Climate Change and Energy: How Can Justice Be Achieved for Young People and Nature?

James Hansen

22 December 2015

Beijing, China

Global Climate Situation

1. Little-Understood Global Crisis

- Climate Inertia → Warming in Pipeline
- Amplifying Feedbacks → Losing Control

2. Rapid Reduction of Forcings Needed

- Fossil Fuel CO_2 Emissions Dominate
- Remain in Climate System for Millennia

3. Solution is Technically Possible

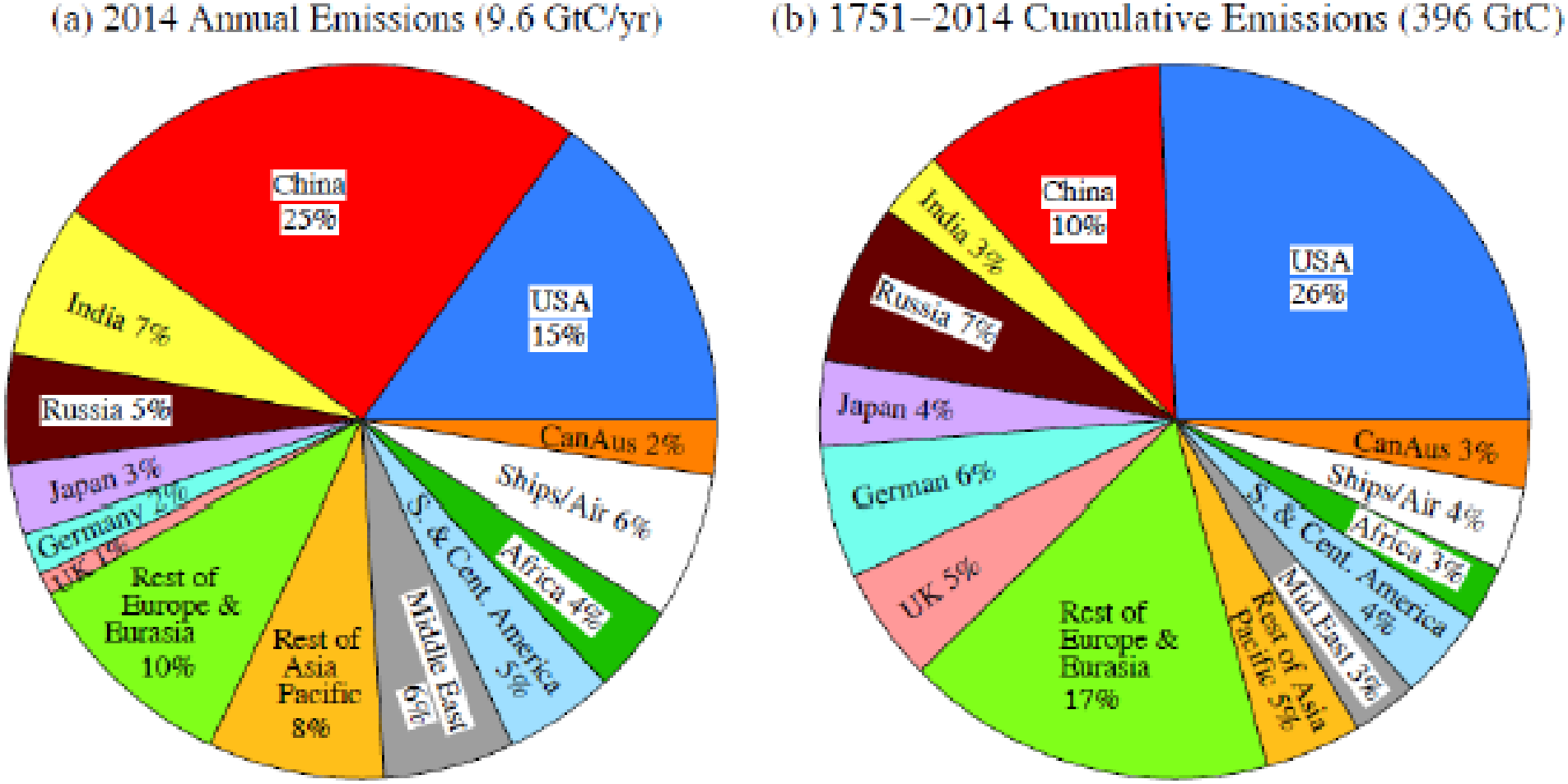
- and is Economically Sensible
- but it is Not Being Pursued

Potential Injustice

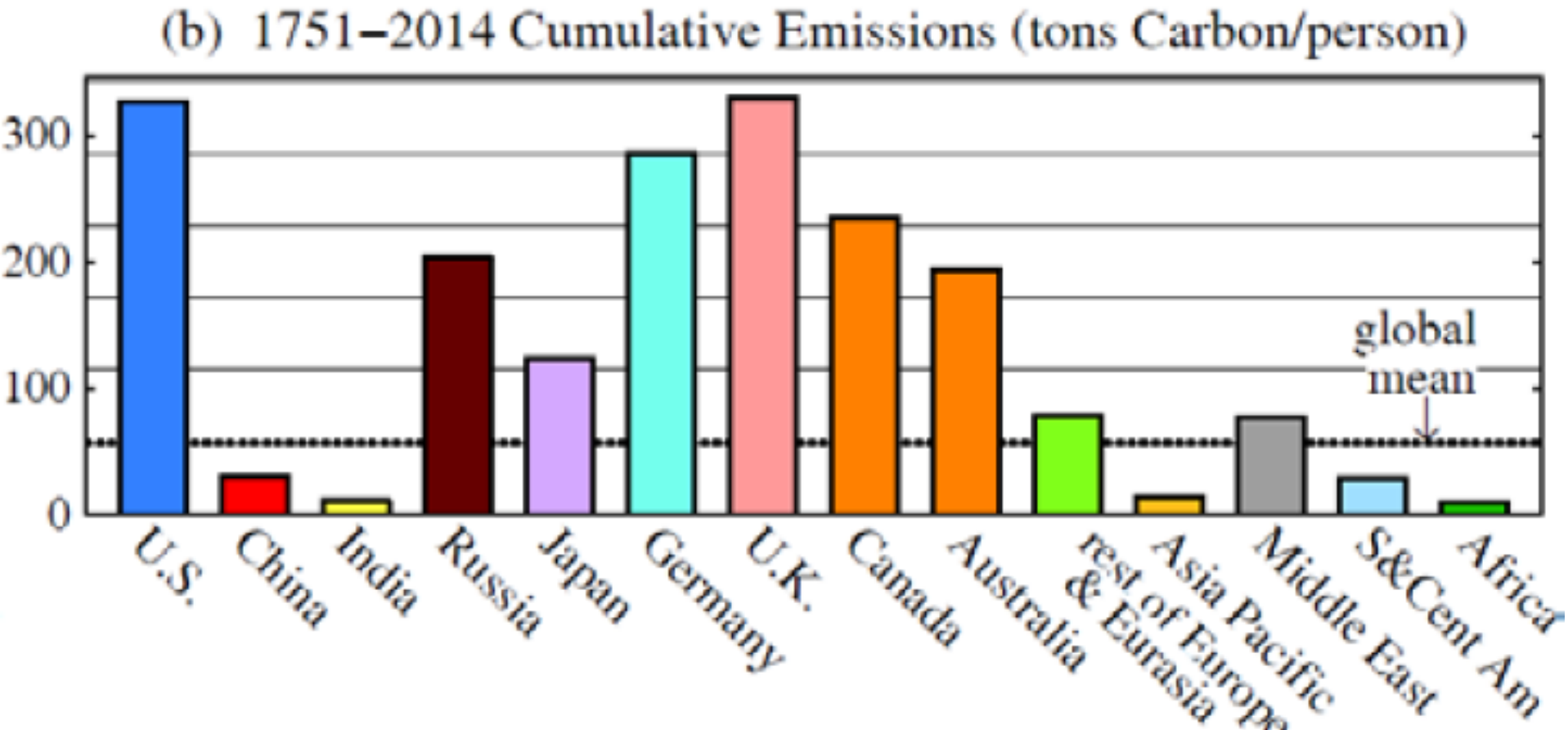
1. **Today's Adults to Young People**
   - Warming in Pipeline, **Amplifying Feedbacks**
   → **Climate Close to Out of Control**

2. **North to South**
   - North burned most of carbon budget
   - Climate impacts largest in the South

3. **Humans to Other Species**
   - Climate change & other stresses
   - Potential 25-50% extinctions



Fossil fuel CO_2 emissions. Update of Hansen et al (2013) using data of Boden et al (2015) and BP (2015). United States and European Union are each responsible for > 1/4 of total global emissions.


(b) 1751–2014 Cumulative Emissions (tons Carbon/person)
300
200
100
0
global mean
U.S.
China
India
Russia
Japan
Germany
U.K.
Canada
Australia
rest of Europe & Eurasia
Asia Pacific
Middle East
S&Cent Am
Africa

Climate Impacts

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

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

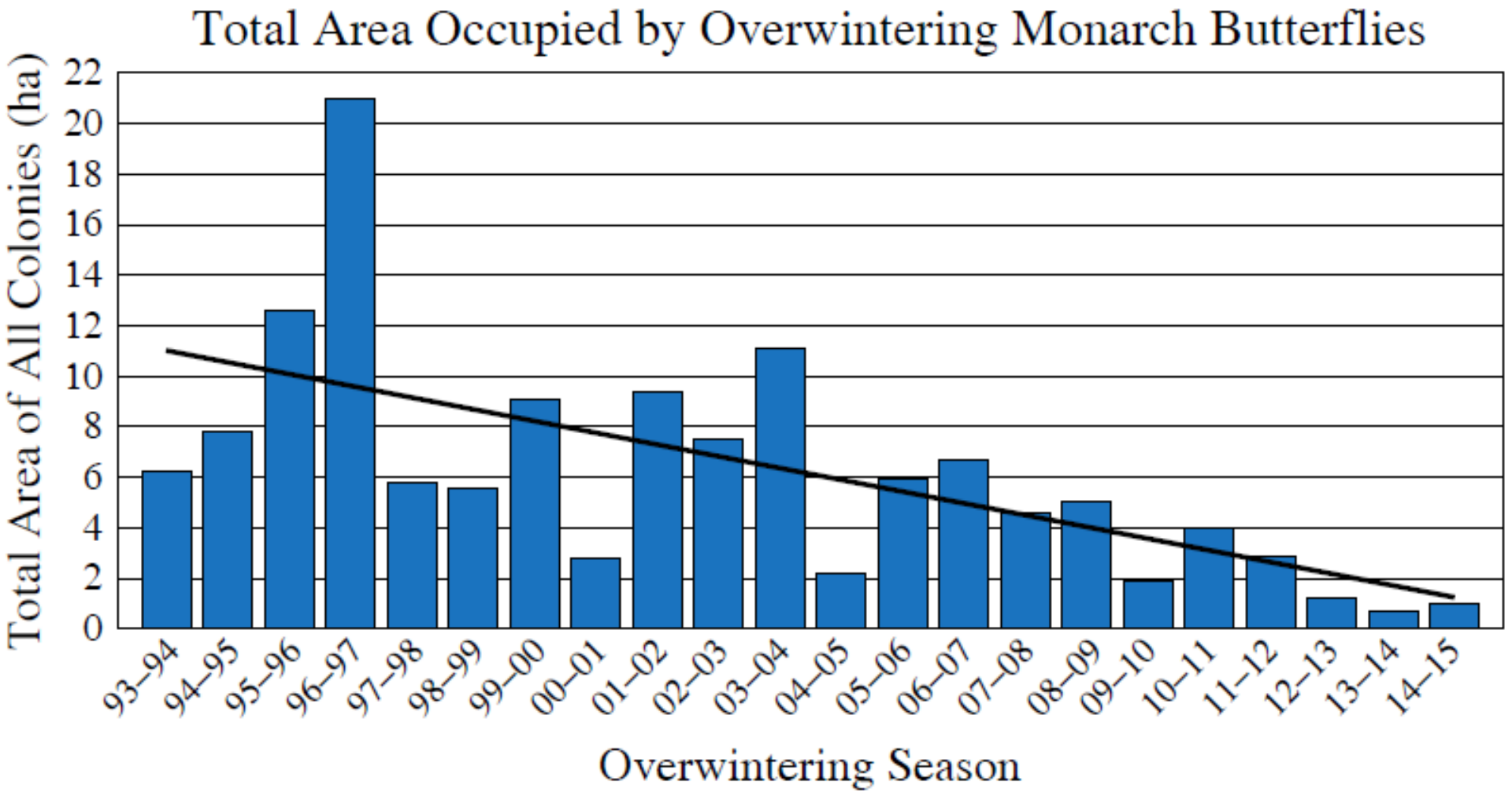
3. **Climate Extremes**
   - Heat Waves, Drought, Fires
   - Heavier Rain, Floods, Stronger Storms

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

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

Current U.S. Drought Monitor

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



Area occupied by overwintering monarch butterflies

Source: Brower, LP, et al., Insect Conservation and Diversity 5, 95-100, 2012.

Stresses on Coral Reefs

Coral Reef off Fiji (Photo: Kevin Roland)

Threat of Mass Exterminations

Multiple Human-Made Stresses

Overharvesting, Land use changes, Nitrogen fertilization, Introducing exotic species, etc.

in Combination with

Rapid Shifting of Climate Zones

IPCC (2007) estimates that business-as-usual greenhouse gas emission will commit to extinction ¼ to ½ of all species.

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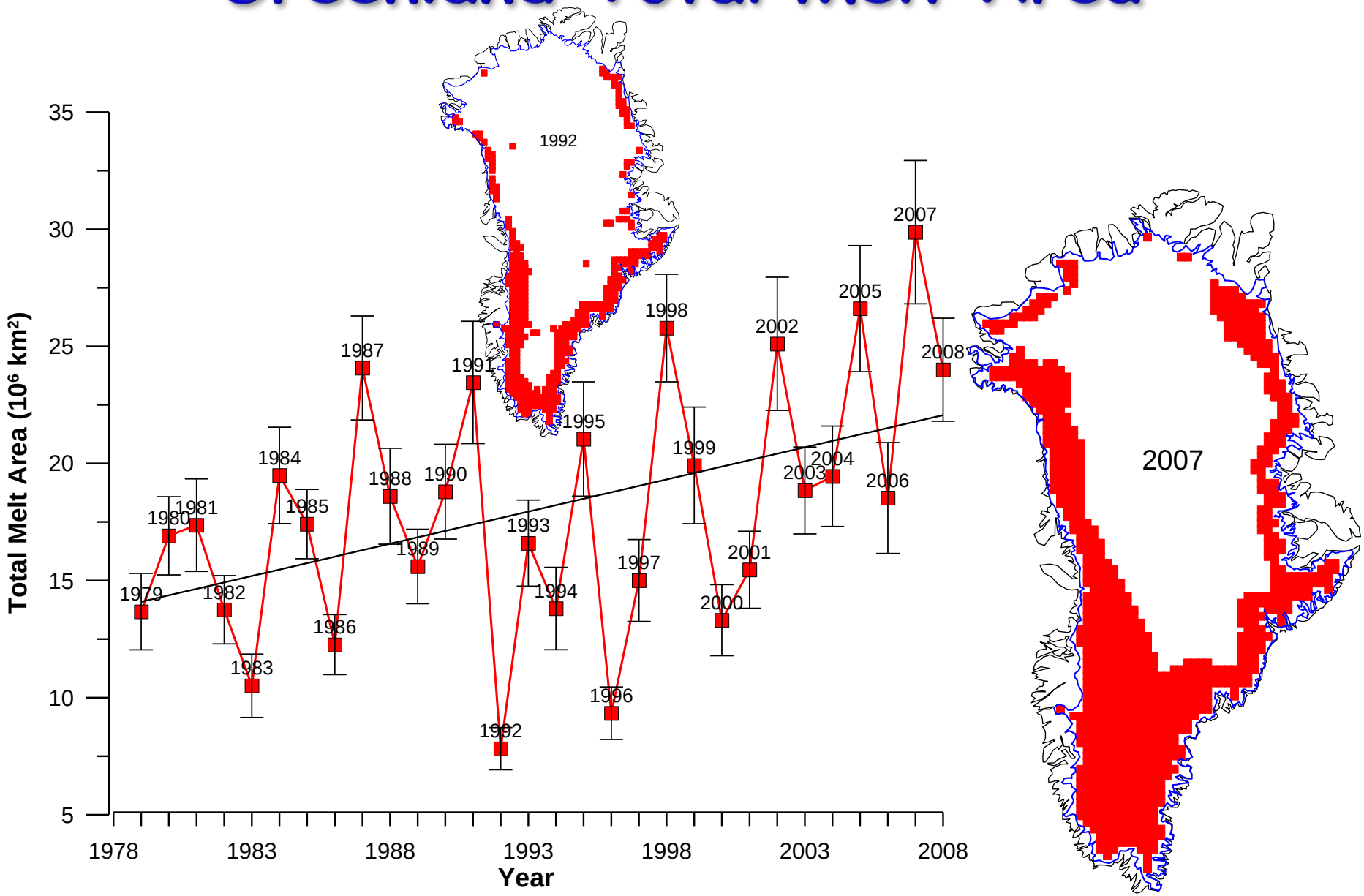
Greenland Total Melt Area



Area on Greenland with snowmelt.

Graph credit: Konrad Steffen, Univ. Colorado

Surface Melt on Greenland

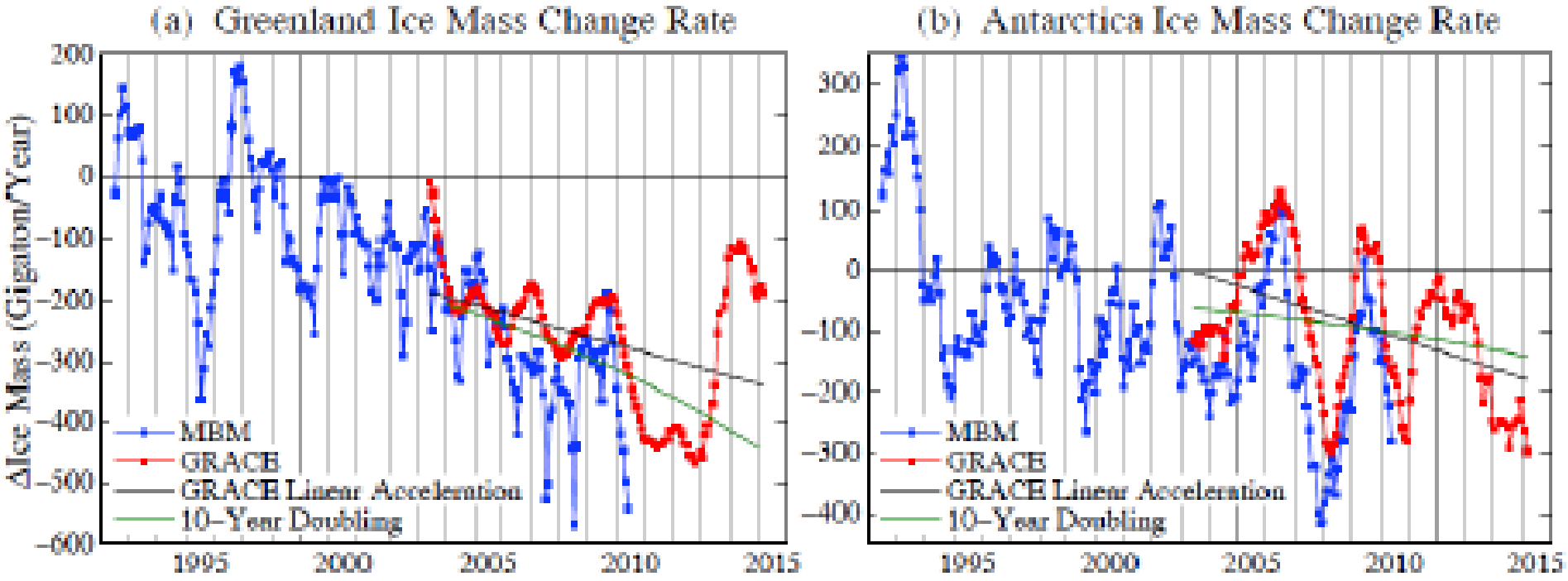
Melt descending
into a moulin,
a vertical shaft
carrying water
to ice sheet base.

Source: Roger Braithwaite,
University of Manchester (UK)

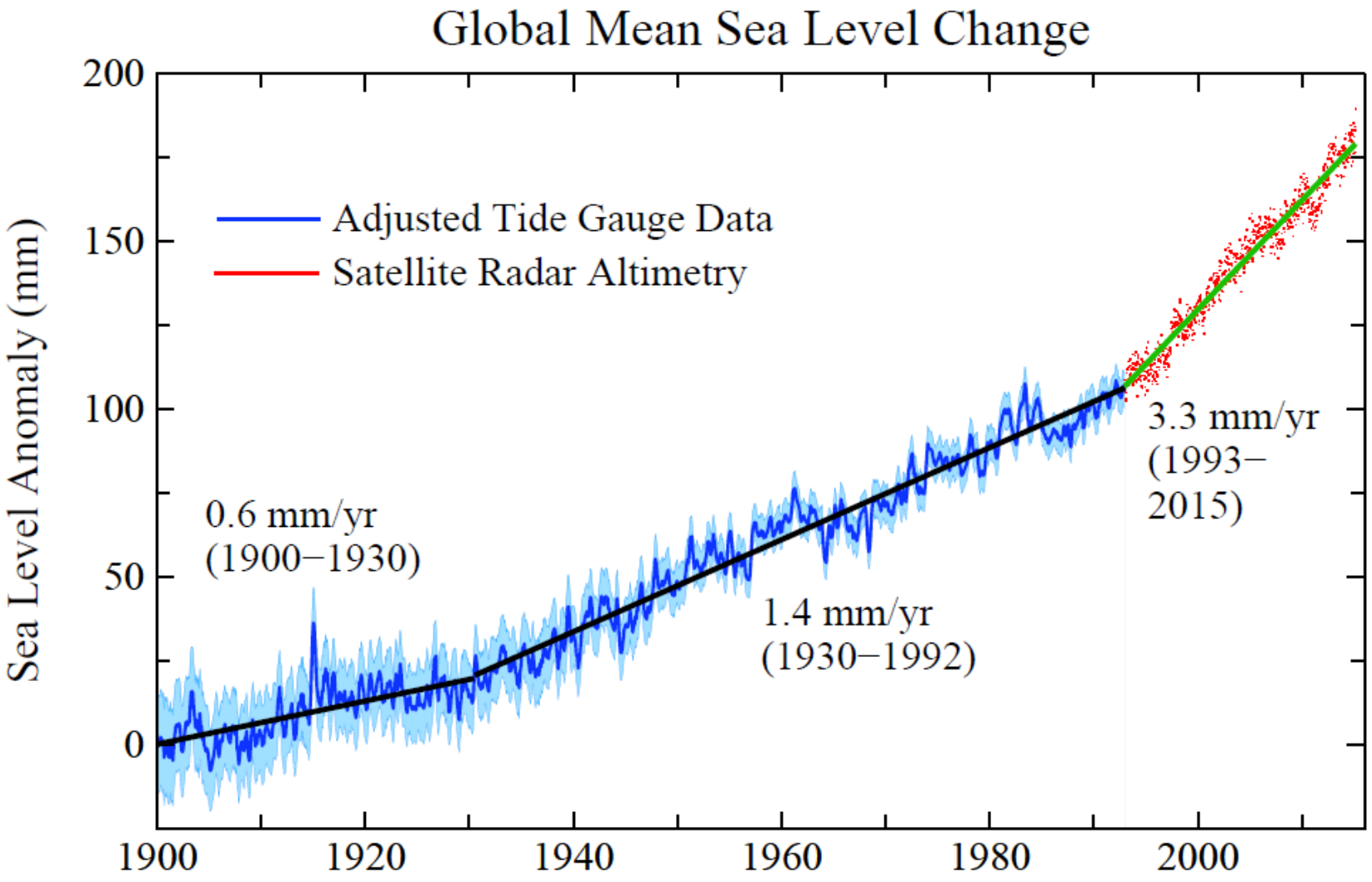
Jakobshavn Ice Stream in Greenland

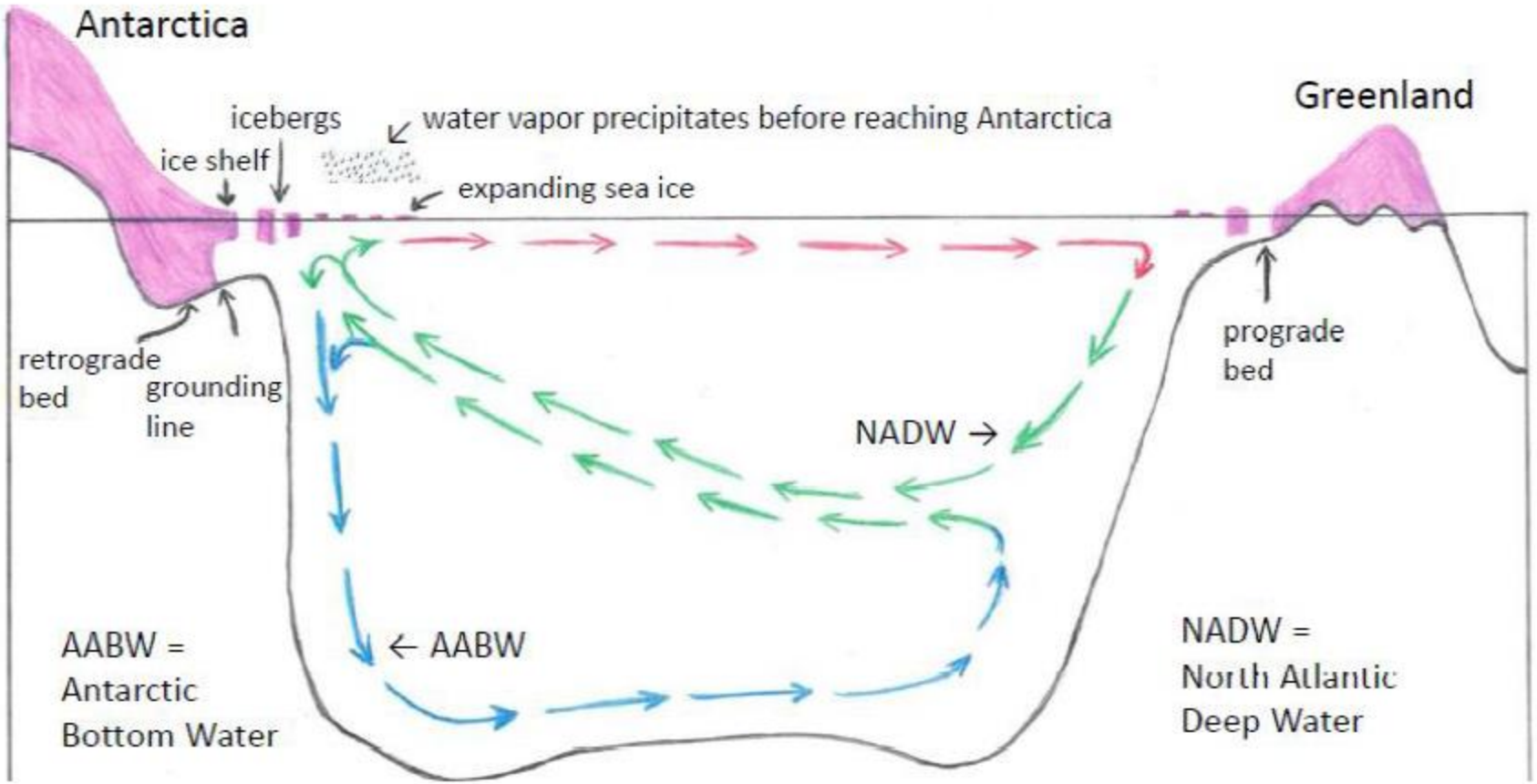
Discharge from major Greenland ice streams is accelerating markedly.

Source: Prof. Konrad Steffen, Univ. of Colorado



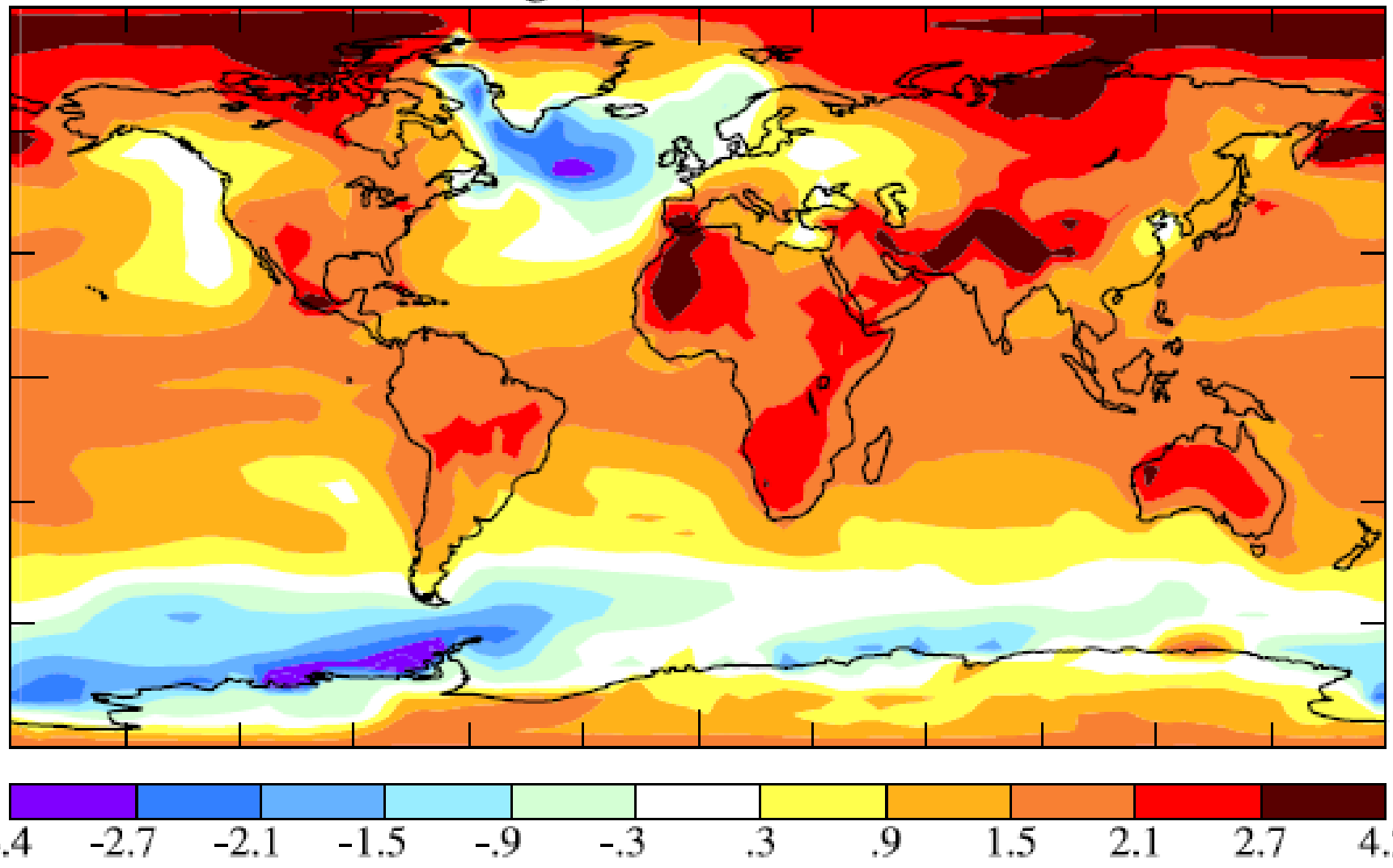
Greenland (a) and Antarctic (b) ice mass change. GRACE data is extension of Velicogna et al. (2014) gravity data. MBM (mass budget method) is update of Rignot et al. (2011).


Global Mean Sea Level Change
Sea Level Anomaly (mm)
200
150
100
50
0
1900
1920
1940
1960
1980
2000
Adjusted Tide Gauge Data
Satellite Radar Altimetry
0.6 mm/yr
(1900–1930)
1.4 mm/yr
(1930–1992)
3.3 mm/yr
(1993–
2015)


Antarctica
Greenland
icebergs
water vapor precipitates before reaching Antarctica
ice shelf
expanding sea ice
retrograde bed
grounding line
prograde bed
NADW →
← AABW
AABW = Antarctic Bottom Water
NADW = North Atlantic Deep Water

2055-2060 Surface Air Temperature (°C) Relative to 1880-1920

A1B + Modified Forcings, Ice Melt to 1 m 1.19



Paleoclimate Guidance

Eemian sea level +5-9 meters

- **Eemian temperature < +2°C***

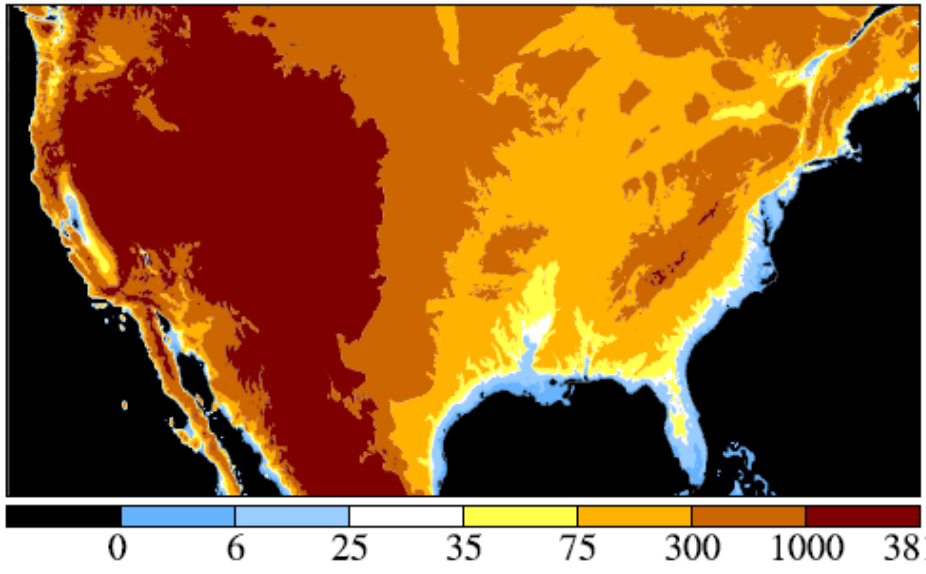
Pliocene sea level up to +15-25 meters

- **Pliocene temperature +3-4°C***

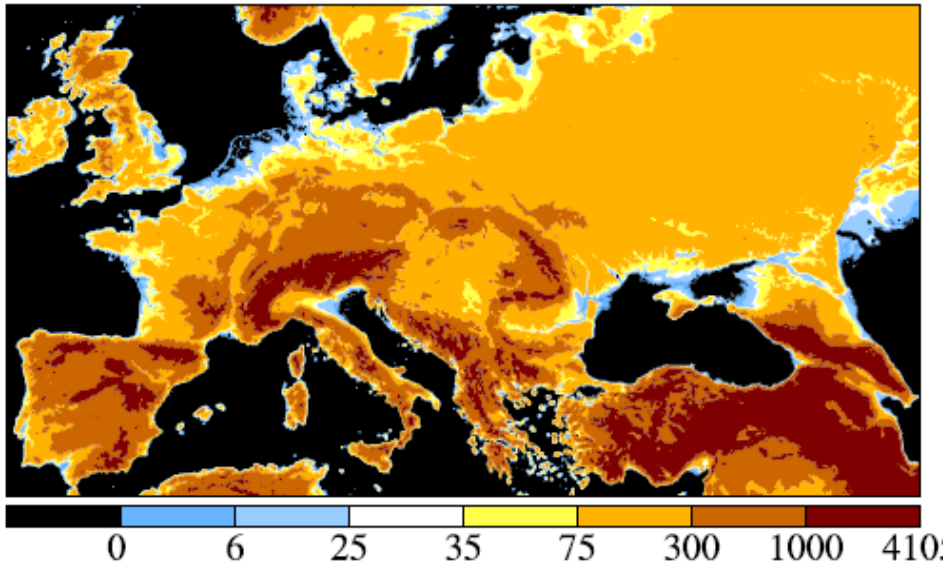
Ice sheet response time uncertain, but it is shorter than the lifetime of fossil fuel carbon and resulting global warming

***relative to pre-industrial times**

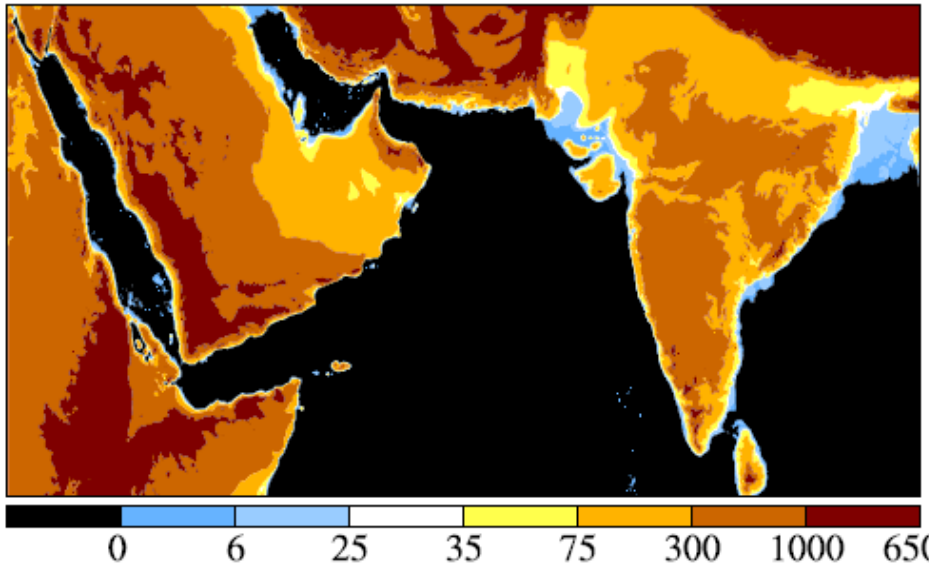
U.S. Area Under Water



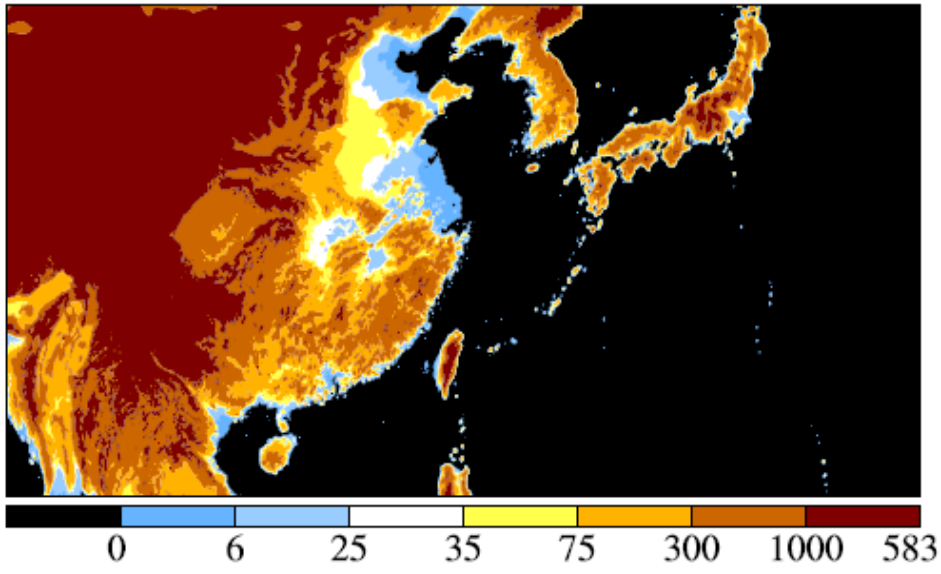
Europe Area Under Water

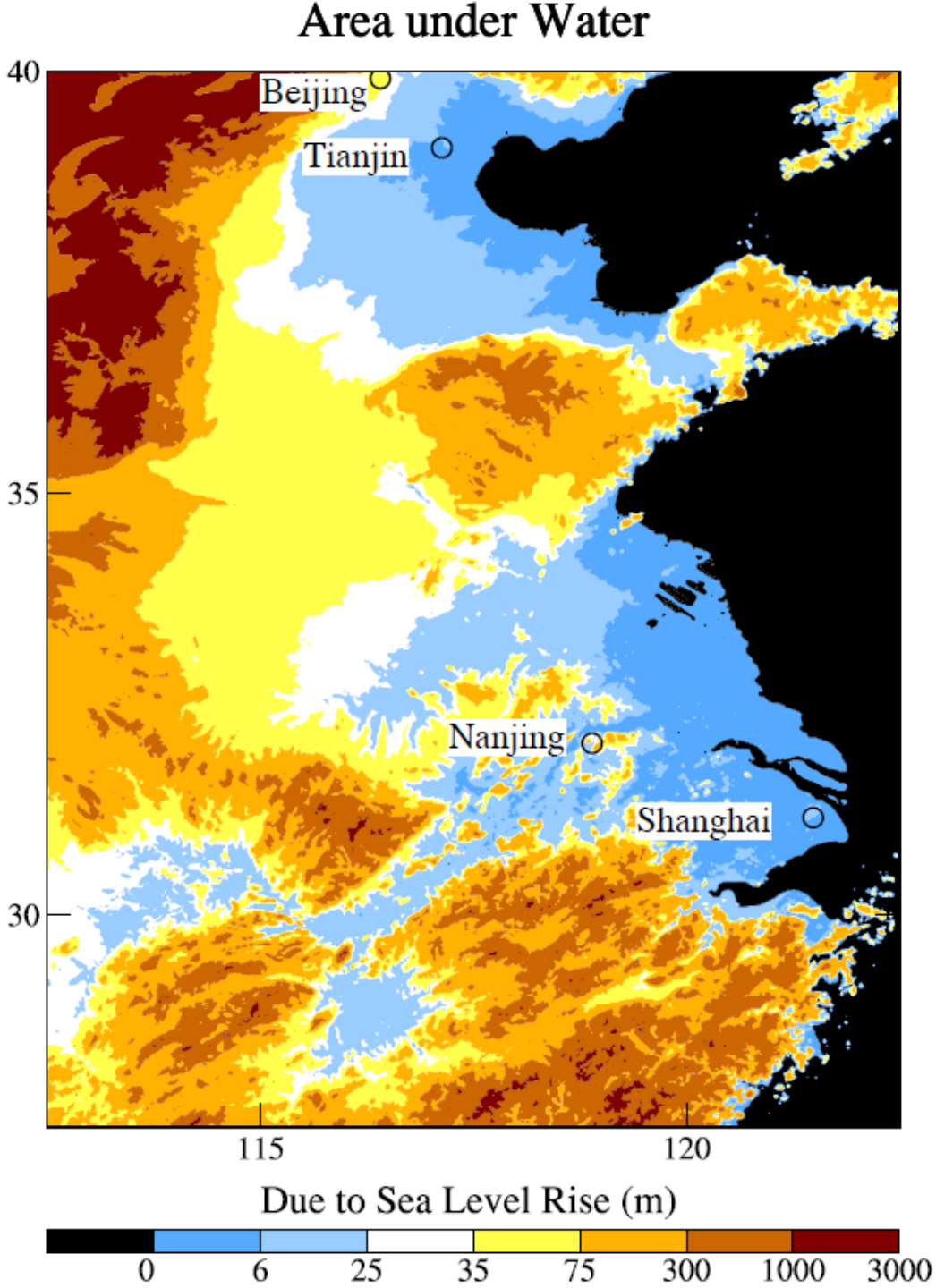


Central Asia: Area under Water



Far East: Area under Water




Area under Water
40
35
30
Beijing
Tianjin
Nanjing
Shanghai
115
120
Due to Sea Level Rise (m)
0
6
25
35
75
300
1000
3000

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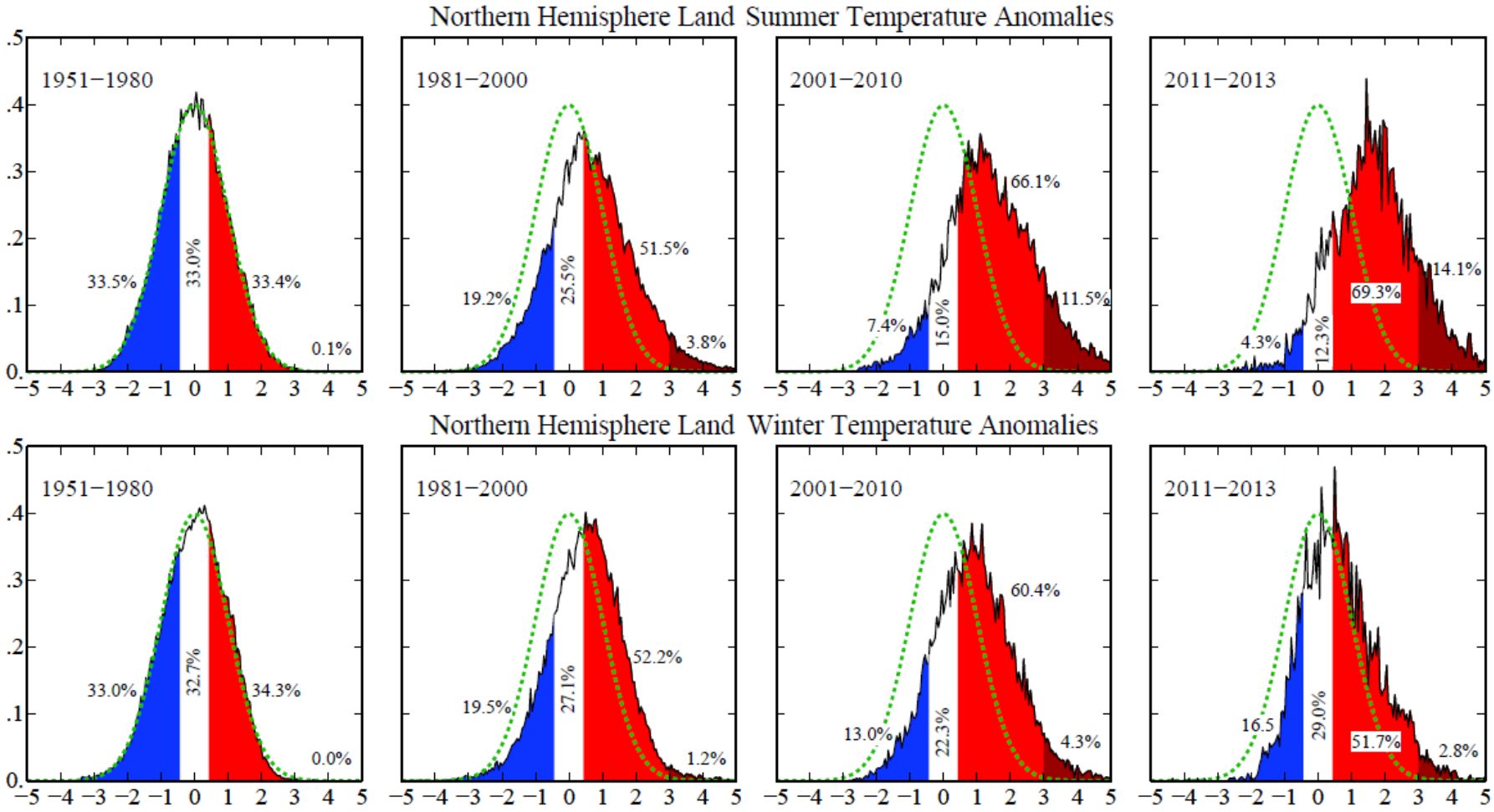
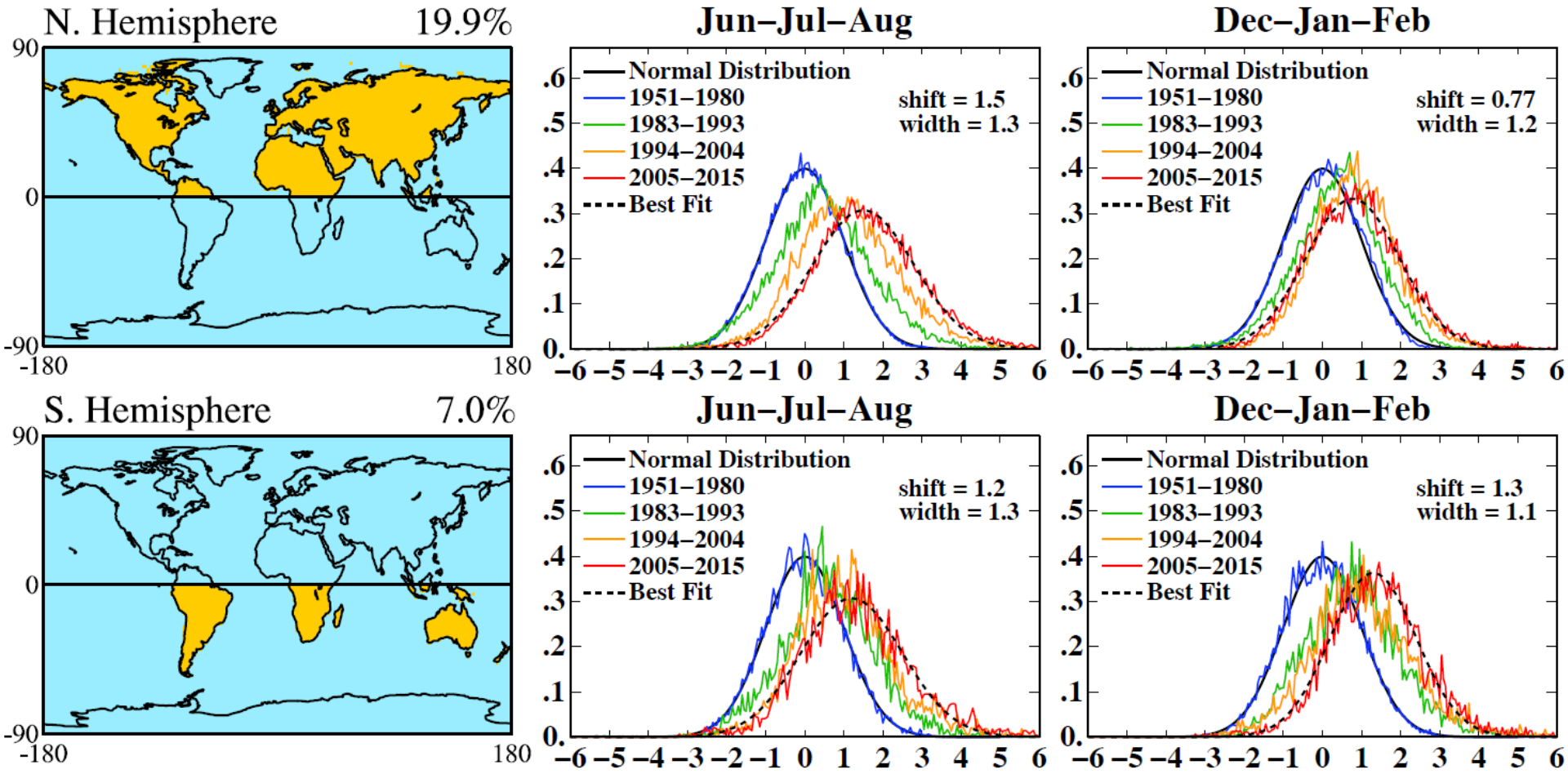


Global warming causes "bell curve" for seasonal-mean temperature to shift to the right.

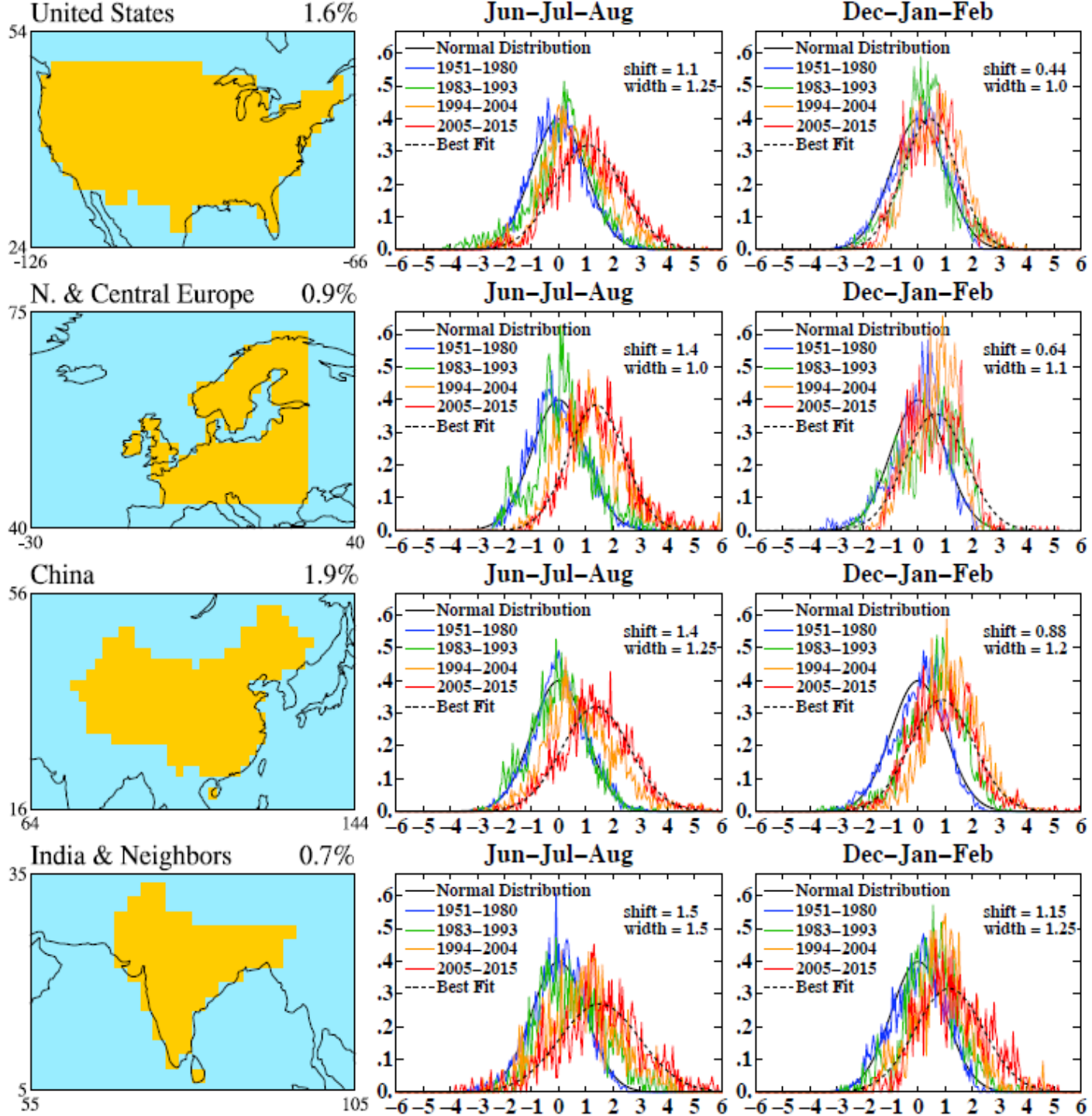
Extreme (> +3σ) anomalies, relative to 1951-1980 climate, are increasing.

Winter warming (°C) is as large as in summer, but σ is much larger (~2-4 × larger) in winter.

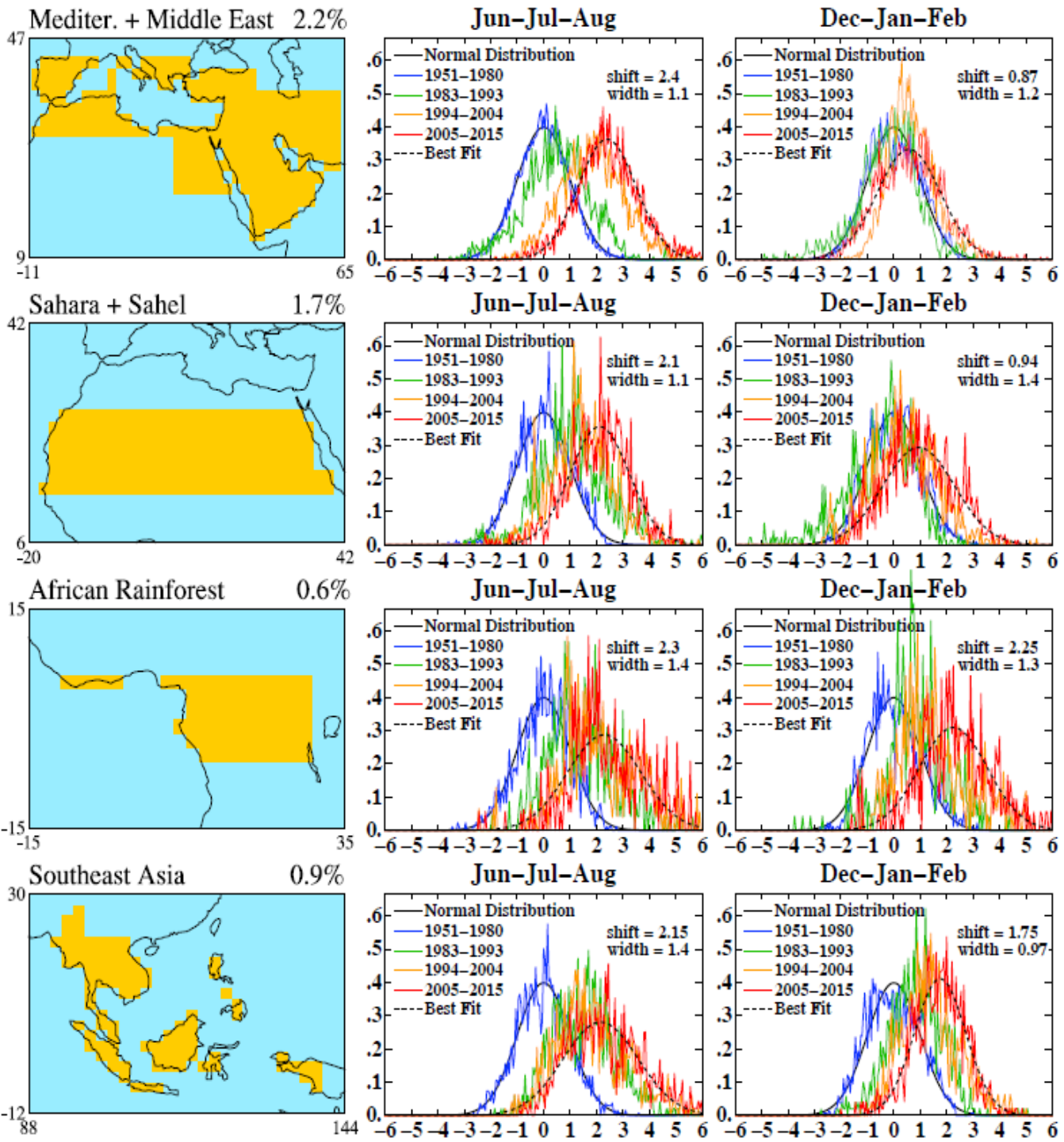


Frequency of occurrence of local seasonal-mean temperature anomalies (relative to 1951-1980 mean) divided by local standard deviation (horizontal axis) for land areas shown on map.

Area under each curve is unity. Numbers above the maps are percent of the globe covered by the selected region. “Shift” and “width” refer to the dashed curve fit to 2005-2015 data and are relative to the 1951-1980 base period



Shifting bell curves that define the frequency of local temperature anomalies relative to the 1951-1980 base period for four regions



Shifting bell curves that define the frequency of local temperature anomalies relative to the 1951-1980 base period for four regions

Impacts of Shifting Bell Curves

1. **Increase of regional climate extremes**
   - More extreme droughts in dry regions
   - Greater rainfall, floods in wet regions

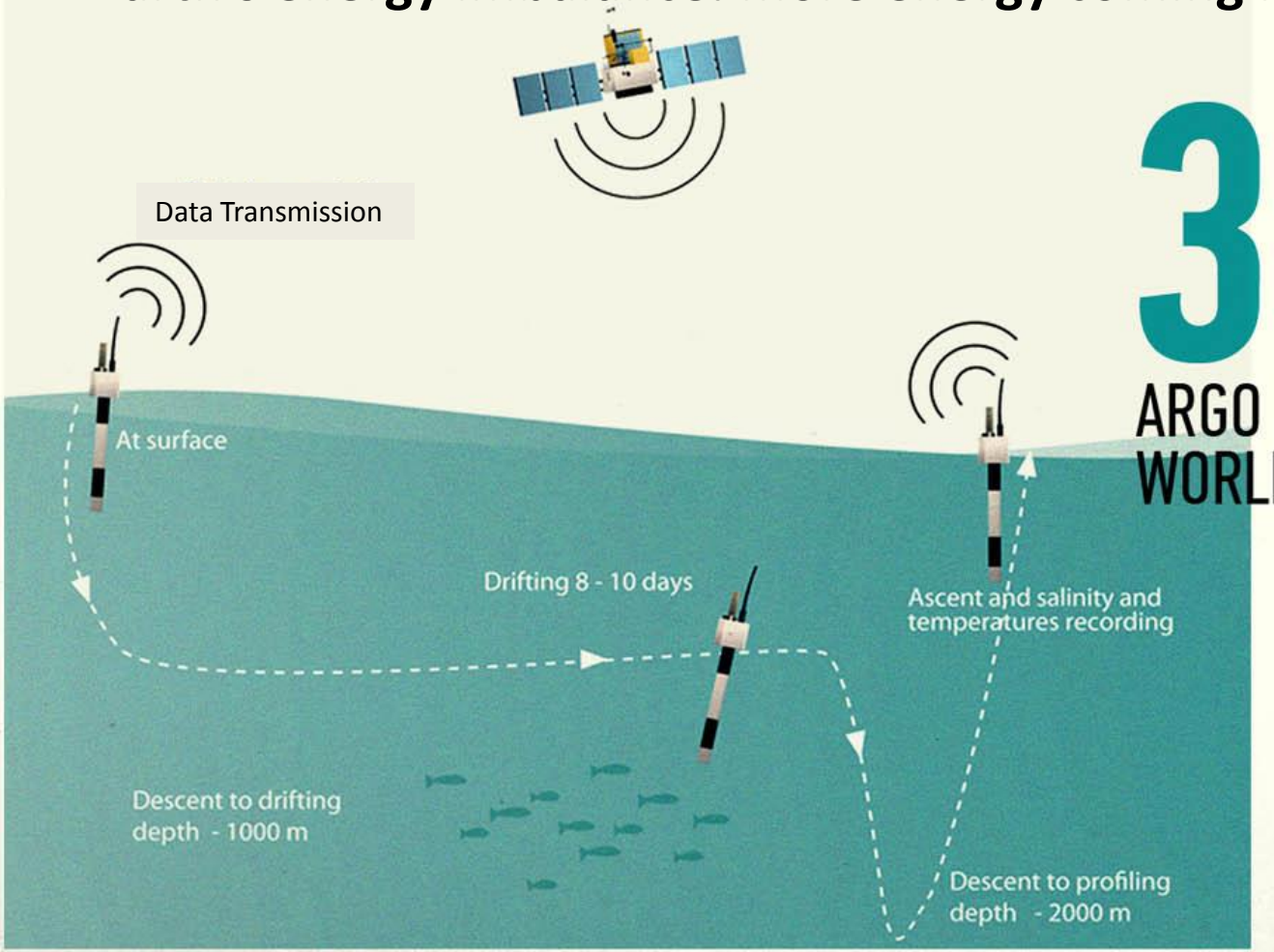
2. **Summer outdoor livability & livelihoods**
   - > half non-household labor is outdoors
   - National economies

3. **Conflicts, Violence (Hsiang et al., 2013)**
   - interpersonal: +4%/standard deviation
   - groups, nations: +14 %/standard deviation

Global Energy Imbalance

- now measured accurately
- defines global warming in the pipeline

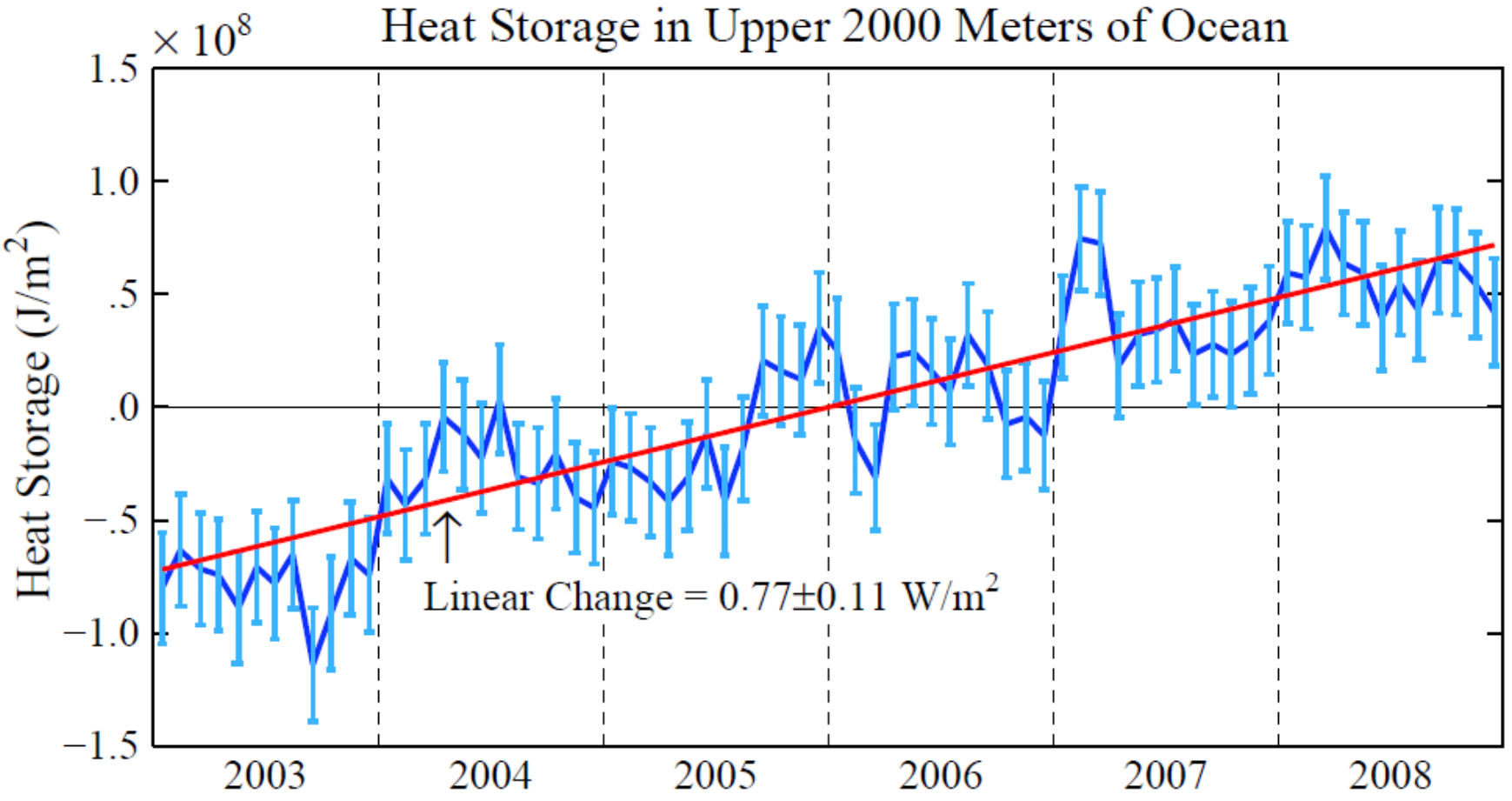
Earth's energy imbalance: more energy coming in than going out



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.

This imbalance continues through the most recent (2013) data.

This imbalance assures that global warming will continue in coming decades.

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

Problem & Solution

1. Fossil Fuels are Cheapest Energy
   - Subsidized & Do Not Pay Costs to Society
   - Partial Solution: Rising Price on Carbon
2. Regulations also Required
   - Efficiency of Vehicles, Buildings, e.g.
   - Rising Carbon Fee Provides Enforcement
3. Technology Development Needed
   - Spurred by Rising Carbon Price
   - Need Clean Energy as Cheap as Coal

Carbon Fee & Dividend

Fee: Collected at Domestic Mine/Port of Entry

Covers all Oil, Gas, Coal → No Leakage

Dividend: Equal Shares to All Legal Residents

Effect is "progressive"; low-income people tend to gain

Merits:

Transparent. Market-based. Stimulates Innovation.

Public: will see declining pollution and understand that they are part of solution

Government: gains deserved credit for pollution decline, & better national data as citizens register to receive dividend

Fee & Dividend Addresses

1. **Economy: Stimulates It**
   - Puts Money in Public's Hands
   - 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
   - Rebates to Domestic Industries on Exports to Nations without an Equivalent Carbon Fee

Merits of Having First Fee & Dividend

1. **Can Set Initial Carbon Fee at Optimum Level**
   - Initial fee moderate, if it is without border adjustments
   - F&D spurs economy; "Merits" offset any trade effects
2. **First Adapter: Headstart in Energy Transition**
   - Industry, businesses obtain investment guideline
   - Consumers learn merits for individuals and nation
3. **Establish International Leadership Position**
   - International climate solution must have carbon fee/tax
   - Demonstrate multiple "merits" of carbon F&D

Climate change deal will not include global carbon price: UN climate chief

A climate change deal to be agreed in Paris in December will not be able to come up with a global carbon price, the United Nations' climate chief, Christiana Figueres, said.

Big multinational companies and investors, and most recently oil majors, have called for a global carbon price to help spur investments in low-carbon energy.

A global carbon price would help to create an incentive for operators of power plants and factories to switch to cleaner fuels such as gas or to buy more energy-efficient equipment.

"(Many have said) we need a carbon price and (investment) would be so much easier with a carbon price, but life is much more complex than that," Figueres told a climate investor event in London.

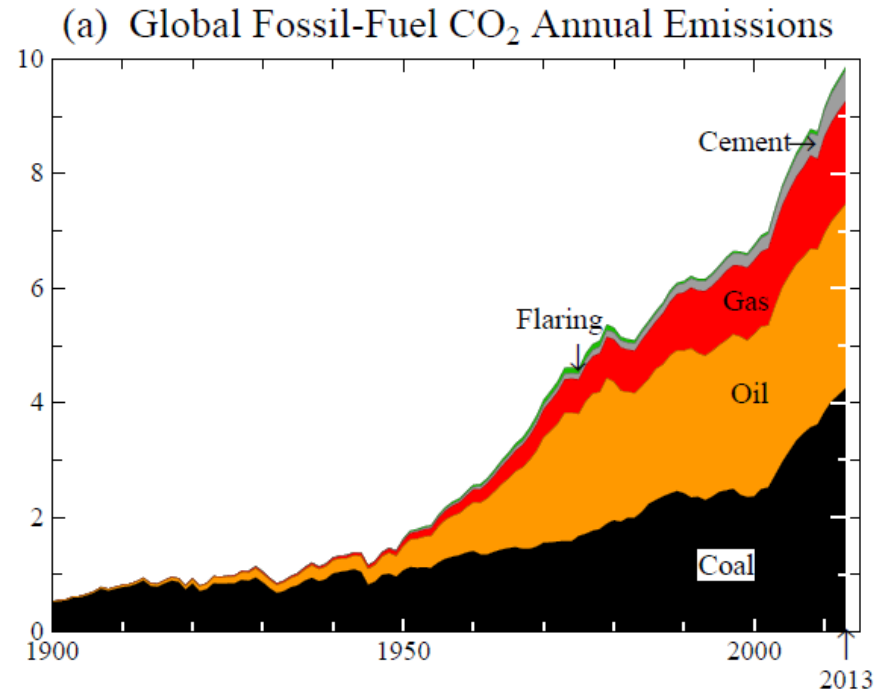
Cap & Trade with Offsets: The Kyoto Approach Again!

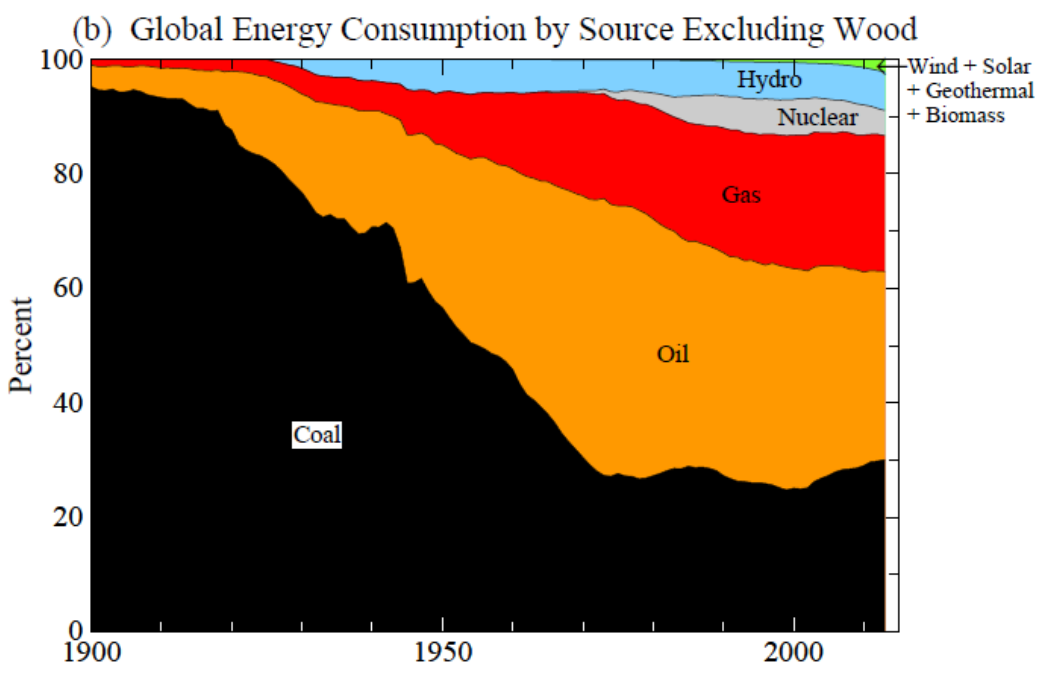
Certain to be Ineffectual

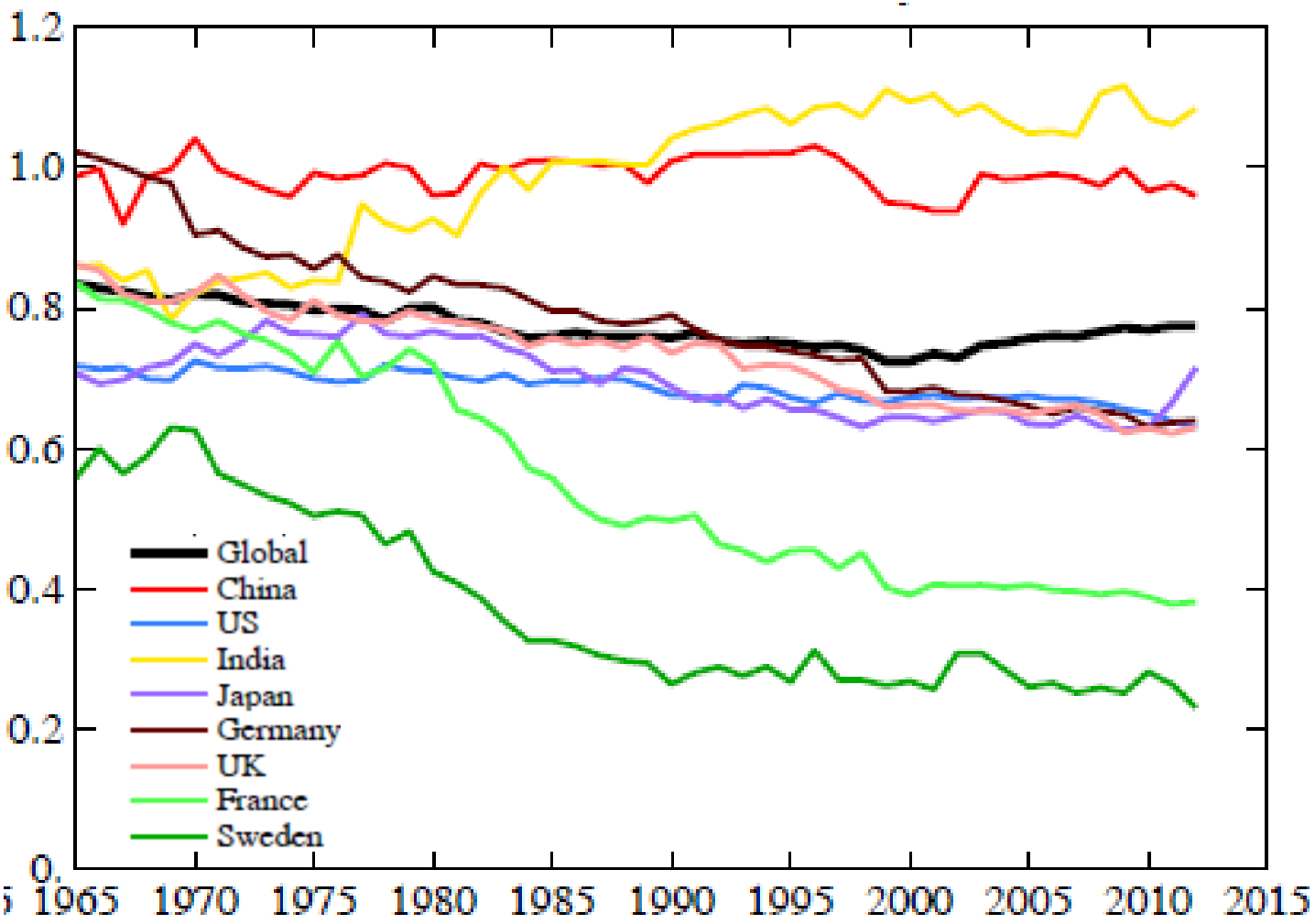
1. **Not Global**

   Must beg each nation for a cap

2. **No Enforcement Mechanism**


(a) Global Fossil-Fuel CO_2 Annual Emissions
10
8
6
4
2
0
1900
1950
2000
2013
Cement
Flaring
Gas
Oil
Coal


(b) Global Energy Consumption by Source Excluding Wood
Percent
100
80
60
40
20
0
1900
1950
2000
Hydro
Nuclear
Wind + Solar
+ Geothermal
+ Biomass
Gas
Oil
Coal



<u>Carbon intensity</u>, defined as fossil fuel carbon emissions (GtC) divided by energy consumption (Gt of oil equivalent)

Advancing Nuclear Energy to Help Address Climate Change and Air Pollution

Climate change and air pollution combine to create a crisis that threatens to derail progress towards elimination of poverty. Growing demand for energy must be met in ways that provide clean air and abundant clean water and not leave young people a climate system running out of control. The urgency of expanding clean energy implies that nuclear power, presently the largest source of carbon-free energy and historically the clean-energy source capable of fastest scale-up, likely must play an important role in meeting needs for dispatchable electric power, carbon-neutral liquid fuels, and fresh water.

Enormous potential for innovation in modern nuclear reactors offer promise of obtaining clean energy competitive with or lower than fossil fuel costs while maintaining the highest standards for safe operation and efficient management and utilization of nuclear waste. Nuclear power will need to complement renewable energies, providing sufficient baseload electric power to help address the challenge of replacing energy presently obtained from fossil fuels.

China, because of the rapid pace required for its clean energy development, has the opportunity to lead the world in moving the nuclear innovation agenda forward in cooperation with other nations. Indeed, such cooperative progress seems to be an imperative for the well-being of young people and future generations of the entire world.

Grandsons Connor and Jake – Connor reading Indiana Jones book.

Connor's Thoughts

If we keep doing what we are doing now then the environment will be ruined when the people who are kids now are grownups.

And unless we can figure out how to make a time machine that actually works, there will be no way to go back in time to fix it.

It's not fair that the grownups now are ruining the atmosphere for the grownup in the future.

Grownups now are scared of nuclear power but they should be scared of what will happen if they keep doing what they're doing now because we know the ways to use nuclear power safe and we know that using fossil fuels is not safe. It is very dangerous.

An Example of Technology

Thorium-Powered Molten Salt Reactor

- Operates at Atmospheric Pressure
- Factory or Shipyard Construction
- Uses Most Nuclear Fuel, Not <1%
- Reduced Waste, Shorter Half-Life
- Passively Safe Operation
- Not Well-Suited for Weapons Material

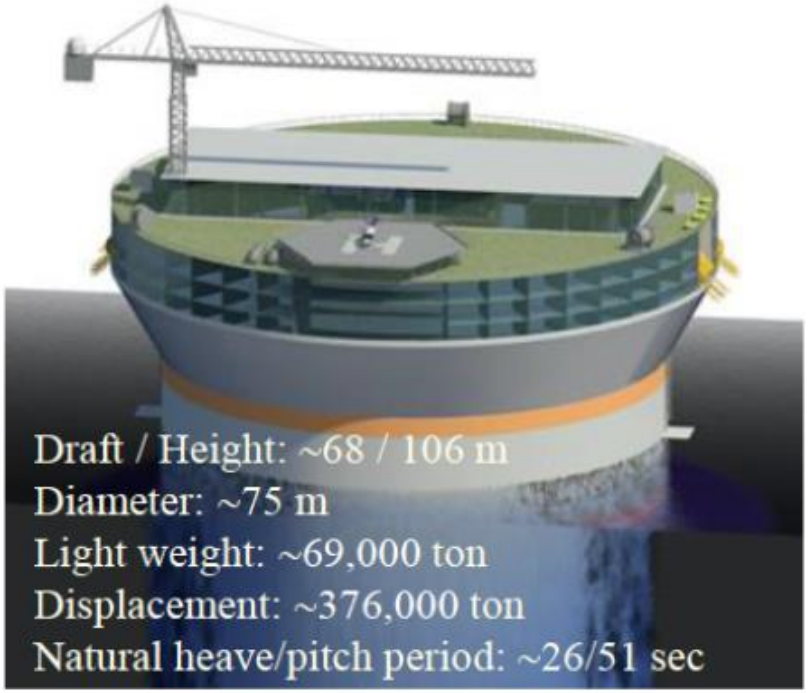
Shipyard construction of deep-water, floating plants has potential to greatly reduce construction cost/time

OFNP-300 (300 MW_e)

Credit: MIT

Draft / Height : ~48 / 75 m
Diameter: ~45 m
Light weight: ~22,000 ton
Displacement: ~115,000 ton
Natural heave/pitch period: ~25/33 sec

OFNP-1100 (1100 MW_e)



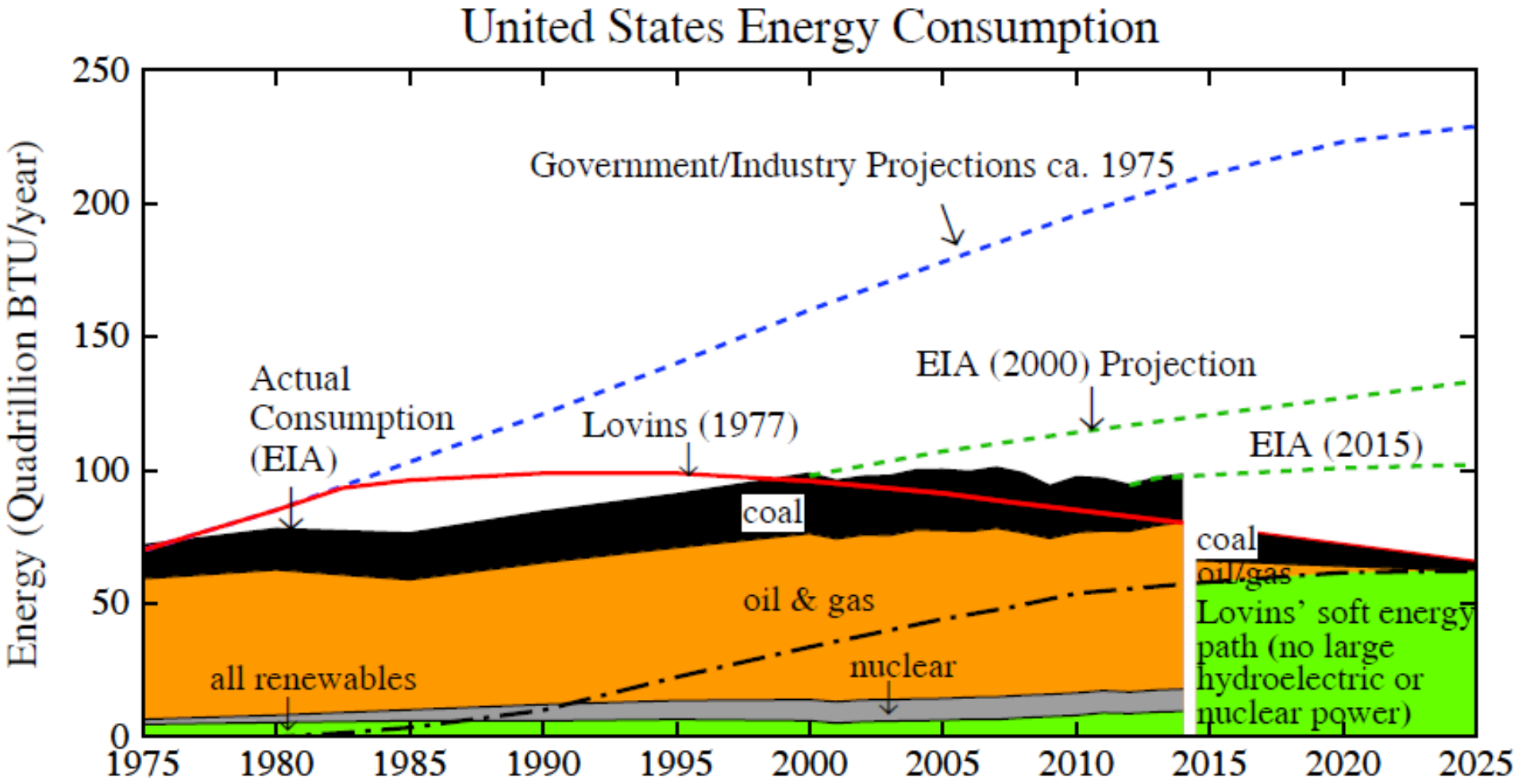
Draft / Height: ~68 / 106 m
Diameter: ~75 m
Light weight: ~69,000 ton
Displacement: ~376,000 ton
Natural heave/pitch period: ~26/51 sec

Natural period must be < tsunami wave period (plant rides tsunami) and > peak storm wave period (minimized oscillations in storms)

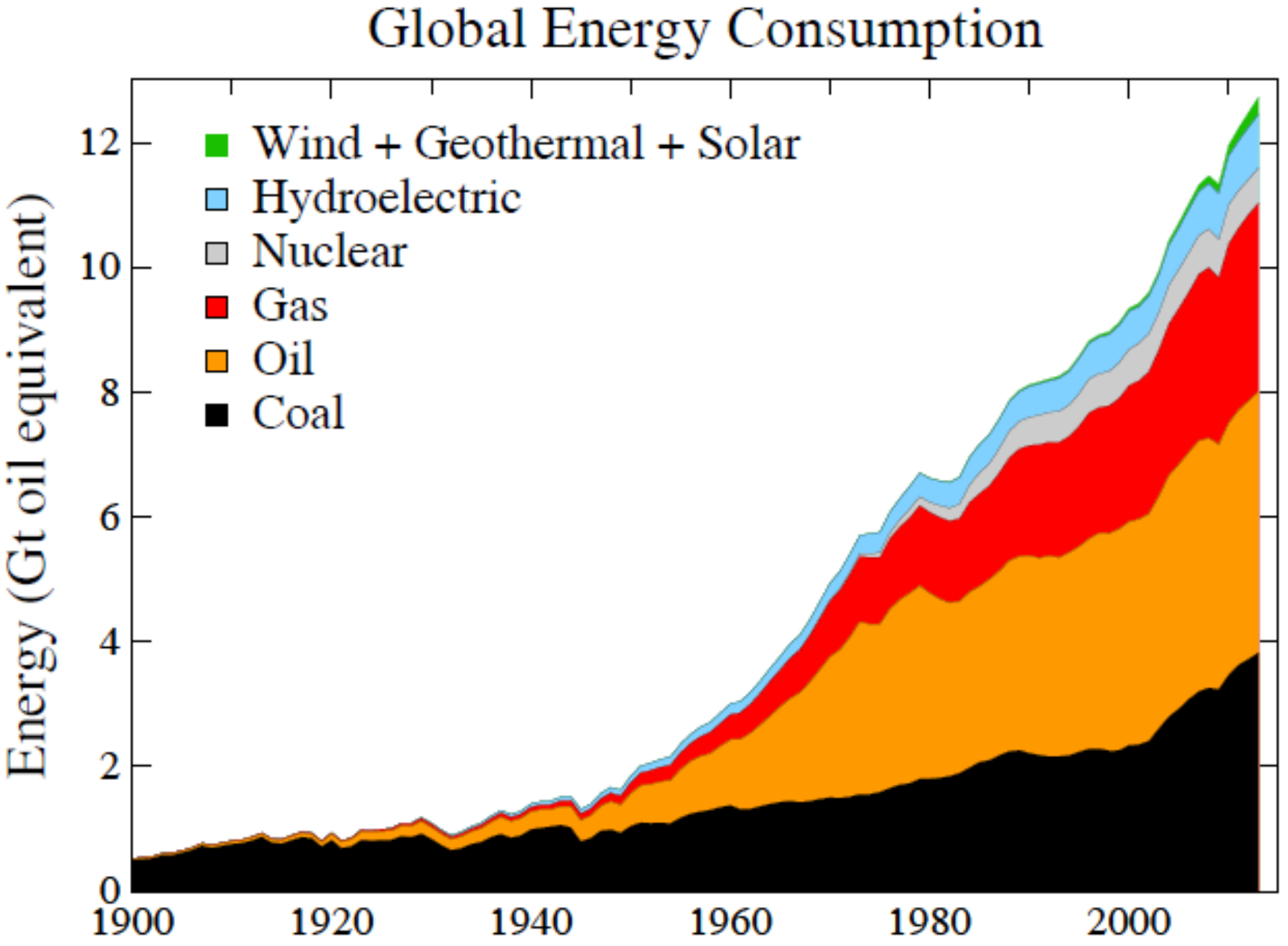
Coherent Discussion Available at:

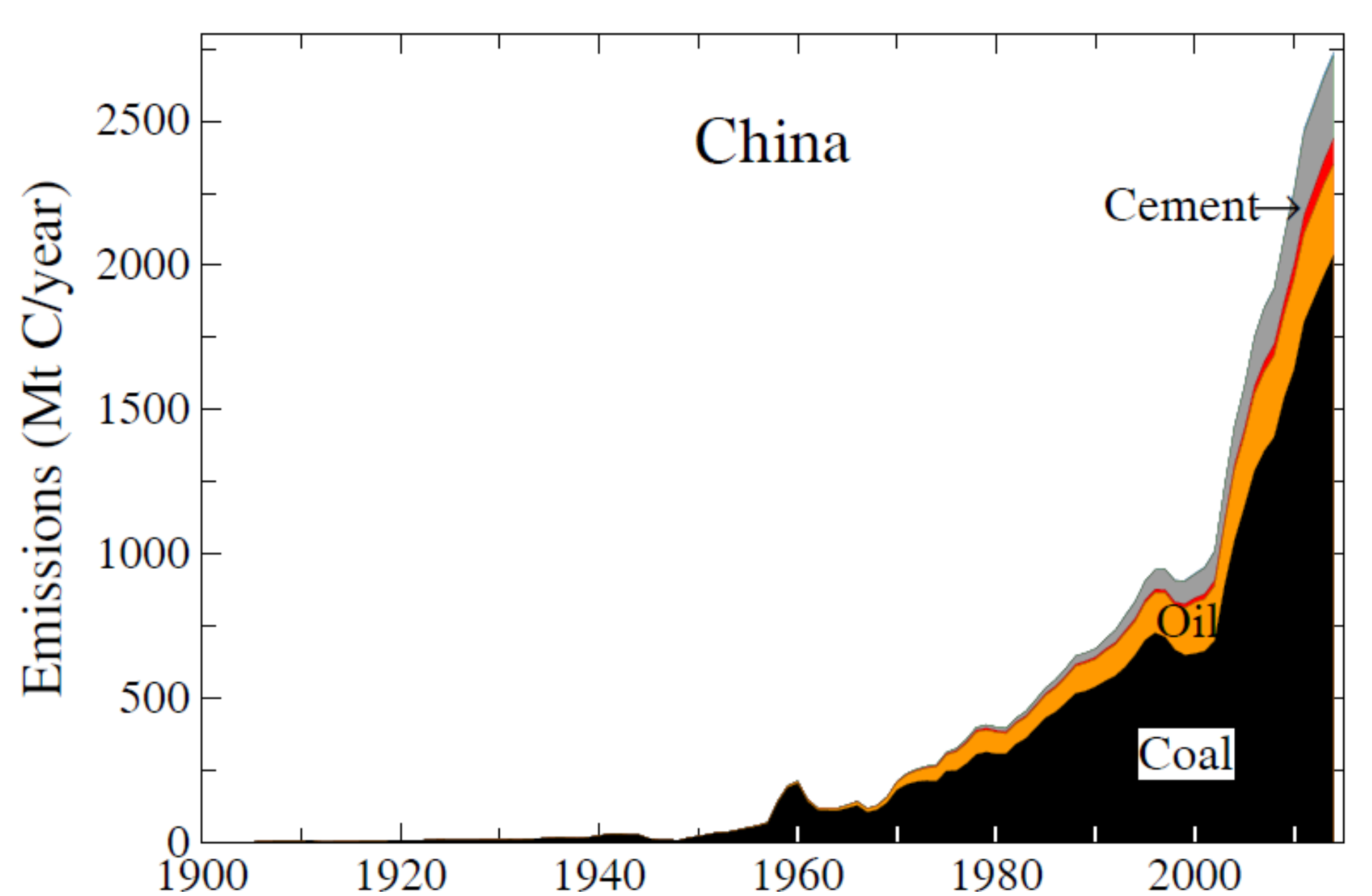
www.Columbia.edu/~jeh1

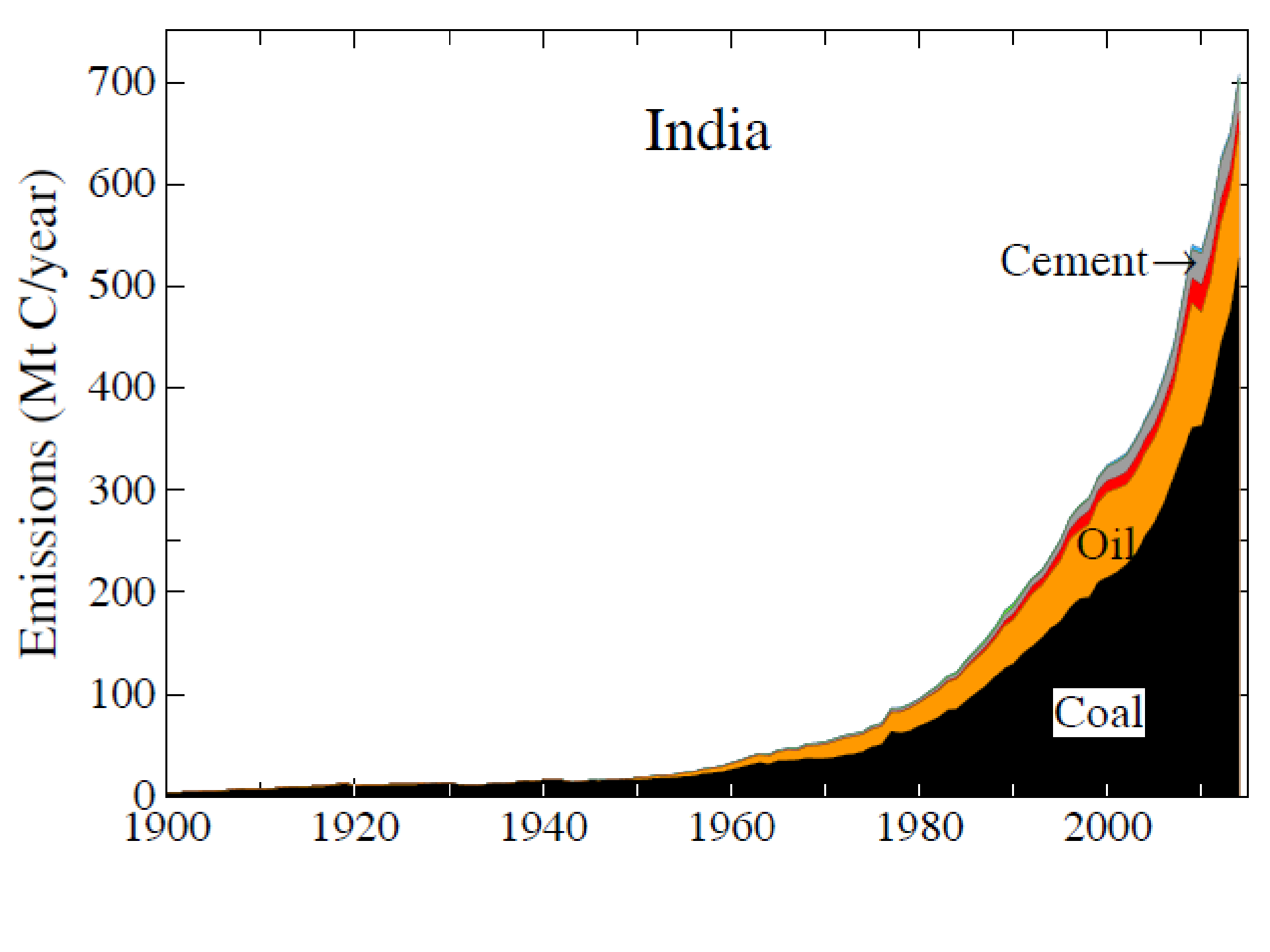
Isolation of 1600 Pennsylvania Avenue: Part I
(Communication of 27 November 2015)



Update of Fig. X in "Storms of My Grandchildren"


Global Energy Consumption
Wind + Geothermal + Solar
Hydroelectric
Nuclear
Gas
Oil
Coal
Energy (Gt oil equivalent)
0
2
4
6
8
10
12
1900
1920
1940
1960
1980
2000


China
Emissions (Mt C/year)
2500
2000
1500
1000
500
0
1900
1920
1940
1960
1980
2000
Cement
Oil
Coal


India
Emissions (Mt C/year)
0
100
200
300
400
500
600
700
1900
1920
1940
1960
1980
2000
Cement
Oil
Coal

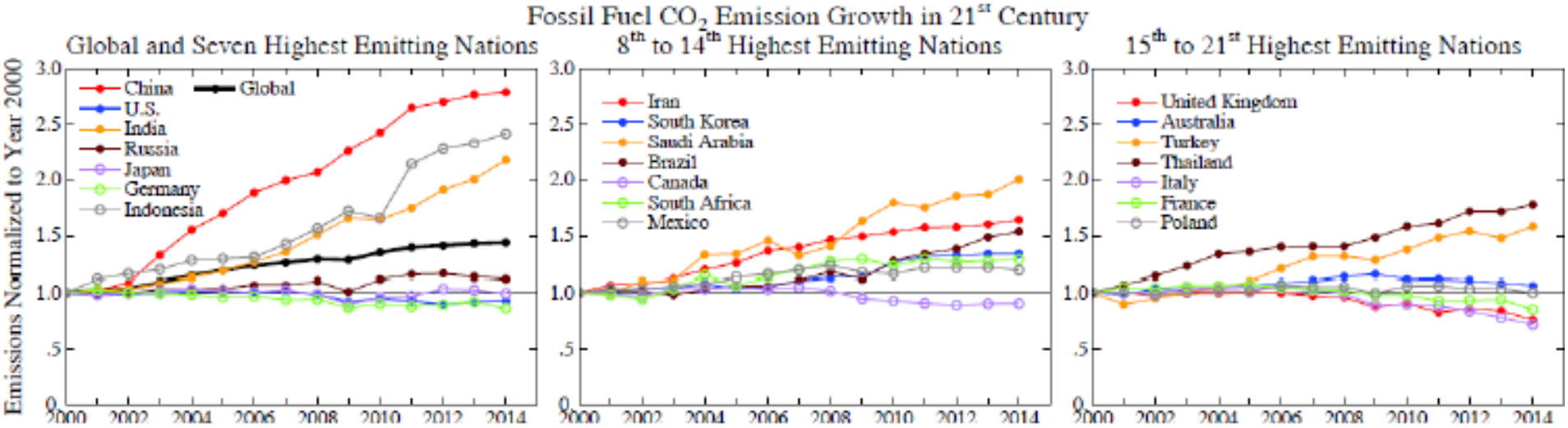


Fig. 6. Fossil fuel emissions growth this century in the 21 nations with largest current emissions.[4]