Global change and ecosystem health

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Topics

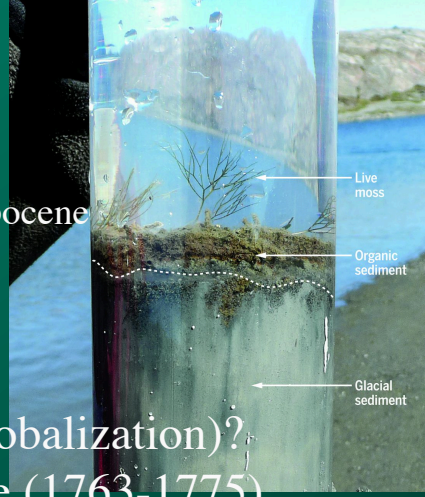
- Human global impacts on planet's geological processes
- Global change vs. climate change
- Effects of global change phenomena individually and synergistically
  - On ecosystem health
  - On human health

Human "asteroid"?

Asteroid impact, Chixulub, Yucatan, ~65.5 MYA

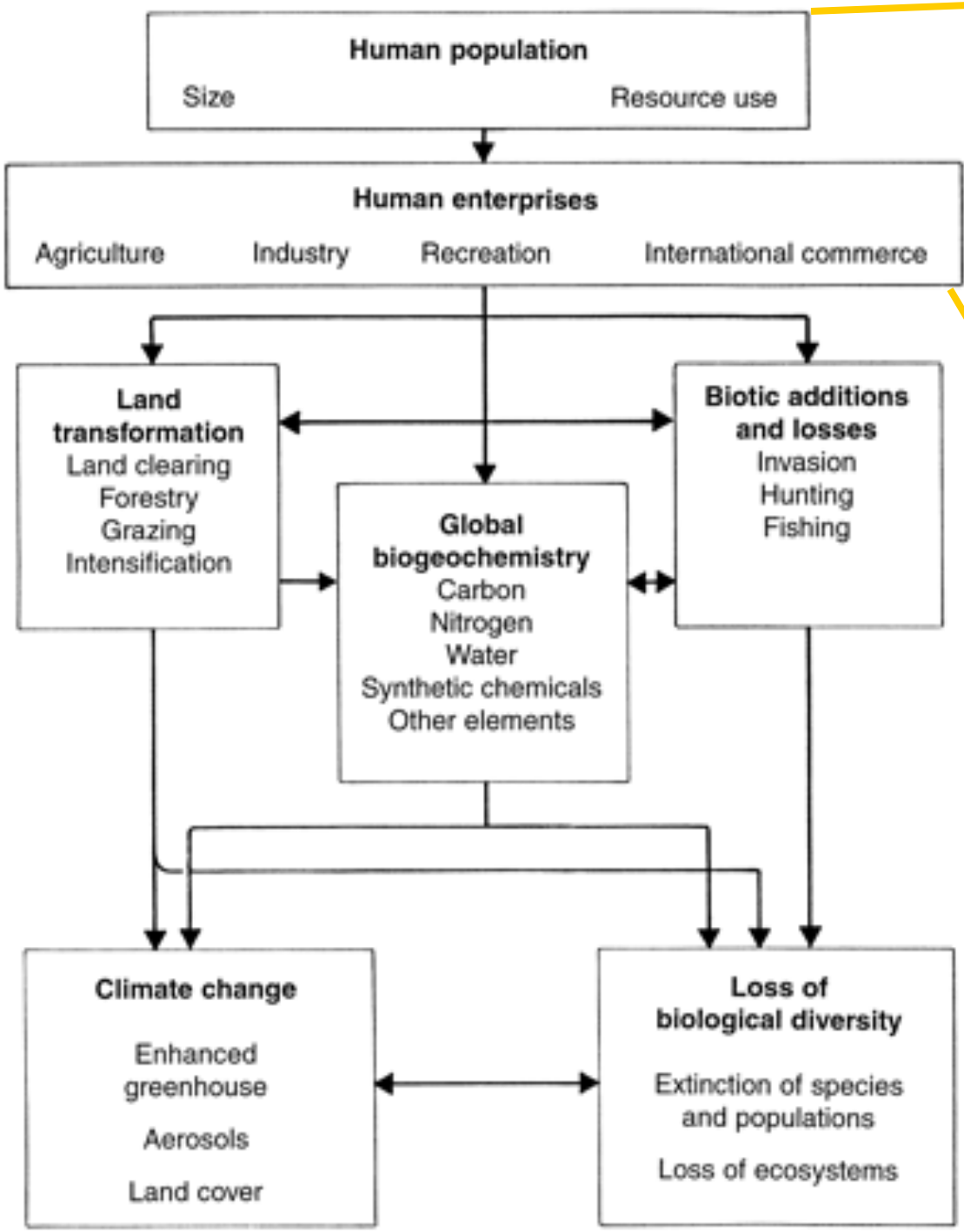
Anthropocene Epoch?

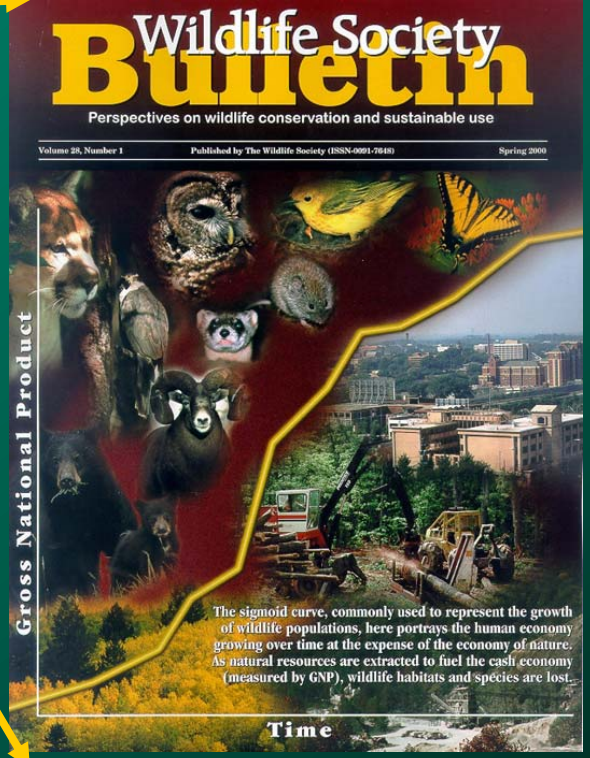
Lake sediments now show human footprint



- Formally proposed, not yet formally accepted (Waters, et al., The Anthropocene is functionally and stratigraphically distinct from the Holocene, *Science* 351, 8th Jan., 2016)
- Start date?
  - Spread of agriculture?
  - Columbian exchanges between Old & New Worlds (colonization, globalization)?
  - Industrial Revolution (~1800), James Watt invention of steam engine (1763-1775)
  - Mid-20th Century "great acceleration" of human population growth, nuclear explosions
- Stratigraphic evidence
  - Global human deposits = plastics, aluminum, concrete (→technofossils)
  - Fossil fuel combustion accelerated ~1950→global warming, global increase in CO_2 concentration in atmosphere (& black carbon, inorganic ash spheres, spherical carbonaceous particles)
  - Enhanced erosion (& ocean sedimentation) caused by global deforestation
  - Widespread sediment retention behind dams
- Geochemical evidence
  - Polyaromatic hydrocarbons, PCBs, pesticide residues globally, $^{206/207}Pb$ signature from leaded gasoline, change in carbon isotope ratios due to fossil fuel combustion
- Biological evidence
  - Global mass extinction, & other global change phenomena

Another kind of environmental signaling??





Interrelated *global change phenomena* threaten climate, biodiversity, humans

Vitousek et al., *Science* 1997

Biggest Threat to Humanity? Climate Change, U.N. Chief Says

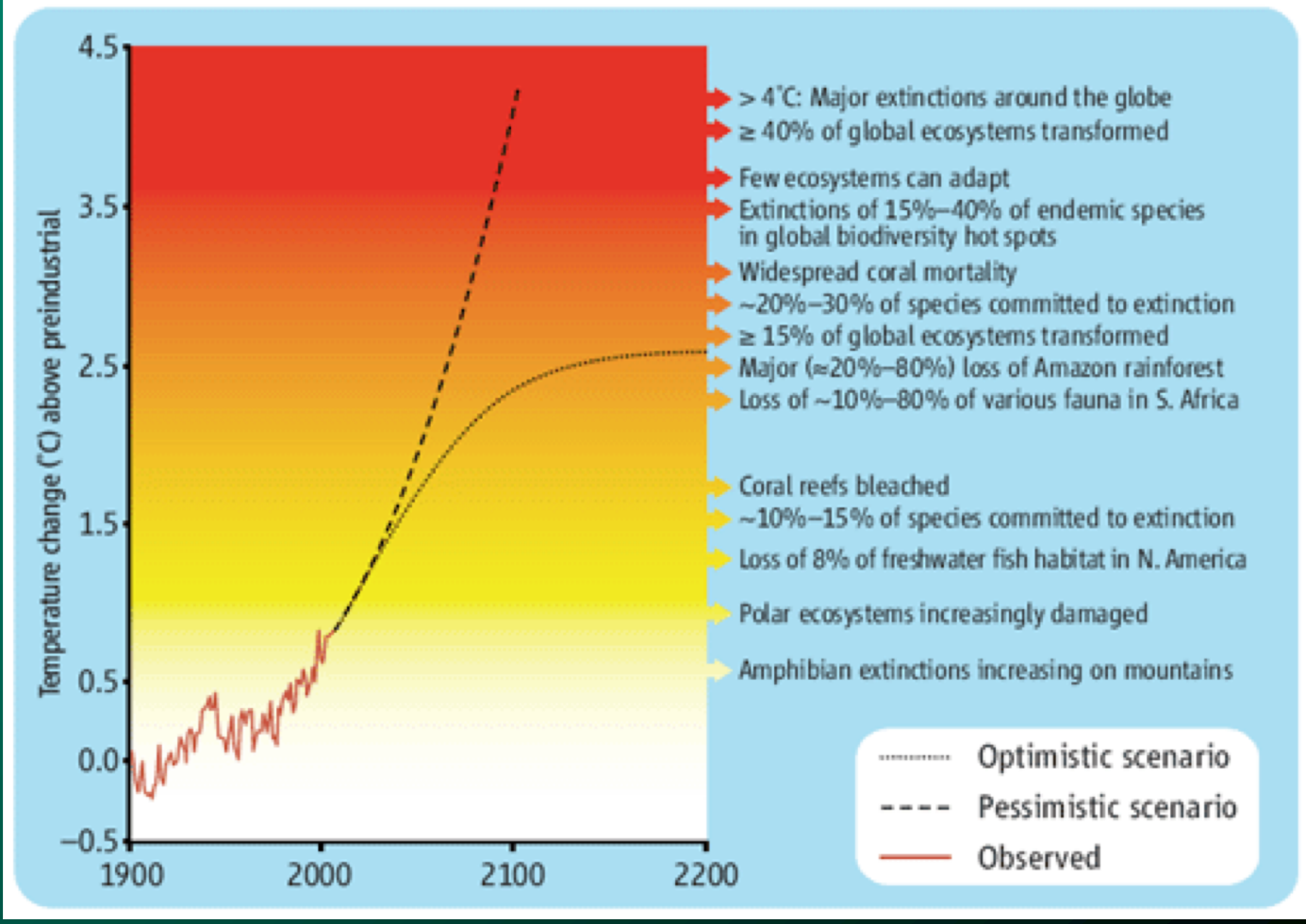
By **Somini Sengupta** March 29, 2018

António Guterres, the United Nations secretary general, said, "I am beginning to wonder how many more alarm bells must go off." Giuseppe Lami/European Pressphoto Agency, via Shutterstock.

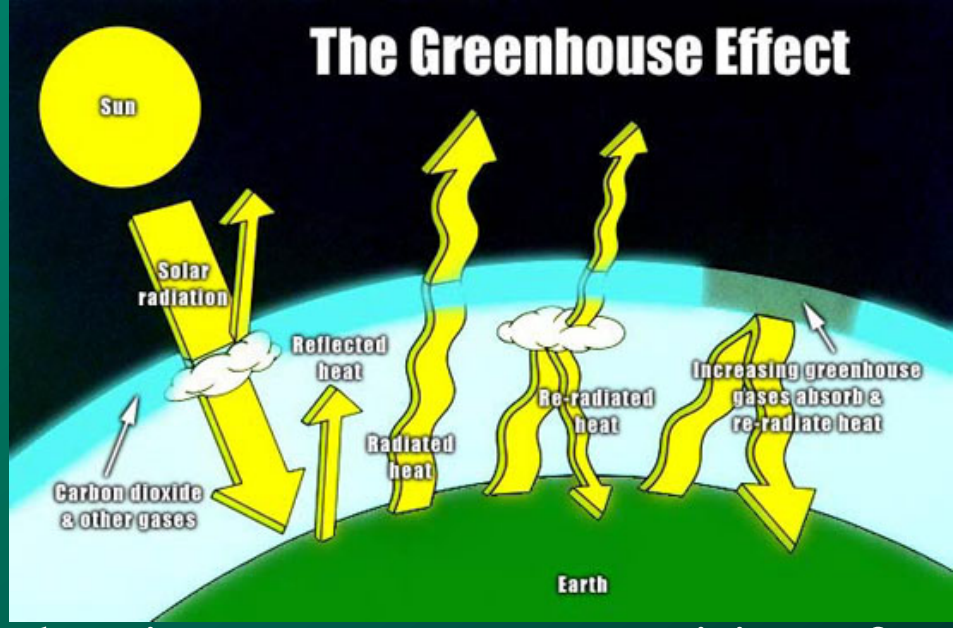
NY Times

Biological effects of global warming?Mass extinction!

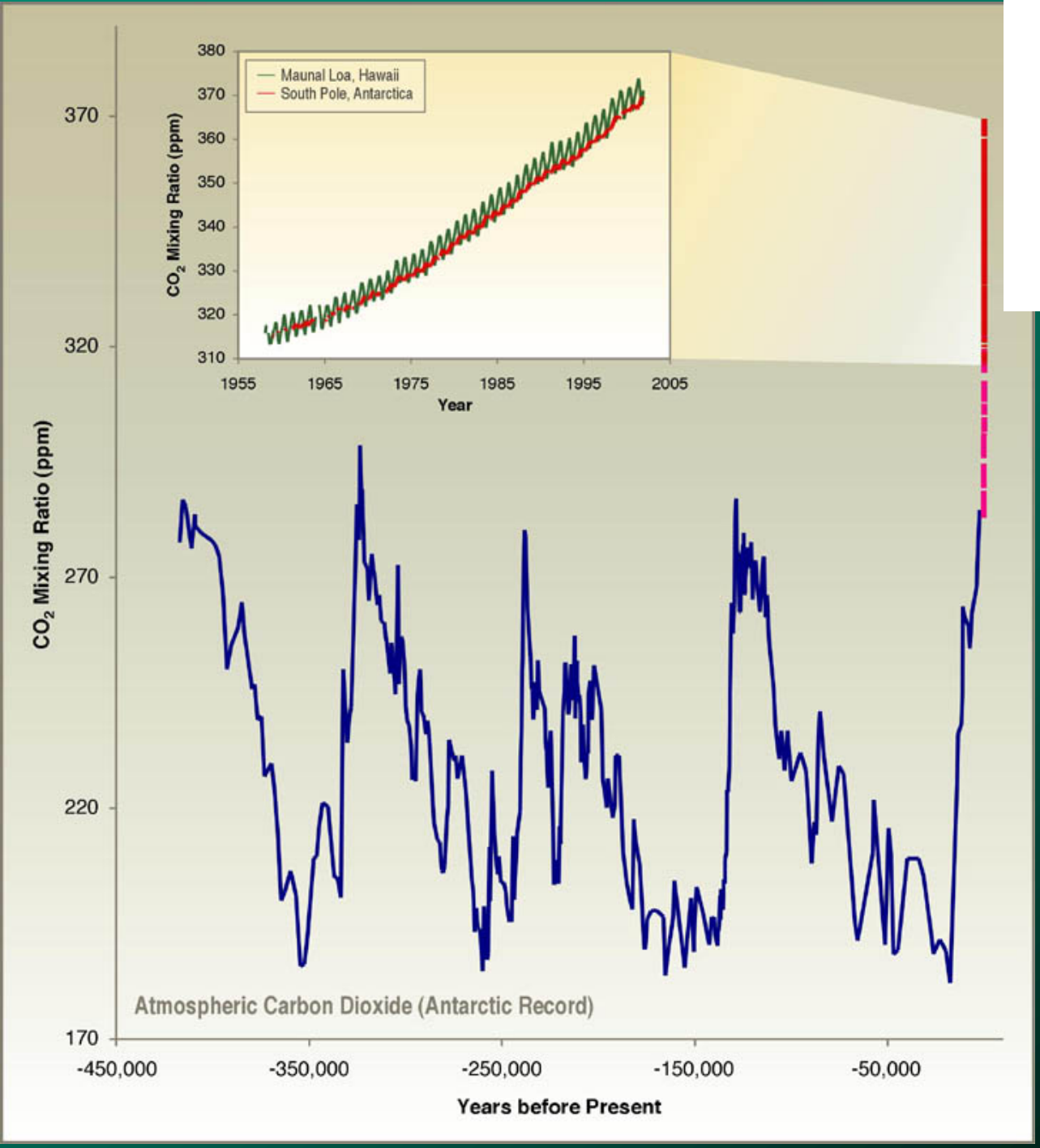
- We’re at 1ºC above preindustrial level (prior slide)
- Climbing steadily
- Reputable forecasts of 4-5º C by end of century “inevitable”
- Intergovernmental Panel on Climate Change (Feb. 2007)
  - 90% scientific consensus humans = cause
  - See figure (right)

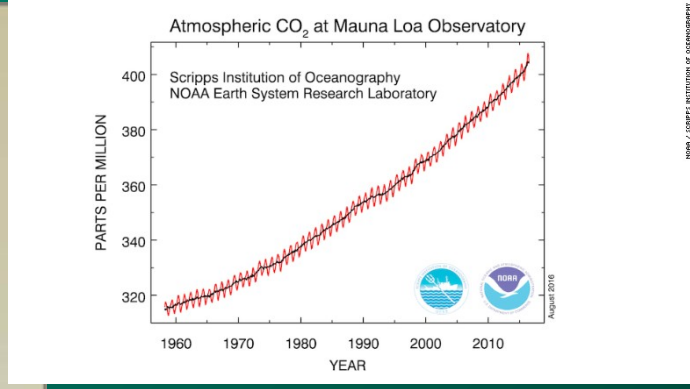


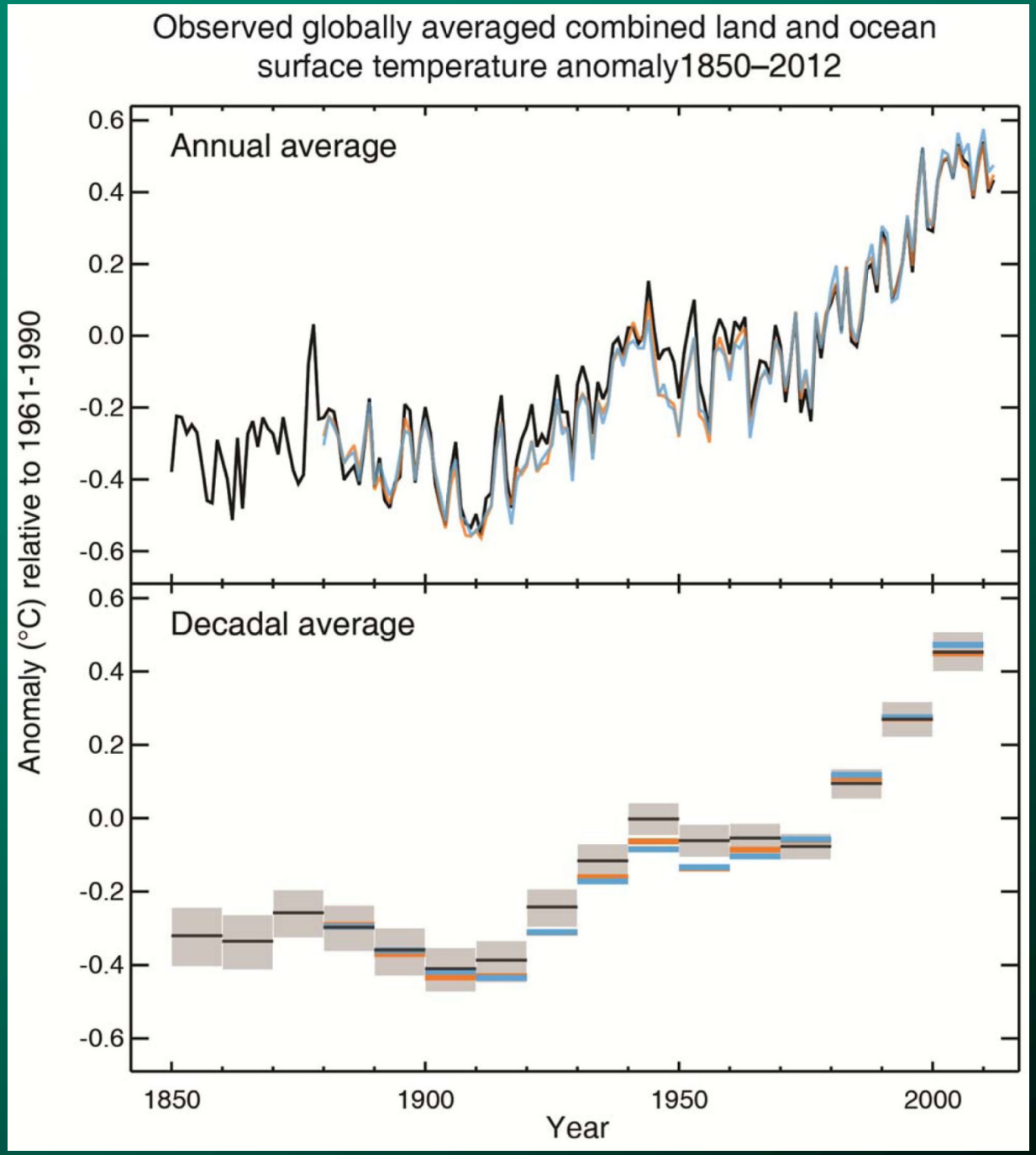
Global climate change



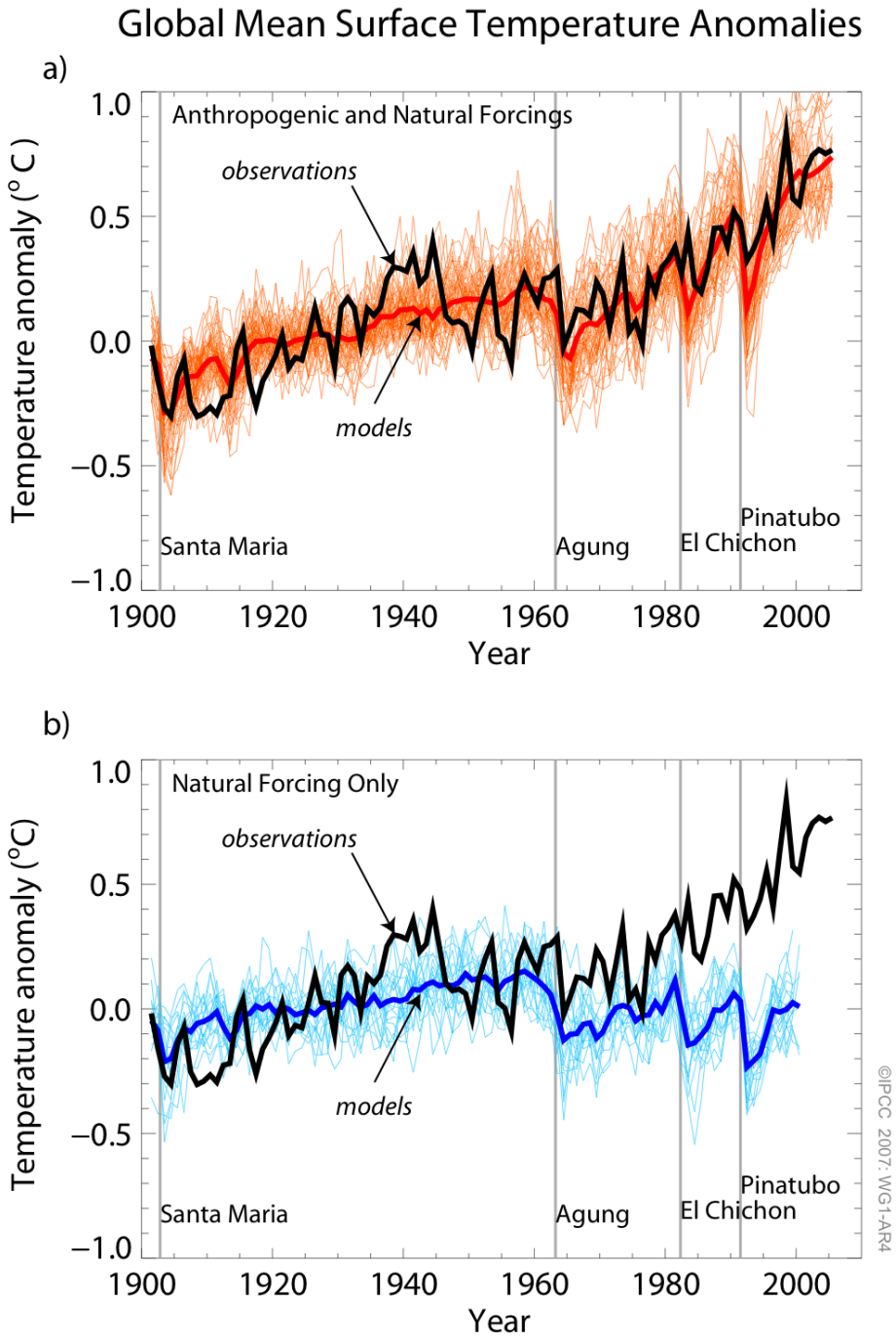
- The problem: human activity releasing enormous quantities of greenhouse gases into atmosphere
  - CO_2 (primarily through combustion of fossil fuels, faster than assimilated by plants, absorbed in oceans)
  - Also methane, ChloroFluoroCarbons (CFCs), Nitrous Oxides
  - Cutting forests globally releases CO_2 into atmosphere, & suppresses uptake
- This "forcing" causing more warming than observed in past
  - Theory & implications of fossil fuel consumption understood by Svante Arrhenius, Swedish physical chemist, in 1896!


Maunal Loa, Hawaii
South Pole, Antarctica
CO_2 Mixing Ratio (ppm)
Year
Atmospheric Carbon Dioxide (Antarctic Record)
CO_2 Mixing Ratio (ppm)
Years before Present

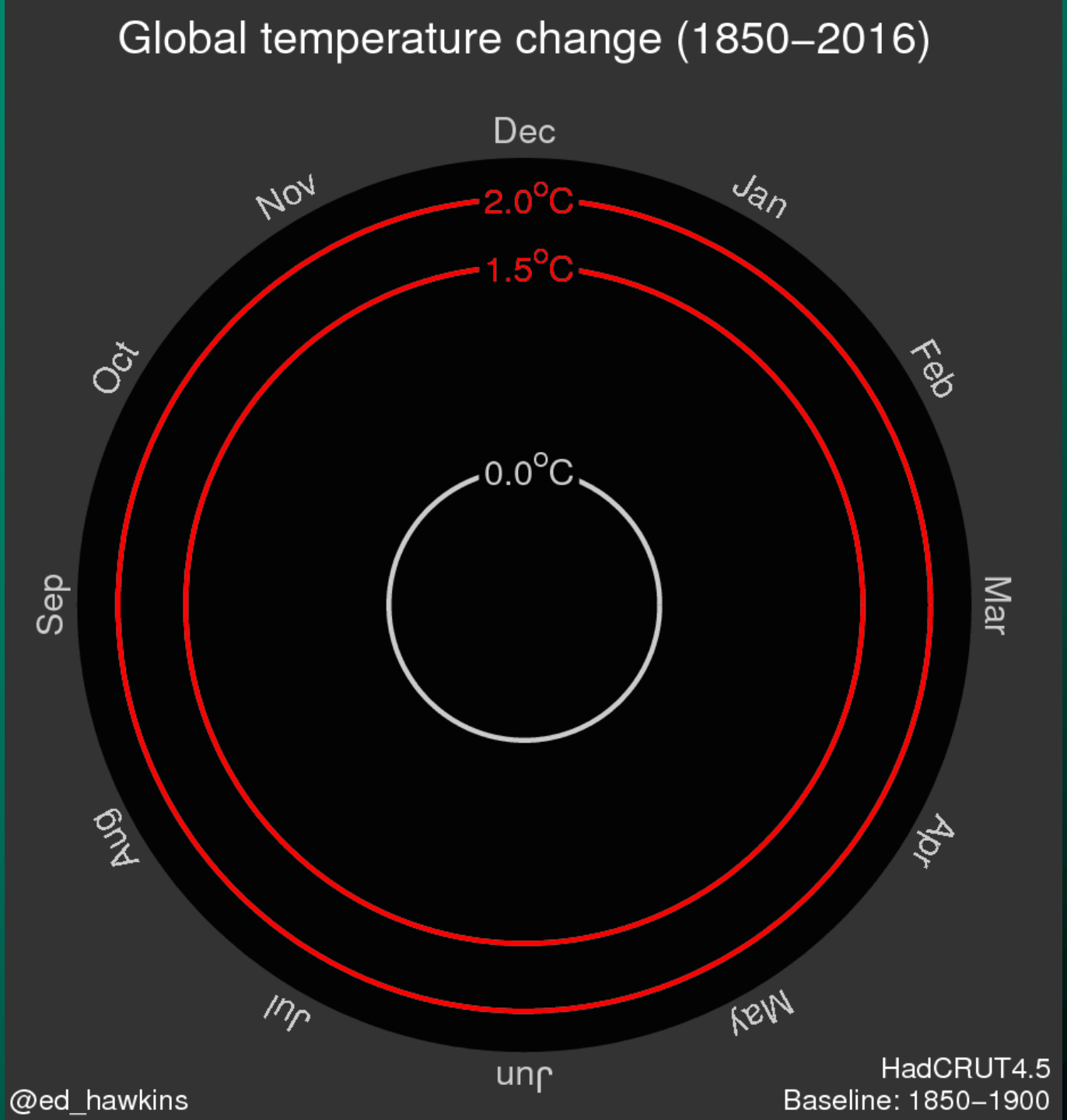

Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
YEAR
August 2016

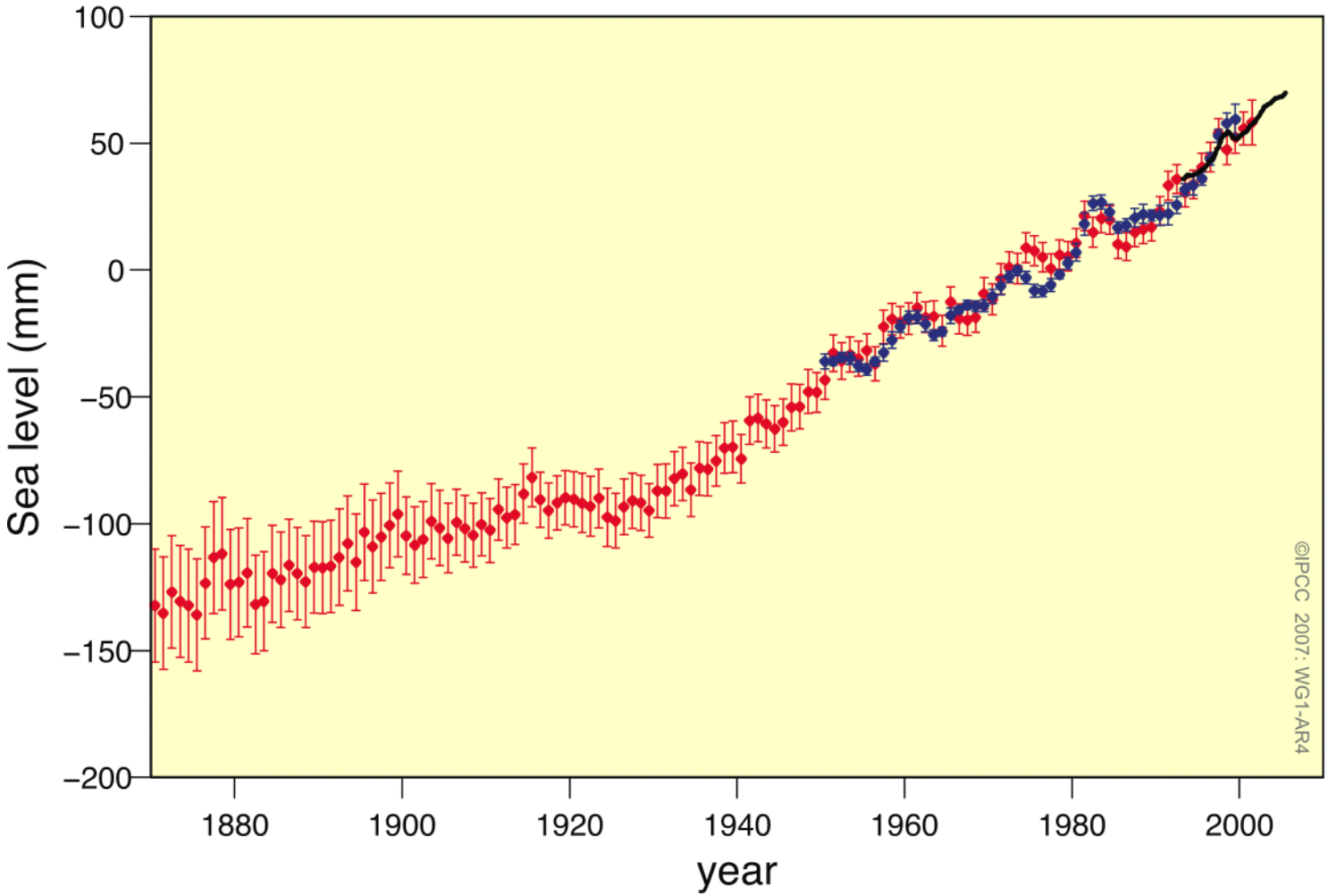

Observed globally averaged combined land and ocean surface temperature anomaly1850–2012
Annual average
Decadal average
Anomaly (°C) relative to 1961-1990
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1850
1900
1950
2000
Year

IPCC (2013)

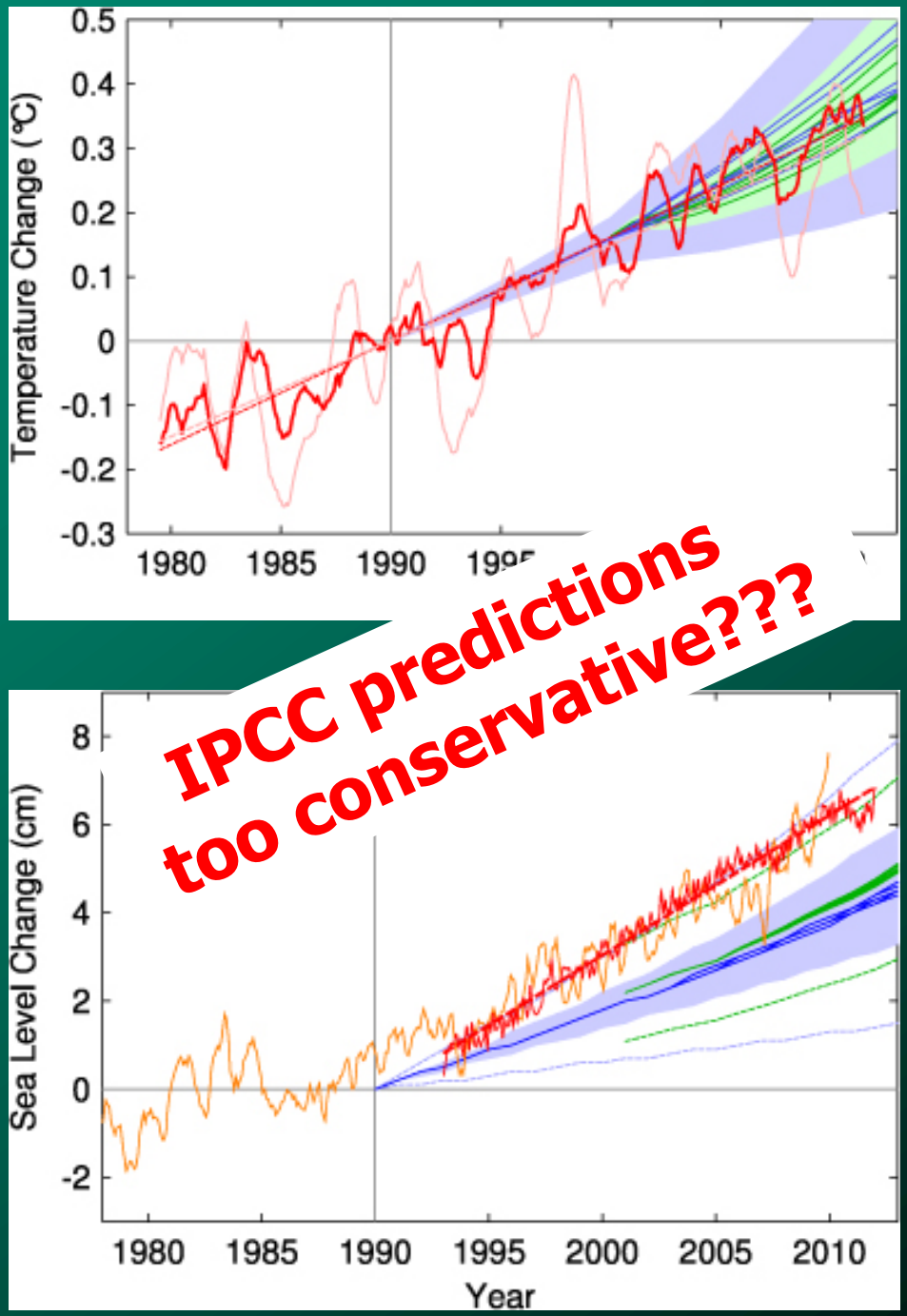

Global Mean Surface Temperature Anomalies
a)
Anthropogenic and Natural Forcings
observations
models
Temperature anomaly (°C)
1.0
0.5
0.0
−0.5
−1.0
Santa Maria
Agung
El Chichon
Pinatubo
1900
1920
1940
1960
1980
2000
Year
b)
Natural Forcing Only
observations
models
Temperature anomaly (°C)
1.0
0.5
0.0
−0.5
−1.0
Santa Maria
Agung
El Chichon
Pinatubo
1900
1920
1940
1960
1980
2000
Year
©IPCC 2007: WG1-AR4

IPCC (2007)


Global temperature change (1850–2016)
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2.0°C
1.5°C
0.0°C
@ed_hawkins
HadCRUT4.5
Baseline: 1850–1900


100
50
0
−50
−100
−150
−200
Sea level (mm)
1880
1900
1920
1940
1960
1980
2000
year
©IPCC 2007: WG1-AR4

IPCC (2007)



IPCC predictions too conservative???

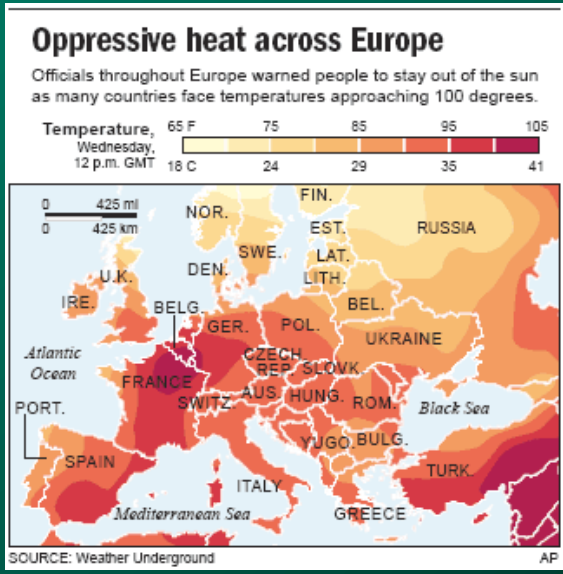
Rahmstorf et al. (2012)

Climate change→multiple impacts

- Higher temperatures
- Greater extremes rainfall, drought
- Stronger storms (hurricanes, & tornadoes?)
- Stronger El Niños
- Oceans
  - Sea level rise
  - Acidification
  - Increased runoff of nutrients (N, P) into water bodies

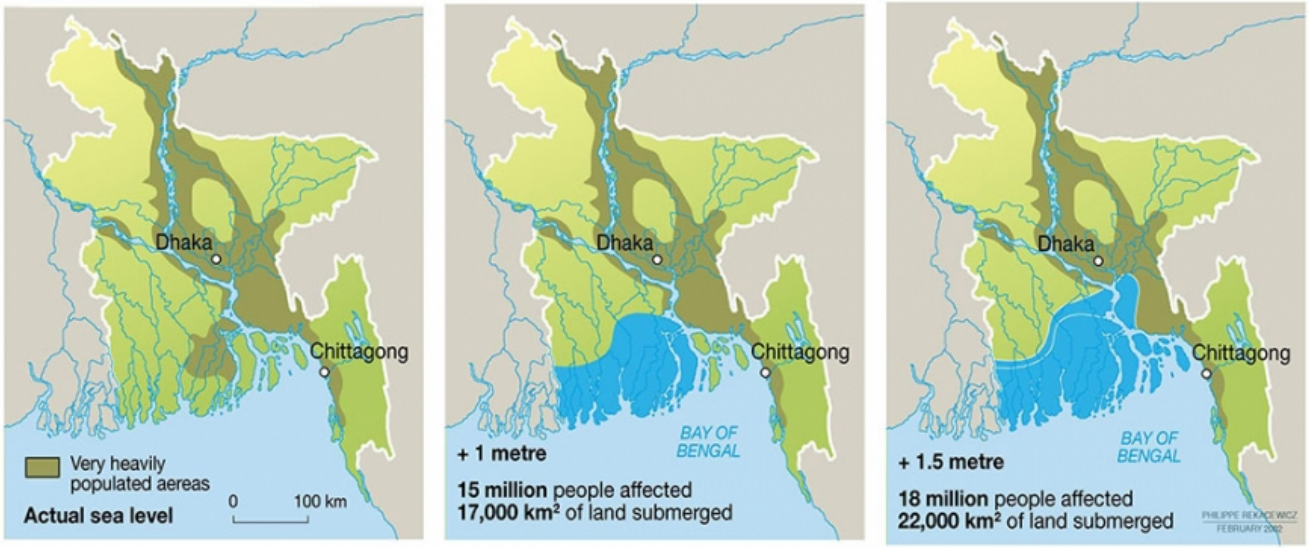
Impacts rising temperatures

- For humans…
  - Direct health effects of excessive heating, sweating→El Salvador "mysterious" kidney failure
  - Los Angeles 2006 heat wave
    - 170 excessive deaths (many misdiagnosed?)
    - Pregnant women & elderly especially vulnerable (dehydration)
    - "Heat waves in U.S. Already kill more people than hurricanes, floods, tornadoes—more than all extreme weather events combined" (*Years of Living Dangerously* TV series, Season 1, episode 8)
  - Deadly heat wave in W. Europe 2003→35,000 deaths (see figure)
  - Heat island effect: cities exacerbate problem
- For planet: Tropical plants cease to grow in warm temperatures (respiration exceeds photosynthesis, given high nighttime temperatures)→Tipping point in Amazonian forests?



Impacts sea level rise

- Massive coastal flooding globally, where most humans live
- Consider Bangladesh (below): 1.5 m sea level rise (expected by end of century) will impact 18 million people
  - Close to Dhaka (14.5 million people)
  - Where will they go? (Muslim country borders Hindu India)
- Sea level rise exacerbates (synergy) hurricane-related flooding: e.g., Hurricane Katrina, Sandy (NY/NJ))

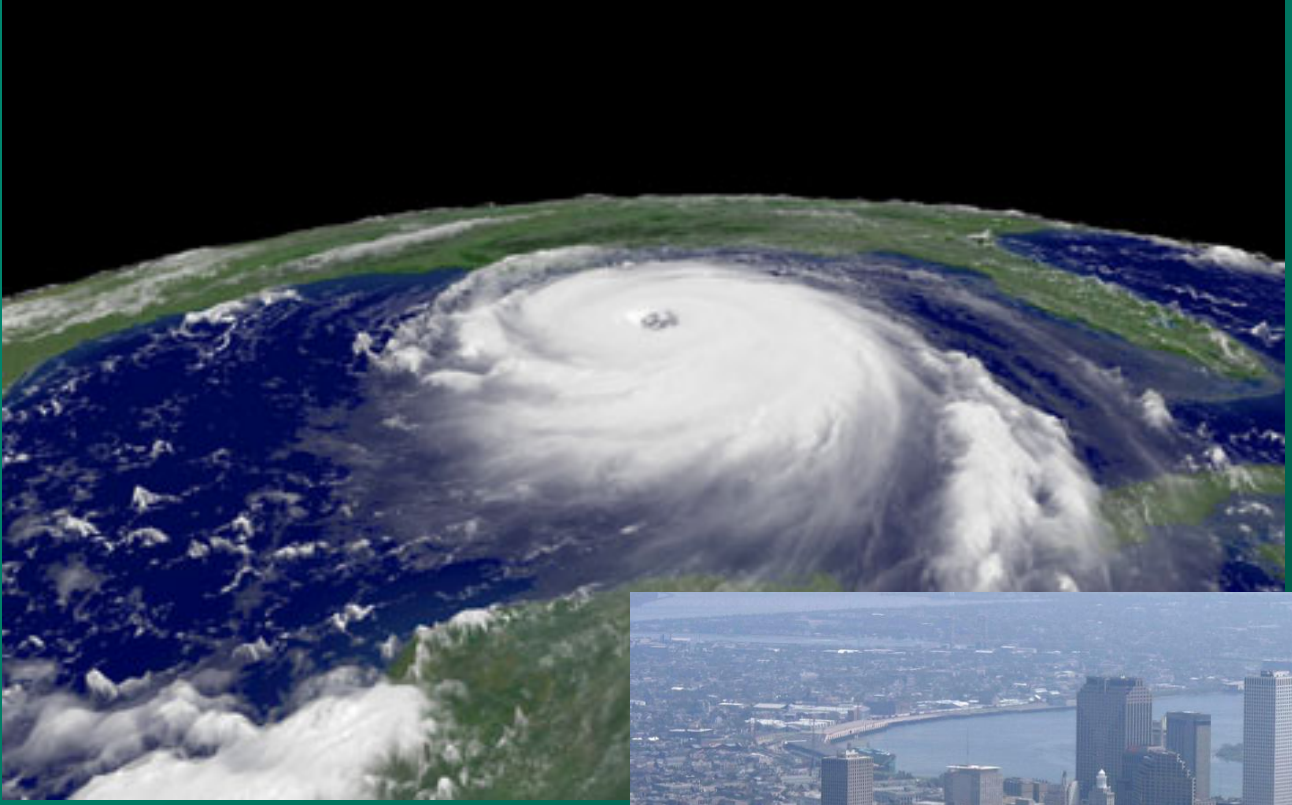


Sources: Dacca University; Intergovernemntal Pannel on Climate Change (IPCC).

Greater extremes rainfall, drought

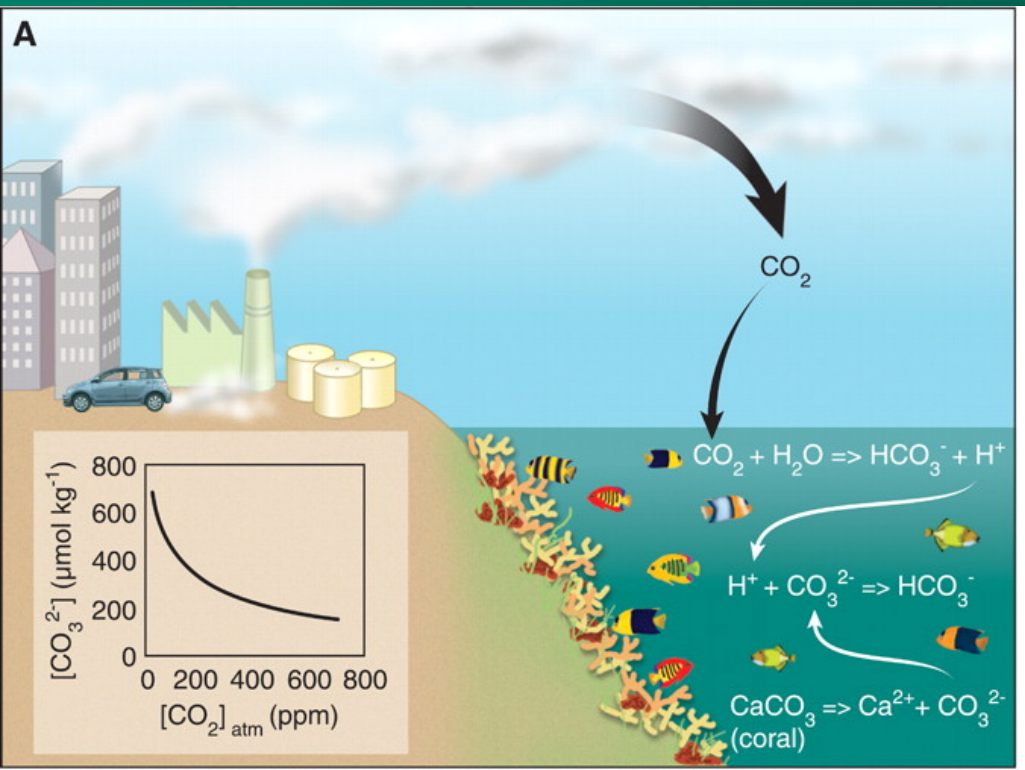
- Rainfall and flooding
  - Flooding in Houston, Baton Rouge/Lafayette ("no-name storms" pump water inland to coastal areas)
- Drought
  - Recent California droughts affected agriculture, health, water rationing
  - Wildfires across the Western US (e.g., N. California, Fall 2017)→loss of property, some deaths
  - Syrian drought triggered war there? (Thomas Friedman, NY Times editorial writer & author)
  - Drought in Kansas exacerbated Arab Spring uprisings (less wheat→higher wheat prices in Mideast)

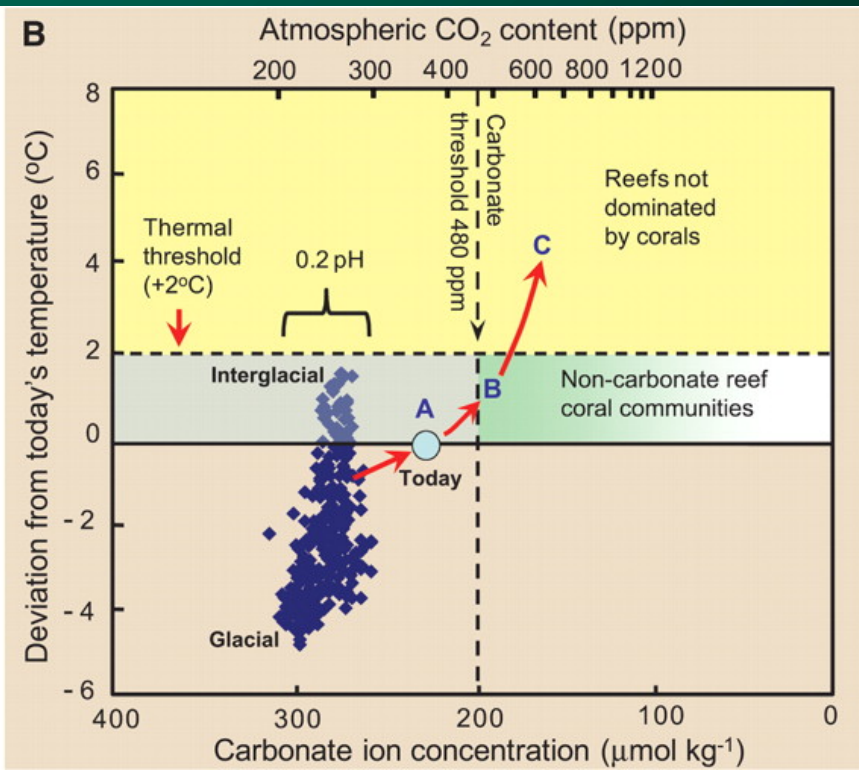
Hurricane Katrina

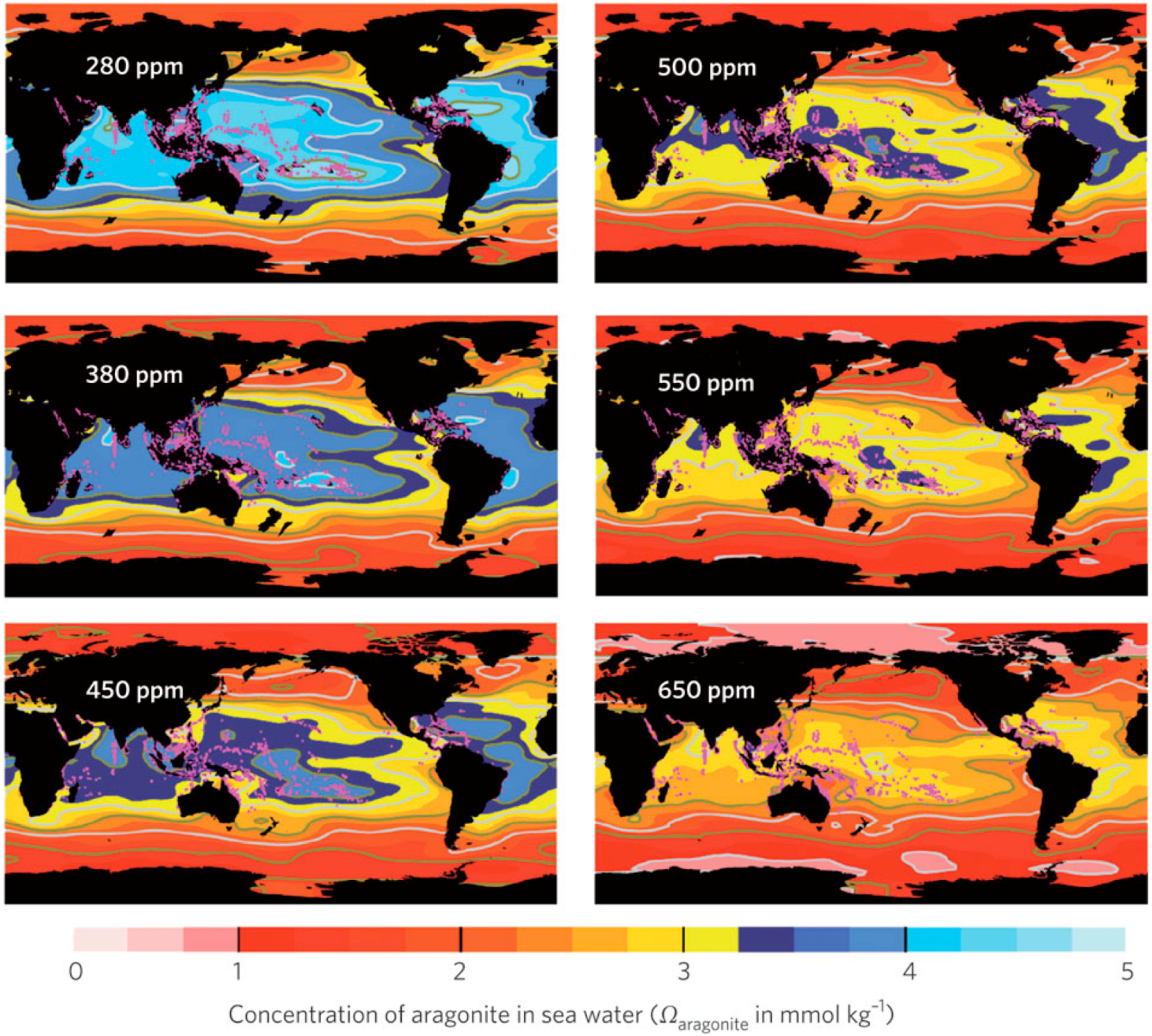


Global mechanisms of coral destruction

- Acidification of oceans
- Increased ocean temperature
- We already see conditions not seen in past 420,000 years







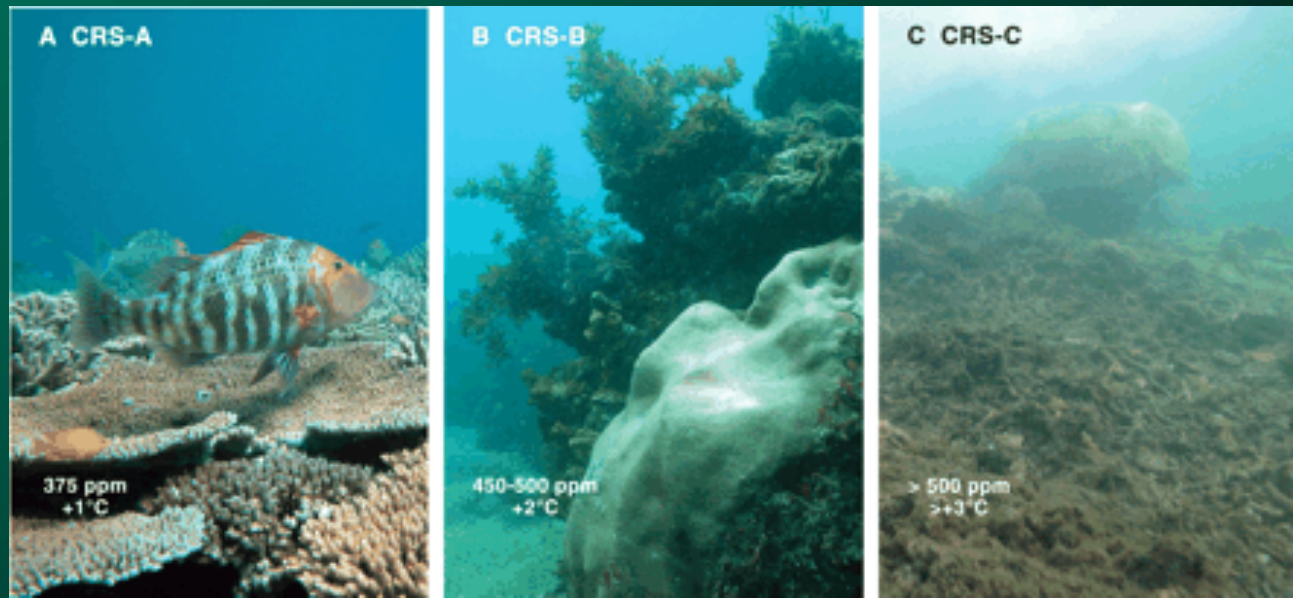
Before the Industrial Revolution (280 ppm), nearly all shallow-water reefs had $\Omega_{aragonite}$ >3.25 mmol kg^{-1}, which is the minimum required for a coral reef. Reefs are likely to contract rapidly at carbon dioxide concentrations >500 ppm. Figure from O. Hoegh-Guldberg *et al. Science* **318**, 1737–1742 (2007); reproduced with permission, © 2007 AAAS.

Warming impact: coral reefs disappear

(aragonite = marine biologically produced $CaCO_3$)

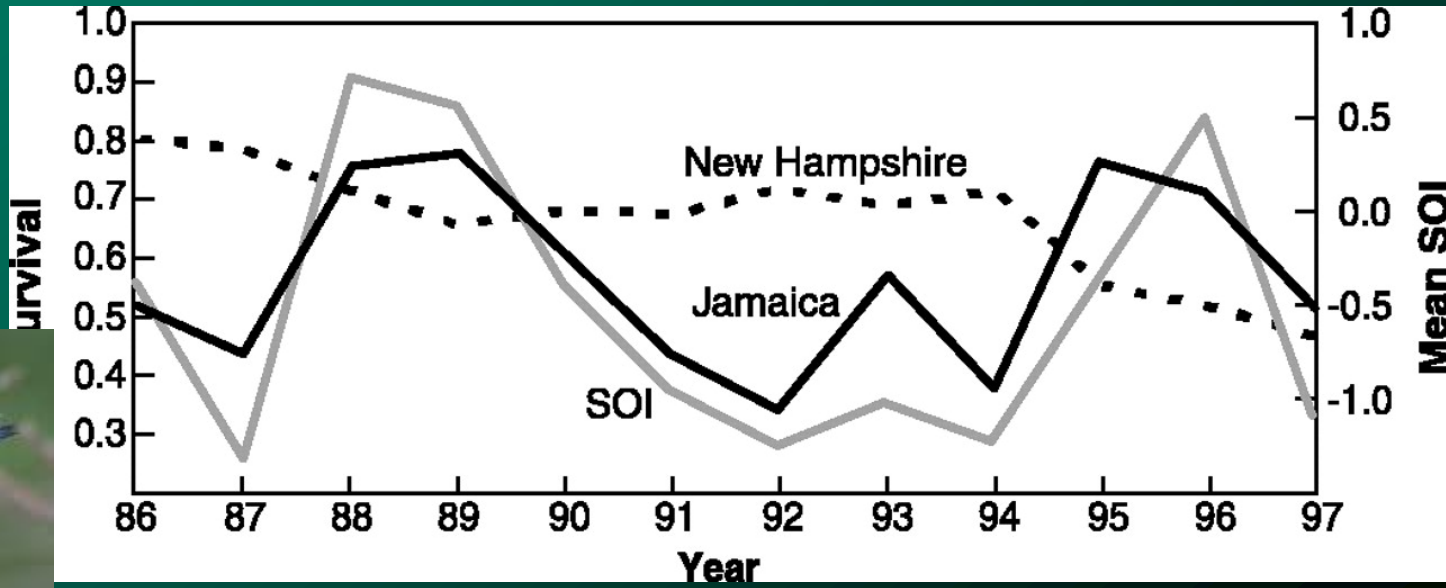
Implications of coral reef destruction

- Loss of extraordinary tropical biological diversity (extinctions due to water quality degradation, loss of reef area globally)
- Reduced oceanic productivity
- Reduced fisheries (impacting 10s of millions of humans)
- Reduced protection from hurricanes, tsunamis



Rainfall (El Niño) → changes in food and survival of migratory birds in Caribbean

- Black-throated blue warbler ***annual survival*** corresponds to Caribbean El Niño-La Niña (ENSO = SOI) fluctuations in rainfall & probably food (Sillett, Holmes, & Sherry, *Science* 2000)



Habitat conversion & loss of native habitat

- Habitat loss
- Habitat fragmentation
- Habitat degradation from intensification of agriculture
  - Chronic loss of nutrients
  - Dependence of industrial scale agriculture on fossil fuels (for energy, fertilizer synthesis)
- Interactions: E.g., fragmentation creates barriers to movements of organisms to higher latitudes & altitudes, as organisms attempt to stay within the climate zones to which they're adapted, exacerbating extirpation (local extinction)

Changing global biogeochemistry

- Altered Carbon cycle (e.g., increased greenhouse effect due to fossil fuel combustion, CO_2 emissions)
  - Same mechanism as caused greatest mass extinction event ever? Burgess et al. 2017. Initial impulse of Siberian Traps sills as the trigger of the end-Permian mass extinction. *Nature communications* 8: 164. See also https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/mar/12/burning-coal-may-have-caused-earths-worst-mass-extinction
- Humans have doubled amounts of Nitrogen going into rivers & oceans→eutrophication
  - Dead zones, e.g., mouth of Mississippi River
  - Hundreds of dead zones globally
  - Serious concern that oceans globally will cease to circulate (slowing of thermohaline pump, N. Atlantic), killing much of ocean life→implications for human protein source

Biotic losses: overexploitation of fish and wildlife

- Terrestrial examples
  - Bushmeat trade globally (human demand for food, especially in impoverished regions)
- Marine examples
  - Collapse of shallow marine ecosystems due to overharvesting, going back into prehistoric times): coral reefs, seagrass beds, rocky intertidal regions, oyster reefs
  - Collapse of many marine fisheries

Bushmeat trade

Exotic meat trade in China

"Winner, Single Image. National Geographic Society. Nothing prepared photographer Paul Hilton for what he saw in the major port of Belawan in Sumatra: some 4,000 defrosting pangolins, part of one of the largest seizures of the scaly anteaters on record. The carcasses were destined for China and Vietnam for the exotic-meat trade or for traditional medicine (their scales are believed to treat a variety of ailments)."

Overfishing on Cocos Island, Costa Rica (1984-85)

Photos by T. Sherry

Biotic gains: Invasive species

- Invasive disease vectors and pathogens
  - West Nile virus
  - Zika, Chikungunya, dengue viruses
  - Mosquitoes such as asian tiger mosquito, a vector for WNV, Equine Encephalitus, dengue, yellow fever (currently making a comeback in Brazil)

Surprising indirect (cascading) effects of invasive Burmese pythons in Everglades

- Story in NY Times: https://www.nytimes.com/interactive/2017/10/07/climate/everglades-pythons-mosquitoes.html?emc=edit_th_20171017&nl=todaysheadlines&nlid=42364604
- Pythons have knocked out most native mammals (deer, racoons, oppossums)
- Native rats somehow survived (why is not known!), and became major food source for mosquitoes.
  - Rat is a source of encaphalitis in humans, other animals!

Hippopotamus in the wild

(Years of Living Dangerously, Yr. 2, Episode 6)

- Many ways in which humans depend on Biological Diversity generally.
- Hippo is just one example of a Keystone species = species with disproportionately large impact ecologically (on ecosystems) for its population size.
  - Exclosure experiments show that its loss would lead to explosion of rodent populations, and human diseases; hence its value to humans
  - In nature it injects huge amounts of carbon and nutrients (feces) into rivers, supporting aquatic ecosystems
  - What's its value? To humans? Intrinsically?

Puzzle of declining Indian vultures

- As recently as 1990s, >30 million (!) vultures in India/Pakistan
  - Important scavengers of dead cattle & other animals (ecological service)
- Vultures declined to almost none ("functionally extinct") by ~yr. 2000

Puzzle of declining Indian vultures

- Dr. Lindsay Oaks (Washington St. Univ.) tested for pesticides, metals, diseases, etc.
  - Decline due to kidney failure from drug (diclofenac) given cattle as an anti-inflammatory and pain killer (Hindu reverence for cattle)!
- Long-term consequences:
  - Explosion of feral dog populations eating cattle, rabies epidemics (35,000 human deaths annually!)
  - Hundreds human deaths annually due to leopards, attracted to cities to eat dogs!
  - Only viable populations of Indian vultures today in Cambodia, Burma
- Solutions:
  - Safe replacement drug found
  - Very recent cessation in use of diclofenac
- Stabilization, even slight increase in vulture populations recently

Conclusions

- Global change = human impacts to entire biosphere & geosphere
- Global warming arguably worst global change phenomenon (and growing)
- Many examples of global warming (climate change) having direct and indirect effects on humans
- Many global change phenomena interact, exacerbating all of them
- Effects of global change on other organisms impact humans indirectly→ humans depend on nature, safe environment
- Humans so far doing little to address global warming