Why and How to Decarbonize Global Energy

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08 August 2013

Arendal, Norway

Global Warming Status

1. Knowledge Gap Between

- What is Understood (scientists)
- What is Known (public)

2. Planetary Emergency

- Climate Inertia → Warming in Pipeline
- Tipping Points → Could Lose Control

3. Limit on Fossil Fuel Emissions

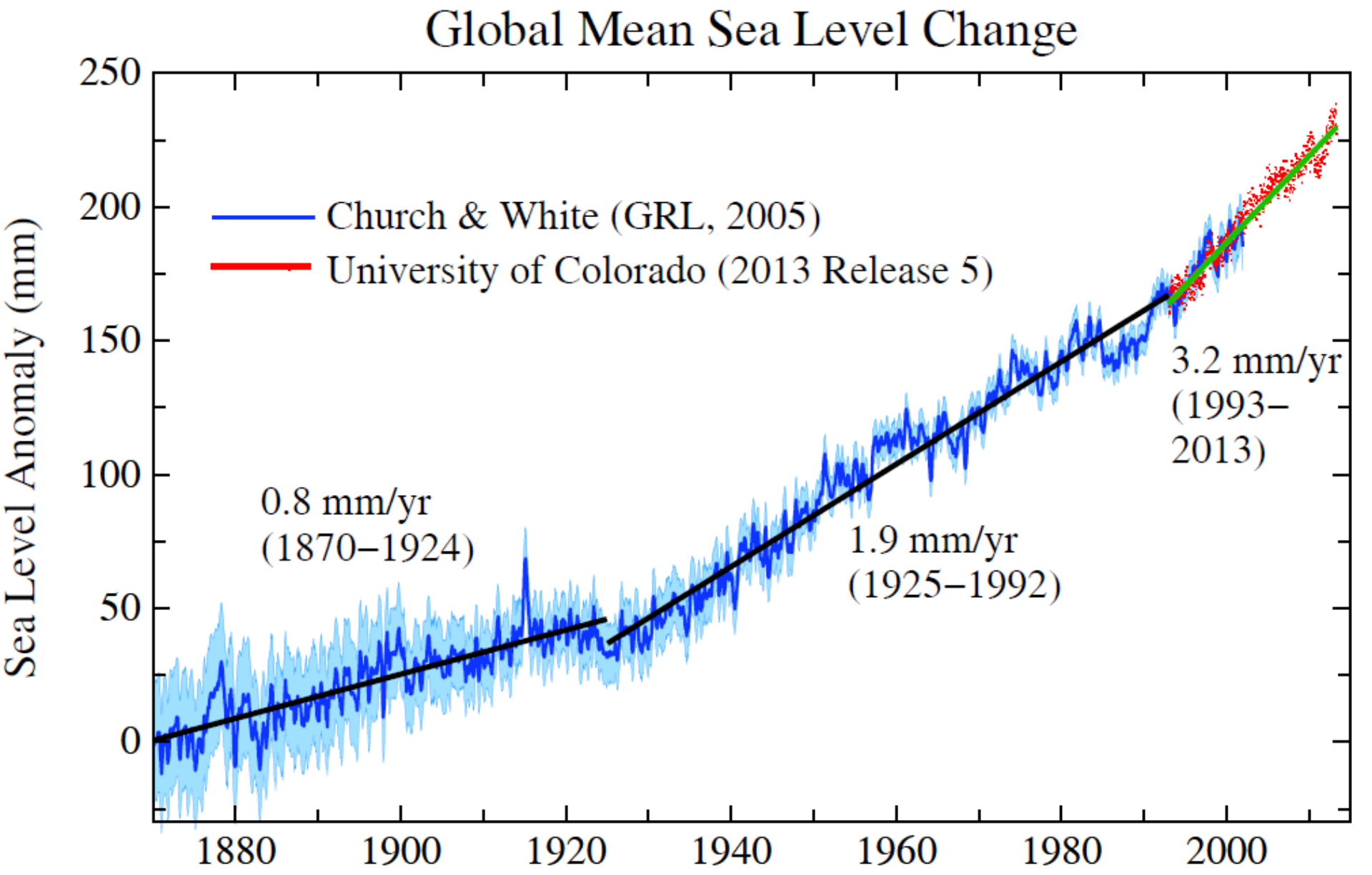
- Already Approaching the Limit
- Governments Feign Ignorance of Crisis

Climate Impacts

1. **Ice Sheet Disintegration & Sea Level**
   - Ocean Warming → Ice Shelves Melt → Ice Streams Surge → Disintegration

2. **Species Extermination**
   - Shifting Climate Zones, Multiple Stresses, Species Interdependencies

3. **Climate Exremes**
   - Heat Waves, Drought, Fires
   - Heavier Rain, Floods, Stronger Storms



Accelerating rate of sea level rise during the past century.

Paleoclimate Guidance

Eemian sea level +5-9 meters

- **Eemian temperature +2°C***

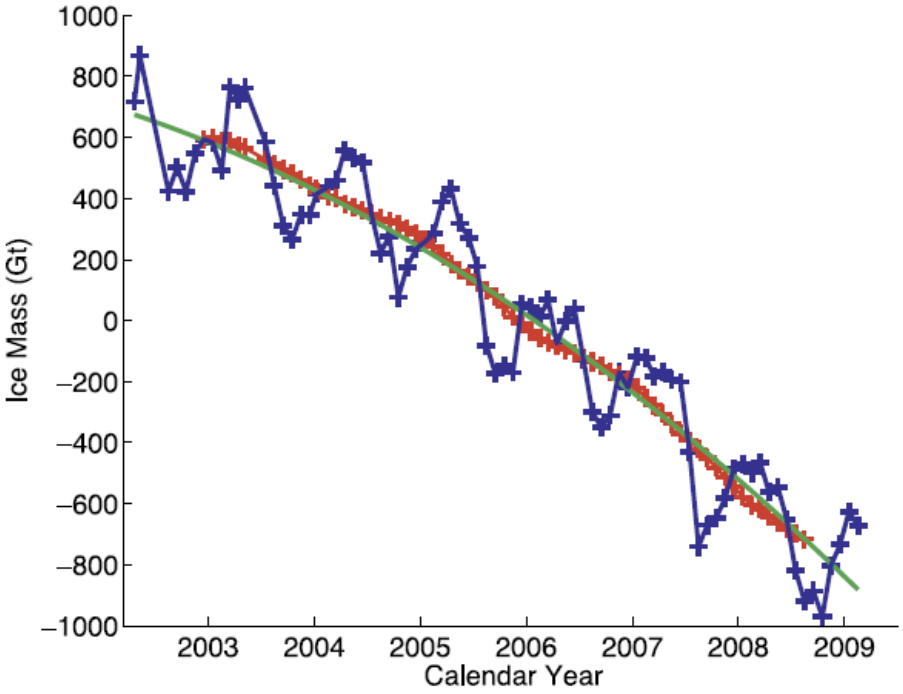
Pliocene sea level +15-25 meters

- **Pliocene temperature +3-4°C***

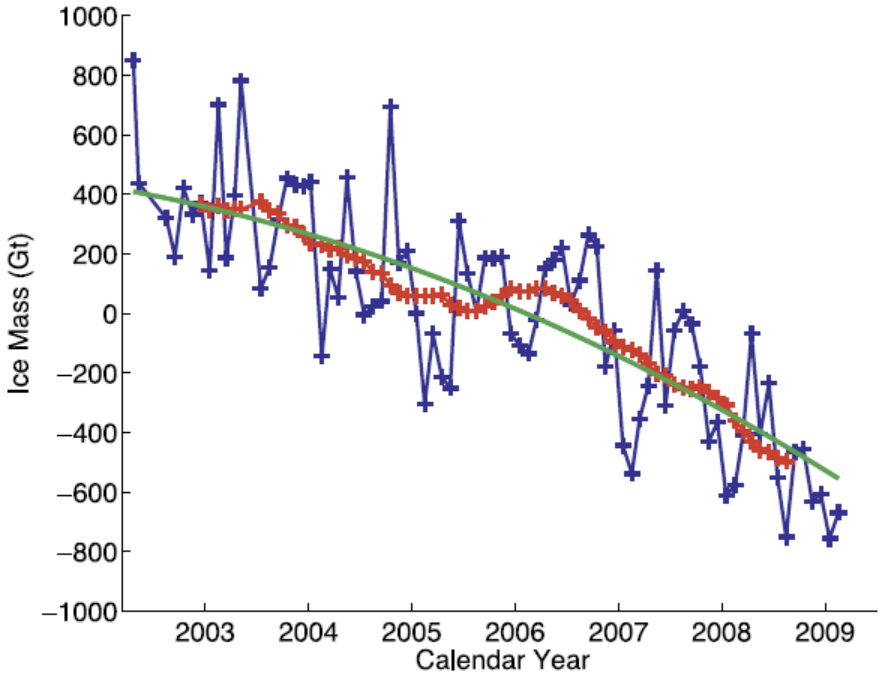
Ice sheet response time uncertain, but it is shorter than the lifetime of fossil fuel carbon and resulting global warming

***relative to pre-industrial times**

Gravity Satellite Ice Sheet Mass Measurements



Greenland Ice Sheet



Antarctic Ice Sheet

Source: Velicogna, I. *Geophys. Res. Lett.*, **36**, L19503, doi:10.1029/2009GL040222, 2009.

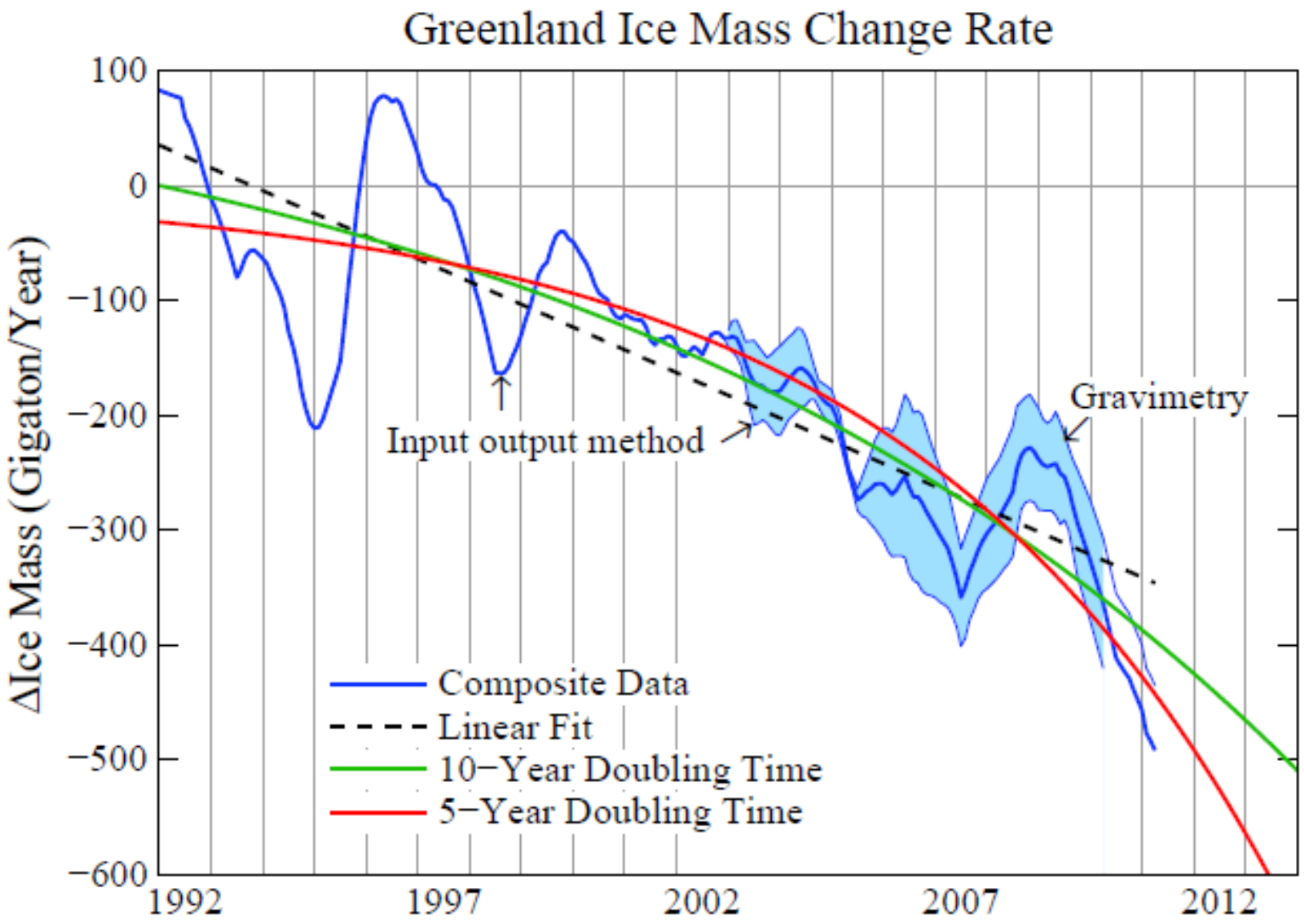
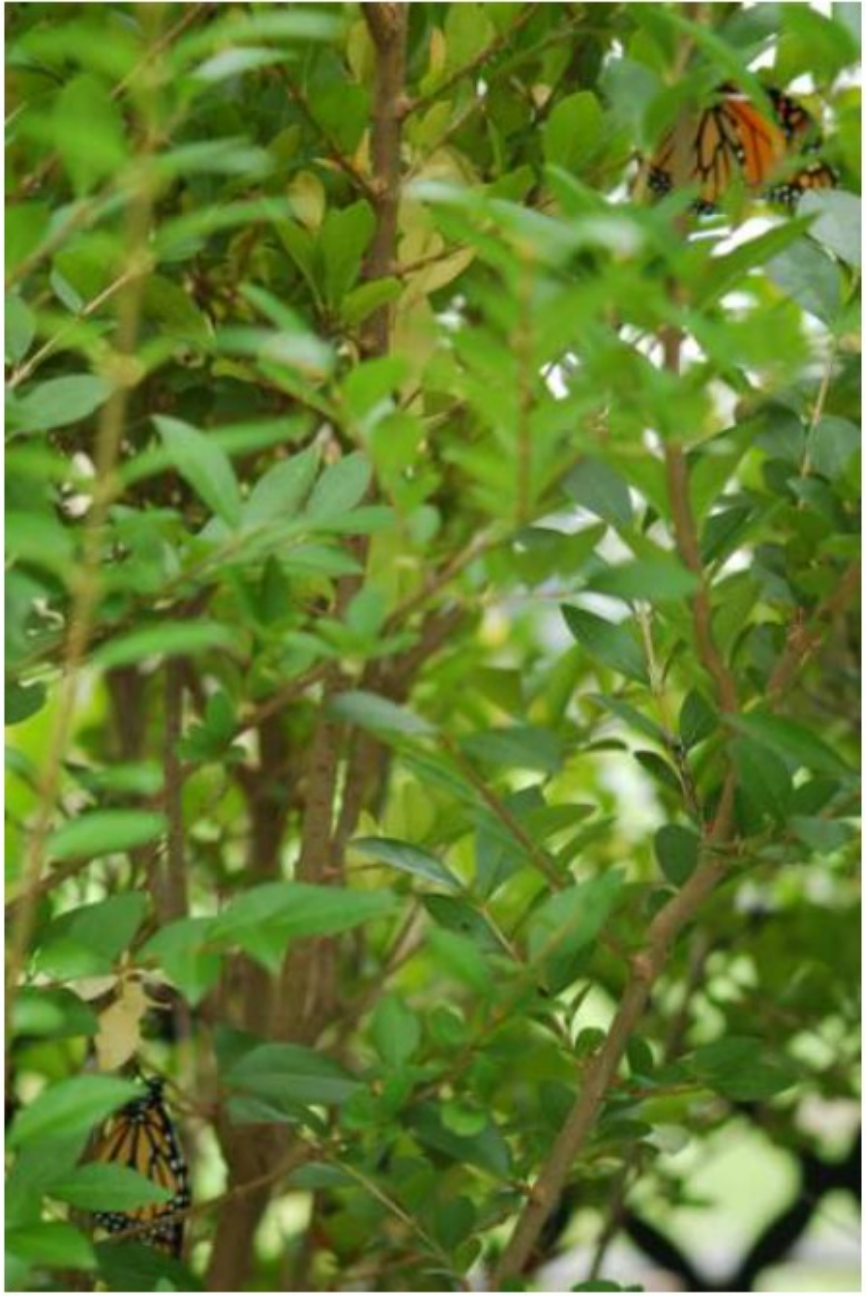

Greenland Ice Mass Change Rate
ΔIce Mass (Gigaton/Year)
100
0
−100
−200
−300
−400
−500
−600
1992
1997
2002
2007
2012
Input output method
Gravimetry
Composite Data
Linear Fit
10−Year Doubling Time
5−Year Doubling Time

Figure 1. The broken-wing female Monarch on our butterfly bush.

Figure 2. The larvae devouring the milkweeds.



Newly emergent Monarchs, each beside its popped chrysalis, waiting for its wings to dry.

Figure 6. The male Monarch after its first landing, on the butterfly bush.

Figure 7. The female Monarch on the remains of a wildflower.

Current U.S. Drought Monitor

June 2011: Record 7.6% of U.S. in ‘Exceptional’ drought category, simultaneous with record flooding on Mississippi River.

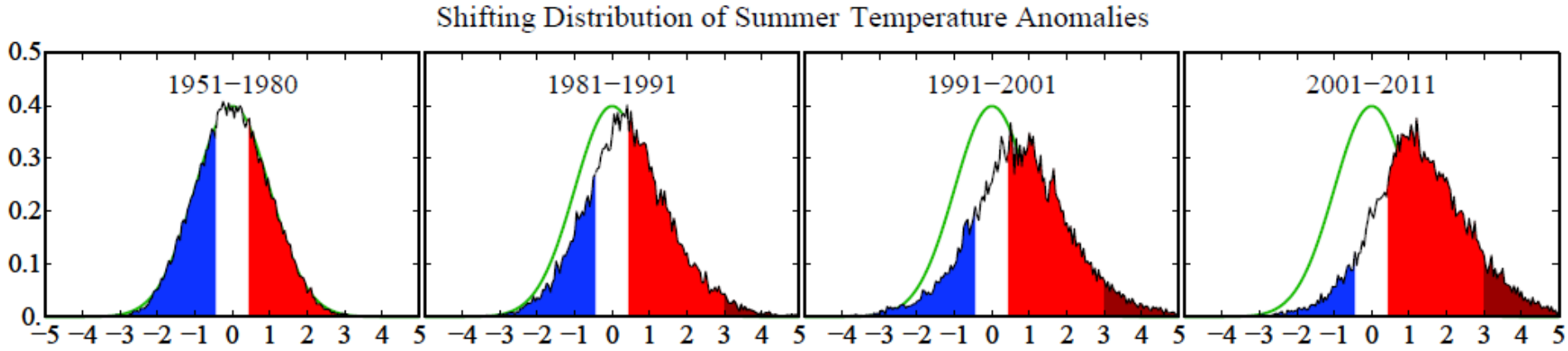
Stresses on Coral Reefs

Coral Reef off Fiji (Photo: Kevin Roland)

Loaded Climate Dice: global warming is increasing extreme weather events.

Extreme summer heat anomalies now cover about 10% of land area, up from 0.2%.

This is based on observations, not models.



Frequency of occurrence (vertical axis) of local June-July-August temperature anomalies (relative to 1951-1980 mean) for Northern Hemisphere land in units of local standard deviation (horizontal axis). Temperature anomalies in the period 1951-1980 match closely the normal distribution ("bell curve", shown in green), which is used to define cold (blue), typical (white) and hot (red) seasons, each with probability 33.3%. The distribution of anomalies has shifted to the right as a consequence of the global warming of the past three decades such that cool summers now cover only half of one side of a six-sided die, white covers one side, red covers four sides, and an extremely hot (red-brown) anomaly covers half of one side.
Source: Hansen, J., Sato, M., and Ruedy, R., Proc. Natl. Acad. Sci., 2012.

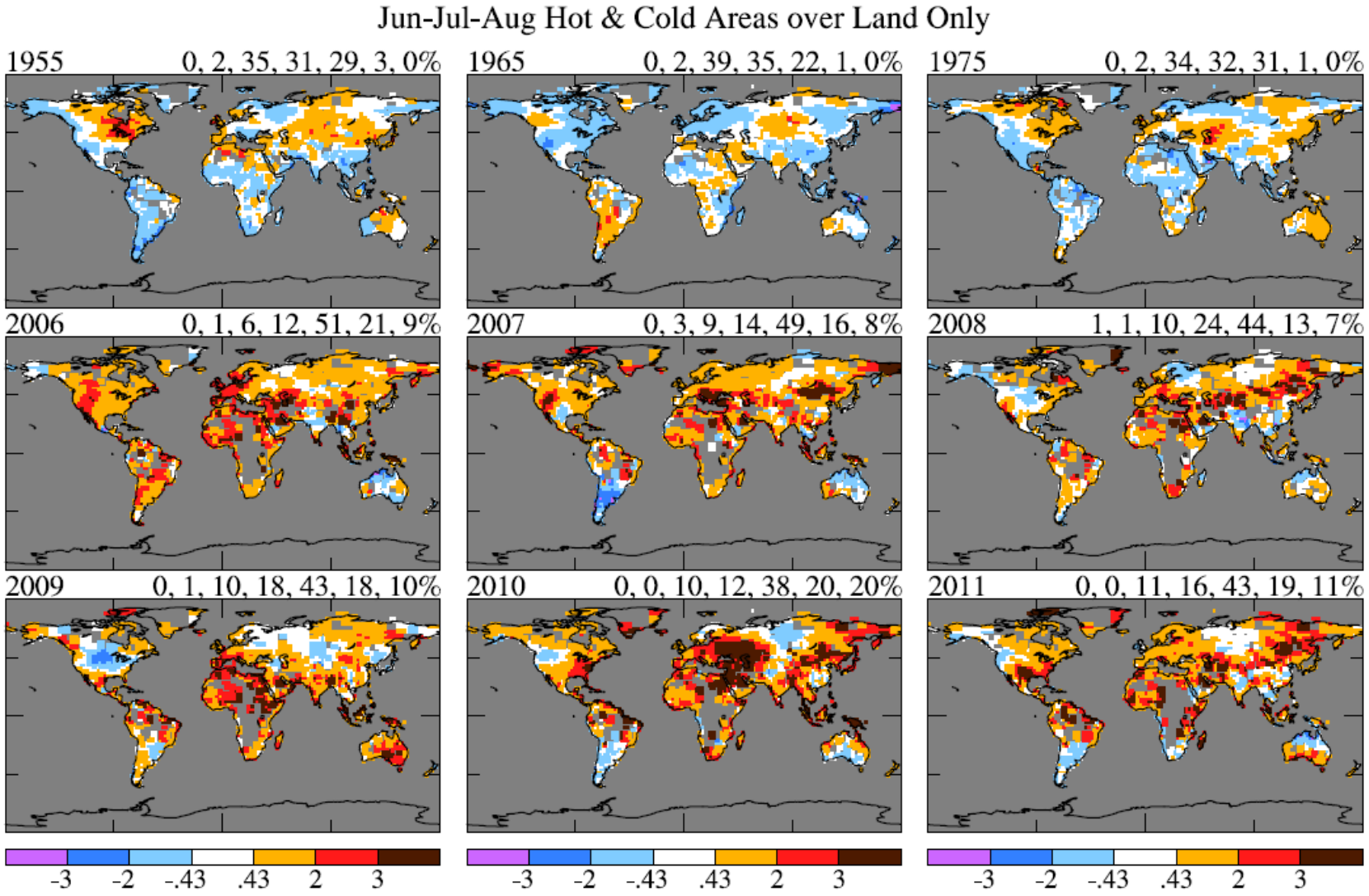
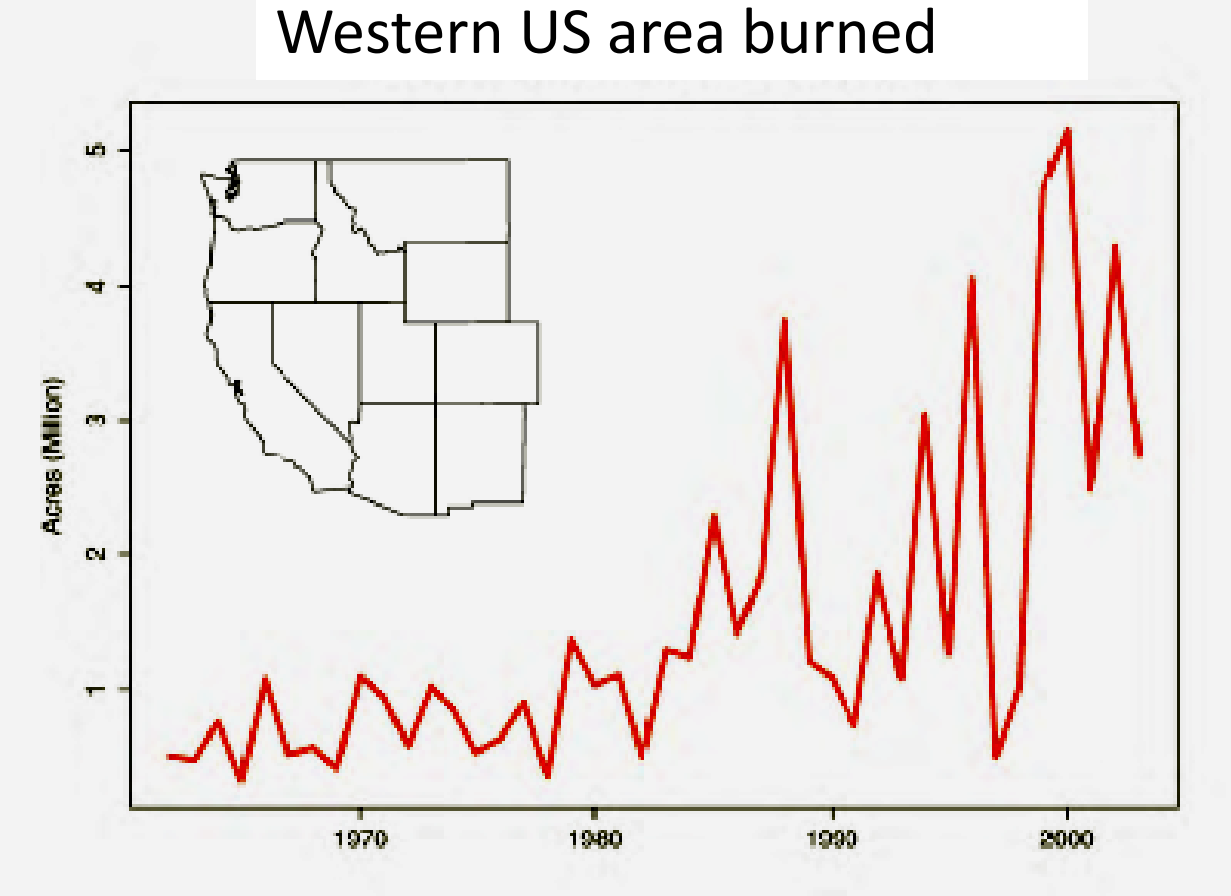


Fig. 6. Jun-Jul-Aug surface temperature anomalies over land in 1955, 1965, 1975 and 2006-2011 relative to 1951-1980 mean temperature in units of the local 1951-1980 standard deviation of temperature. Numbers above each map are the percent of surface area covered by each category in the color bar.

Homes are destroyed in Colorado Springs, June 2012

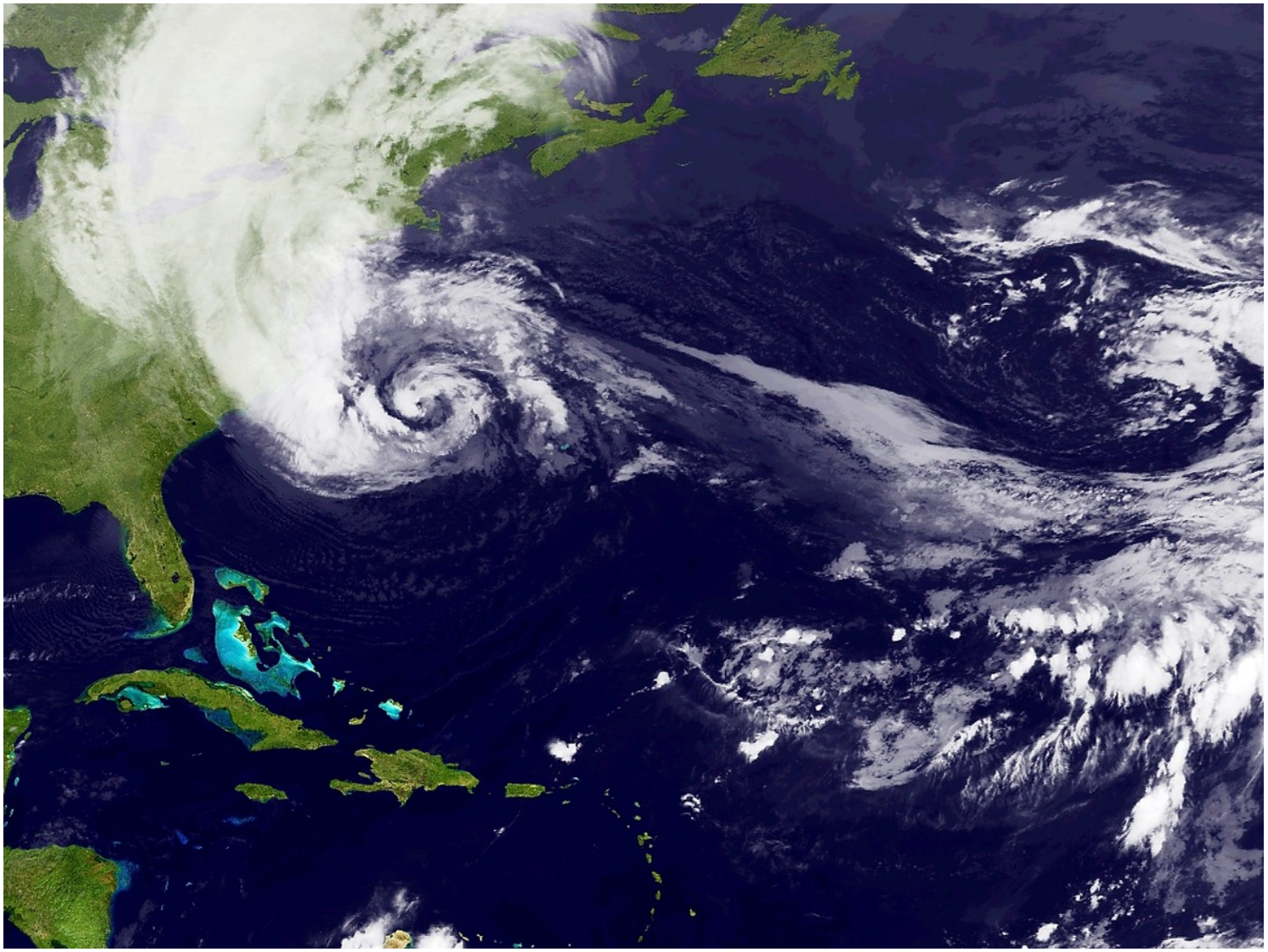
Fires Are Increasing World-Wide

Wildfires in Western US have increased 4-fold in 30 years.



Source: Westerling et al. 2006

Russia flash floods: 144 killed in Krasnodar region
(BBC News, 8 July 2012)



AT SEA - OCTOBER 28: In this handout satellite image provided by National Oceanic and Atmospheric Administration (NOAA), Hurricane Sandy, pictured at 00:15 UTC, churns off the east coast on October 28, 2012 in the Atlantic Ocean. Sandy which has already claimed over 50 lives in the Caribbean is predicted to bring heavy winds and floodwaters to the mid-atlantic region. (Photo by NASA via Getty Images)

Global temperature fluctuates, but the world is getting warmer

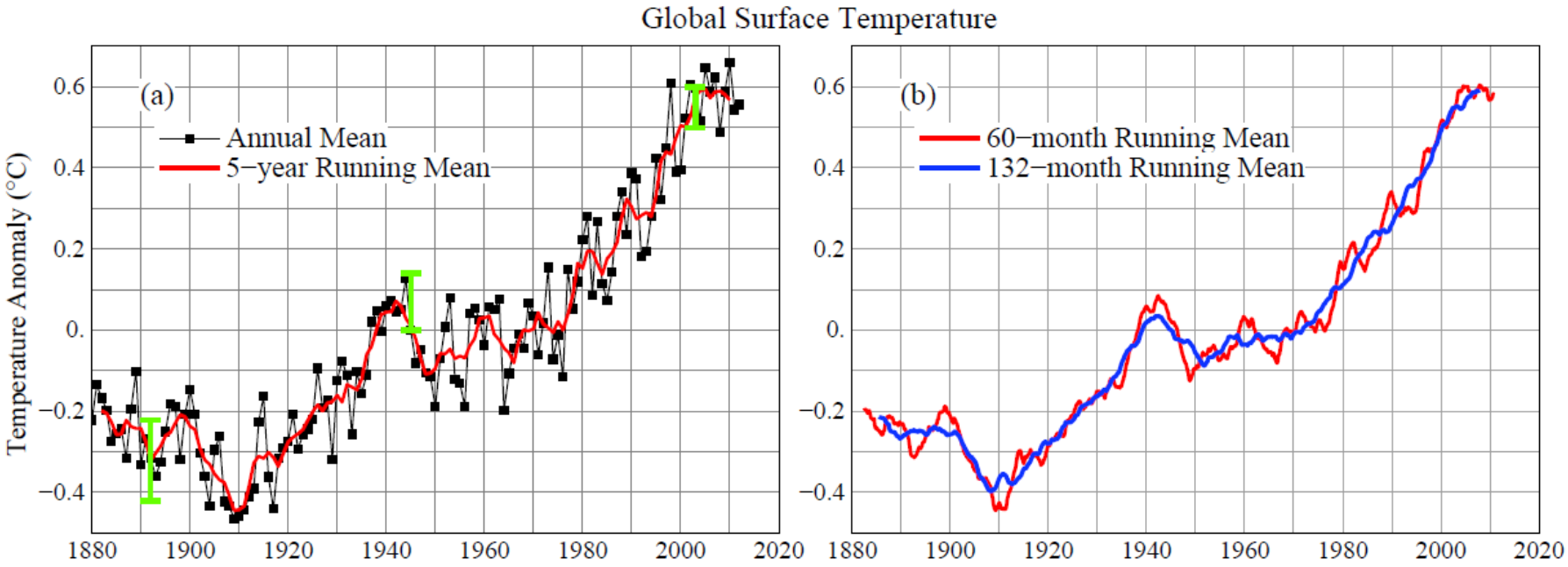
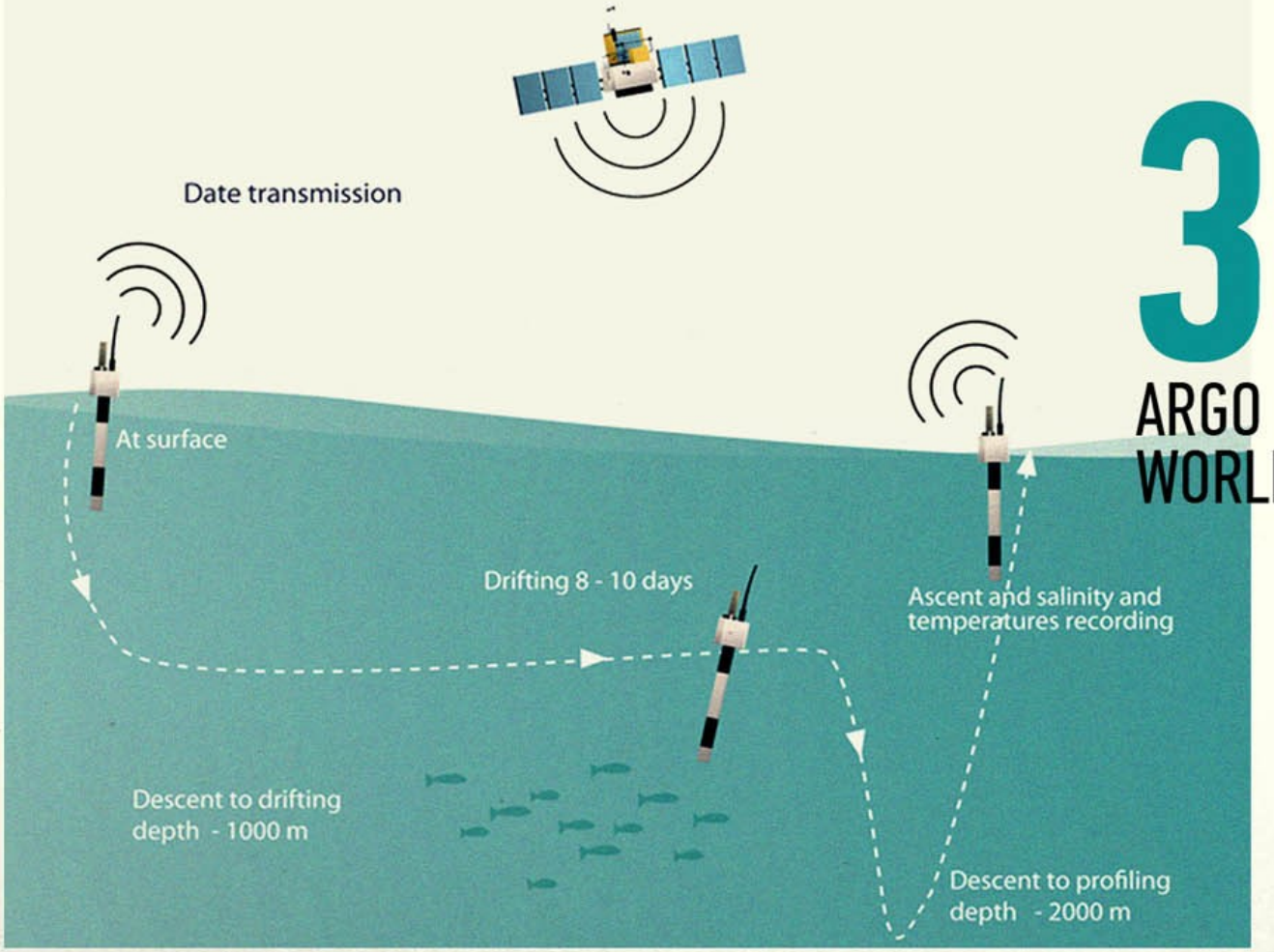


Figure 1. Global surface temperature anomalies relative to 1951-1980 average for (a) annual and 5-year running means through 2012, and (b) 60-month and 132-month running means through March 2013. Green bars are 2-σ error estimates.

(Hansen, J., Ruedy, R., Sato, M., and Lo, K., 2010: Global surface temperature change, Rev. Geophys. ***48****, RG4004.)*

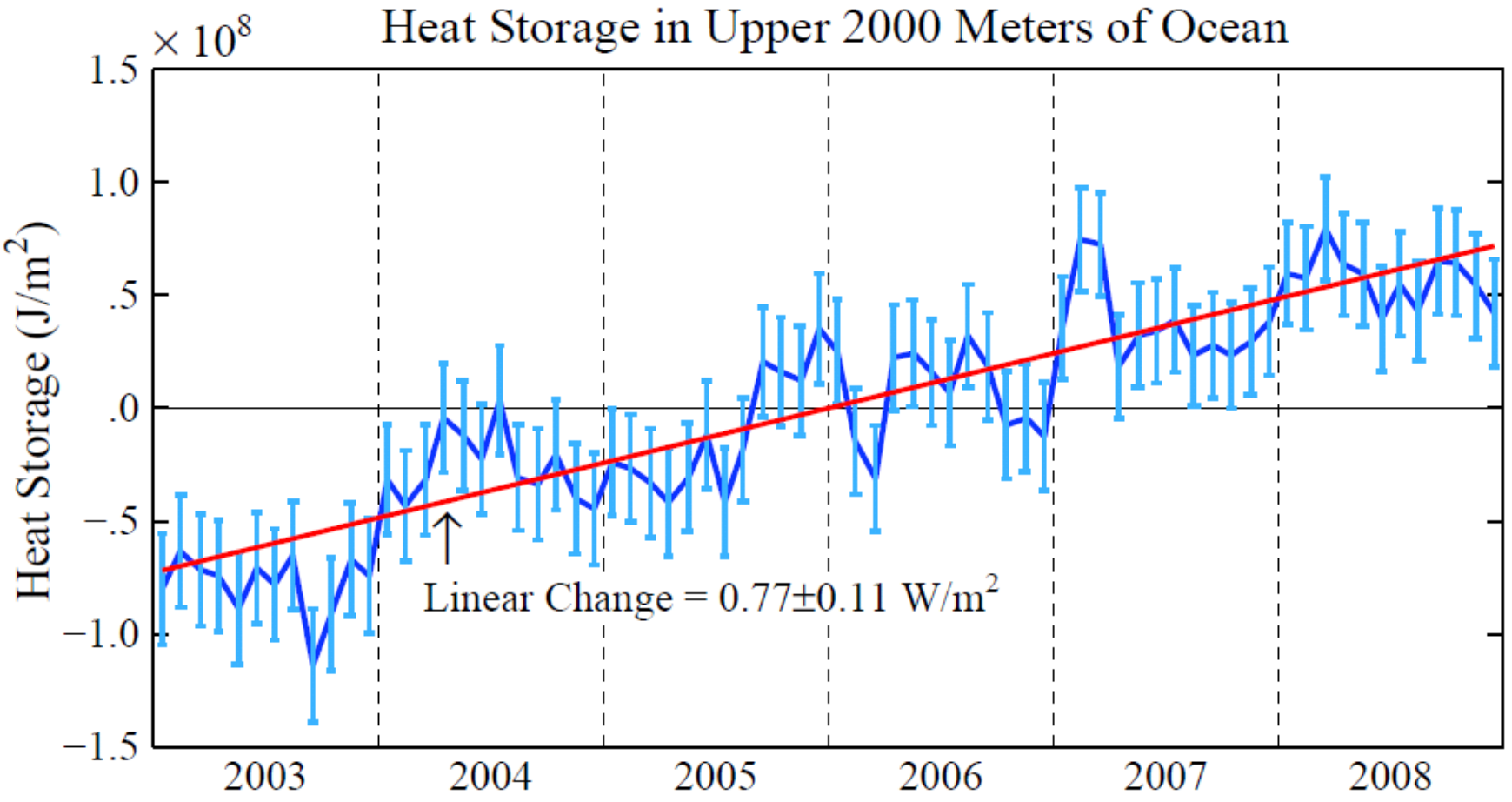
Earth's energy imbalance: more energy coming in than going out



3000

ARGO FLOATS AROUND WORLD OCEANS

ARGO floats have allowed accurate measurement of ocean heat gain since 2005. Earth is gaining energy at a rate 0.6 W/m^2, which is 20 times greater than the rate of human energy use. That energy is equivalent to exploding 400,000 Hiroshima atomic bombs per day, 365 days per year.



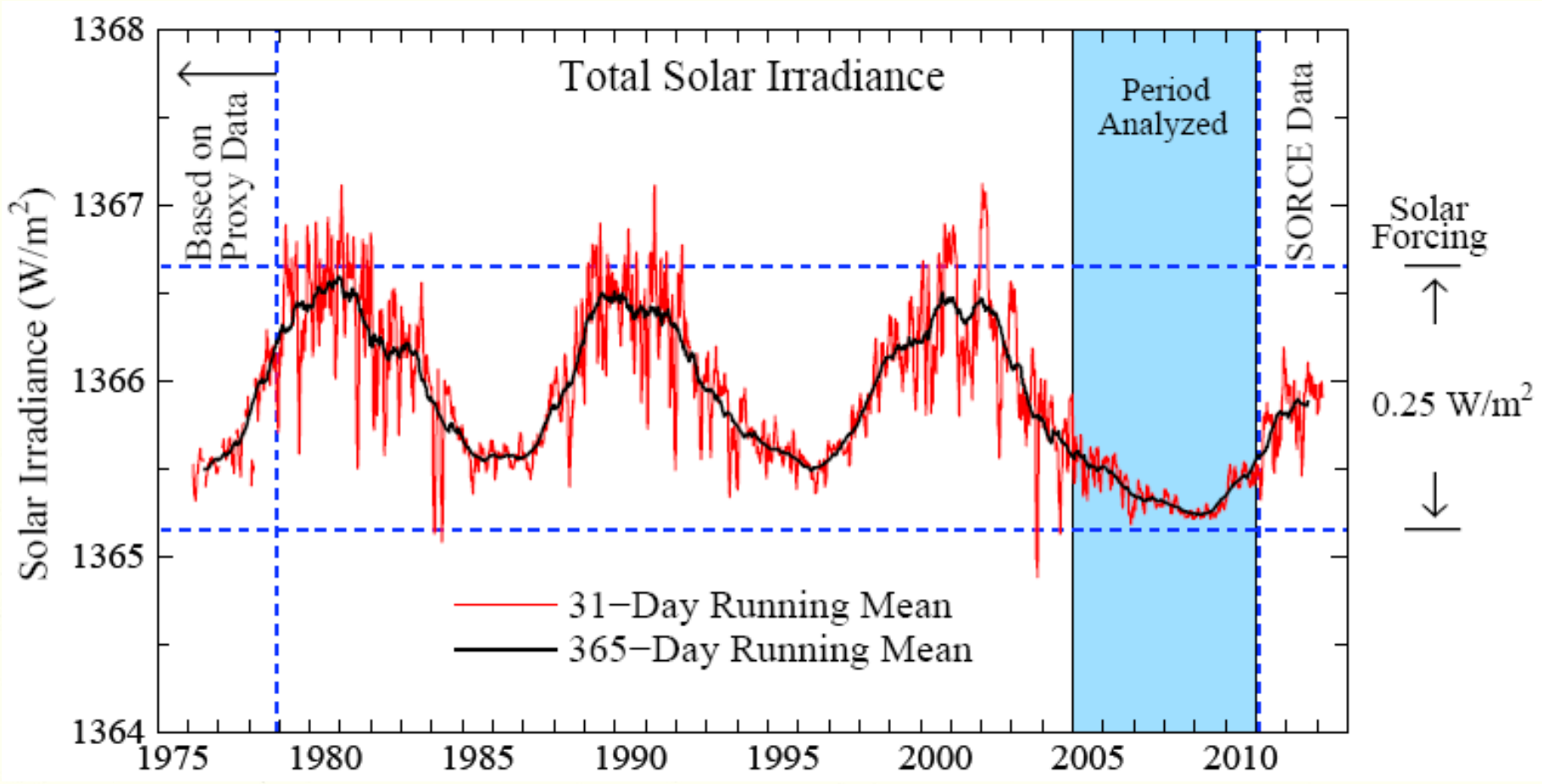
Heat storage in upper 2000 meters of ocean during 2003-2008 based on ARGO data.

Knowledge of Earth's energy imbalance is improving rapidly as ARGO data lengthens.

Data must be averaged over a decade because of El Nino/La Nina and solar variability.

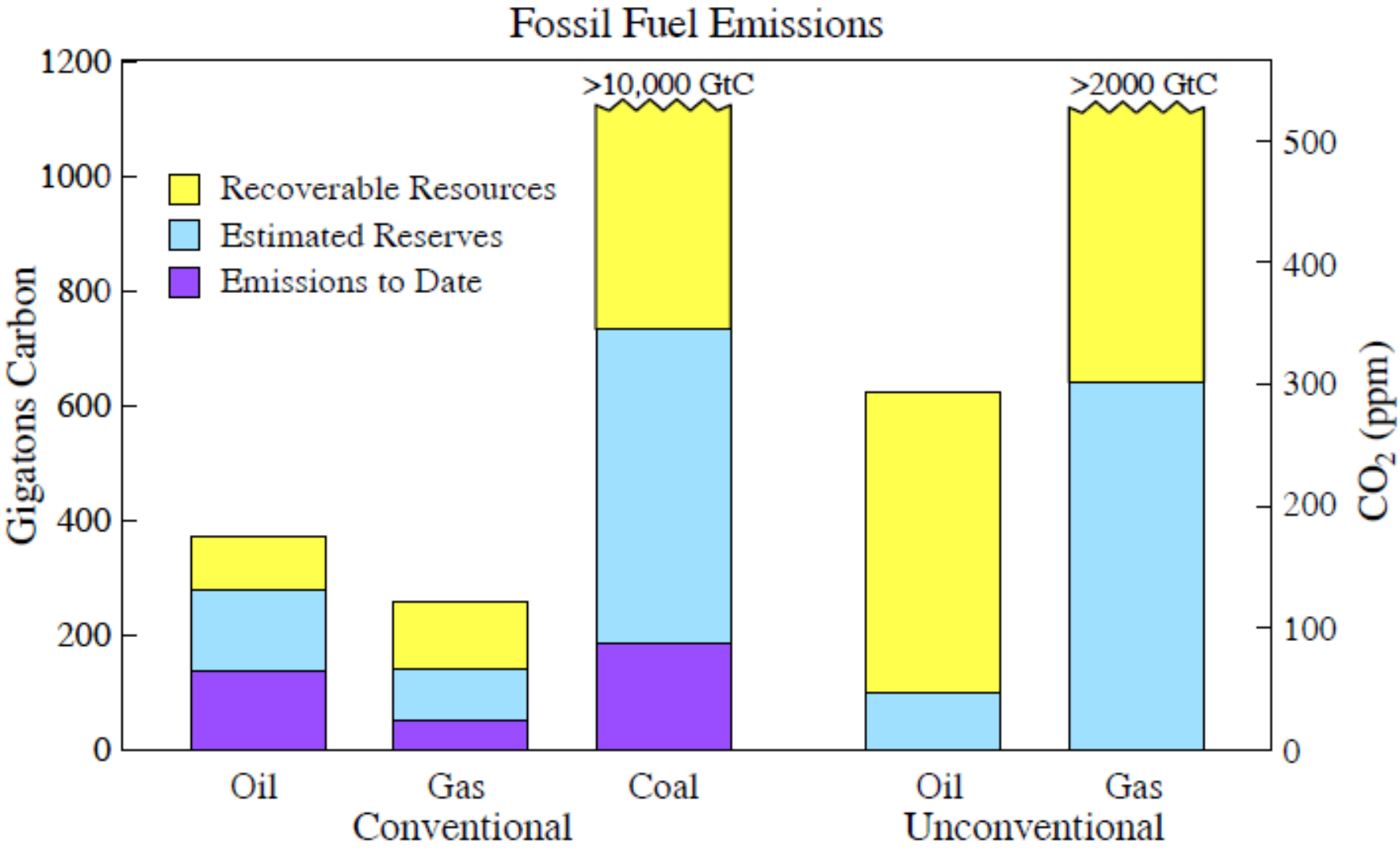
Energy imbalance is smoking gun for human-made increasing greenhouse effect.

Data source: von Schuckmann *et al. J. Geophys. Res.* **114**, C09007, 2009, doi:10.1029/2008JC005237.



Solar energy reaching Earth; energy absorbed per m^2 of Earth's surface is ~240 W, so 0.1% solar variability is a climate forcing of almost 0.25 W/m^2.

(Update of Fig. 17 of Hansen et al., Atmos. Chem. Phys., 11, 13421-13449, 2011. Data through 2 Feb. 2011 is from Frohlich and Lean; more recent data from Univ. Colorado, SORCE experiment.)



Fossil fuel emissions; purple are emissions through 2012.

1 GtC (gigaton carbon) = 1 billion tons of carbon or ~3.7 $GtCO_2$; 1 ppm CO_2 ~2.12 GtC

Fossil Fuel Emissions/Targets

370 GtC = Emissions through 2012

+100 GtC from deforestation – but must bookkeep separately

500 GtC Target for Fossil Fuel Emissions

& store 100 GtC in forests and soil via improved practices

Result: energy balance at about 1°C above pre-industrial

Stays close to Holocene range; slow feedbacks minimized

1000 GtC Target for Fossil Fuel Emissions

Slow feedbacks (ice sheet melting, forest movement, GHG release) surely come into play → warming > 2dC

Climate Stabilization is Possible, But…

Essential Requirements

1. **Quick Coal Phase-Out Necessary**
   Coal emissions halted in next few decades

2. **No Unconventional Fossil Fuels**
   Tar sands, Tar shale, Methane hydrates

3. **Don’t Pursue Last Drops of Oil**
   Polar regions, Deep ocean, Pristine land

What's Really Happening

1. **New Coal-fired Power Plants**
   - Rationalized by 'Clean Coal' mirage
2. **Tar Sands, Tar Shale Developed for Oil**
   - Long-lived Infrastructure Planned
3. **Hydro-Fracking for Gas**
   - "Transition Fuel" Rationalization
4. **Extraction Expands Everywhere**
   - Arctic, Deep Ocean, Public Lands

What's Really Needed

Fossil Fuels seem to be Cheapest Energy

- Subsidized & Do Not Pay Costs
- Solution: Rising Carbon Fee

Regulations also Required

- Efficiency of Vehicles, Buildings,e.g.
- Carbon Price Provides Enforcement

Technology Development Needed

- Driven by Certainty of Carbon Price
- Government Role Limited

Fee & Dividend

Fee: Collected at Domestic Mine/Port of Entry

Covers all Oil, Gas, Coal → No Leakage

Dividend: Equal Shares to All Legal Residents

Not One Dime to the Government.

Merits:

Transparent. Market-based. Stimulates Innovation.

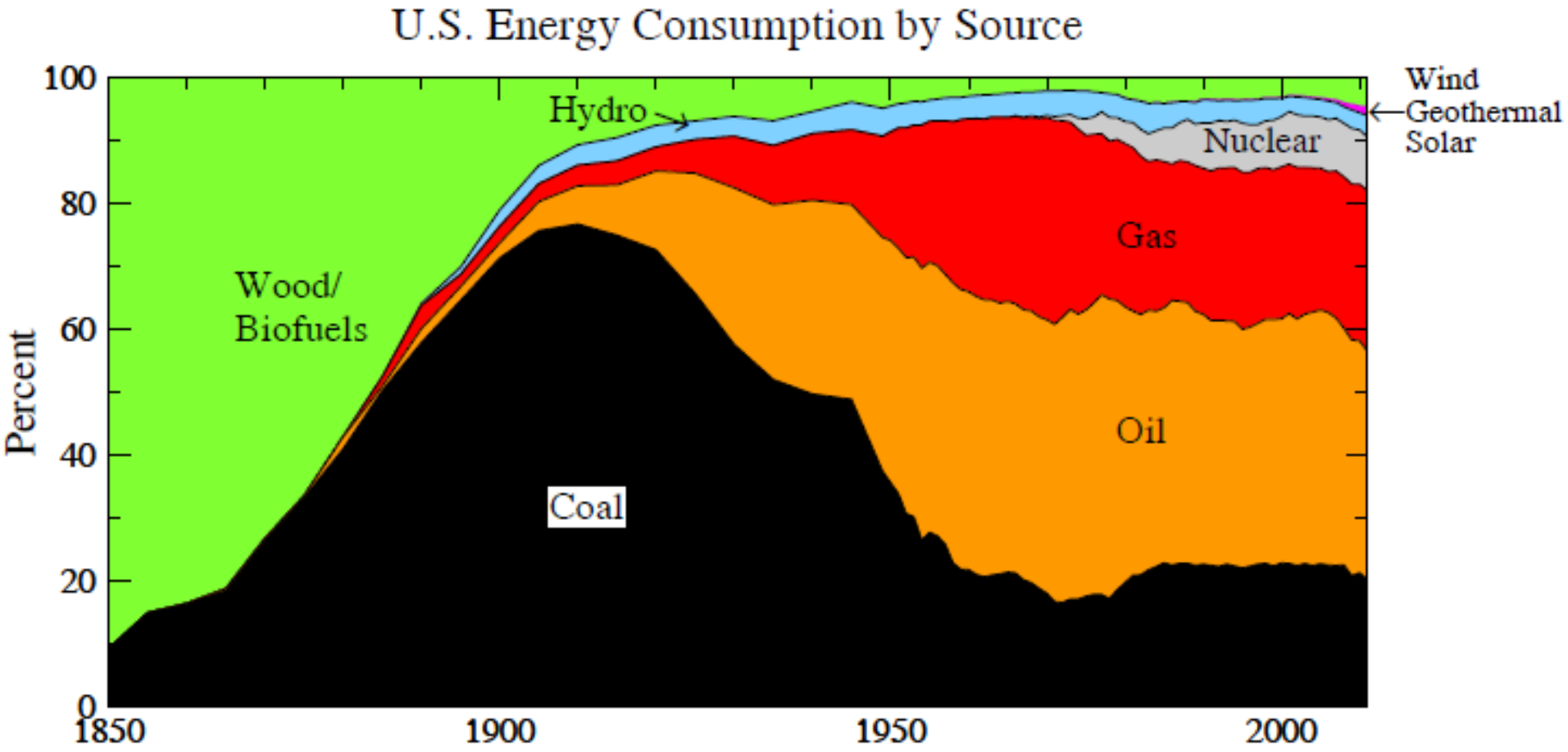
Does Not Enlarge Government.

Leaves Energy Choices to Individuals & Free Competition.

A Conservative Energy & Climate Plan.

Fee & Dividend Addresses

1. **Economy: Stimulates It**
   - Puts Money in Public's Hands – A Lot
   - Provides Certainty to Businesses and Entrepreneurs
2. **Energy: Solves Fossil Fuel Addiction**
   - Stimulates Innovation – Fastest Route to Clean Energy
   - Complements Efficiency Regulations & Energy RD&D
3. **Climate: Viable International Approach**
   - Border Duties on Products from Nations without Fee
   - Most Coal & Unconventional Fossil Fuel left in Ground



Sources: [EIA Table E1 Estimated Primary Energy Consumption in the United States, 1635-1945] and [EIA Table 1.3 Primary Energy Consumption Estimates by Source, 1949-2011.]

Can Emissions Be Decreased Rapidly?

1. **France in One Decade (1977-1987)**
   - Nuclear Power Increased 15-fold
   - Nuclear Portion of Electricity (8% → 70%)
2. **Germany in One Decade (2001-2011)**
   - Non-hydro Renewable (4% → 19%)
   - Hydro + Nuclear (34% → 21%)
   - Fossil Fuels (62% → 60%)

“We are eliminating programs that are no longer needed, such as nuclear power research and development.”

President William Clinton,
1993 State of the Union address

Argonne National Laboratory was ready to construct a commercial-scale reactor that:

(1) Burns >99% of nuclear fuel, compared with ~1% in existing reactors,

(2) Leaves a smaller waste pile with half-life of decades rather than millennia,

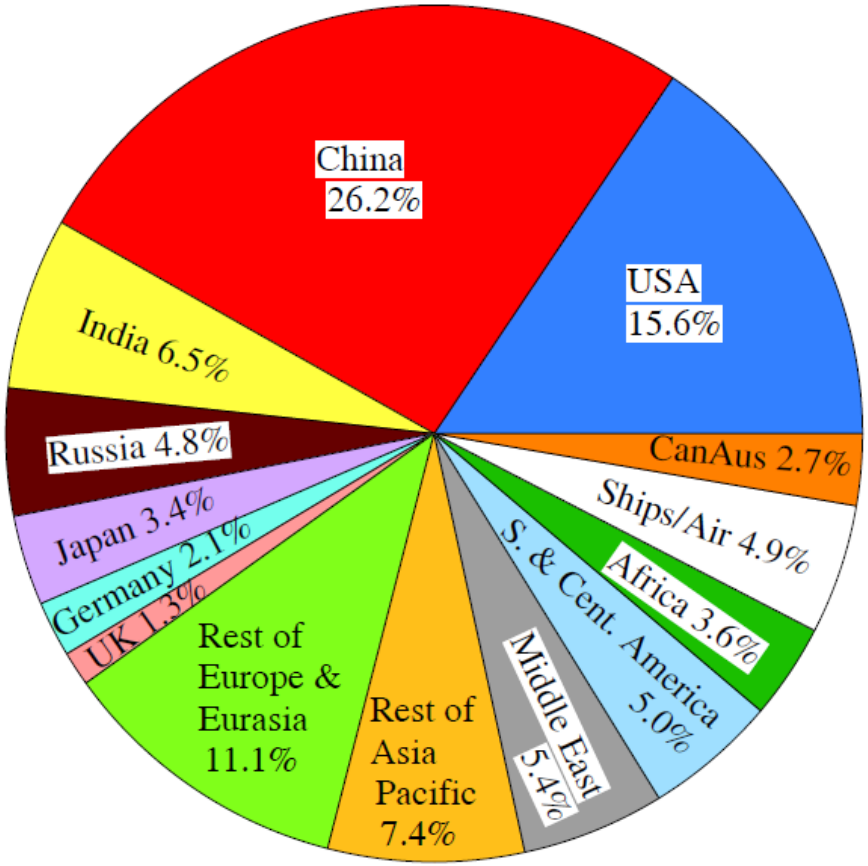
(3) Can utilize existing nuclear waste and excess weapons material as fuel,

(4) Can shut down automatically in the event of an anomaly (e.g., earthquake),

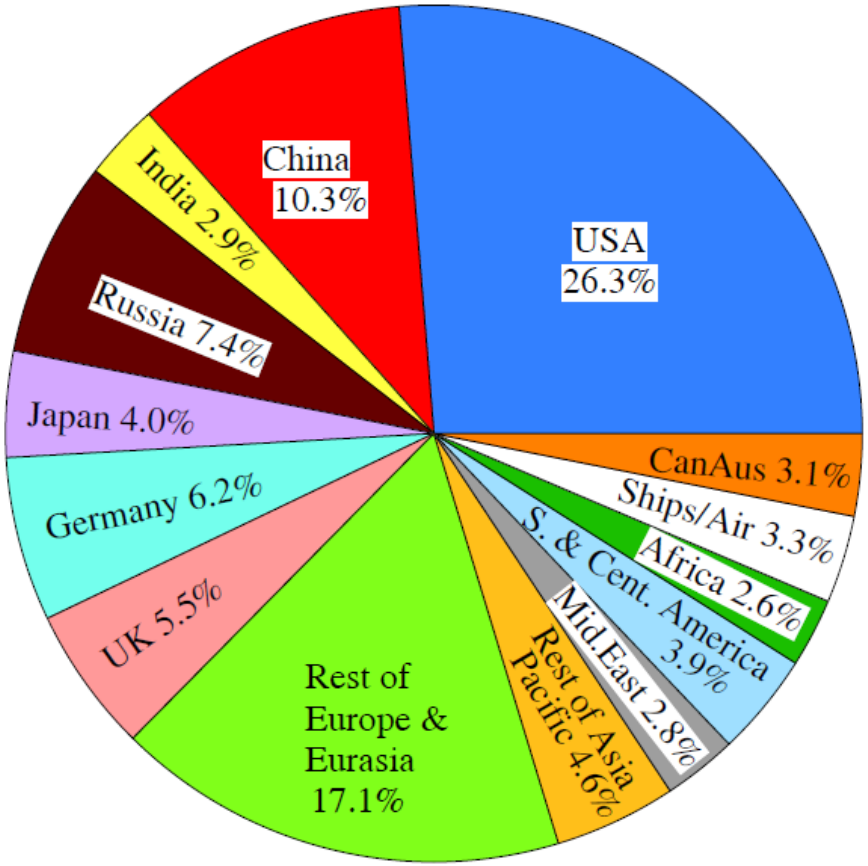
(5) Does not require power to cool reactor in case of shut down,

(6) Does not require uranium mining for centuries; indeed, it has been demonstrated that fuel can be sieved from the ocean – the supply will last billions of years.

(a) 2011 Annual Emissions (9.5 GtC/yr)



(b) 1751–2011 Cumulative Emis. (374 GtC)



Bilateral Agreement: China & U.S.

Rising Internal Carbon Fees

- Spurs life style changes & Innovation
- Stimulates economies

Border Duty, Products of Nations w/o Fee

- WTO rules allow equivalent duty
- Strong incentive to join with fee/tax

Technology Cooperation Required

- Includes advanced generation nuclear power with safeguards

A piece of the tar sands operations in Canada.

Pristine forest is replaced by a ghoulish scene.

Tar sands goop, a.k.a. bitumen.

Goop carrier; man in lower right is 6’ (183 cm) tall.

Tar sands goop on the move.

Preliminary processing is done on-site…

…with waste dumped into large lagoons.

Bird stopped for a drink – his last – won’t live long.

Tar sands workers … good jobs, huh?

“Hypocrisy is the tribute that vice pays to virtue.”

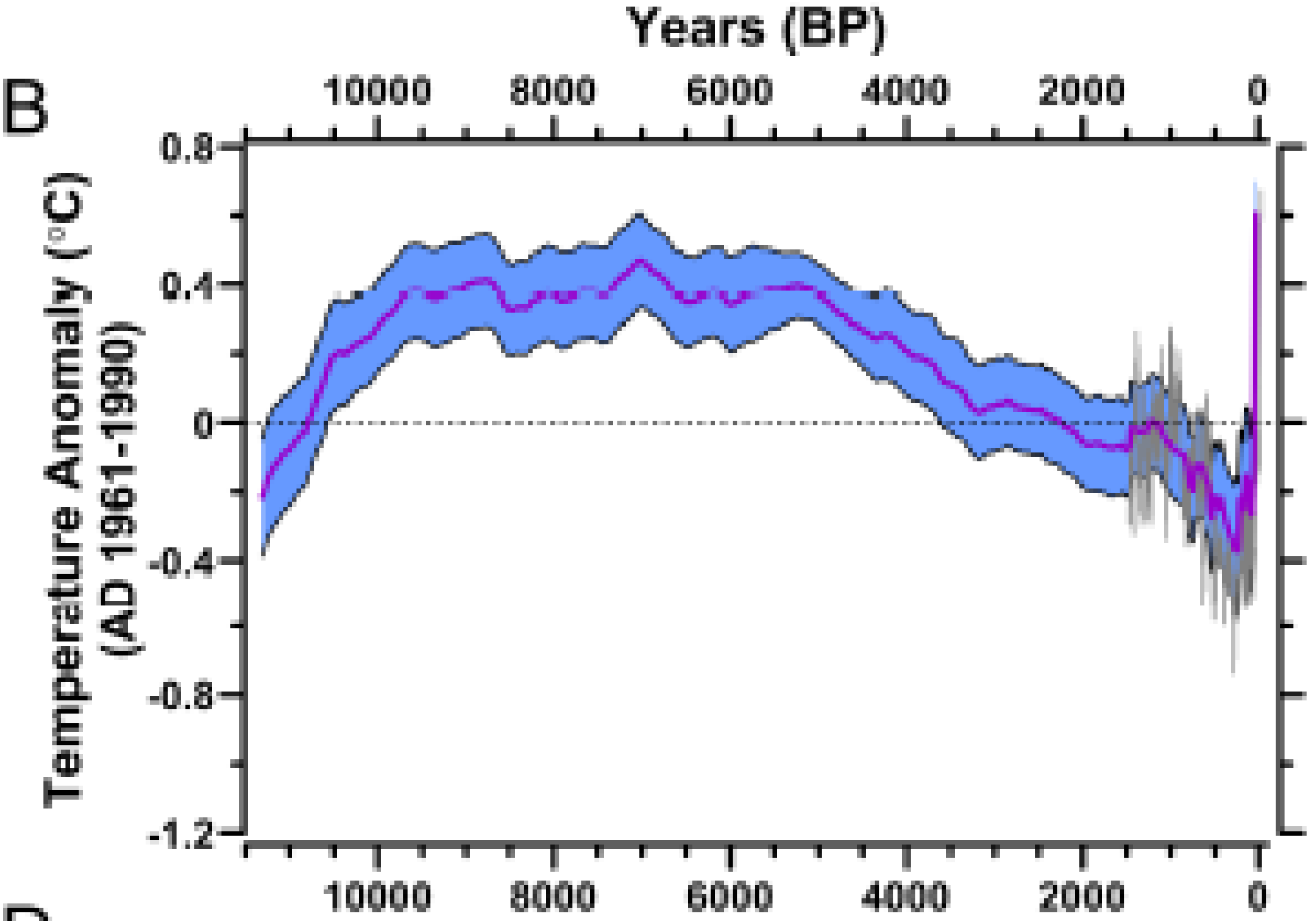
-- Norwegian Grandparent
(after Saint Augustine)

Web Sites

www.columbia.edu/~jeh1

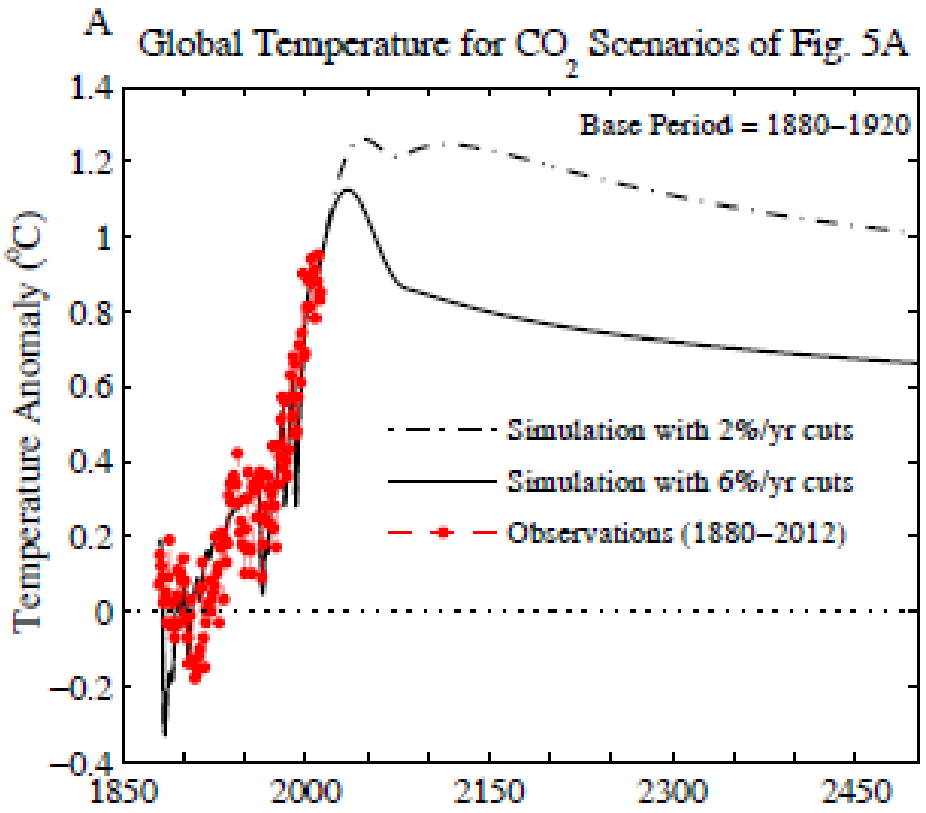
www.CitizensClimateLobby.org

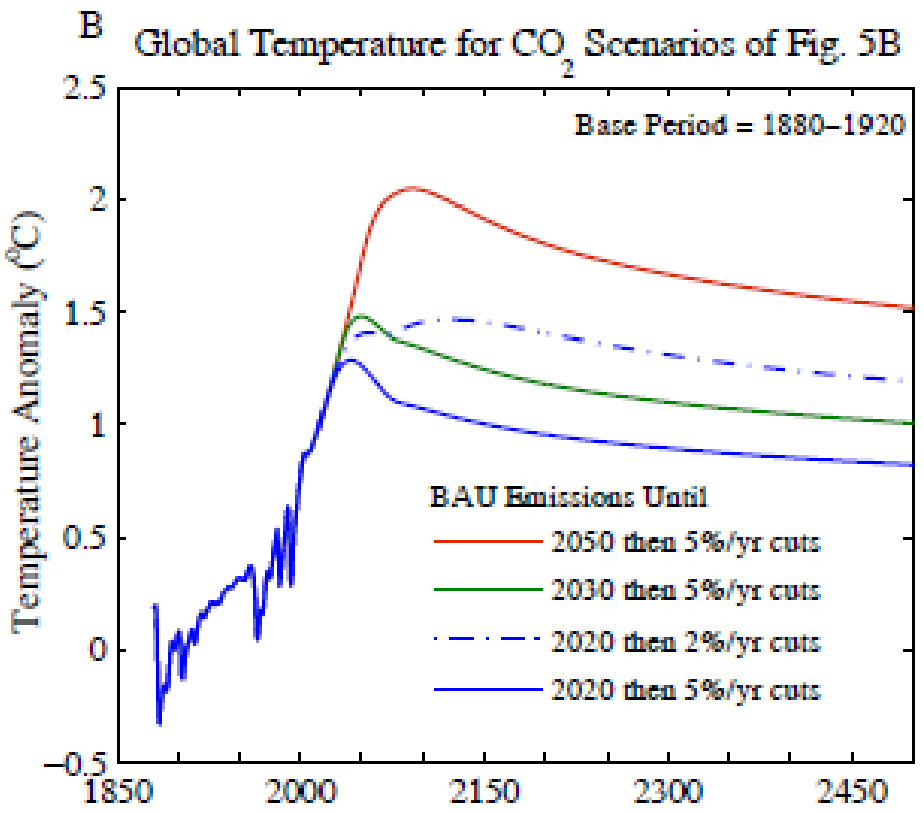
www.OurChildrensTrust.org



Global mean temperature declined about 0.7C in last half of Holocene.

Source: Marcott et al., Science, 2013.





Simulated global temperature relative to 1880-1920 mean for indicated CO_2 scenarios