# Young People's Burdens & Opportunities

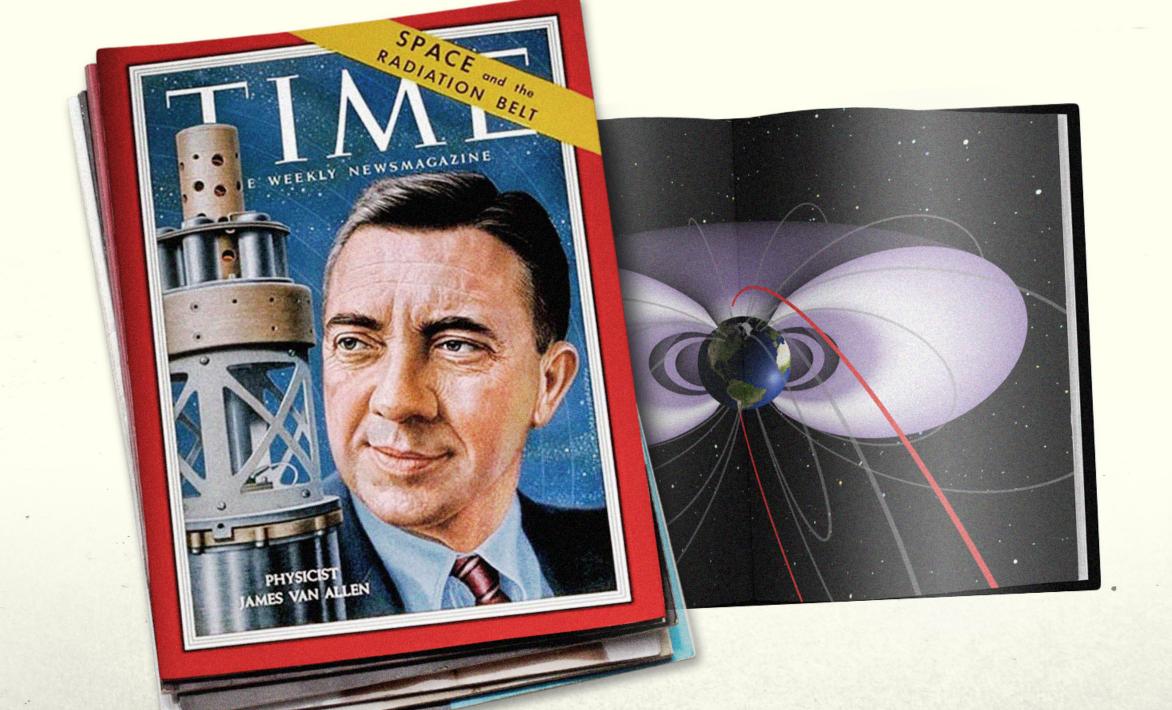
Global Energy, Climate & Human Health:

James Hansen

22 September 2018

Tang Laureate Lecture
Taiwan

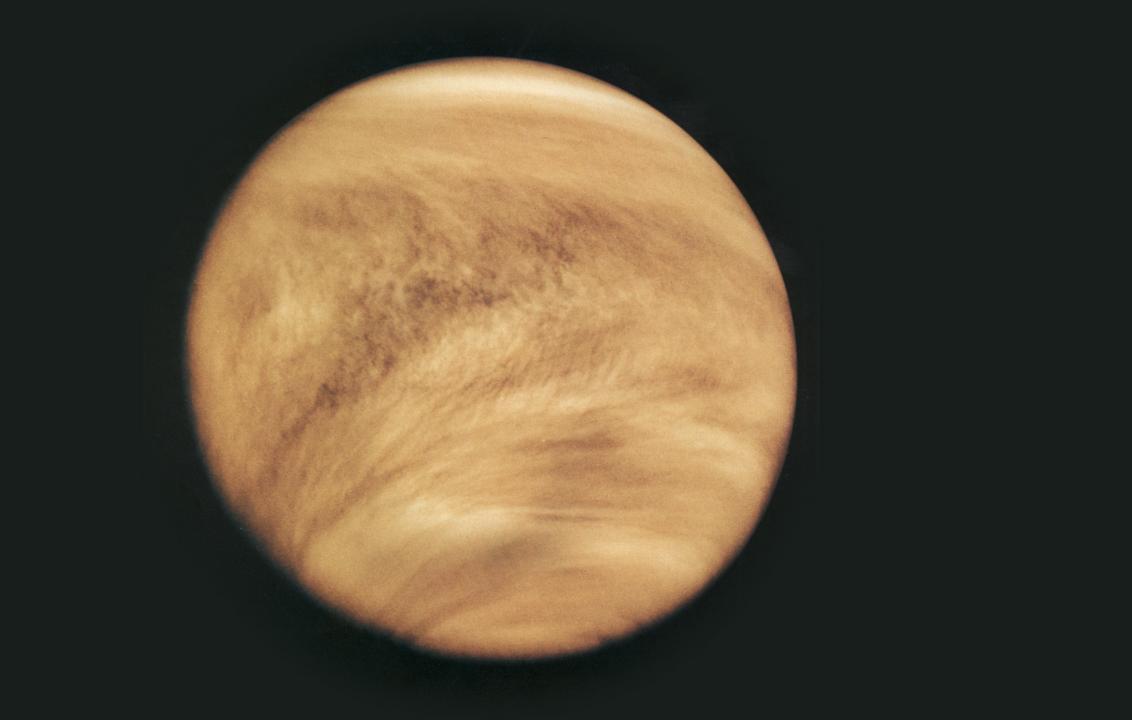




## **Goldilocks Planets**



Greenhouse warmings are about 5°C, 33°C and 500°C on Mars, Earth and Venus, respectively.





# SCIENCE

## Climate Impact of Increasing Atmospheric Carbon Dioxide

J. Hansen, D. Johnson, A. Lacis, S. Lebedeff P. Lee, D. Rind, G. Russell

Atmospheric CO2 increased from 280 to 300 parts per million in 1880 to 335 to 340 ppm in 1980 (1, 2), mainly due to burning of fossil fuels. Deforestation and changes in biosphere growth may also

The major difficulty in accepting this theory has been the absence of observed warming coincident with the historic CO2 increase. In fact, the temperature ir

SCIENCE MAGAZIN

Summary. The global temperature rose by 0.2°C between the middle 1960's and opening a warming of 0.4°C in the past century. This temperature increase is almospheric carbon dioxide. Variations of volcanic aerosols and possibly solar functions about the middle 1960's and almospheric carbon dioxide. Variations of volcanic aerosols and possibly solar functions about the measured increases of the primary causes of observed fluctuations about the middle 1960's and almospheric carbon dioxide. Variations of volcanic aerosols and possibly solar functions about the middle 1960's and almospheric carbon dioxide. luminosity appear to be primary causes of observed fluctuations about the mean trend of increasing temperature. It is shown that the anthropogenic carbon dioxide warming should emerge from the noise level of natural climate variability by the end of the century, and there is a high probability of warming in the 1980's. Potential effects on climate in the 21st century include the creation of drought-prone regions in North America and central Asia as part of a shifting of climatic zones, erosion of the West Antarctic ice sheet with a consequent worldwide rise in sea level, and opening of the

have contributed, but their net effect is probably limited in magnitude (2,3). The CO2 abundance is expected to reach 600 ppm in the next century, even if growth of fossil fuel use is slow (4).

Carbon dioxide absorbs in the atmospheric "window" o

about 0.5°C between 1940 and 1970 (9), a time of rapid CO2 buildup. In addition, recent claims that climate models overestimate the impact of radiative pertur-

#### Greenhouse Effect

The effective radiating temperature of the earth, Te, is determined by the need for infrared emission from the planet to balance absorbed solar radiation:

$$\pi R^2 (1 - A)S_0 = 4\pi R^2 \sigma T_c$$
 (1)

$$T_e = [S_0(1 - A)/4\sigma]^{1/4}$$
 (2)

where R is the radius of the earth, A the albedo of the earth,  $S_0$  the flux of solar radiation, and  $\sigma$  the Stefan-Boltzmann constant. For  $A \sim 0.3$  and  $S_0 = 1367$ watts per square meter, this yields

The mean surface temperature is  $T_s \sim 288$  K. The excess,  $T_s - T_e$ , is the greenhouse effect of gases and clouds, which cause the mean radiating level to be above the surface. An estimate of the greenhouse warming is

$$T_{\rm s} \sim T_{\rm e} + \Gamma H$$

where H is the flux-weighted mean altitude of the emission to space and  $\Gamma$  is the mean temperature gradient (lapse rate) between the surface and H. The earth's troposphere is sufficiently opaque in the infrared that the purely radiative vertical temperature gradient is convectively unstable, giving rise to atmospheric motions that contribute to vertical transport of heat and result in  $\Gamma \sim 5^{\circ}$  to 6°C per kilometer. The mean lapse rate is less than the dry adiabatic value because of latent heat release by condensation as moist air rises and cools and because the atmospheric motions that transport heat

# The New York Eimes

# STUDY FINDS WARMING TREND THAT COULD RAISE SEA LEVELS

By WALTER SULLIVAN (The New York Times); National Desk August 22, 1981, Saturday

A team of Federal scientists says it has detected an overall warming trend in the earth's atmosphere extending back to the year 1880. They regard this as evidence of the validity of the "greenhouse" effect, in which increasing amounts of carbon dioxide cause steady temperature increases. The seven atmospheric scientists predict a global warming of "almost unprecedented magnitude" in the next century. It might even be sufficient to melt and dislodge the ice cover of West Antarctica, they say, eventually





(EFFECTS OF GLOBAL WARMING ON EARTH'S BIOLOGICAL SYSTEMS)



BASED ON SCIENTIFIC DATA
BY THE NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

(EFFECTS OF GLOBAL WARMING ON EARTH'S BIOLOGICAL SYSTEMS)

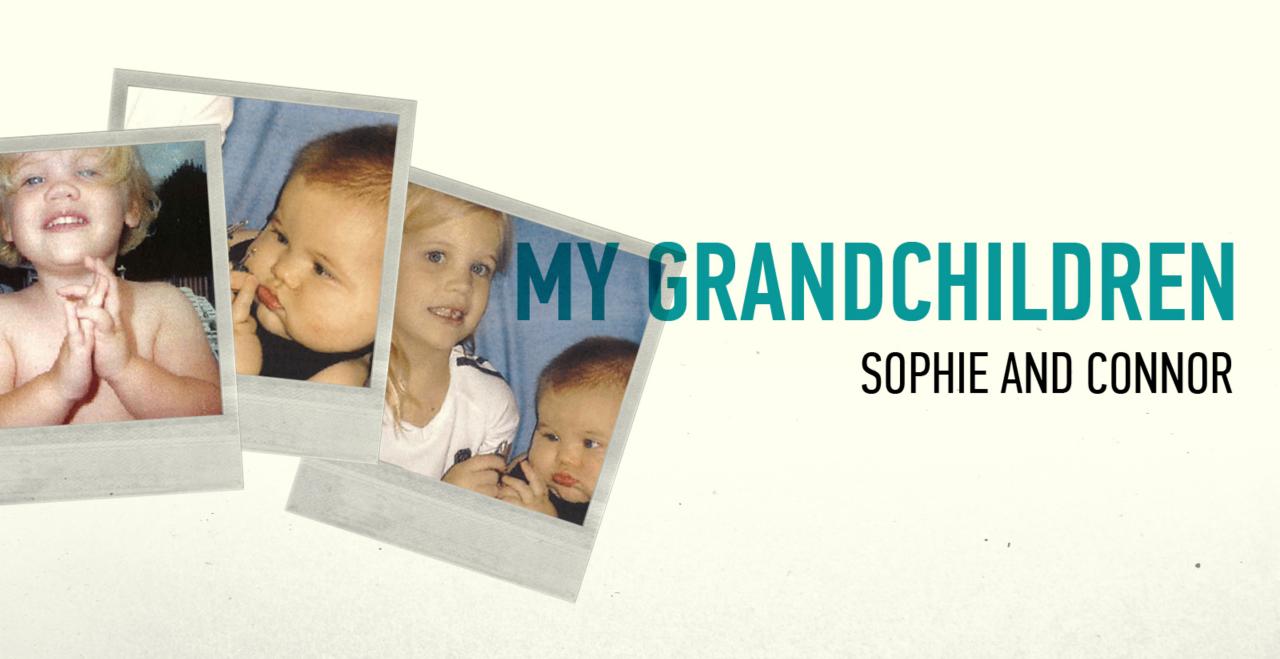


REVISED BY THE OFFICE OF MANAGEMENT AND BUDGET

@1989 FORT WORTH STAR-TELEGRAM\_\_\_HULME







# Dangerous Anthropogenic Interference

A Discussion of Humanity's Faustian Climate Bargain and the Payments Coming Due

James E. Hansen Distinguished Lecture Van Allen Hall, University of Iowa

# 'Dangerous Anthropogenic Interference' with Global Climate?

# A Tribute to Charles David Keeling

James Hansen presentation 6 December 2005
American Geophysical Union, San Francisco



# The New York Eimes

Late Edition

Today: Cloudy, afternoon showers, high 53. Tonight, an early shower, low 46. Tomorrow, continued mild, cloudy, high 56. Yesterday, high 58, low 37, Details and weather map, Page 33.

Caparight © 2006 The New York Times

NEW YORK, SUNDAY, JANUARY 29, 2006

\$4.50 beyond the greater New York meropolitan area.

\$3.50

Scott Neison/World Picture News, for The New York Times

### Hamas Leader Sees No Change Toward Israelis

# Firm Refusal to Disarm — Role for Fatah

#### By STEVEN ERLANGER

JERUSALEM, Jan. 28 — The exiled political head of the radical Islamic group Hamas said Saturday in Damascus, Syria, that the group would adopt "a very realistic approach" toward governing the Palestinian Authority and would work with the Fatah president, Mahmoud Abbas, on an acceptable political program.

But the leader, Khaled Meshal, also said Hamas would not "submit to pressure to recognize Israel, because the occupation is illegitimate and we will not abandon our rights," nor would it disarm, but would work to create a unified Palestinian army.

He insisted that "resistance is a legitimate right that we will practice and protect," and he defended attacks on Israeli civilians, which included many suicide bombings until a cease-fire nearly a year ago. Then he said Hamas was "ready to work

## CLIMATE EXPERT SAYS NASA TRIED TO SILENCE HIM

#### GLOBAL WARMING AT ISSUE

Space Agency Says Limits Apply to All Employees on Policy Issues

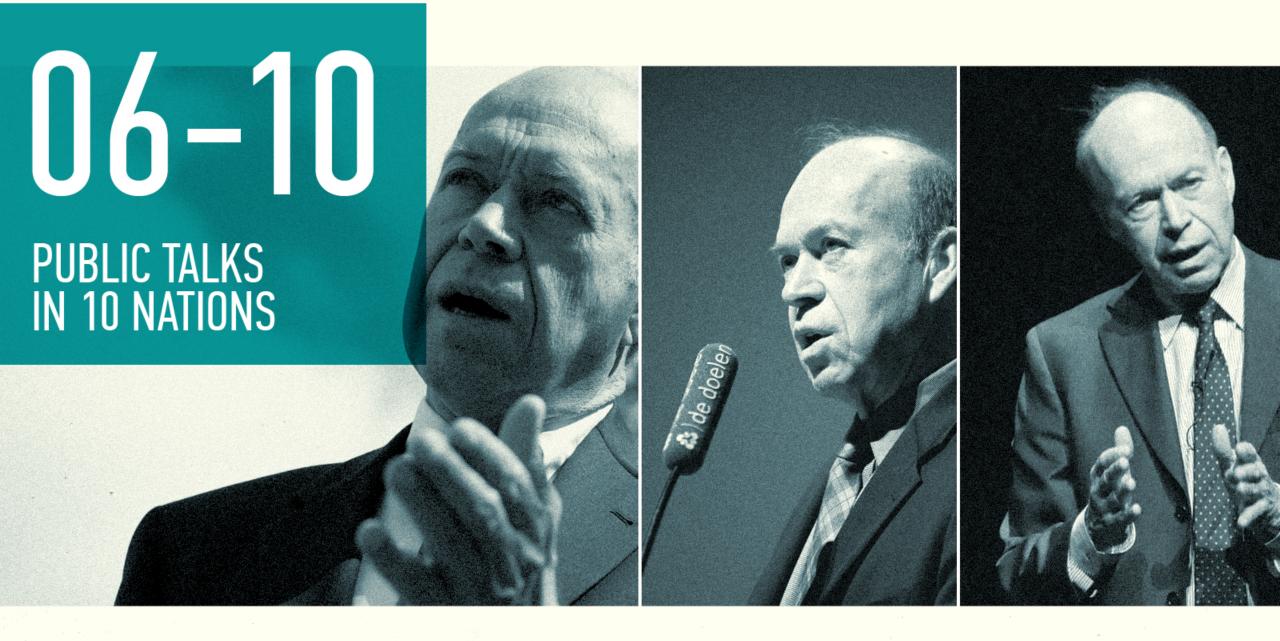
#### By ANDREW C. REVKIN

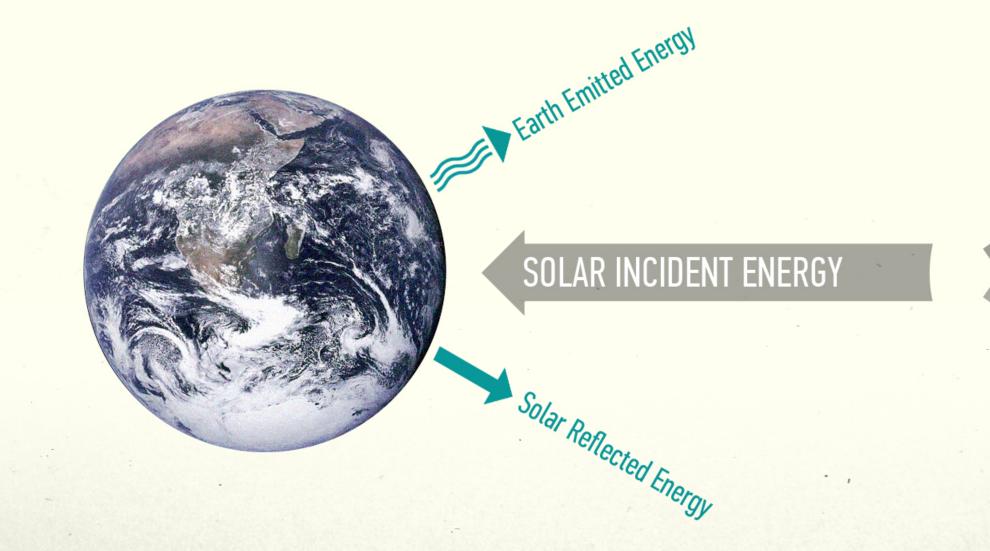
The top climate scientist at NASA says the Bush administration has tried to stop him from speaking out since he gave a lecture last month calling for prompt reductions in emissions of greenhouse gases linked to global warming.

The scientist, James E. Hansen, longtime director of the agency's Goddard Institute for Space Studies, said in an interview that officials at NASA headquarters had ordered the public affairs staff to review his coming lectures, papers, postings on the Goddard Web site and requests for interviews from journalists.

## NASA MISSION STATEMENT

# IINDEDCTAND AND DOOTECT THE IOME DI AMET







Date transmission



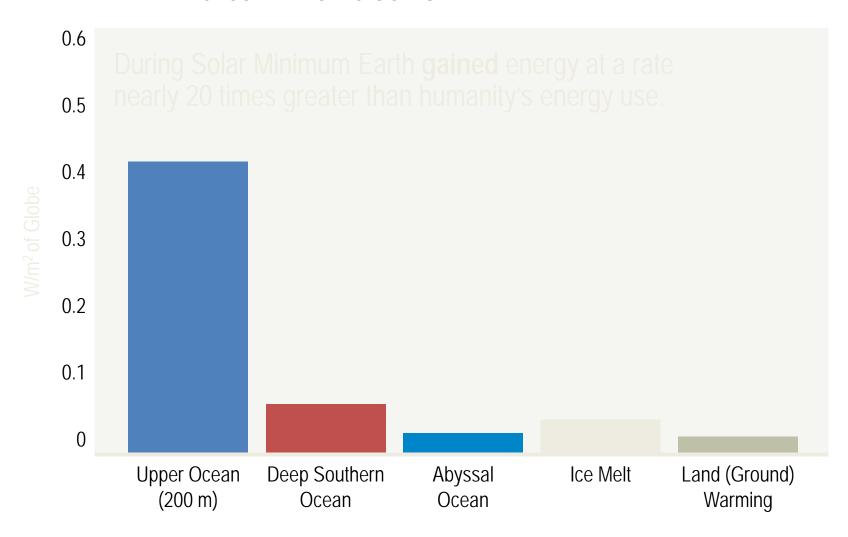
Descent to drifting depth - 1000 m

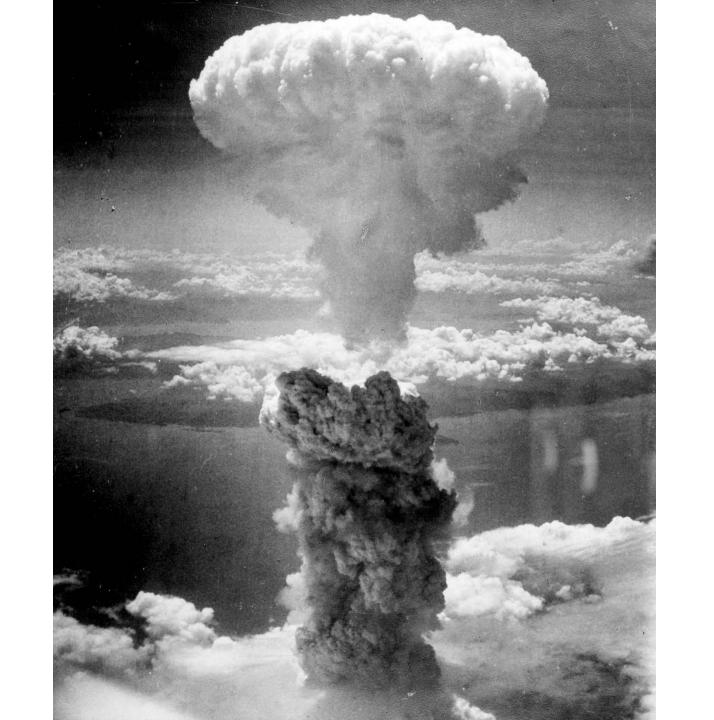
# ARGO FLOATS AROUND WORLD OCEANS

Ascent and salinity and temperatures recording

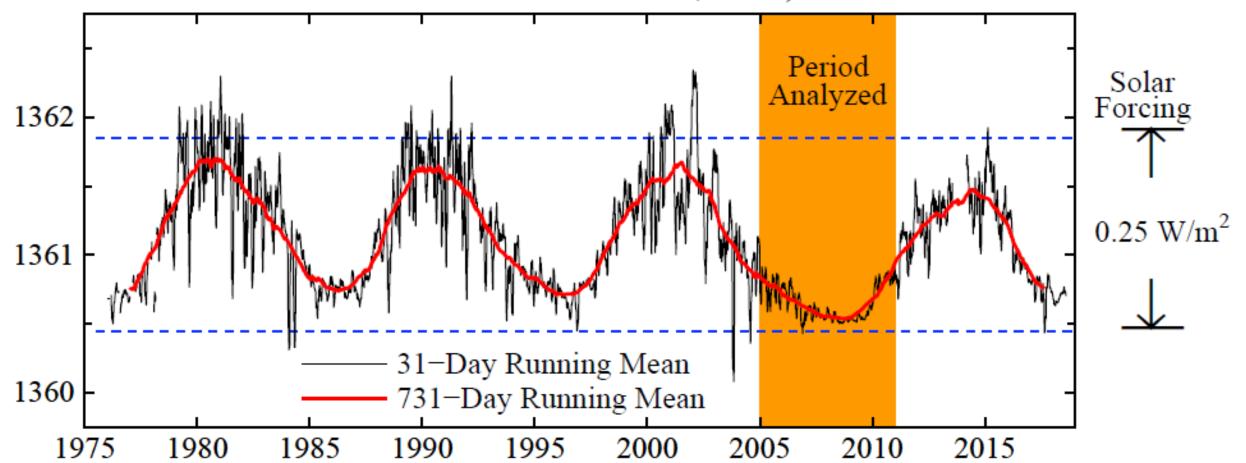
Descent to profiling depth - 2000 m

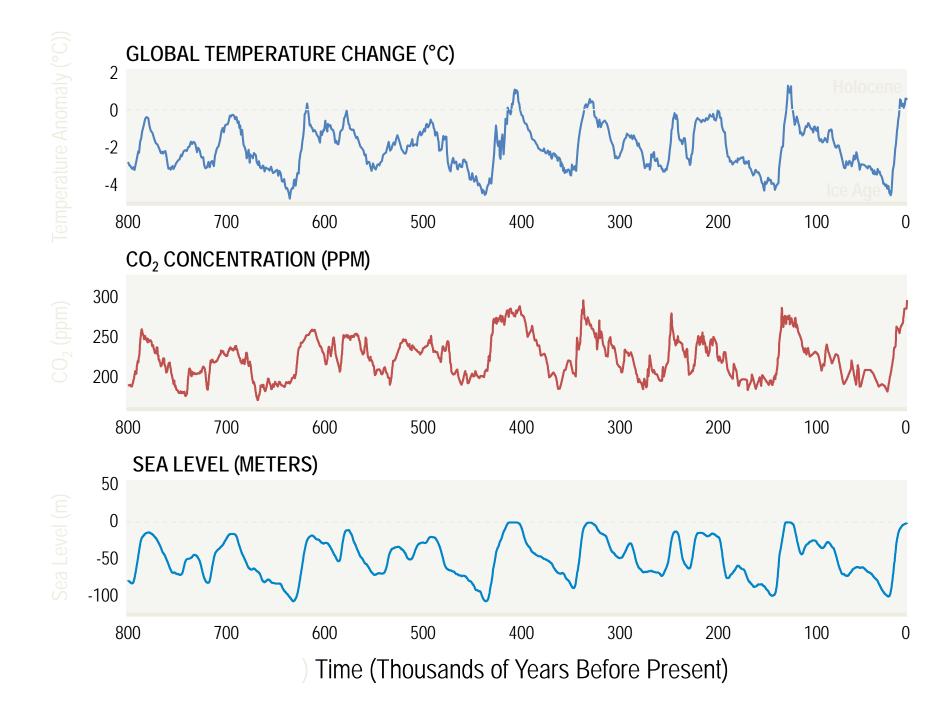
#### WHERE EXCESS ENERGY IS GOING



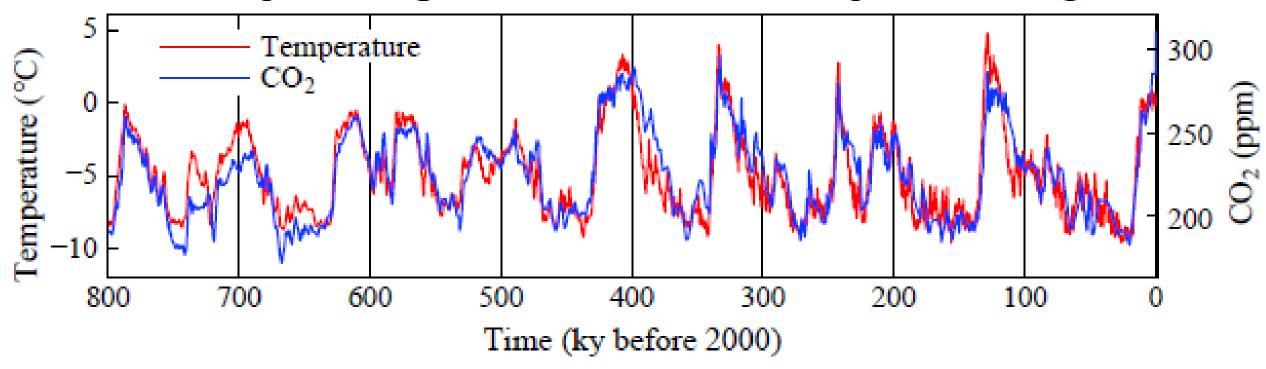


Total Solar Irradiance (W/m<sup>2</sup>)



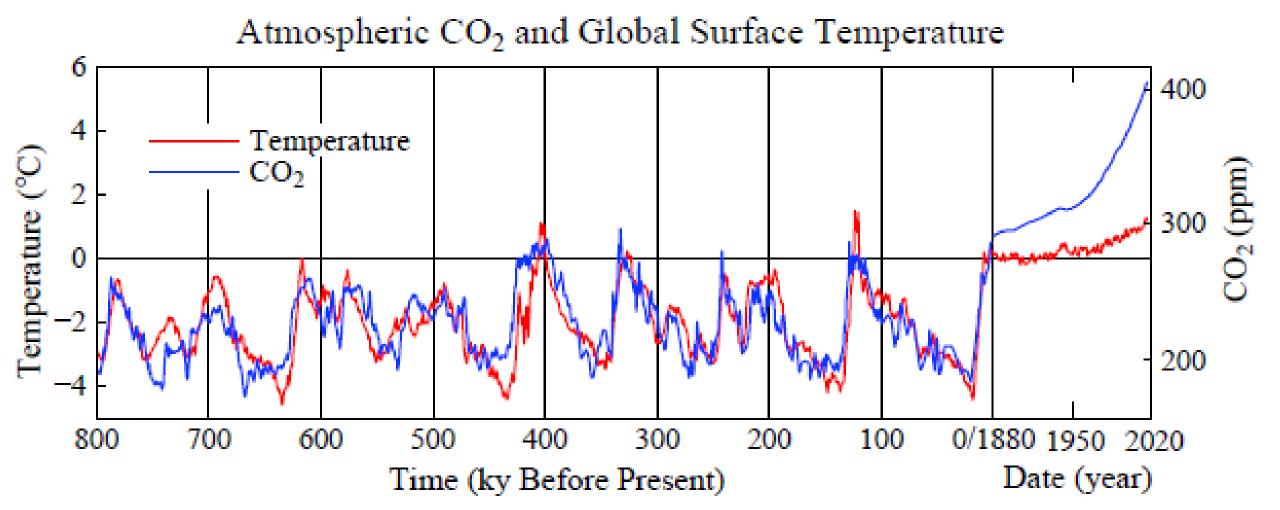


## Atmospheric CO<sub>2</sub> Amount and Antarctic Temperature Change



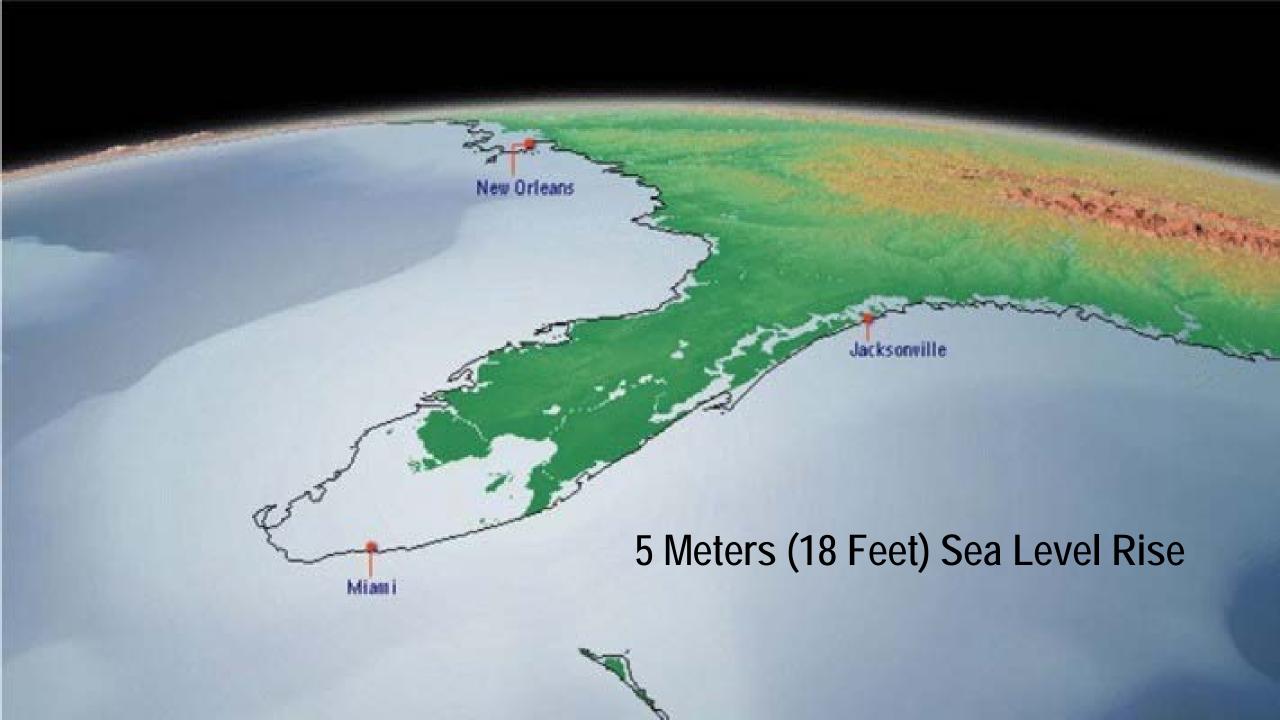
Atmospheric CO<sub>2</sub> amount (right scale) during past 800,000 years. Global temperature change is approximately half of the Antarctic temperature change (left scale).

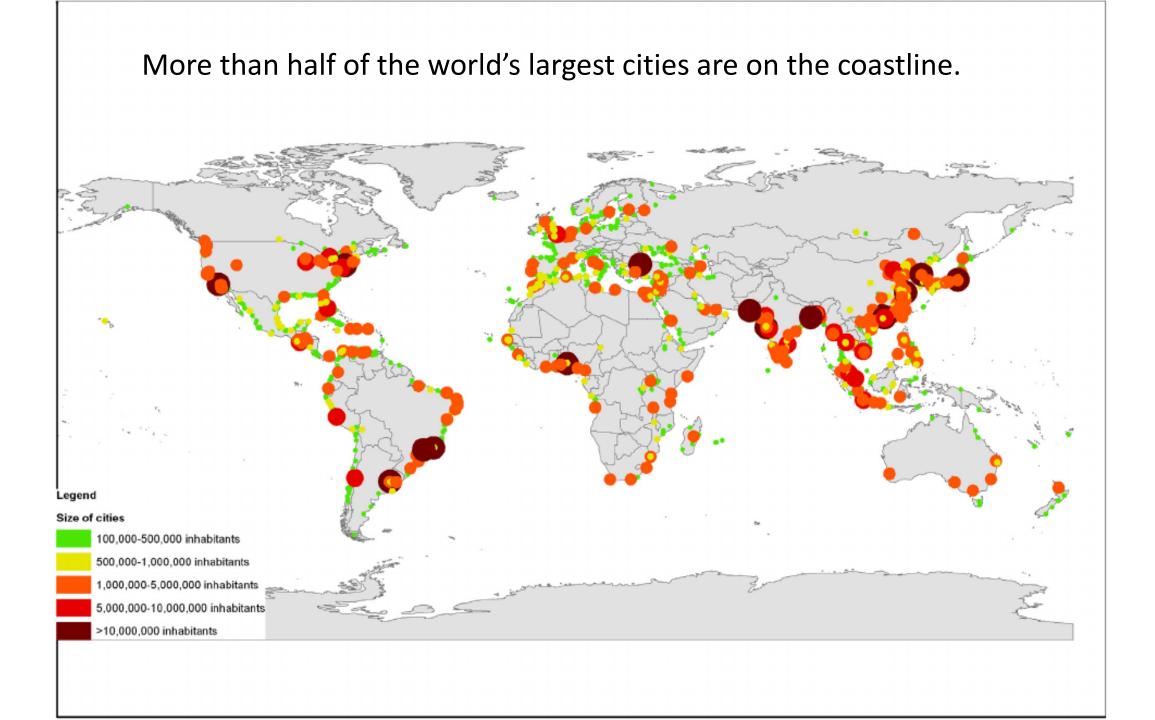
Source: Ice Melt, Sea Level Rise and Superstorms, Hansen et al., Atmos. Chem. Phys., 16, 1-52, 2016.

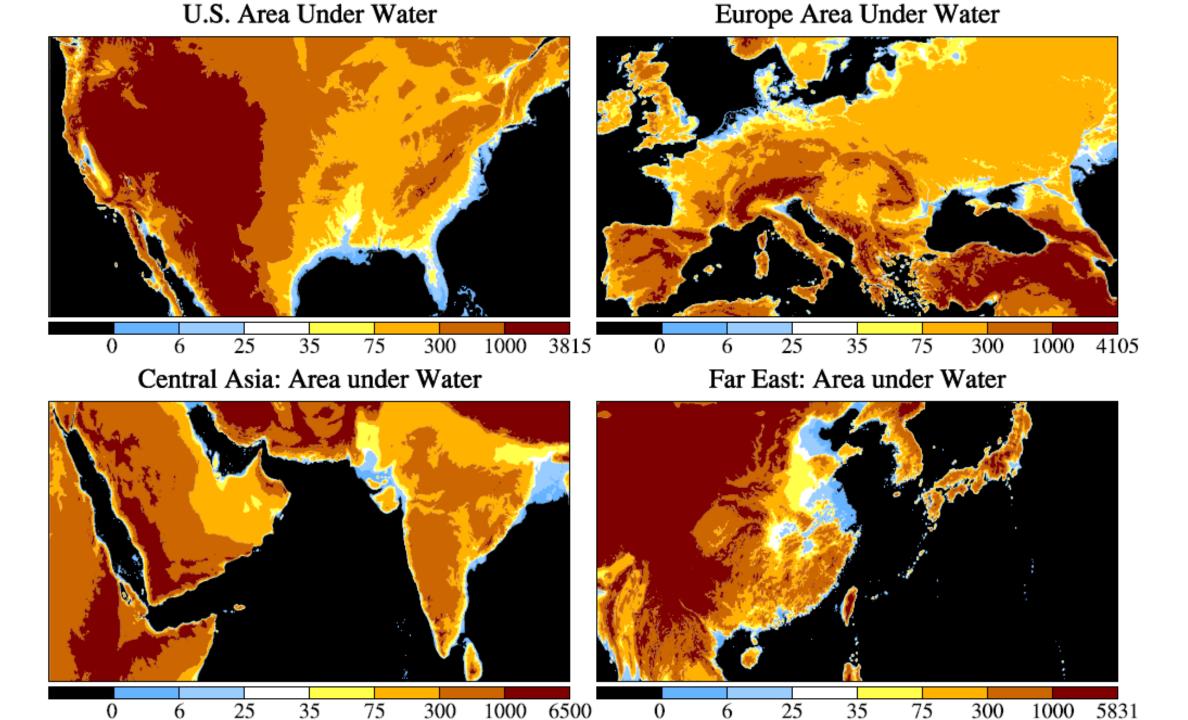


Note that the time scale for the past century has been expanded.

Paleo global surface temperature change is from ocean core data of Zachos et al. (Nature 451, 279-283, 2008) via equations of Hansen et al. (Phil. Trans. Roy. Soc. A, 371, 20120294, 2013).







# **Threat of Mass Exterminations**

# Multiple Human-Made Stresses

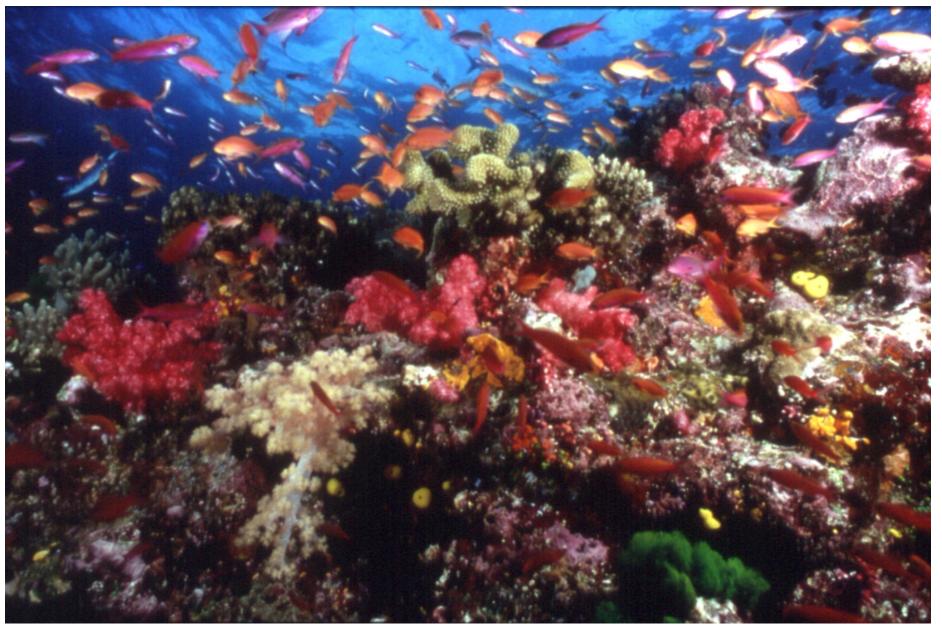
Overharvesting, Land use changes, Nitrogen fertilization, Introducing exotic species, etc.

in Combination with

# Rapid Shifting of Climate Zones

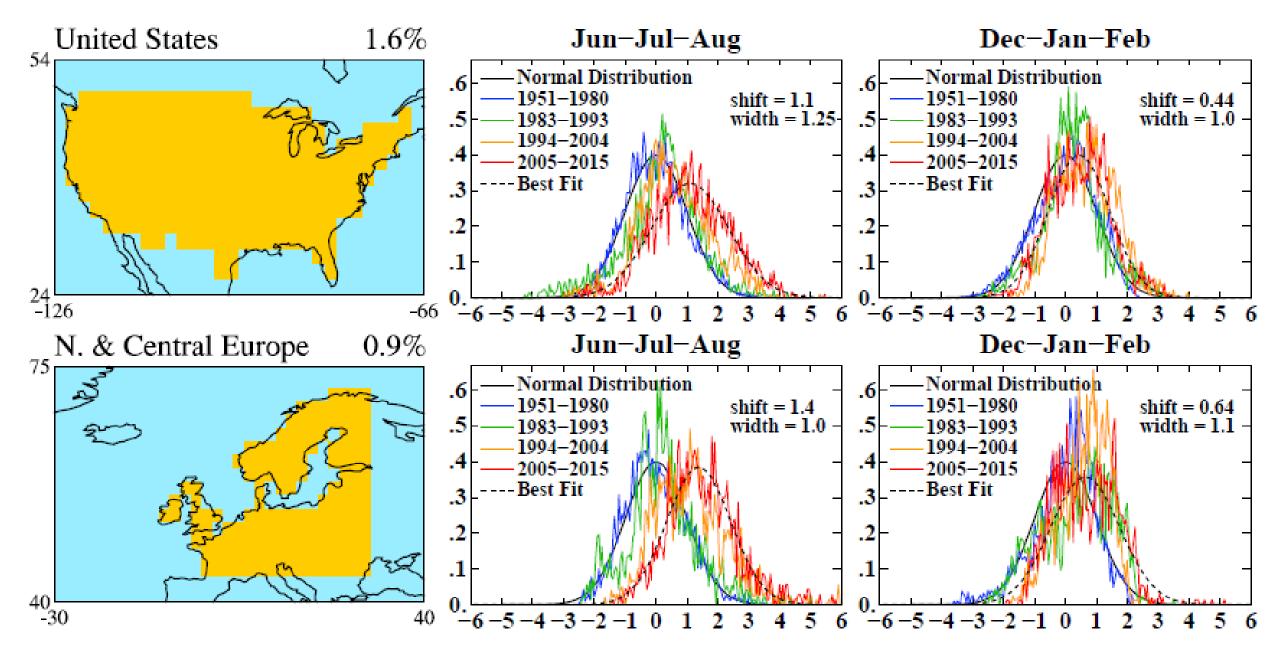
IPCC (2007) estimates that business-as-usual greenhouse gas emission will commit to extinction  $\frac{1}{2}$  of all species.

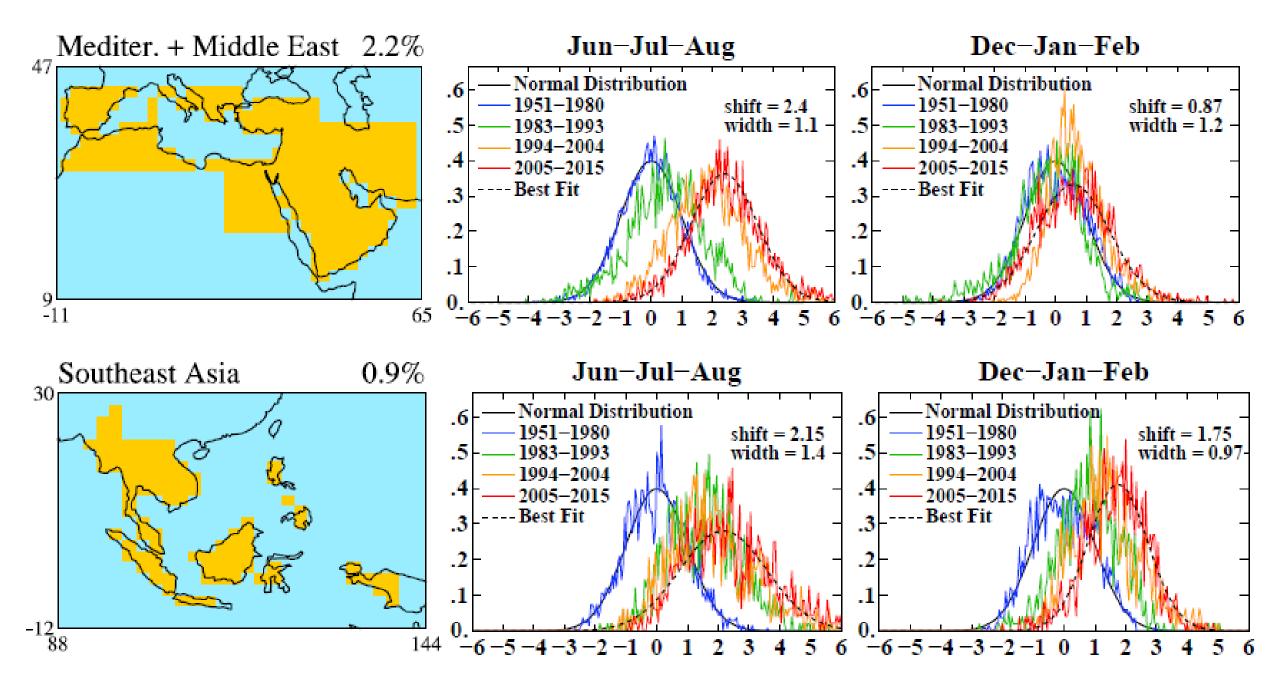
# **Stresses on Coral Reefs**



**Coral Reef off Fiji (Photo: Kevin Roland)** 

N.H. Land, Summer N.H. Land, Summer 2005-2015 1951-1980 67.0% 33.3% 33.5% 33.1% 14.5% 5.8% 0.1%3 -6 -5 -4 -3 -2 -1 0





# **Impacts of Shifting Bell Curves**

# 1. Increase of Regional Climate Extremes

- Dry regions: Greater heat, drought, fire
- Wet regions/times: Greater rain, floods, storms

# 2. Summer Outdoor Livability Declines

- More than half non-household labor is outdoors
- Measurable impact on national economies

# 3. Conflicts, Violence Increase (Hsiang et al., 2013)

- Interpersonal: +4%/standard deviation
- Groups, Nations: +14 %/standard deviation



Flames rise as a wildfire burns in the town of Rafina, near Athens, 23 July 2018.

Photo by Angelos Tzortzinis/AFP/Getty Image



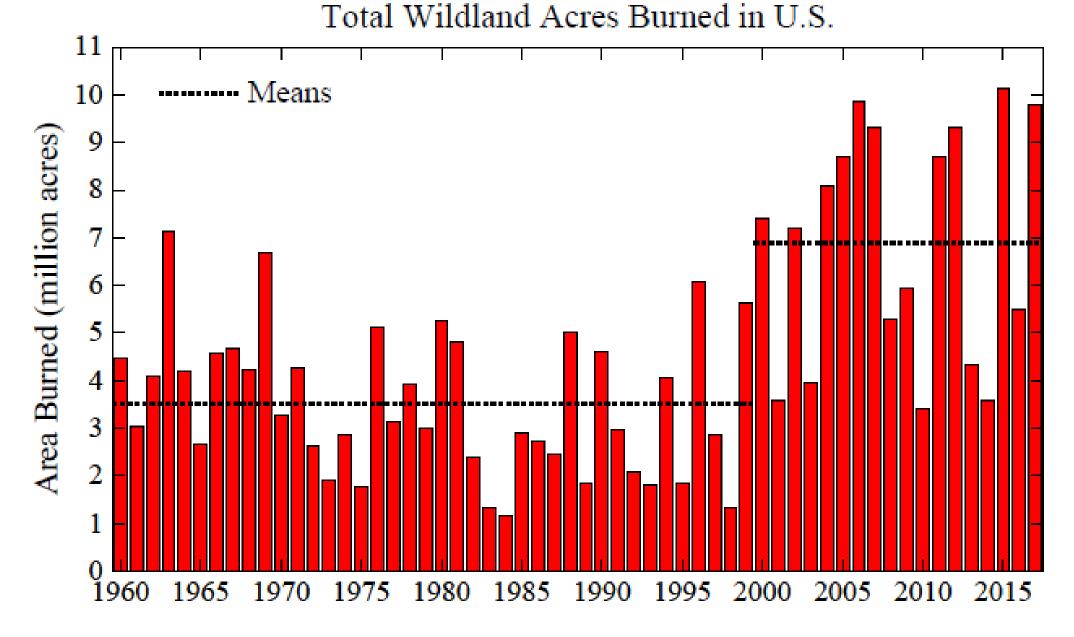


Photo by Valerie Gache/AFP/Getty

Cars blocked at closed National Road as wildfire rages in Kineta, west of Athens.

Photo by Angelos Tzortzinis/AFP/Getty

Charred cars lined a roadway in the village of Mati, east of Athens, July 24.



Data source: National Interagency Fire Center 1960-2016: <a href="https://www.nifc.gov/fireInfo\_stats\_totalFires.html">https://www.nifc.gov/fireInfo\_stats\_totalFires.html</a>



Flood in Germany, June 2013. Third "100-year flood" in 30 years.



#### The Guardian





Historic Floods in Japan kill more than 100. Millions Forced to Flee, Okayama prefecture. 8 July 2018. Rainfall in a few days was more than three times the normal amount for the entire month of July



Photo by REUTERS/ROMEO RANOCO

Sustained measured winds of 195 mph, with gusts of 235 mph, made Super Typhoon Haiyan, known as Yolanda in the Philippines, the strongest storm ever recorded on land.



Photo by Joezel Constan

# Climate Situation Global Crisis, but not Recognized

Thermal Inertia 

Warming in Pipeline

+

**Amplifying Feedbacks** → **Losing Control** 

## **Potential Injustices**

#### 1. Today's Adults to Young People

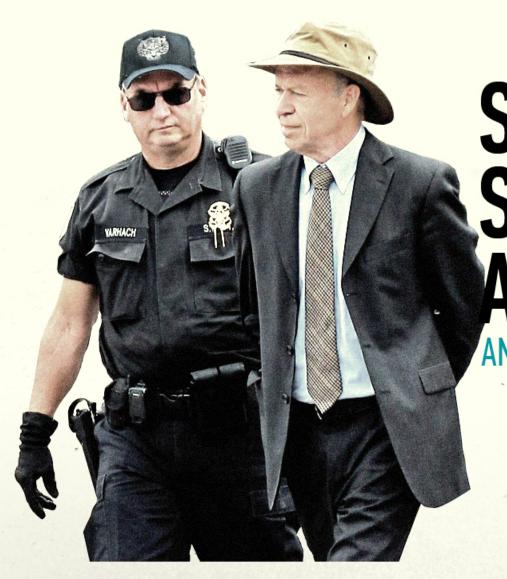
- Because of continuing fossil fuel emissions
- → Climate Close to Being Out of Control

#### 2. North to South

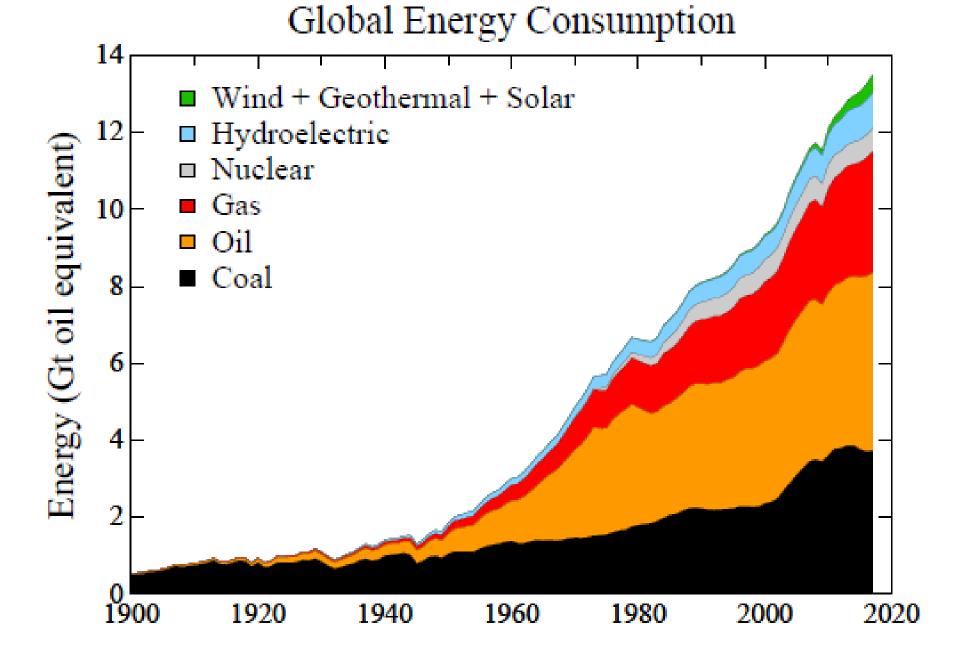
- North burned most of carbon budget
- Climate impacts largest at low latitudes

#### 3. Humans to Other Species

- Climate change & other stresses
- Potential 25-50% extinctions

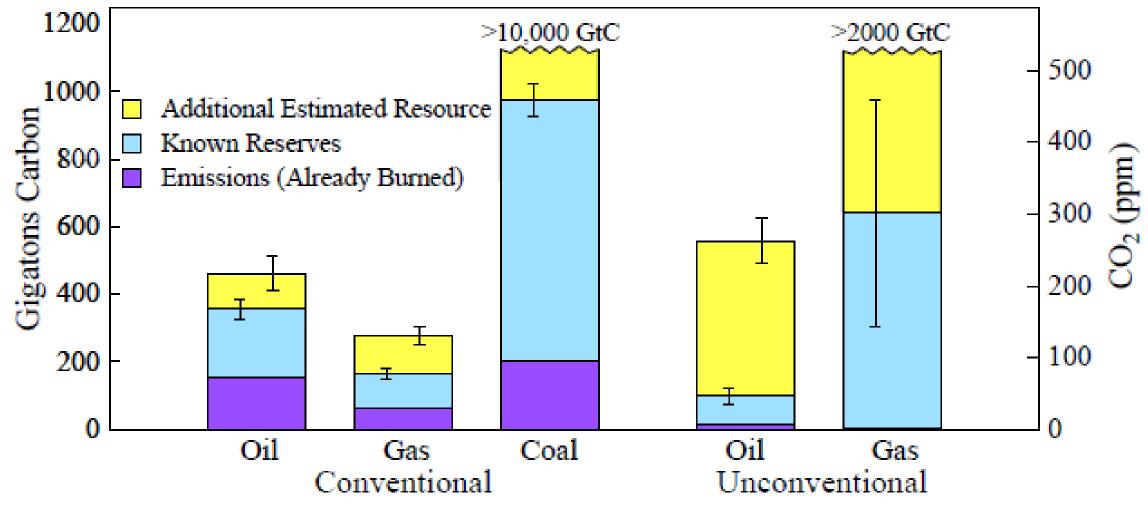


SCIENTIST SPOKESMAN ACTIVIST AND CIVIL DISOBEDIENCE



Hansen, J. and Kharecha, P., Cost of carbon capture: can young people bear the burden?, Joule 2, 1405-1407, 2018.

#### Fossil Fuel Emissions



Fossil fuel emissions; purple are emissions through 2017.

1 GtC (gigaton carbon) = 1 billion tons of carbon or ~3.7 GtCO<sub>2</sub>; 1 ppm CO<sub>2</sub> ~2.12 GtC

Update of Fig. 2 of Hansen et al., Assessing 'dangerous climate change', *PLOS One*, **8** (12), e81648, 2013. Error bars on reserves and resources, from reference 9 in that paper, likely are underestimates of uncertainty. Update is average of four recent assessments, available from author.

# Young People's Burden: Requirement of Negative CO<sub>2</sub> Emissions

James Hansen, Makiko Sato, Pushker Kharecha, Karina von Schuckmann, David J Beerling, Junji Cao, Shaun Marcott, Valerie Masson-Delmotte, Michael J Prather, Eelco J Rohling, Jeremy Shakun, Pete Smith, Andrew Lacis, Gary Russell, Reto Ruedy "Young People, do not underestimate your potential, aided by the Scientific Method, to change the World's Course."

From **Sophie's Planet** (coming soon)

# **Scientific Method**

Study All Available Data on the Matter

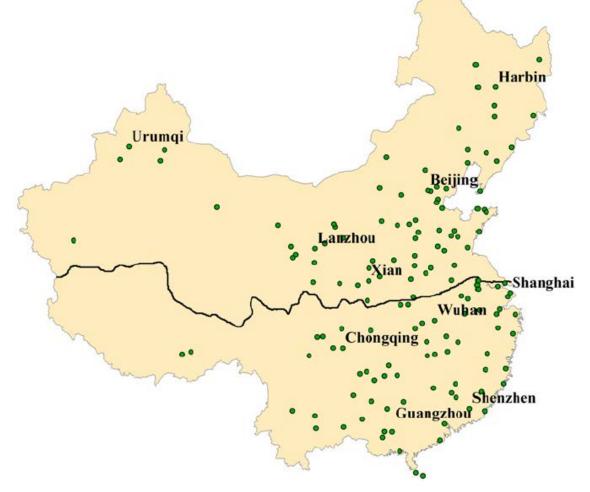
Be Very Skeptical of Your Interpretation

Reassess from Scratch with any New Data

# Evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River policy\*

Yuyu Chen, Avraham Eberstein, Michael Greenstone and Hongbin Li

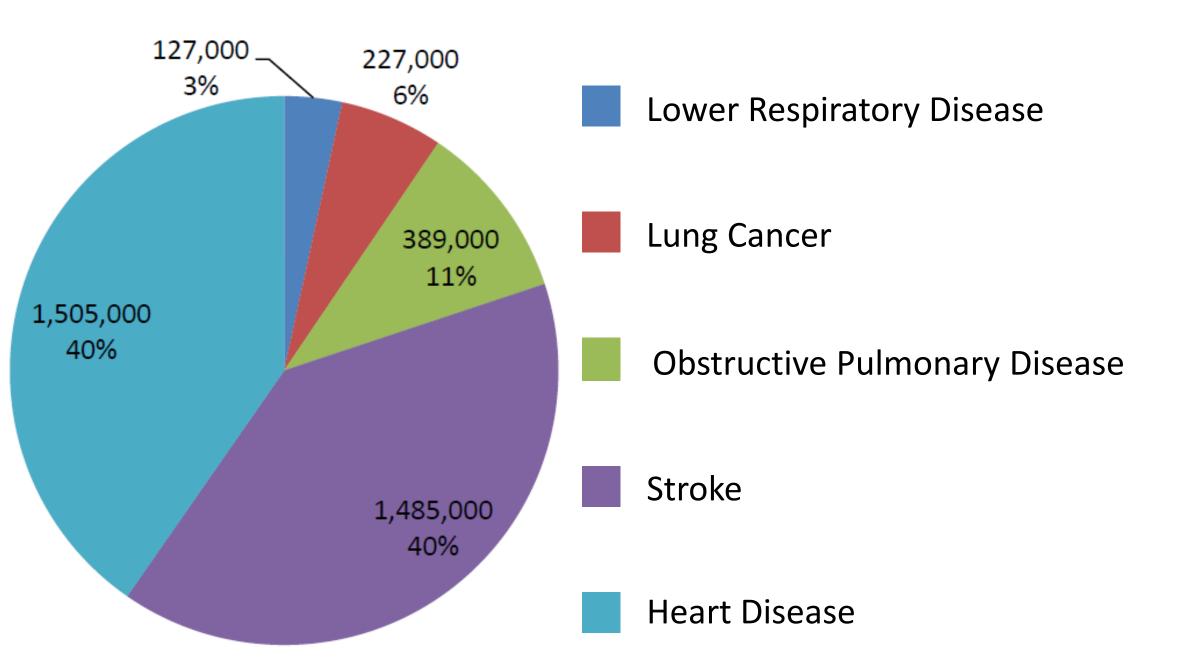
Principal finding: particulate air pollution caused by provision of free coal to 500 million residents in North China [north of Huai River] for winter heating for several decades reduced life expectancy of people in North China by 5.5 years.



People north of line received free home-heating coal.

<sup>\*\*</sup>Proc. Natl. Acad. Sci. USA, 110, 6 August 2013

#### Annual Deaths Attributable to Outdoor Air Pollution (WHO)

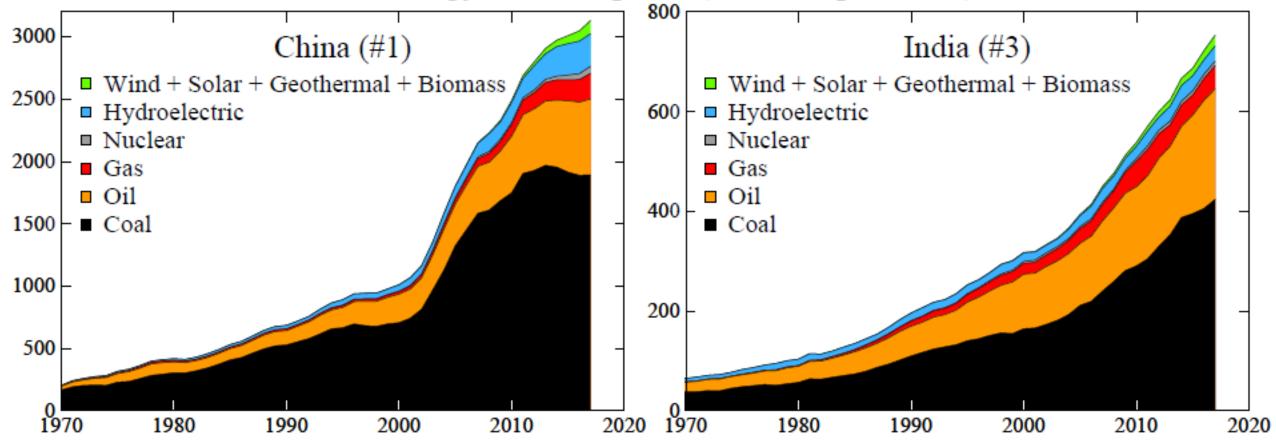


# **Crucial Requirement**

# **Abundant Clean Carbon-Free Energy**

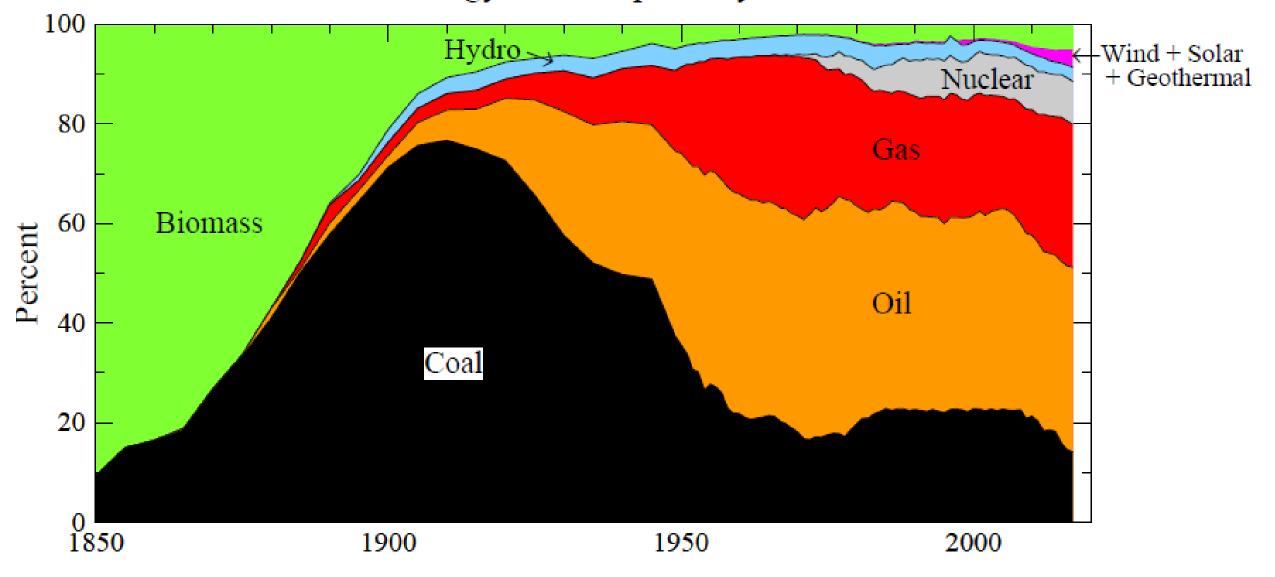
This can happen on the required scale, that is fossil fuels will be replaced, only if the entire energy system is economic relative to coal and gas

#### Energy Consumption (Mt oil equivalent)



Data through 2017. Source: BP (2018) Statistical Review of World Energy.

U.S. Energy Consumption by Source



Sources: <u>EIA Table E1 Estimated Primary Energy Consumption in the United States, 1635-1945</u> and <u>EIA Table 1.3 Primary Energy Consumption Estimates by Source, 1949-2015.</u>

#### **Biological Effect of Low Level Atomic Radiation**

#### 1. Threshold Criterion

- Doses comparable/less than natural radiation O.K.
- This was the Recommended Criterion until 1956

#### 2. Radiation Hormesis: Positive Biologic Response

- Low radiation levels beneficial: stimulate activation of repair mechanisms that protect against disease
- 3. Linear-No-Threshold (LNT) Criterion
  - Even the tiniest radiation presumed to be harmful
  - NAS BEAR Committee recommended LNT in 1956

#### **Public Concern About Radiation**

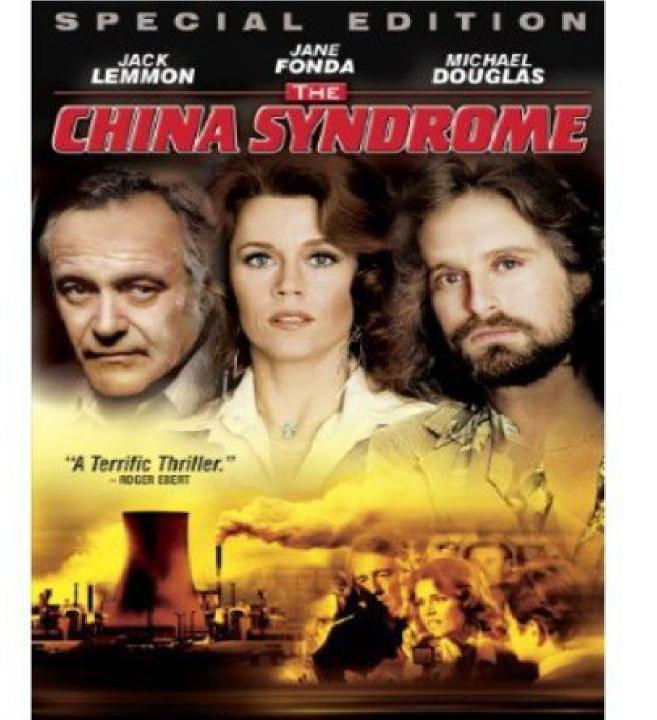
#### **Atmospheric Tests of Nuclear Bombs**

Concern about radioactive fallout from nuclear weapons testing helped spur the Limited Test Ban Treaty in 1963.

#### **China Syndrome + Three-Mile-Island Accident**

Popular film about the danger of a nuclear core meltdown.

Actual accident exposed Pennsylvania residents to radiation



# 200,000 People at Anti-Nuclear Concert

In New York City in 1979

#### **Biological Effect of Low Level Atomic Radiation**

#### 1. Threshold Criterion

- Doses comparable/less than natural radiation O.K.
- This was the Recommended Criterion until 1956

#### 2. Radiation Hormesis: Positive Biologic Response

- Low radiation levels beneficial: stimulate activation of repair mechanisms that protect against disease
- 3. Linear-No-Threshold (LNT) Criterion
  - Even the tiniest radiation presumed to be harmful
  - NAS BEAR Committee recommended LNT in 1956

"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 >90% of nuclear fuel, compared with ~1% in existing reactors,
- (2) Can utilize nuclear waste, depleted uranium and excess weapons material as fuel,
- (3) Leaves less waste, which can be disposed of safely,
- (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 shown that fuel can be sieved from the ocean the supply will last billions of years.

# **Another Potential Technology**

**Thorium-Powered Molten Salt Reactor Operates near Atmospheric Pressure Factory or Shipyard Construction Inexhaustible Fuel Supply** Reduced Waste, Shorter Half-Life **Passively Safe Operation Not Well-Suited for Weapons Material** 



**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.

## Solution

- 1. Fossil Fuel Price Must Include Costs to Society
  - Human Health & Climate Change Costs
  - Practical Solution: Rising Carbon Fee

## **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 gain

#### **Merits:**

Transparent; Public can understand & support it Market-based; Stimulates Innovation

#### Carbon 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

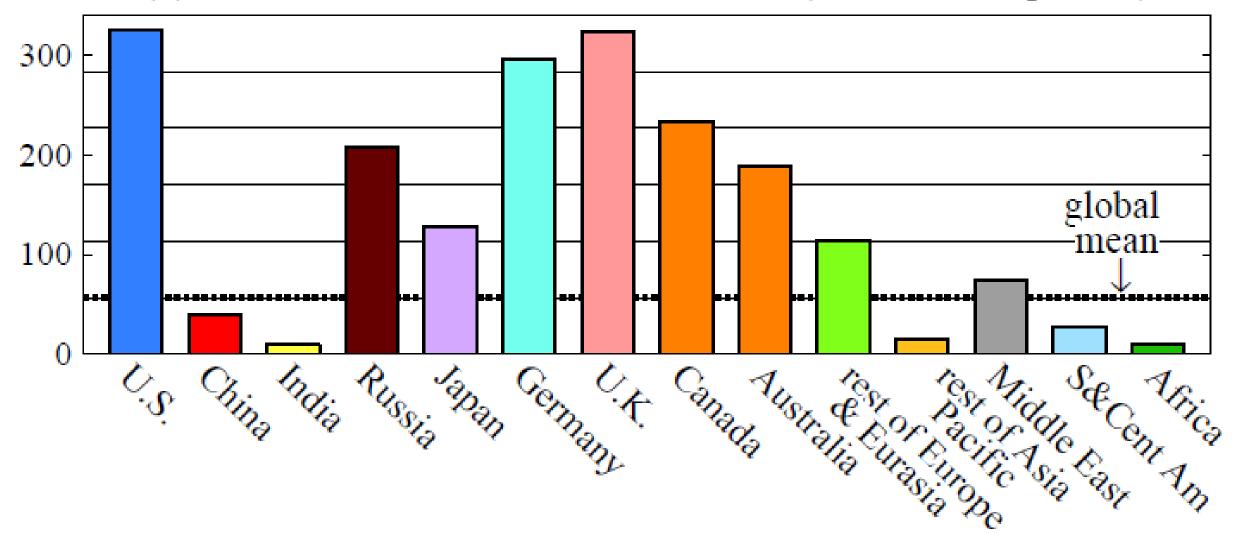
#### 3. Climate: Viable International Approach

Border Duties on Products from Nations w/o Carbon Fee Rebate Industry on Exports to Nations w/o Carbon Fee

## Solution

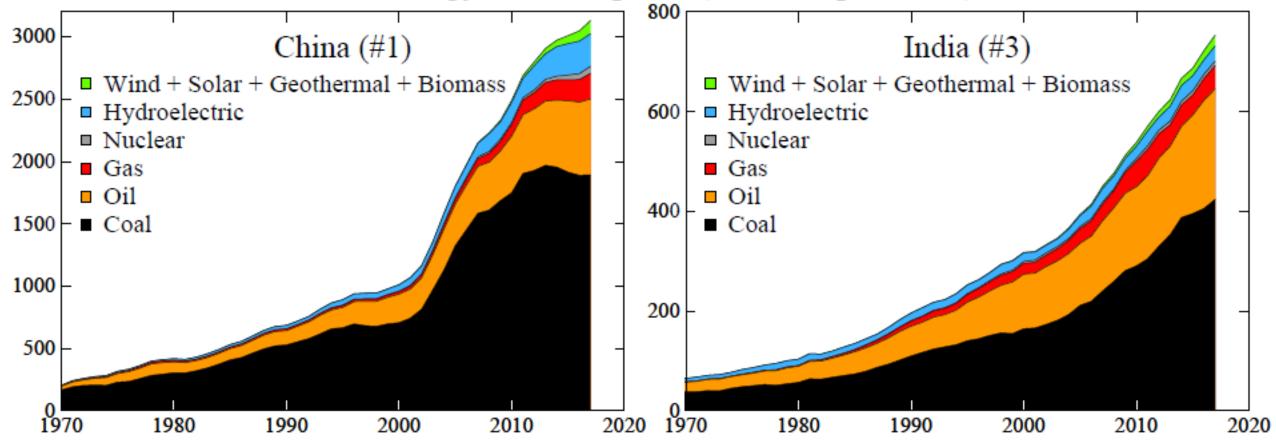
- 1. Fossil Fuel Price Must Include Costs to Society
  - Human Health & Climate Change Costs
  - Practical Solution: Rising Carbon Fee
- 2. Some Regulations Still Required
  - Refrigerator Efficiency, for example
  - No Power Use by Idle Electronic Products
- 3. Technology Development Needed
  - Rising Carbon Fee Will Spur Tech Development
  - but Government must Facilitate Long-Lead RD&D

#### (b) 1751–2016 Cumulative Emissions (tons Carbon/person)



Update of Fig. 6 of Hansen and Sato, Regional Climate Change and national responsibilities, *Environ. Res. Lett.*, 11, 2016. Proportionality of global warming to cumulative emissions was shown by Hansen et al., Dangerous human-made interference with climate: a GISS modelE study, *Atmos. Chem. Phys.*, 7, 2287-2312, 2007.

#### Energy Consumption (Mt oil equivalent)



Data through 2017. Source: BP (2018) Statistical Review of World Energy.

# Trilateral Agreement Needed: China, U.S., India

#### **Rising Internal Carbon Fees**

- Spurs life style changes & Innovation
- Stimulates economies

## Border Duty on Products from Nations w/o Fee

- WTO rules allow equivalent duty
- Strong incentive for others to join

## **Technology Cooperation Required**

- Includes advanced generation nuclear power



#### **FEDERAL LAWSUIT:**

- U.S. District Court, District of Oregon: Trial Begins October 29, 2018
- Plaintiffs: 21 U.S. Youth & Future Generations
- Defendants: U.S. President & Federal Agencies
- Constitutional Basis: Due Process, Equal Protection, and Public Trust Doctrine
- Seeking: Science-based National Climate Recovery Plan



# CitizensClimateLobby.org

Citizens Climate Lobby is a volunteer nonprofit organization advocating for <u>Carbon Fee and Dividend</u>, which would place a steadily-rising fee on the carbon dioxide content of fuels and distribute all the revenue to households as equal payments.

CCL now has more than 400 chapters with more than 90,000 members in 30 countries and is growing rapidly.

Please visit CitizensClimateLobby.org and consider joining!

#### **Discussion Available at:**

www.Columbia.edu/~jeh1