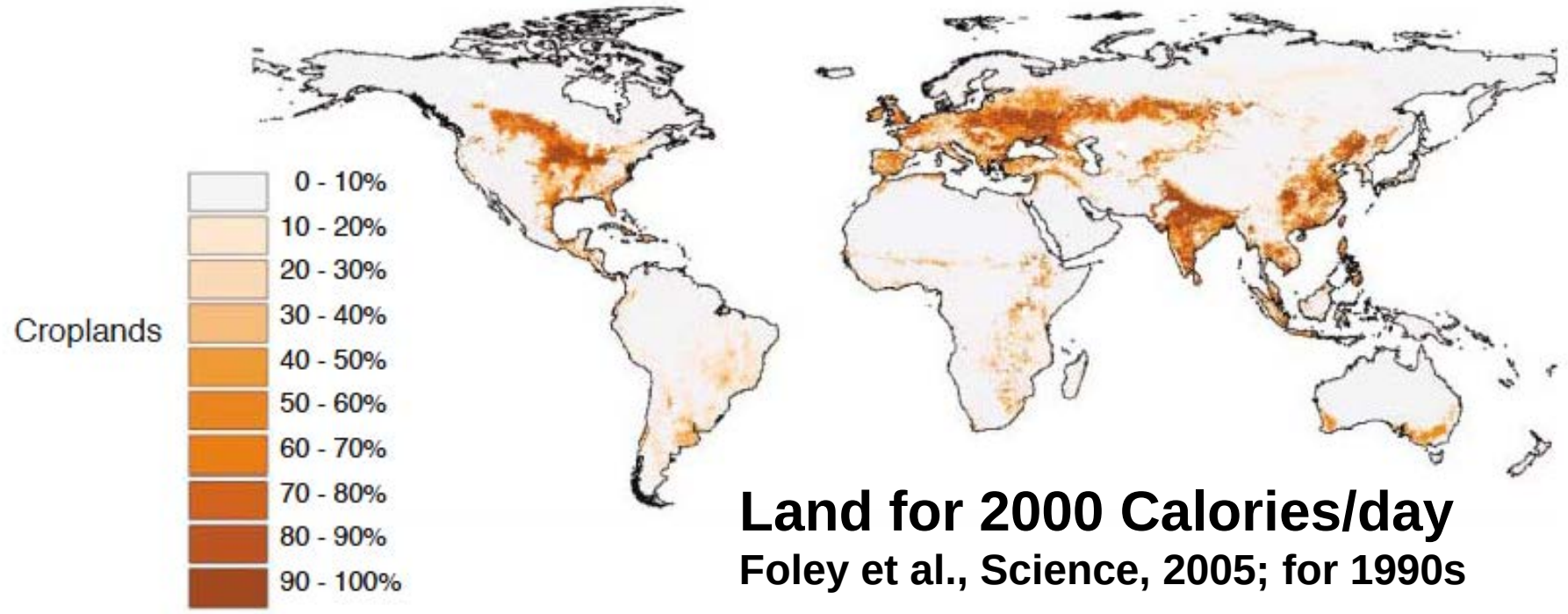
But can we do it? Yes!
Might take 30 years,
but I'm 58, and expect
to be on the green side
of the grass for a while



Land for 2000 Calories/day

Foley et al., Science, 2005; for 1990s





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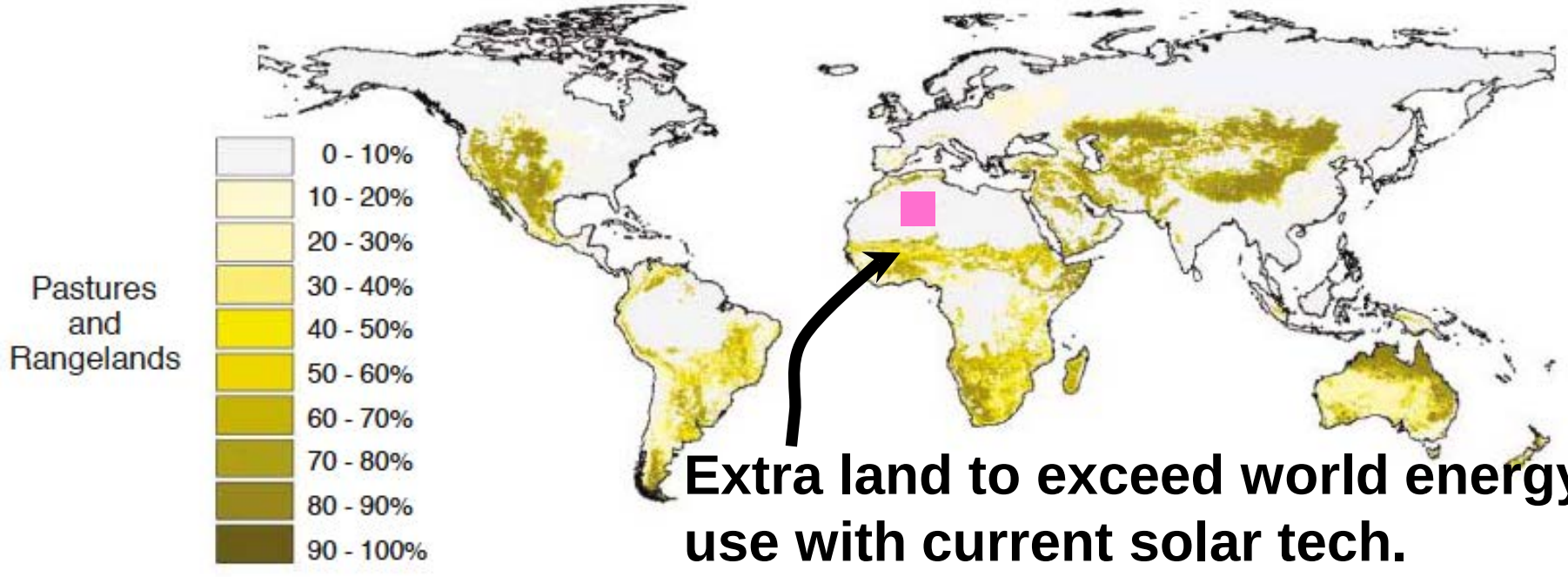
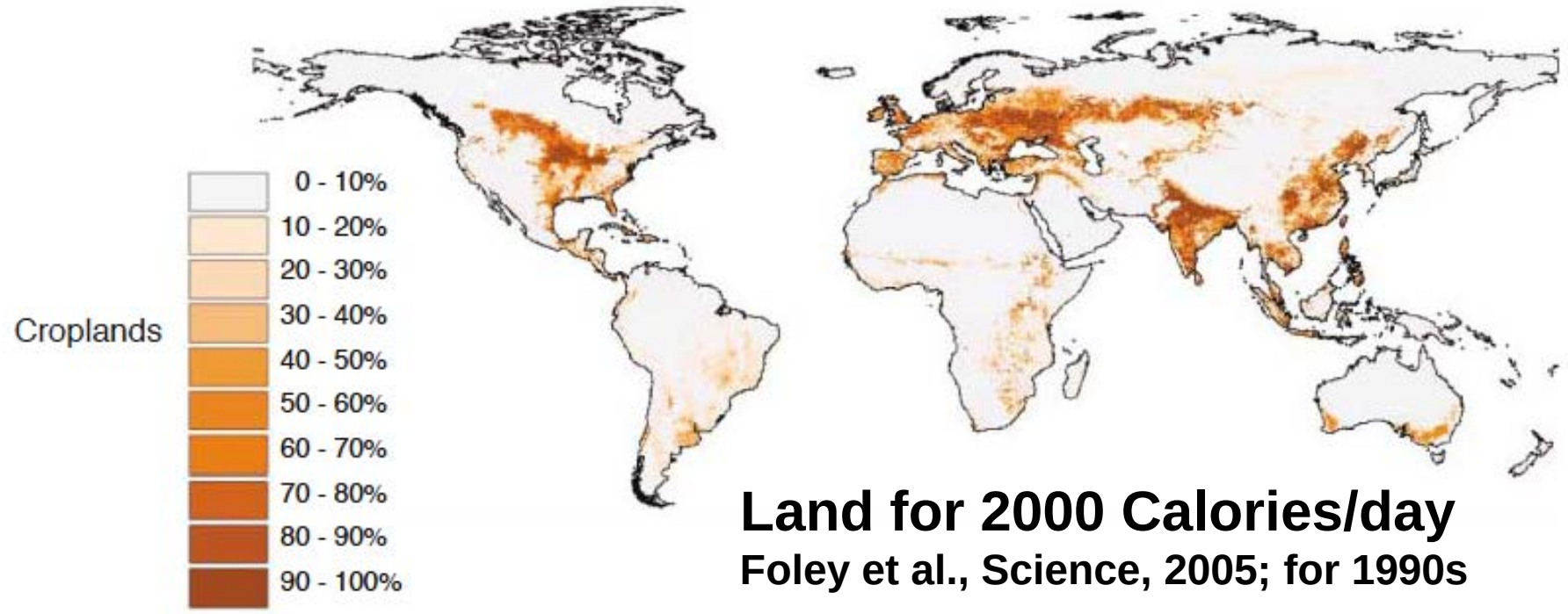


Extra land to exceed world energy use with current solar tech.



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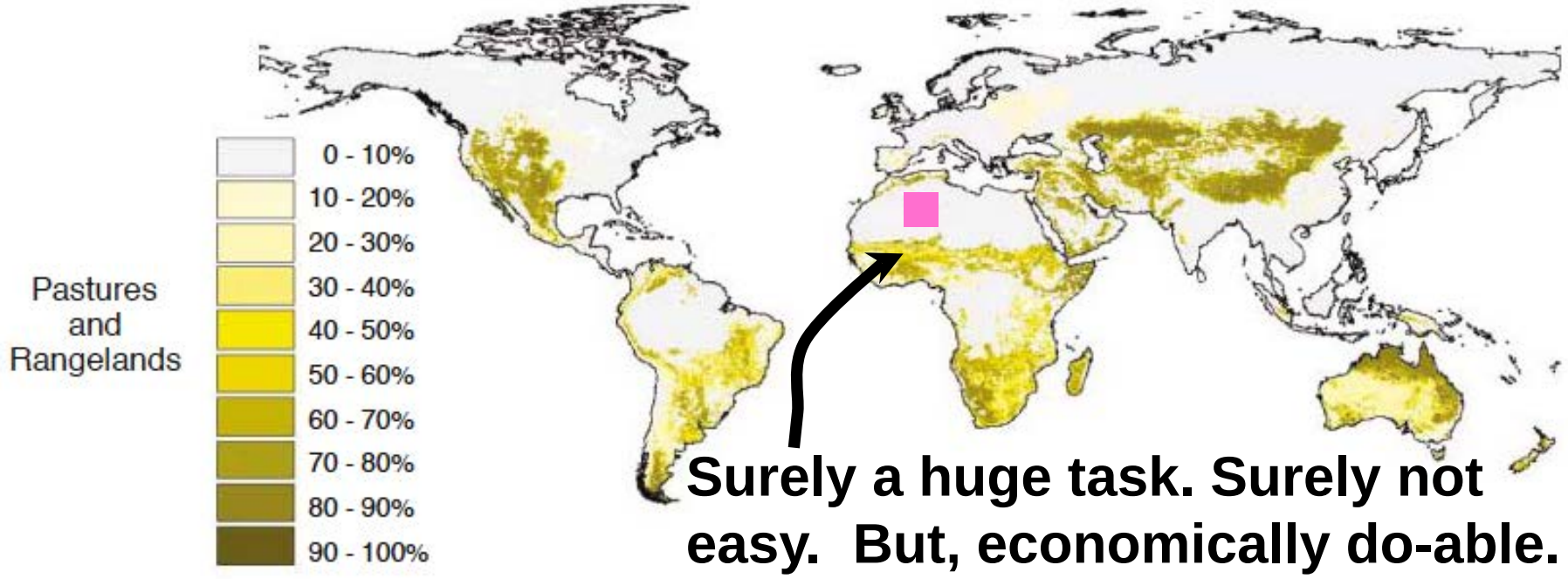
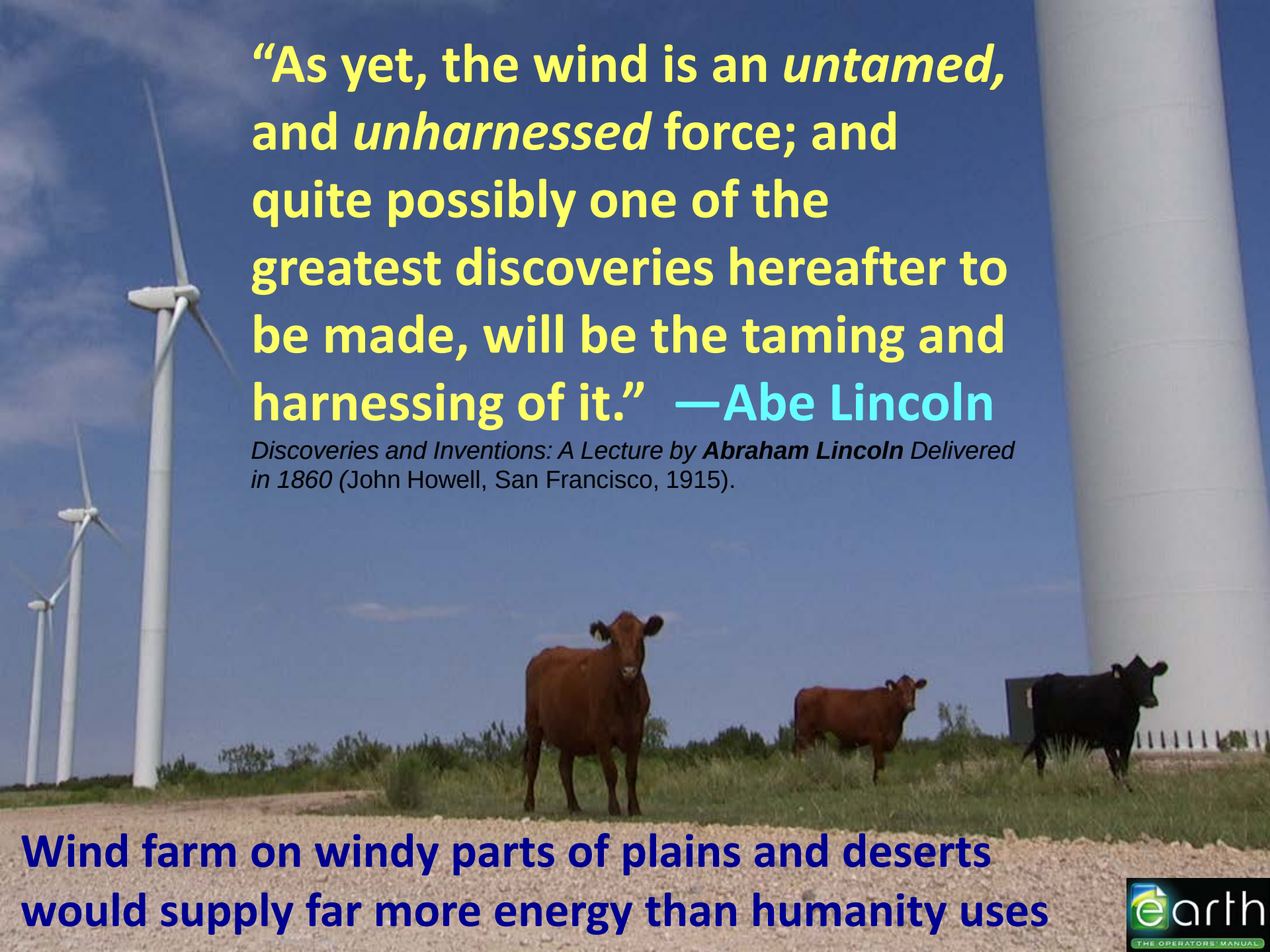
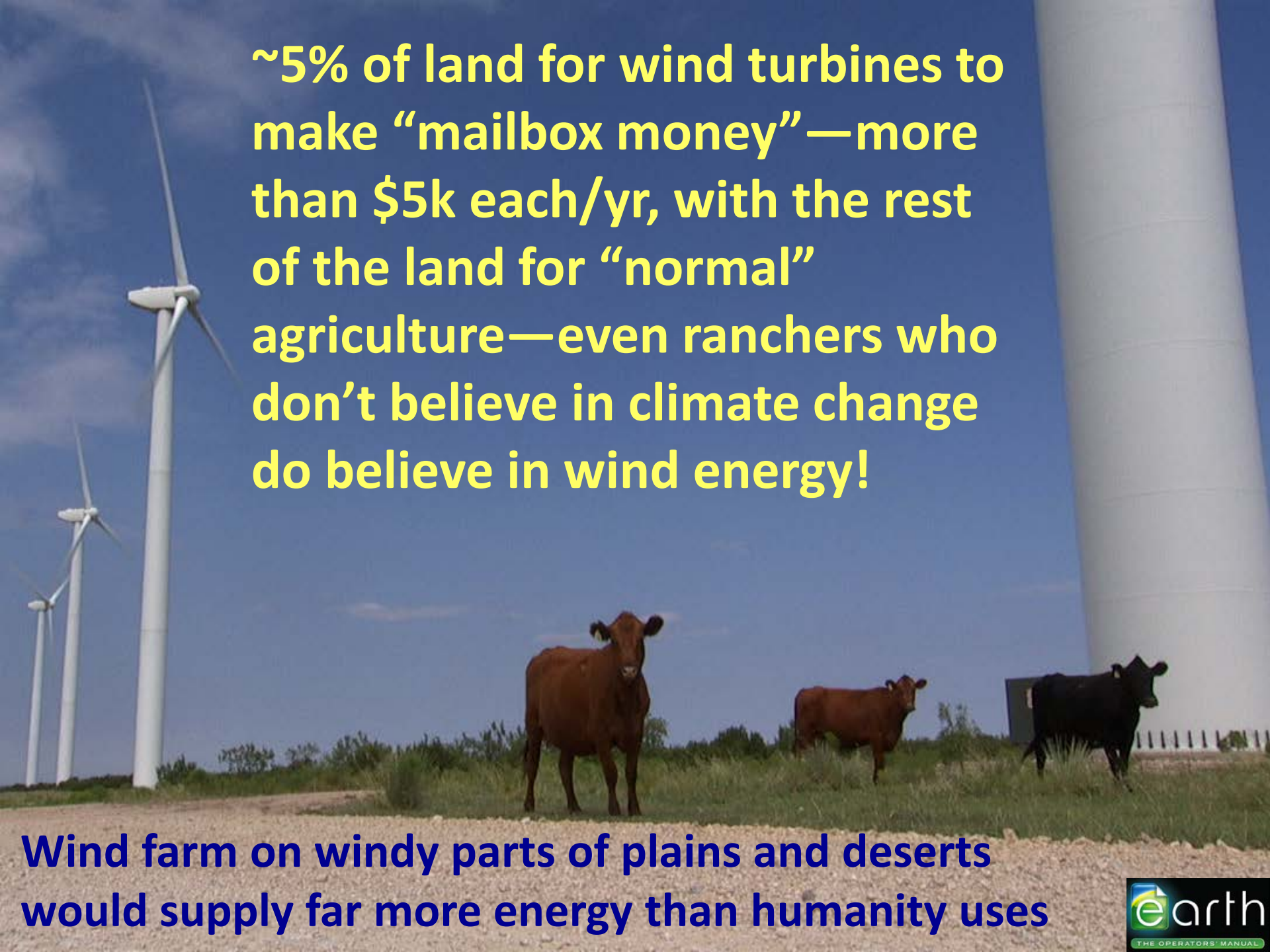


Surely a huge task. Surely not easy. But, economically do-able.


"As yet, the wind is an *untamed,* and *unharnessed* force; and quite possibly one of the greatest discoveries hereafter to be made, will be the taming and harnessing of it." —Abe Lincoln
Discoveries and Inventions: A Lecture by ***Abraham Lincoln*** *Delivered in 1860* (John Howell, San Francisco, 1915).
Wind farm on windy parts of plains and deserts would supply far more energy than humanity uses
earth
THE OPERATORS' MANUAL


~5% of land for wind turbines to make “mailbox money”—more than $5k each/yr, with the rest of the land for “normal” agriculture—even ranchers who don’t believe in climate change do believe in wind energy!
Wind farm on windy parts of plains and deserts would supply far more energy than humanity uses
earth
THE OPERATORS' MANUAL


TXU Energy in Texas now offering some customers FREE electricity at night because the wind farms produce so well.
Wind farm on windy parts of plains and deserts would supply far more energy than humanity uses
earth
THE OPERATORS' MANUAL

We can do this

→Get 100x more energy than from food, from less area

→Quit emitting 40,000 pounds CO2 apiece each year that dwarf our 1000 pounds trash

→Help the economy

→Maybe 30 years… but I'm almost twice that (58), with another 30 to go, I hope!

Fantastic opportunities

→ Farming food saved lives

→ We hunt-gather energy

→ We're 1st generation that can farm sustainable energy

→Ancestors met challenges

→We can, too…

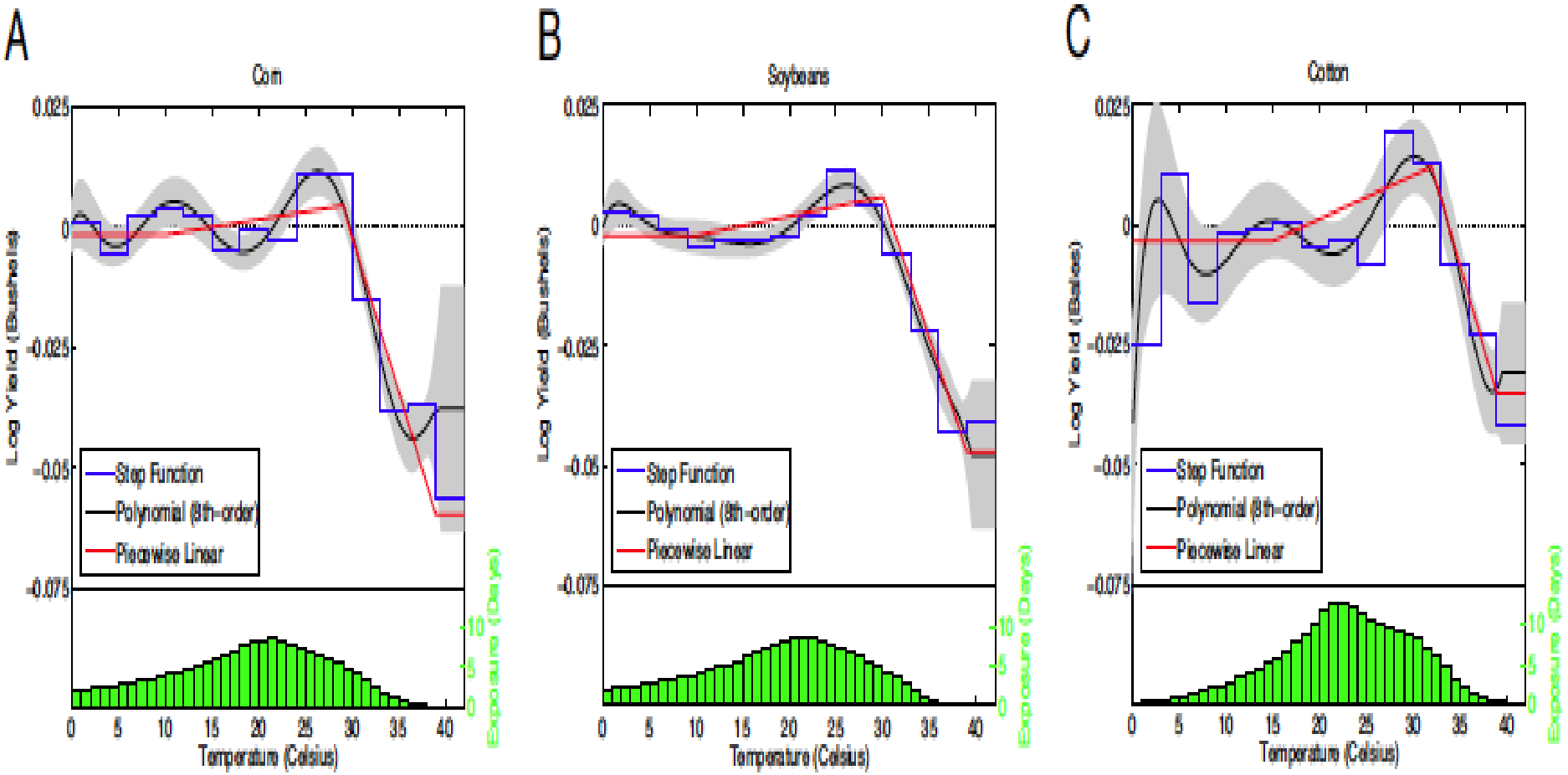
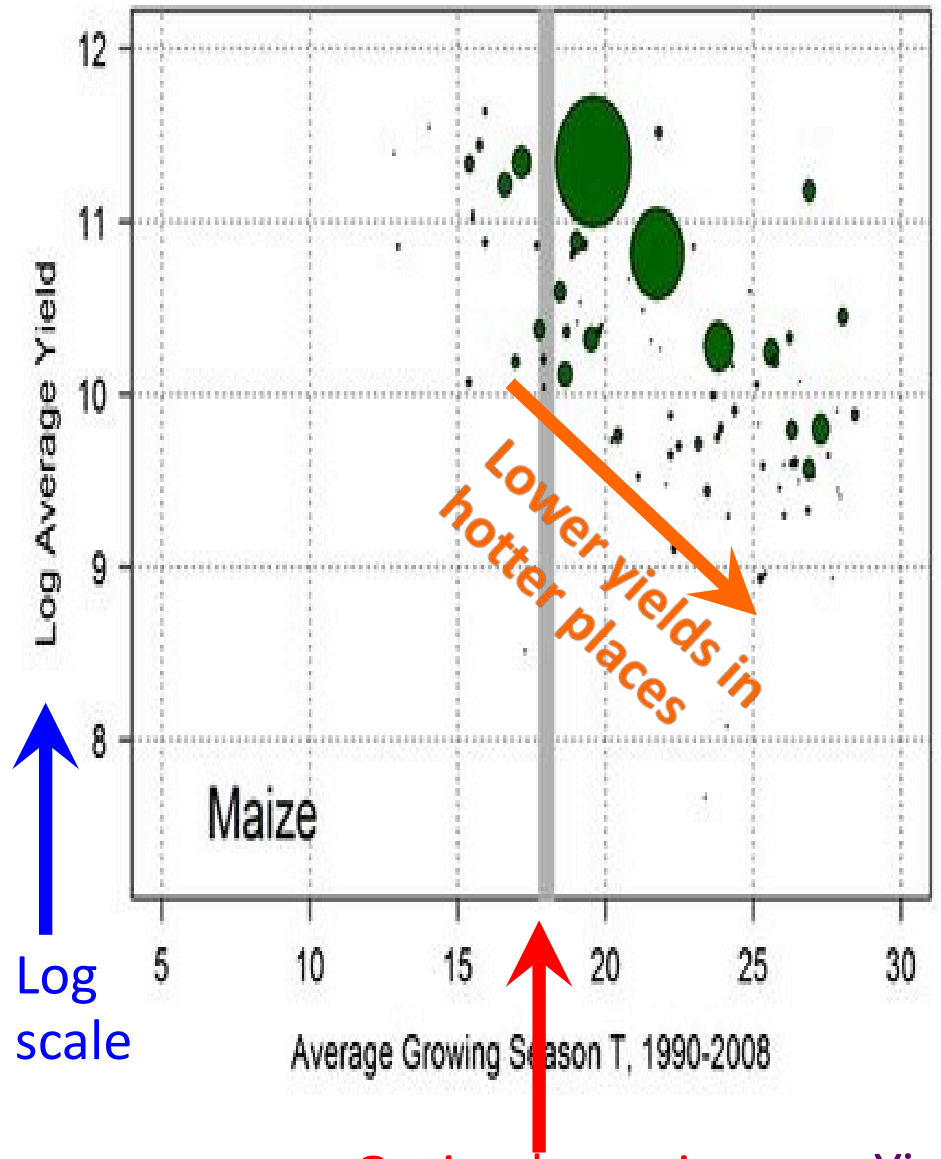


Fig. 1. Nonlinear relation between temperature and yields. Graphs at the top of each frame display changes in log yield if the crop is exposed for one day to a particular 1° C temperature interval where we sum the fraction of a day during which temperatures fall within each interval. The 95% confidence band, after adjusting for spatial correlation, is added as gray area for the polynomial regression. Curves are centered so that the exposure-weighted impact is zero. Histograms at the bottom of each frame display the average temperature exposure among all counties in the data.

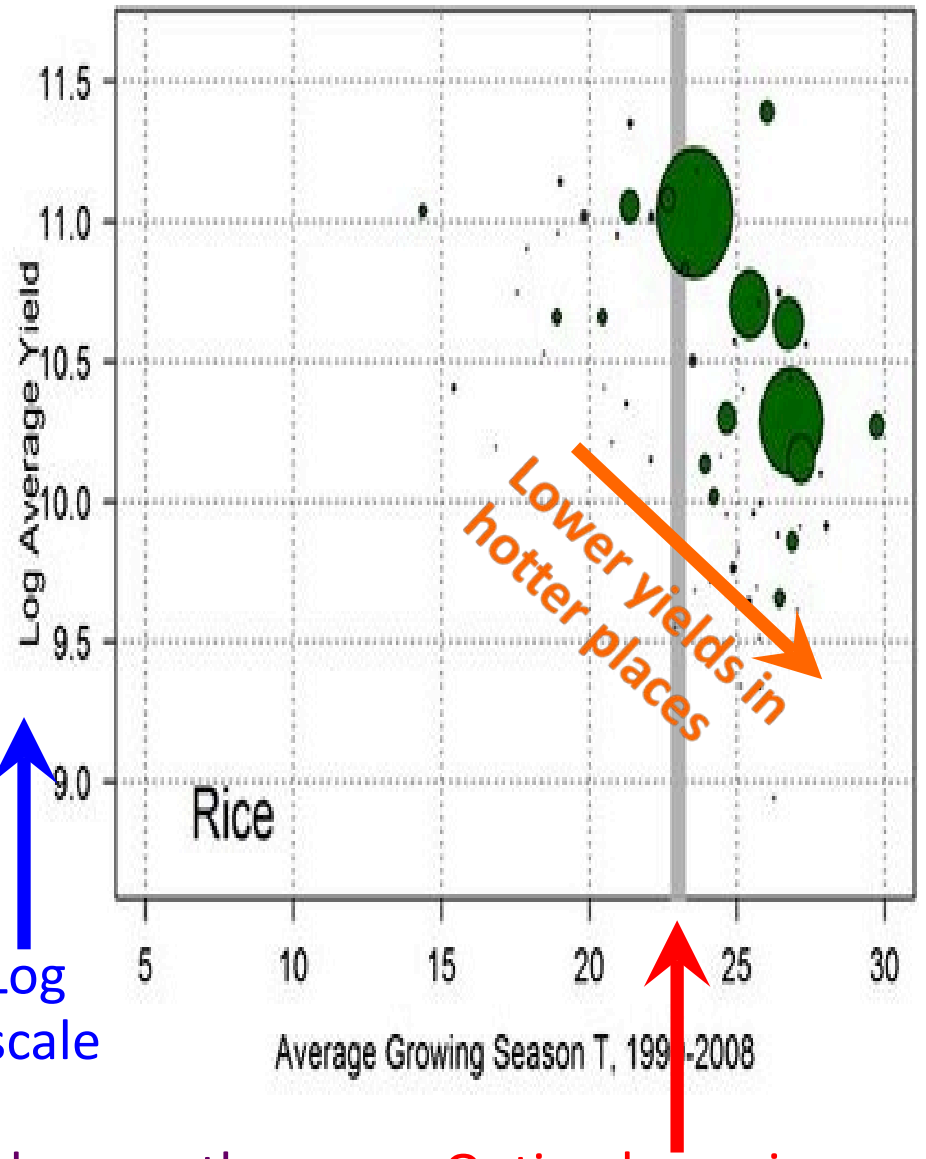
Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change W. Schlenker and M.J. Roberts, 2009, PNAS 106, 15594–15598.

Most corn and rice grown in already-hotter-than-optimum places



Log scale

Optimal growing temperature based on experiments



Log scale

Yields more than temperature, but it matters

Optimal growing temperature based on experiments

Lobell D B , and Gourdji S M Plant Physiol. 2012;160:1686-1697

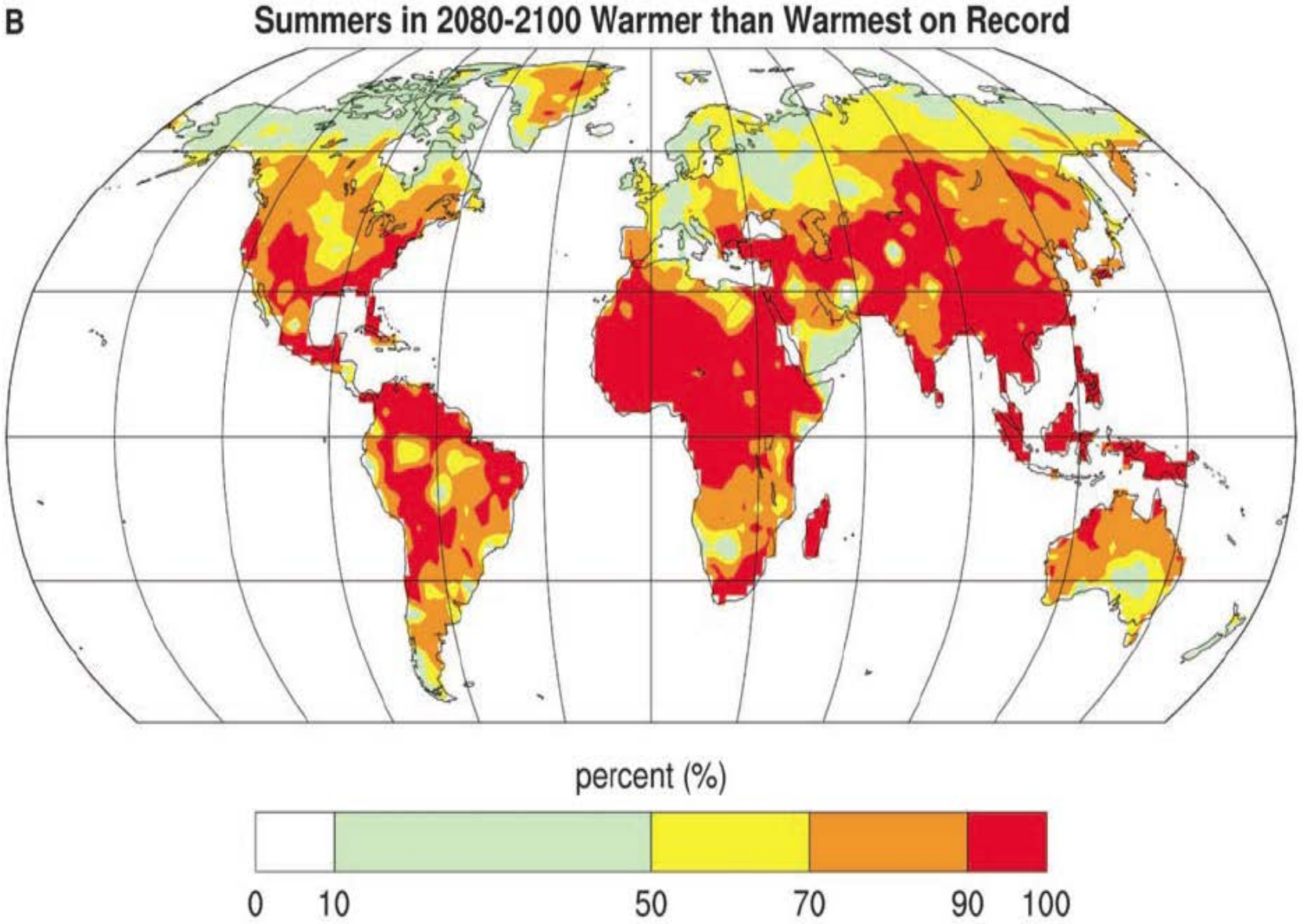


Fig. 3. Likelihood (in percent) that future summer average temperatures will exceed the highest summer temperature observed on record (**A**) for 2050 and (**B**) for 2090. For example, for places shown in red there is greater than a 90% chance that the summer-averaged temperature will exceed the highest temperature on record (1900–2006) (*22*).

Battisti and Naylor, 2009, Science