Climate Change and Human Health

Brunel University Symposium on Planetary Health
June, 2017

Howard Frumkin, M.D., Dr.P.H.
Professor of Environmental and Occupational Health Sciences
University of Washington School of Public Health

How to Talk About
Climate Change and Human Health

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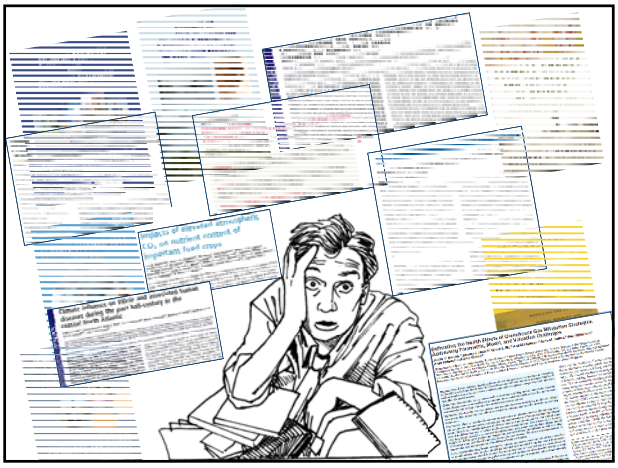

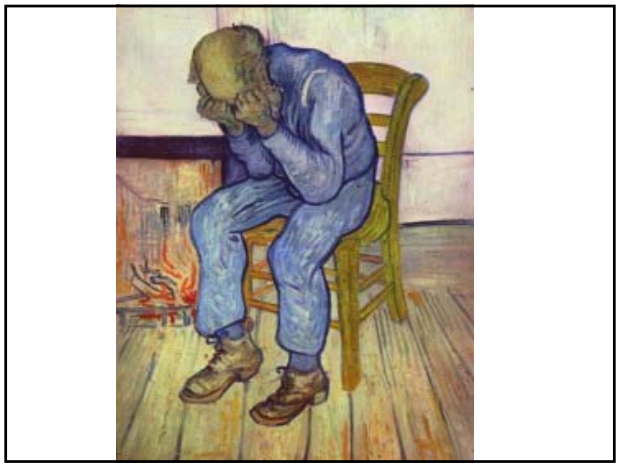

What to include?

- Health effects of climate change

What to include?

- A bit about climate science
- Health effects of climate change

What to include?

- A bit about climate science
- Health effects of climate change
- Some solutions

What to include?

- A bit of background climate science
- Health effects of climate change
- Some solutions
- Some good news

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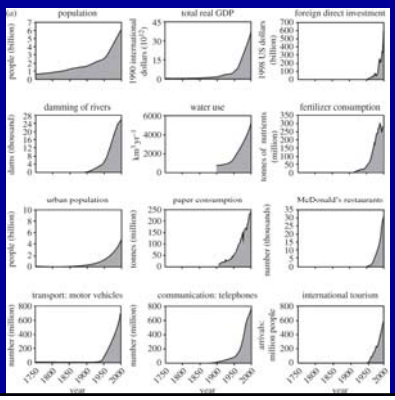
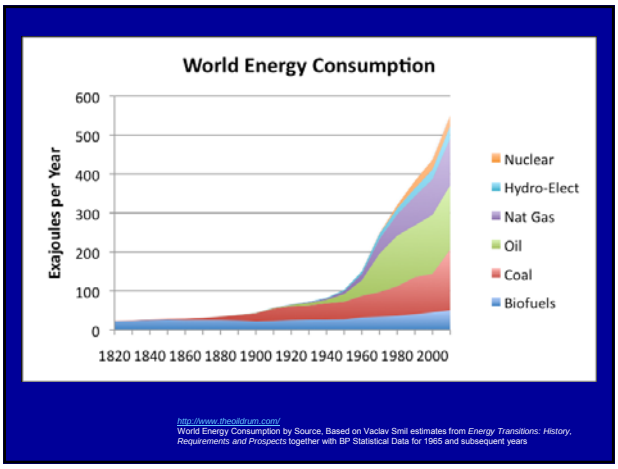
What to include?

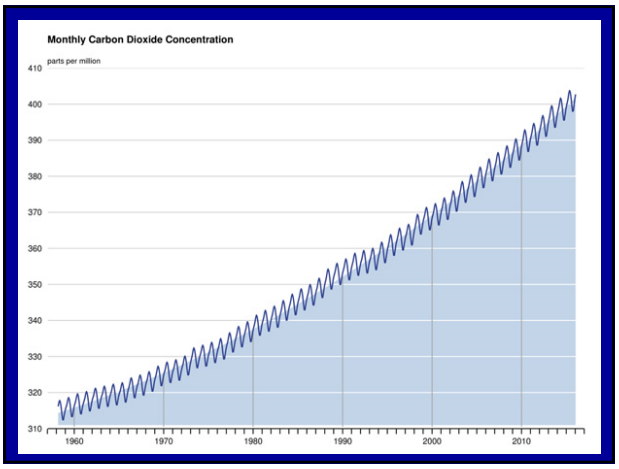
- A bit of background climate science
- Health effects of climate change
- Some solutions
- Some good news
- A bit about communication
- Some hope

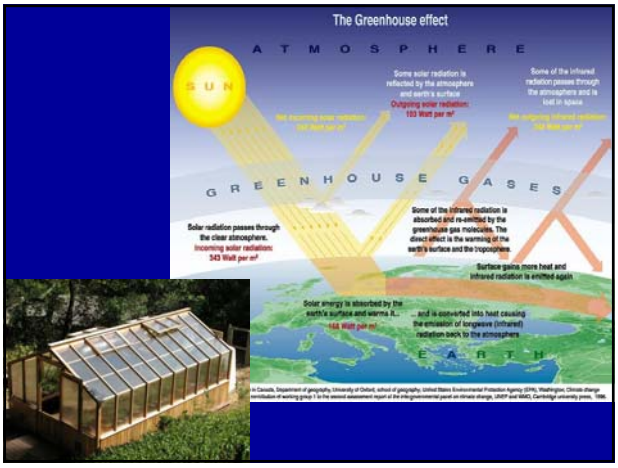
The Great Acceleration:
Metrics of human activity since the early Industrial Revolution



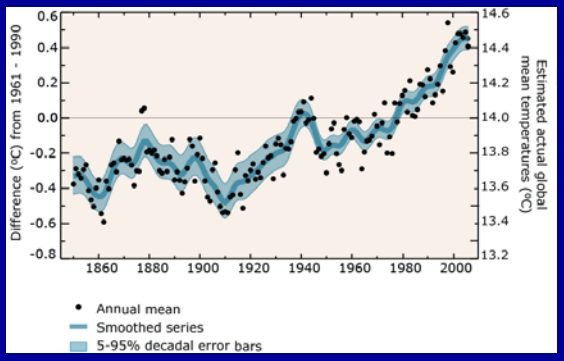
Steffen W et al. The Anthropocene: conceptual and historical perspectives. *Phil. Trans. R. Soc. A* 2011;369:842-67





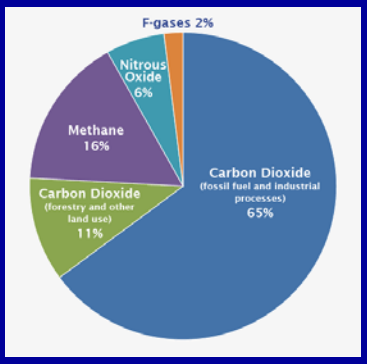


Global average temperature



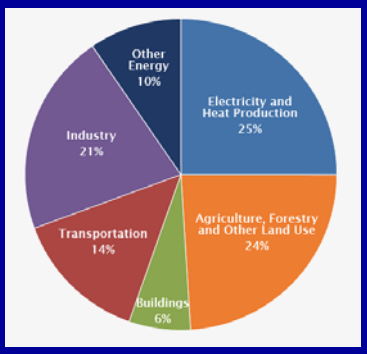
Graham Environmental Sustainability Institute | http://provost.umich.edu/gesi

Global GHG emissions by gas



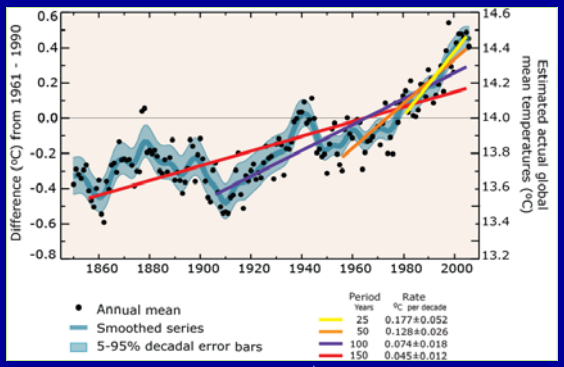
https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

Global GHG emissions by source



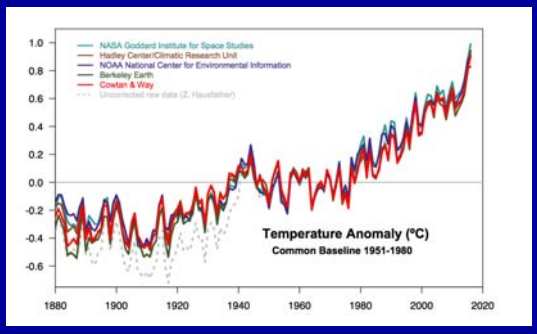
https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

Global average temperature



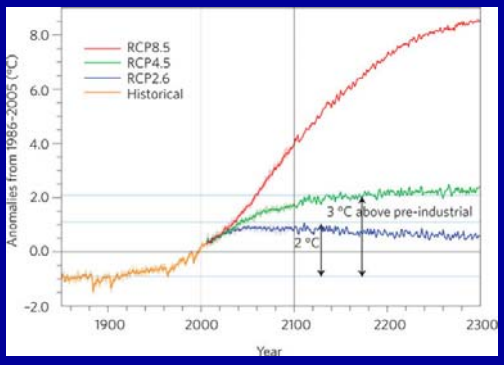
Graham Environmental Sustainability Institute | http://provost.umich.edu/gesi

2016: The hottest year on record



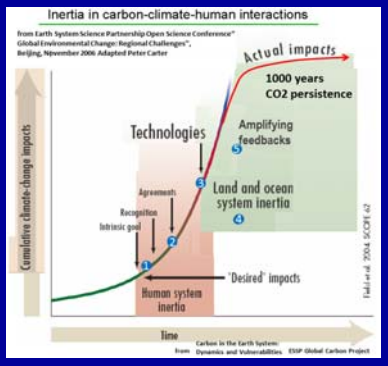
Source: www.realclimate.org/index.php/archives/2017/01/2016-temperature-records/

Projecting future trends



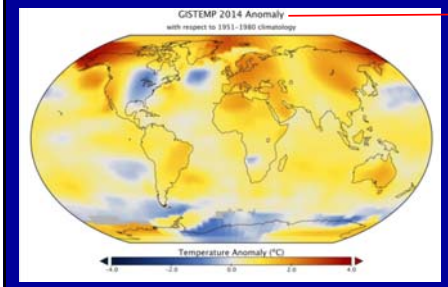
Meehl et al. 2012. Relative outcomes of climate change mitigation related to global temperature versus sea-level rise. *Nature Climate Change* 2:576-580.

The "global warming commitment"



https://www.climateemergencyinstitute.com/committed_climate_change.html

Warming not evenly spread across the globe



2014 global anomaly: 0.68°C

Unusually warm:
- Europe
- Parts of Asia
- Alaska
- The Arctic

Unusually cold:
- Eastern US

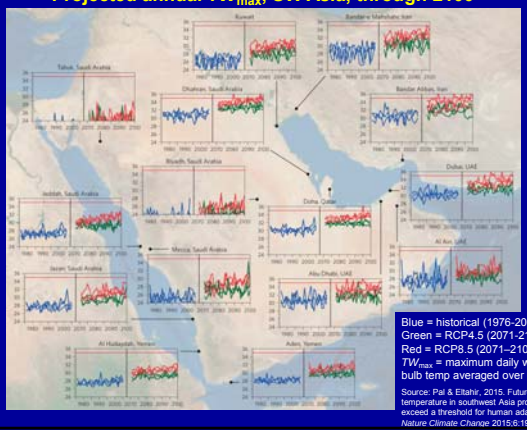
Source: NOAA/NASA Annual Global Analysis for 2014. http://www.ncdc.noaa.gov/sotc/briefings/201501.pdf

2015 hot spots

Source: http://www.weather.com/news/news/iraq-iran-heat-middle-east-125-degrees

http://earthsky.org/earth/heat-wave-kills-1100-in-india

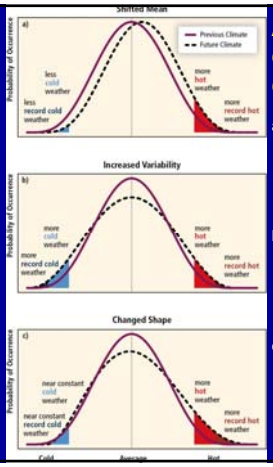
Projected annual TW_{max}, SW Asia, through 2100



Blue = historical (1976-2005)
Green = RCP4.5 (2071-2100)
Red = RCP8.5 (2071–2100)
TW_{max} = maximum daily wet bulb temp averaged over 6h

Source: Pal & Eltahir, 2015. Future temperature in southwest Asia projected to exceed a threshold for human adaptability. *Nature Climate Change* 2015;6:197-200.

Altered temperature distribution: effects on extremes



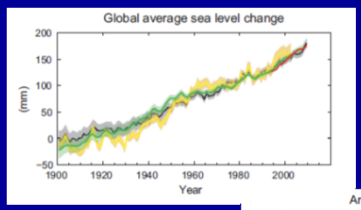
a) simple shift of the entire distribution toward a warmer climate

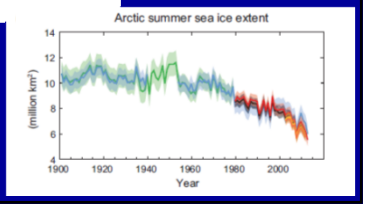
b) increased temperature variability with no shift of the mean

c) altered shape of the distribution, in this example an increased asymmetry toward the hotter part of the distribution.

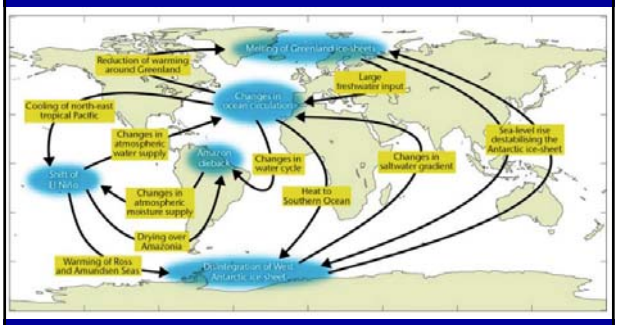
http://ipcc.ch/report/srex/

Other earth system changes



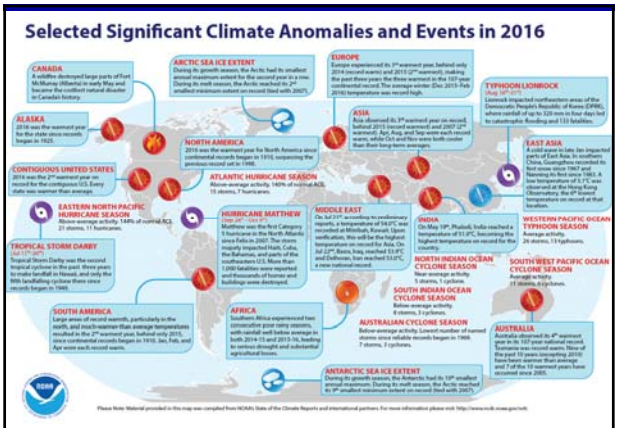


Source: IPCC AR5, Figure SPM 1 (2013)



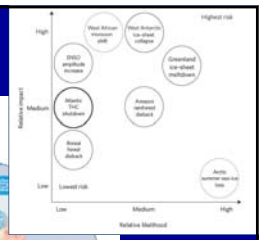
Source: King, D. W., Schrag, D., Dadi, Z., Ye, Q., & Ghosh, A. (2015). *Climate Change: A Risk Assessment*. Centre for Science and Policy, University of Cambridge.

Selected Significant Climate Anomalies and Events in 2016



Source: http://www.ncdc.noaa.gov/sotc/service/global/extremes/201613.gif

Tipping points



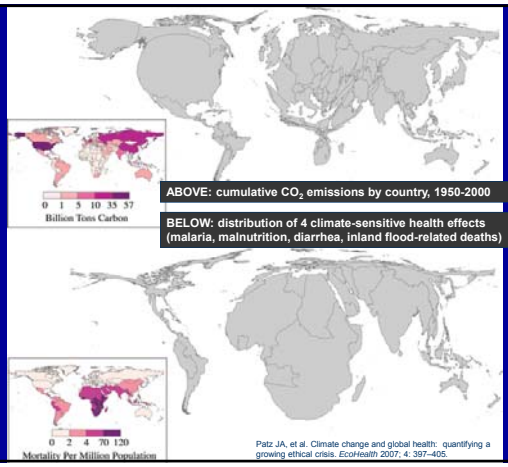
Tipping elements in the climate system
Presented by Prof Tim Lenton

Melting
Circulation Change
Biome Loss

Population Density [persons per km²]

Source: Lenton TM. 2011. Early warning of climate tipping points. *Nature Climate Change* 1:201-209..

Source: UK Government Office for Science. Tipping Points meeting, London, 14 March 2011. http://www.bis.gov.uk/assets/goscience/docs/t/11-974-tipping-points-meeting-london-14-march-2011.pdf



ABOVE: cumulative CO_2 emissions by country, 1950-2000

BELOW: distribution of 4 climate-sensitive health effects (malaria, malnutrition, diarrhea, inland flood-related deaths)

Patz JA, et al. Climate change and global health: quantifying a growing ethical crisis. *EcoHealth* 2007; 4: 397–405.

So the planetary impacts of climate change are…

- Widespread and varied
- Redefining normal
- Committed
- Subject to sudden changes
- Rapidly accelerating
- Ethically troubling

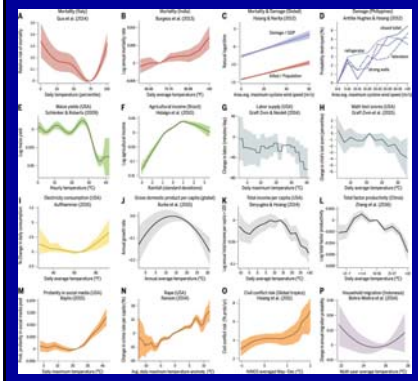
OK, enough climate science.

How to introduce the really complex issue of health impacts?

Framing health information

- ✓Climate change threatens health.
- ✓We need complex thinking to grasp it fully.
- ✓You can do this.
- ✓The threats are familiar.
- ✓There are effective public health responses.
- ✓Prevention is essential.

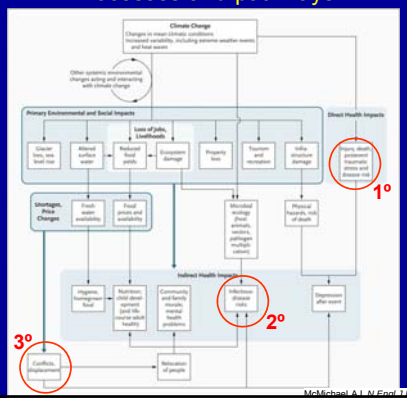
Climate impacts on social and economic outcomes



Red: mortality
Blue: storm damage
Green: agriculture
Teal: labor productivity
Yellow: electricity
Grey: economic
Orange: violence
Purple: migration

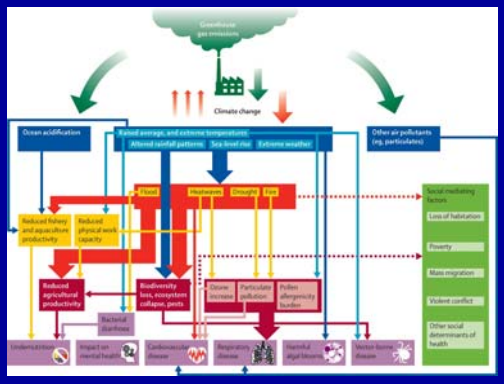
Carleton & Hsiang (2016). Social and economic impacts of climate. *Science*, 353(6304). doi:10.1126/science.aad9837

Climate change impacts on health: Processes and pathways



McMichael A J. *N Engl J Med* 2013;368:1335-43

Climate change and health: pathways



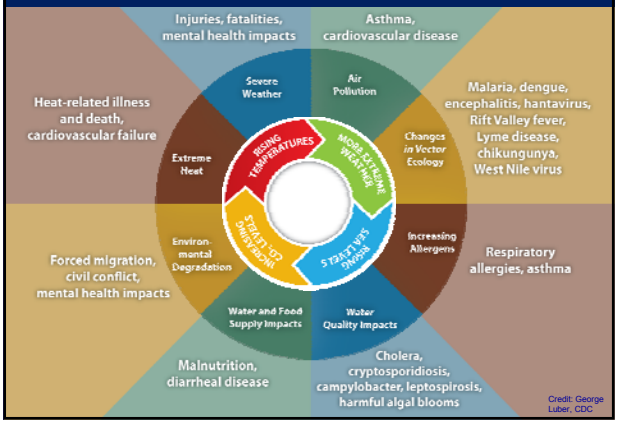
Watts et al. Health and climate change: policy responses to protect public health. *The Lancet*, 386(10006), 1861-1914.

Climate impacts on health

Climate change:
- ↑ temperature
- Sea level rise
- Extreme weather

HEAT	Heat stress, cardiovascular failure, ↓ work capacity
SEA LEVEL RISE AND SEVERE WEATHER	Injuries, fatalities
AIR POLLUTION	Asthma, cardiovascular disease
ALLERGIES	Resp allergies, poison ivy
VECTOR-BORNE DISEASES	Malaria, dengue, hantavirus, encephalitis, Rift Valley fever
WATER-BORNE DISEASES	Cholera, cryptosporidiosis, campylobacter, leptospirosis
WATER AND FOOD SUPPLY	Malnutrition, diarrhea, harmful algal blooms
MENTAL HEALTH	Anxiety, post-traumatic stress, depression, despair
RESOURCE SCARCITY AND COMPETITION	Forced migration, civil conflict

Impacts of Climate Change on Human Health



Discussing individual health impacts

- Too much data to present in full
- Identify key points
- Select illustrative data responsibly
- Foreshadow solutions
- Summarize key points

Climate impacts on health

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1. The direct health effects of heat

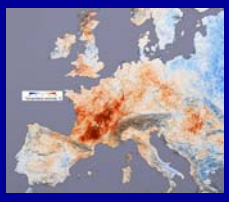
HEAT RASH

HEAT CRAMPS

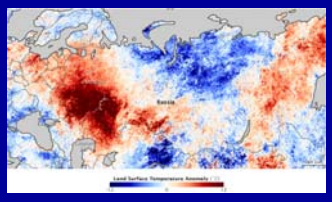
HEAT EXHAUSTION

HEAT STROKE

Recent heat waves

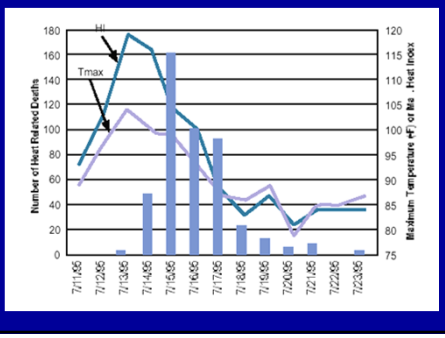


Europe, 2003
70,000 excess deaths



Russia, 2010
11,000 excess deaths

Heat Related Deaths
Chicago, July 1995



Epidemiology of heat waves

Risk factors for hyperthermia:

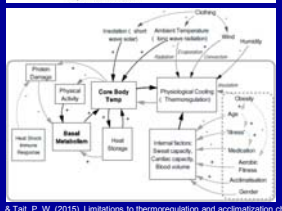
Individual

- Age
- Underlying medical conditions / mental illness
- Income and poverty status
- Homelessness
- Social isolation
- Lack of access to health care and cooling facilities
- Neighborhood characteristics: land use/ land cover, crime rate, housing type, urban heat island

Community Characteristics

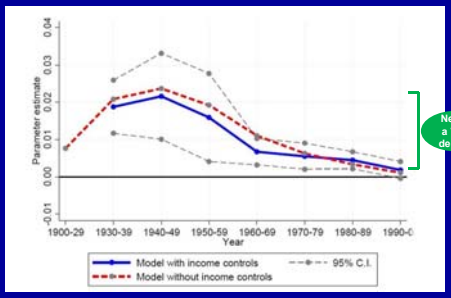
Heat acclimatization

- ↑ oxygen uptake
- ↓ core temperature
- ↑ sweating
- ↑ skin blood flow
- ↓ heart rate
- ↑ stroke volume
- ↓ electrolyte loss
- ↑ plasma volume



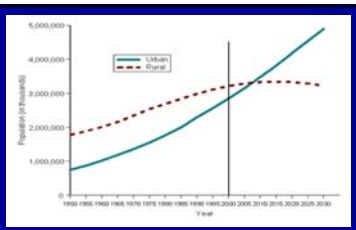
Hanna, E. G., & Tait, P. W. (2015). Limitations to thermoregulation and acclimatization challenge human adaptation to global warming. *Int J Environ Res Public Health*, 12(7), 8034-8074.

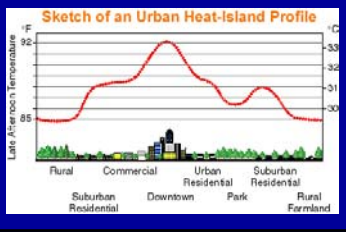
Declining temperature-related mortality over the 20th century, U.S.



Barreca et al. Adapting to climate change: The remarkable decline in the U.S. temperature-mortality relationship over the 20th century. *J Political Econ* 2015.

A concurrent trend: urbanization





…which amplifies heat waves impacts

More heat, less work

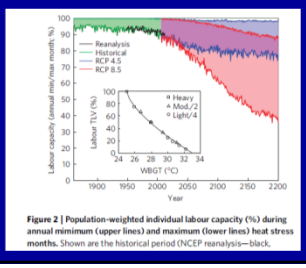
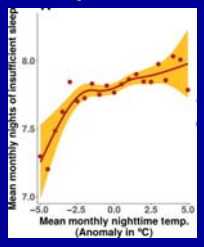


Figure 2 | Population-weighted individual labour capacity (%) during annual minimum (upper lines) and maximum (lower lines) heat stress months. Shown are the historical period (NCEP reanalysis—black,

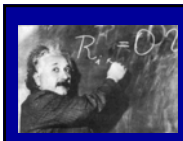
More heat, less sleep

- A study of self-reported nights with insufficient sleep in 765,000 respondents (2002-11).
- ↑ temp associated with ↑ nights of insufficient sleep.
- Strongest effect among
  - poor
  - elderly



Obradovich et al. Nighttime temperature and human sleep loss in a changing climate. *Science Advances* 2017; 3. doi 10.1126/sciadv.1601555.

Heat wave preparedness

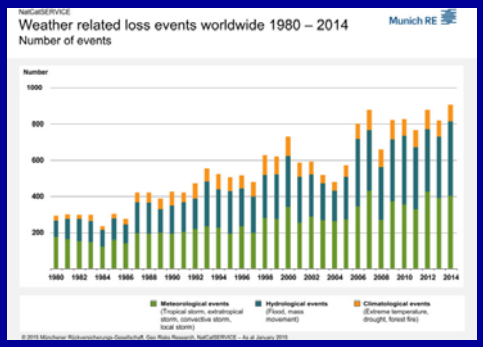


Extreme heat: Lessons learned

- Biomedical understanding is key
- Social and environmental circumstances matter
- Concurrent trends (urbanization) matter
- Impact extends beyond the medical
- Preparedness can help

2. Severe weather events

Increasing disaster frequency

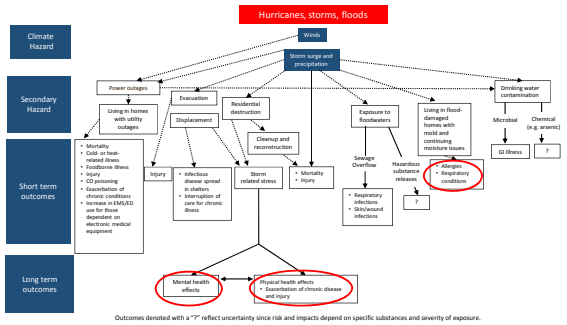


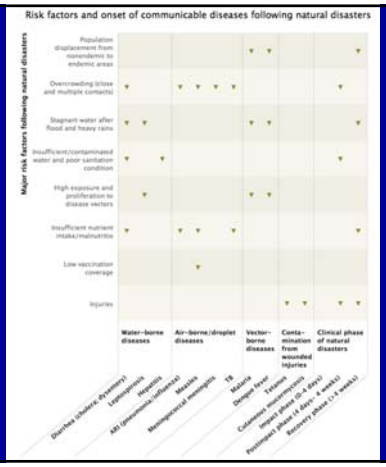
Hoeppe P. 2016. Trends in weather related disasters – consequences for insurers and society. *Weather and Climate Extremes* 11:70-79.

IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation ("SREX")

Events	Likelihood
↑ heavy precipitation	Likely (many regions)
↑ warm temperature extremes	Virtually certain (global)
↑ heat waves	Very likely (most land areas)
↑ cyclone intensity	Likely (most ocean basins)
↓ or no change in cyclone number	Likely
↑ droughts	Medium confidence (many regions)
↑ sea level rise, ↑ extreme coastal high water levels	Very likely
↑ floods	Low confidence at global scale

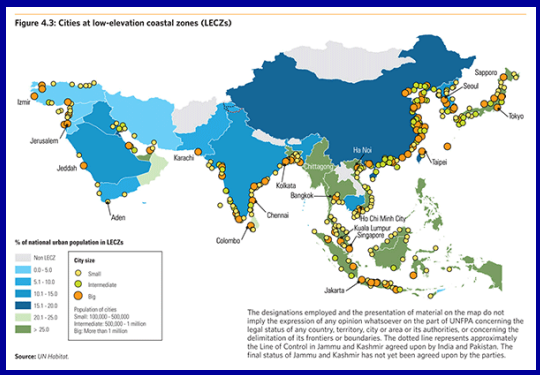
http://ipcc-wg2.gov/SREX/
Report issued 2012



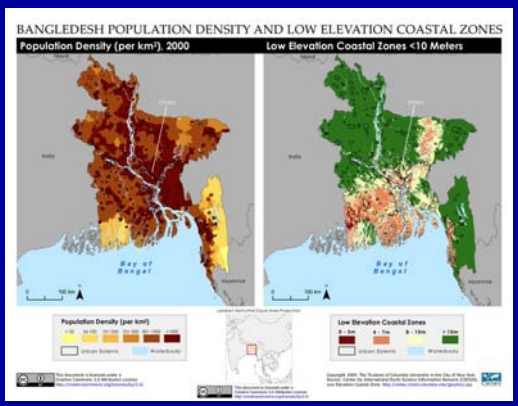


Source: Kouadio et al. Infectious diseases following natural disasters: prevention and control measures. *Expert Rev Anti Infect Ther*, 2012;10(1):95-104.

Sea level rise: Coastal cities



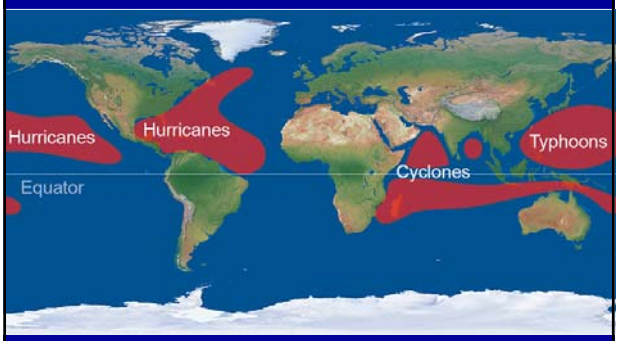
http://ecojesuit.com/climate-change-and-conflict/1619/



McGranahan, G., D. Balk, and B. Anderson. 2007. Low Elevation Coastal Zone (LECZ) Urban-Rural Population Estimates, Global Rural-Urban Mapping Project (GRUMP), Alpha Version. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://sedac.ciesin.columbia.edu/data/set/lecz-low-elevation-coastal-zone.

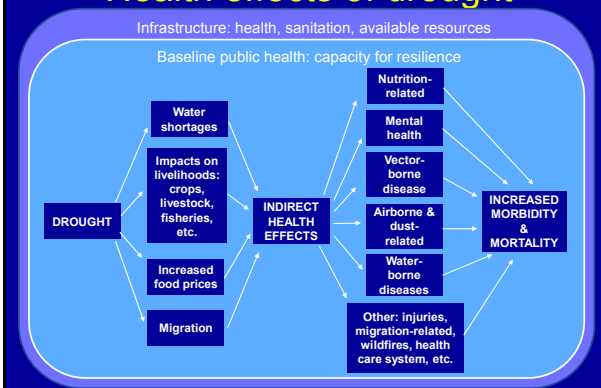
Climate Central. Surging Seas, Seeing Choices. http://seeing.climatecentral.org/

Tropical cyclone distribution



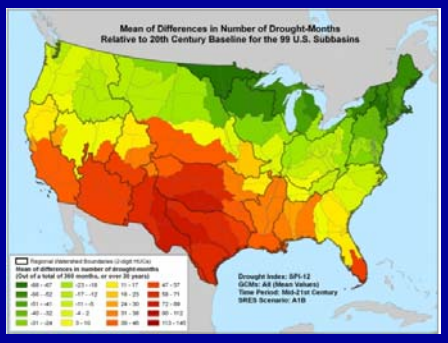
http://www.metoffice.gov.uk/weather/tropicalcyclone/facts

Health effects of drought



Stanke et al. (2013). Health effects of drought: a systematic review of the evidence. *PLoS Currents Disasters*, 5. doi:10.1371/currents.dis.7a2cee9e980f91ad7697b570bcc4b004

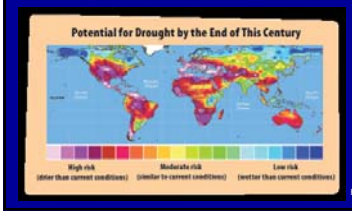
Predicted change in the number of drought months during 2036-2065 relative to 20th century baseline



Source: Strzepek et al. Characterizing changes in drought risk for the United States from climate change. *Environ Res Lett* 2010;5:1-9.

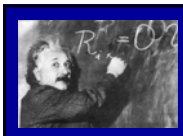
Drought and health

- Malnutrition
- Compromised sanitation
- Dust generation
- Mental health



http://epa.gov/climatestudents/impacts/signs/droughts.html

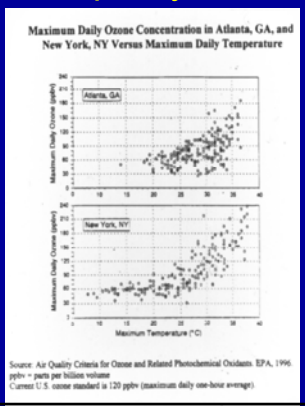
Climate justice



Severe weather events: Lessons learned

- Vulnerability factors identified (physical and social)
- Health consequences, including mental health impacts, may persist
- (All-hazard) Preparedness is essential
- Resources for resiliency and recovery are essential

3. Air quality - Ozone

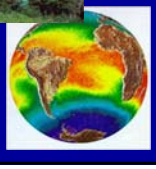


3. Air quality - Wildfires

Bark Beetles (Killing frost <20^{0}F x 10 days)

Droughts

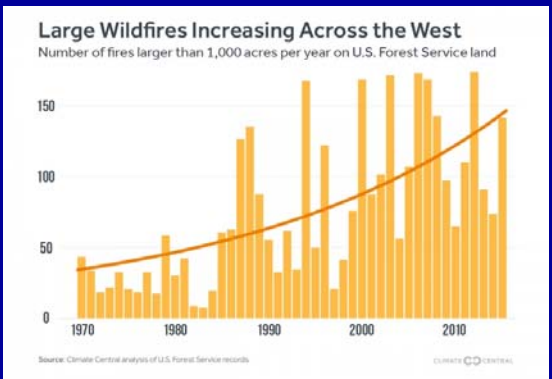
Warming



Climate Change is Tipping Scales Toward More Wildfires

Large Wildfires Increasing Across the West

Number of fires larger than 1,000 acres per year on U.S. Forest Service land



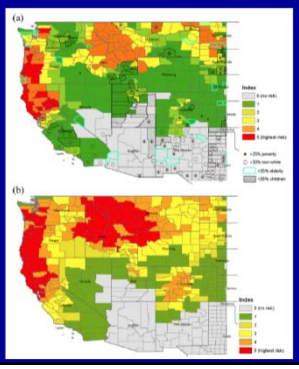
Source: Climate Central, June 2016
http://www.climatecentral.org/news/western-wildfires-climate-change-20475

Fire Smoke Risk Index, Western U.S.

Fire season (May through October)

2004-2009 (observed)

2046-2051 (predicted)

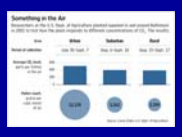


Liu JC, et al. Particulate air pollution from wildfires in the Western US under climate change. *Climatic Change* 2016:1-12.

4. Allergies

Some climate change *winners*:

•Ragweed

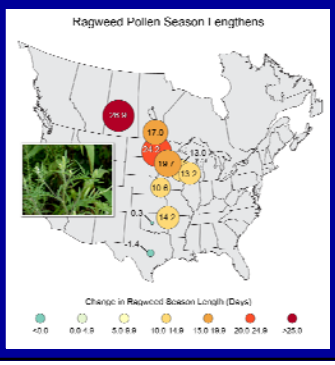


Source: Ziska et al., *J Allerg Clin Immunol* 2003;111:290-95. Graphic: *Wall Street Journal*, 3 May 2007.

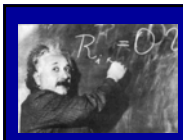
•Poison ivy

Source: Mohan et al. PNAS 2006;103:9086-89.

Longer ragweed pollen season
U.S., 1995-2011



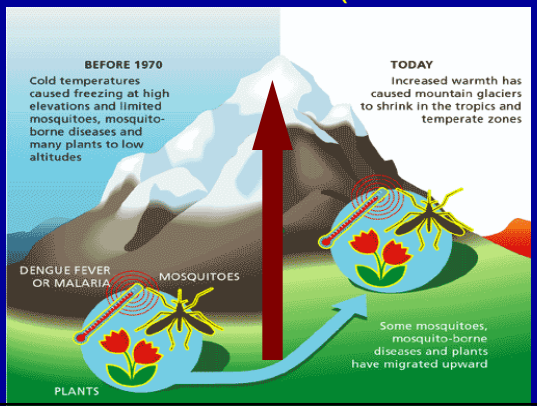
Source: USGCRP. http://data.globalchange.gov/report/nca3/chapter/human-health/figure/ragweed-pollen-season-lengthens

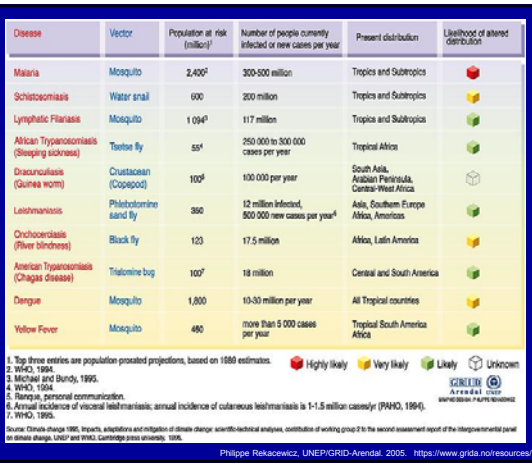


Air pollution and allergies: Lessons learned

- Existing research and practice are highly applicable to climate change
- Medical vulnerability (co-morbidities) matter
- Access to health care matters

5. Infectious diseases (vector-borne)



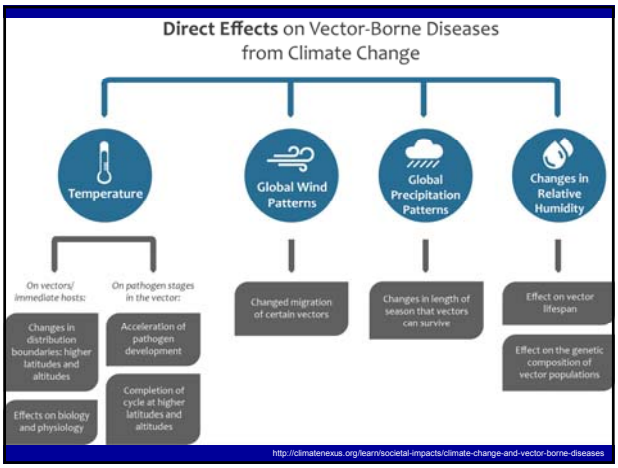


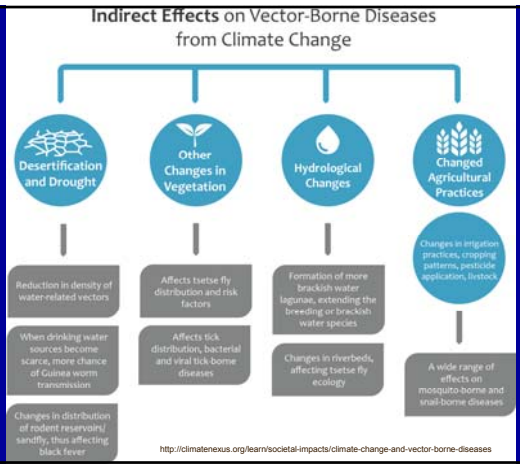
Disease	Vector	Population at risk (million)[1]	Number of people currently infected or new cases per year	Present distribution	Likelihood of altered distribution
Malaria	Mosquito	2,400[2]	300-500 million	Tropics and Subtropics	
Schistosomiasis	Water snail	600	200 million	Tropics and Subtropics	
Lymphatic Filariasis	Mosquito	1 094[3]	117 million	Tropics and Subtropics	
African Trypanosomiasis (Sleeping sickness)	Tsetse fly	55[4]	250 000 to 300 000 cases per year	Tropical Africa	
Dracunculiasis (Guinea worm)	Crustacean (Copepod)	100[5]	100 000 per year	South Asia, Arabian Peninsula, Central-West Africa	
Leishmaniasis	Phlebotomine sand fly	350	12 million infected, 500 000 new cases per year[6]	Asia, Southern Europe Africa, Americas	
Onchocerciasis (River blindness)	Black fly	123	17.5 million	Africa, Latin America	
American Trypanosomiasis (Chagas disease)	Triatomine bug	100[7]	18 million	Central and South America	
Dengue	Mosquito	1,800	10-30 million per year	All Tropical countries	
Yellow Fever	Mosquito	450	more than 5 000 cases per year	Tropical South America Africa	

1. Top three entries are population-prorated projections, based on 1998 estimates.
2. WHO, 1994.
3. Michael and Bundy, 1995.
4. WHO, 1994.
5. Rengua, personal communication.
6. Annual incidence of visceral leishmaniasis; annual incidence of cutaneous leishmaniasis is 1-1.5 million cases/yr (PAHO, 1994).
7. WHO, 1995.

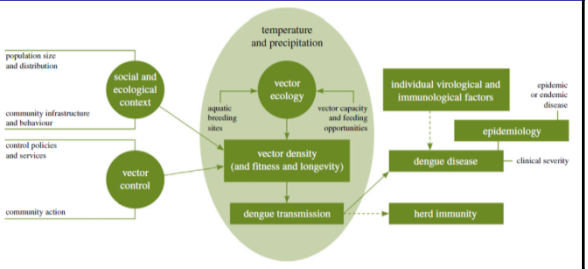
Highly likely · Very likely · Likely · Unknown

Philippe Rekacewicz, UNEP/GRID-Arendal, 2005. https://www.grida.no/resources/6474





Infectious diseases: complexity

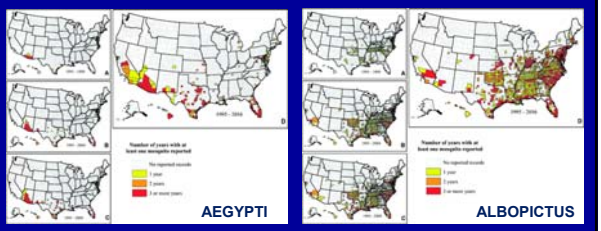


Interaction of meteorological and other determinants of dengue transmission cycles and clinical disease

Campbell-Lendrum, et al. Climate change and vector-borne diseases: what are the implications for public health research and policy? *Phil Trans Royal Soc Lond B: Biol Sci 2015;370*(1665).

Expanded *aedes* range 1995-2016

(Relevant to yellow fever, dengue, chikungunya, and Zika virus)

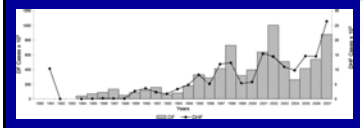


A = 1995-1999
B = 1995-2004
C = 1995-2009
D = 1995-2016

Hahn et al. 2016. Reported distribution of Aedes (stegomyia) aegypti and Aedes (stegomyia) albopictus in the United States, 1995-2016 (diptera: Culicidae). *J Med Entomol* 53:1169-1175.

Dengue in the Americas

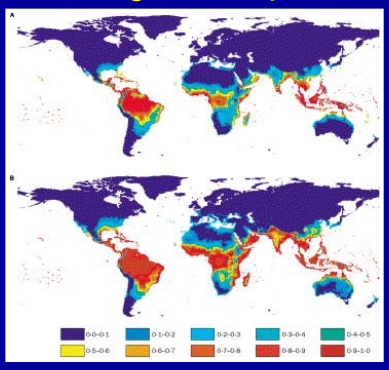
1980-2007



Number of dengue fever (DF) and dengue hemorrhagic fever (DHF) cases, Americas, 1980–2007.

San Martin JL et al. The epidemiology of dengue in the Americas over the last three decades: a worrisome reality. *Am J Trop Med Hyg.* 2010;82(1):128–135.

Dengue risk predictions



1990: 1.5 billion people

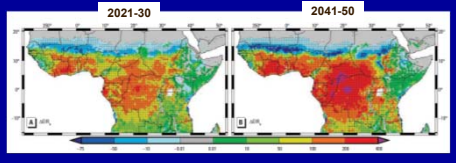
2085: 3.5 billion people

Source: Hales S et al. Potential effect of population and climate changes on global distribution of dengue fever: an empirical model. *Lancet* 2002; 360:830-34.

Malaria

Variable changes across Africa:

- ↓ risk over much of tropical Africa because of ↓ rainfall
- ↑ likelihood of epidemics in southern Sahel
- ↑ intensity of transmission in most of East Africa
- Epidemic malaria in formerly unsuitable highland areas
- ↓ epidemic risk in lower-altitude East African highlands



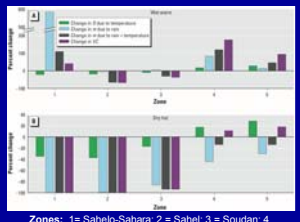
Ermert V et al. The impact of regional climate change on malaria risk due to greenhouse forcing and land-use changes in tropical Africa. *Environ Health Perspect* 2011;120:77-84.

Malaria: modeling variability

HYDREMATS model (Hydrology, Entomology, and Malaria Transmission Simulator) bridges hydrology (rainfall), topography (pooling), mosquito abundance, and human behaviors.

Wet warm

Dry hot

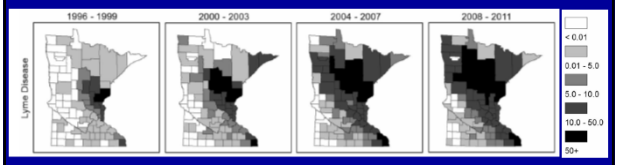


D = infective life
m = mosquito density
VC = vectorial capacity

Zones: 1= Sahelo-Sahara; 2 = Sahel; 3 = Soudan; 4 = Soudano-Guinean; 5 = Guinea Coast

Yamana TK, Eltahir EA. 2013. Projected impacts of climate change on environmental suitability for malaria transmission in West Africa. *Environ Health Perspect* 121:1179–86.

Lyme disease



Incidence of Lyme disease, Minnesota, 1996-2011 (cases/100,000 population)

Robinson et al. Disease risk in a dynamic environment: the spread of tick-borne pathogens in Minnesota, USA. *EcoHealth* 2015;12(1):152-163.

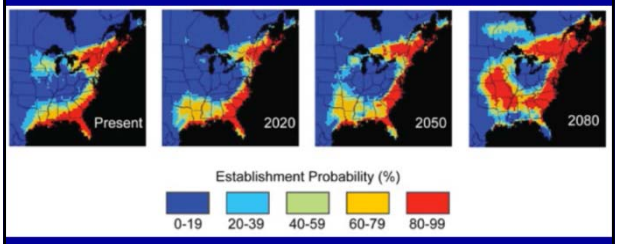
Expansion of ticks in Alaska: 2016

Sampling, Distribution, Dispersal

New Records of Ticks (Acari: Ixodidae) From Dogs, Cats, Humans, and Some Wild Vertebrates in Alaska: Invasion Potential

Lance A. Durden,[1,2] Kimberlee B. Beckmon,[3] and Robert F. Gerlach[4]

Lyme disease



Projected changes in tick habitat range through 2080

Luber et al., Human Health. Chap 9 in Melillo et al. (Eds.), *Climate Change Impacts in the United States* (pp. 220-256): USGCRP, 2014.

West Nile Virus

2008 West Nile Virus Activity in the US
(Provisional Data reported to CDC as of 02/13/09)

- Case-crossover analysis of 16,298 human cases 2001-05.
- ⇧ weekly maximum or cumulative temperature associated with 35-83% ⇧ incidence in next month.
- ≥ 1 day heavy rainfall associated with 29-66% ⇧ incidence in next 1-2 weeks.
- 20 mm ⇧ cumulative weekly rainfall associated with 4-8% ⇧ incidence in next 2 weeks.

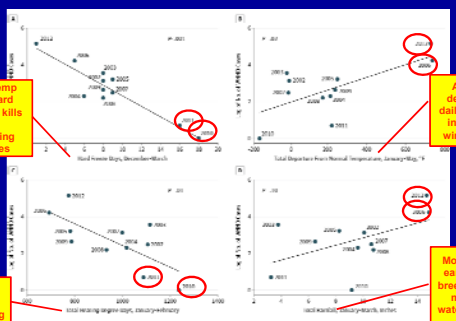
Soverow et al., Infectious disease in a warming world: How weather influenced West Nile Virus in the United States (2001-2005). *Env Health Persp* 2009; 10.1289/ehp.0800487

JAMA 2013;310(3):297-307.

Original Investigation

The 2012 West Nile Encephalitis Epidemic in Dallas, Texas

Wendy M. Chung, MD, SM; Christen M. Buseman, PhD, MPH; Sibeso N. Joyner, MPH; Sonya M. Hughes, MPH; Thomas B. Formby, PhD; James P. Luby, MD; Robert W. Haley, MD



Daily low temp <28°F (“hard freeze”) that kills many overwintering mosquitoes

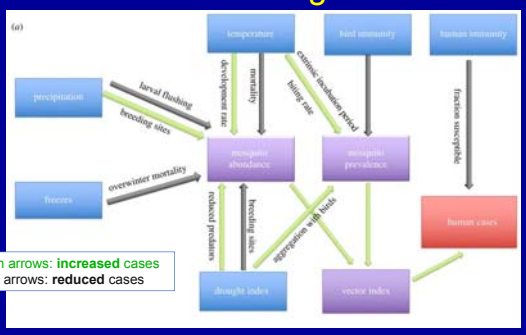
A high sum of departures from daily normal temps indicates a mild winter and spring

Winter days requiring home heating

More rainfall (esp. early in mosquito breeding season) -> more standing water for amplifying mosquito populations

West Nile Neuroinvasive Disease (WNND) cases and weather conditions, Dallas County, Texas, 2002-2012

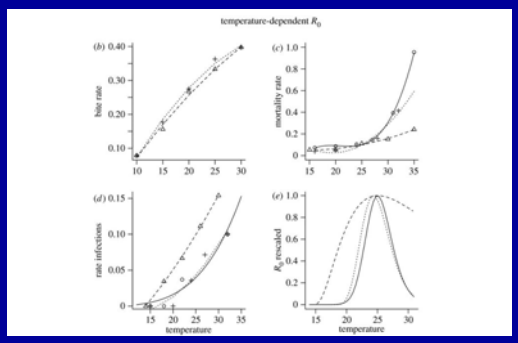
West Nile virus: Mechanisms influencing transmission



Green arrows: **increased** cases
Black arrows: **reduced** cases

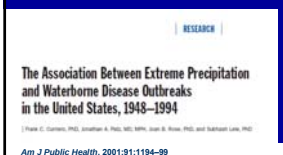
Paull SH et al. 2017. Drought and immunity determine the intensity of west Nile virus epidemics and climate change impacts. *Proc Royal Soc B: Biol Sci* 284.

West Nile virus: Effects of temperature on mosquito biology



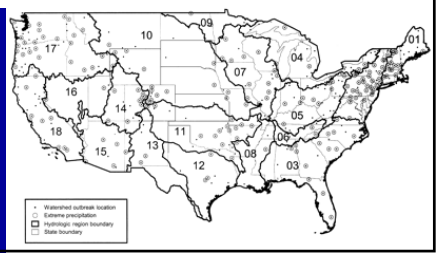
Paull SH et al. 2017. Drought and immunity determine the intensity of west Nile virus epidemics and climate change impacts. *Proc Royal Soc B: Biol Sci* 284.

6. Infectious disease - Waterborne

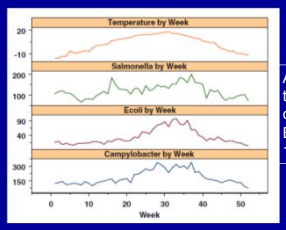

RESEARCH

The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States, 1948–1994

Am J Public Health. 2001;91:1194–99



Temperature and enteric disease

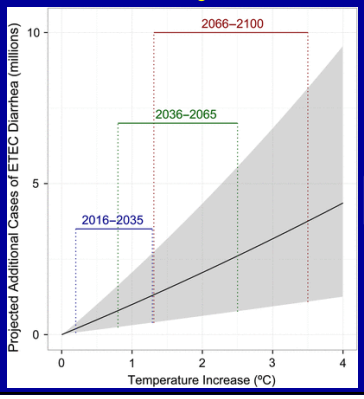


Average weekly temperature (°C) and case counts for Campylobacter, E. coli and Salmonella, 1992-2000, Alberta

- RR of Salmonella increased by 1.2% per degree above -10˚C
- RR of Campylobacter increased by 2.2% (4.5% in Newfoundland) per degree above -10˚C
- RR of E. coli increased by 6.0% per degree above -10˚C

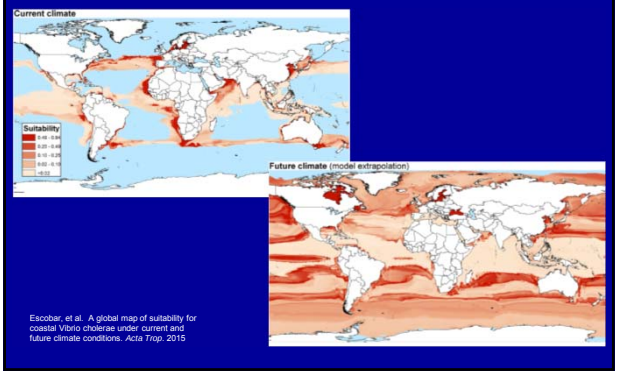
Fleury et al. A time series analysis of the relationship of ambient temperature and common bacterial enteric infections in two Canadian provinces. *Int J Biometeorol* 2006;50(61:385-91.

Estimates of potential annual increase in enterotoxigenic E. coli (ETEC) diarrhea cases in Bangladesh under future climate scenarios




Climatic Drivers of Diarrheagenic *Escherichia coli* Incidence: A Systematic Review and Meta-analysis

Cholera



Escobar, et al. A global map of suitability for coastal Vibrio cholerae under current and future climate conditions. *Acta Trop.* 2015

Infectious surprises

PNAS

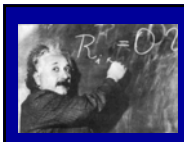
PNAS | December 7, 2004 | vol. 101 | no. 49

A rare genotype of *Cryptococcus gattii* caused the cryptococcosis outbreak on Vancouver Island (British Columbia, Canada)

S. E. Kidd*†‡, F. Hagen§, R. L. Tscharke¶, M. Huynh*, K. H. Bartlett*, M. Fyfe||, L. MacDougall**, T. Boekhout§††, K. J. Kwon-Chung‡‡, and W. Meyer*†‡§§

Discussion

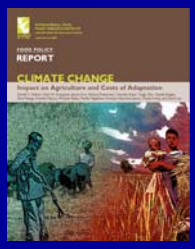
Until the recent emergence of cryptococcal infection on Vancouver Island, *C. gattii* had been considered to be restricted to areas with tropical and subtropical climates (2). The identification of large-scale colonization of *C. gattii* in the environment occurring in a temperate climate zone indicates a striking change in the distribution of this species. Furthermore, the identification of the *C. gattii*



Infectious diseases: Lessons learned

- Many infectious diseases are weather- and climate-sensitive
- Existing risks amplified
- Climate is only one of many important determinants of infectious disease
- Need to be alert for surprises
- Many known public health opportunities

7. Food and nutrition



Potential impact of climate change on world food supply

Cynthia Rosenzweig & Martin L. Parry

Food Security Under Climate Change

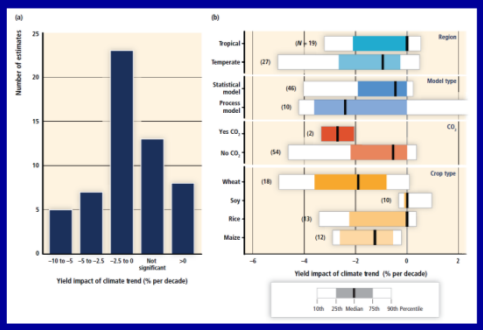
Crop and pasture response to climate change

Climate change and crop production

- "CO_2 fertilization"
  - C3 crops (rice, wheat, soy) more sensitive
  - C4 crops (maize, sugarcane, sorghum) less sensitive
- BUT…negative effects of
  - Changes in rainfall
  - More heat waves
  - More storms
  - Changes growing season timing
  - Saline intrusion near coasts

Impact of climate trends on four food crops

wheat, soy, rice, maize



Porter et al. (2014). Food security and food production systems. In Field et al. (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 485-533). Cambridge and New York: Cambridge University Press.

Science AAAS

Climate Trends and Global Crop Production Since 1980
David B. Lobell *et al.*
Science **333**, 616 (2011);
DOI: 10.1126/science.1204531

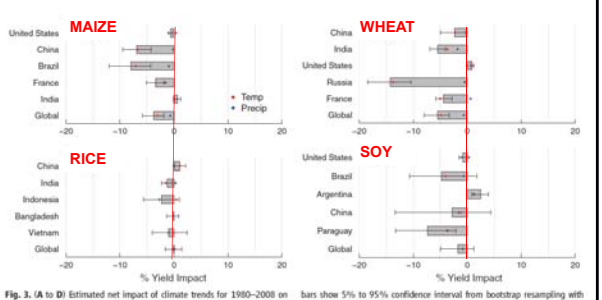
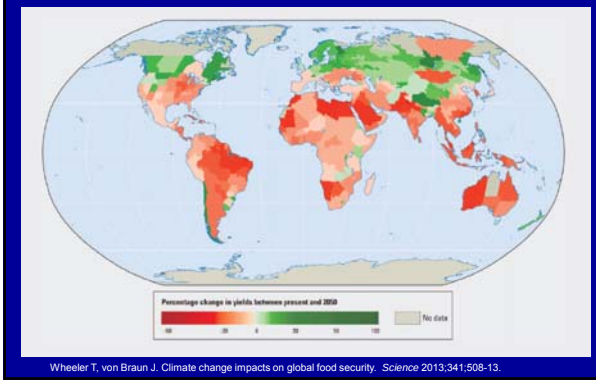


Fig. 3. (A to D) Estimated net impact of climate trends for 1980–2008 on crop yields for major producers and for global production. Values are expressed as percent of average yield. Gray bars show median estimate; error bars show 5% to 95% confidence interval from bootstrap resampling with 500 replicates. Red and blue dots show median estimate of impact for T trend and P trend, respectively.

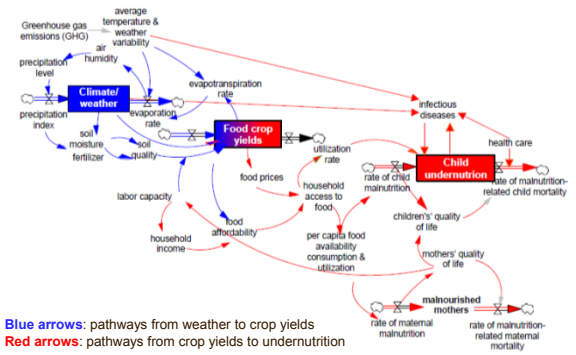
Projected crop yields, 2050

11 crops, averaged across multiple emission scenarios and GCMs



Wheeler T, von Braun J. Climate change impacts on global food security. *Science* 2013;341:508-13.

Reduced crop yields and undernutrition



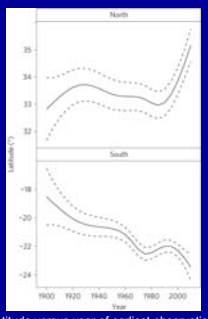
Blue arrows: pathways from weather to crop yields
Red arrows: pathways from crop yields to undernutrition

Phalkey et al. Systematic review of current efforts to quantify the impacts of climate change on undernutrition. *PNAS* 2015;112(33):E4522-E4529.

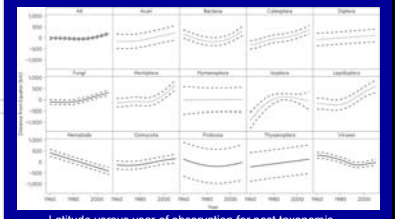
nature climate change

Crop pests and pathogens move polewards in a warming world

Daniel P. Bebber[1], Mark A. T. Ramotowski[2] and Sarah J. Gurr[1]*
Nature Climate Change 2013;3:985-988.

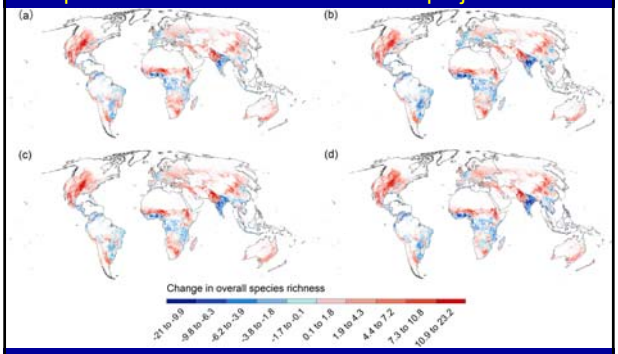


Latitude versus year of earliest observation for all pests, in the Northern and Southern hemispheres.



Latitude versus year of observation for pest taxonomic groups in the Northern Hemisphere from 1960 onwards.

Changes in the invasive crop pest species richness predicted based on future climatic projections:.



(a) 2050-RCP2.6; (b) 2050-RCP4.5;
(c) 2070-RCP2.6; (d) 2070-RCP4.5

Yan et al. Potential distributional changes of invasive crop pest species associated with global climate change. *Appl Geog* 2017; 82:83–92

Weeds: the bad news

Climate change may lead to

More weed growth

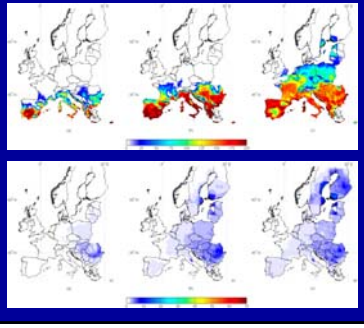
Lower herbicide efficacy

Climate change and aflatoxin

CURRENT +2^{O} +5^{O}

MAIZE

WHEAT



Battilani ET AL. (2016). Aflatoxin B(1) contamination in maize in Europe increases due to climate change. *Sci Rep*, 6, 24328. doi:10.1038/srep24328

Global Change Biology (2008) 14, 565–575, doi: 10.1111/j.1365-2486.2007.01511.x

Effects of elevated CO_2 on the protein concentration of food crops: a meta-analysis

DANIEL R. TAUB*†, BRIAN MILLER* and HOLLY ALLEN†
*Biology Department, Southwestern University, 1001 East University Avenue, Georgetown, TX 78626, USA, †Environmental Studies Program, Southwestern University, 1001 East University Avenue, Georgetown, TX 78626, USA

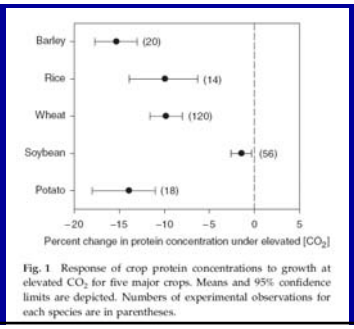
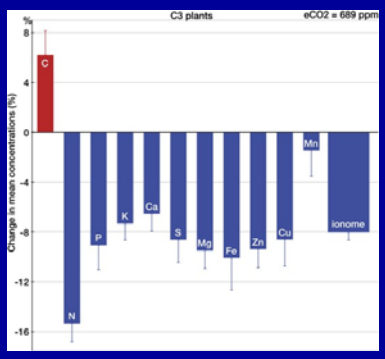


Fig. 1 Response of crop protein concentrations to growth at elevated CO_2 for five major crops. Means and 95% confidence limits are depicted. Numbers of experimental observations for each species are in parentheses.

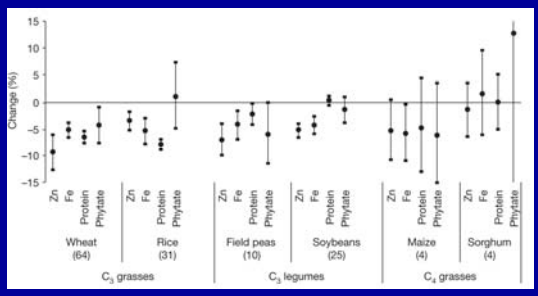
Climate change and the food "ionome"



Loladze I. 2014. Hidden shift of the ionome of plants exposed to elevated co(2)depletes minerals at the base of human nutrition. *eLife* 3:e02245.

Increasing CO_2 threatens human nutrition

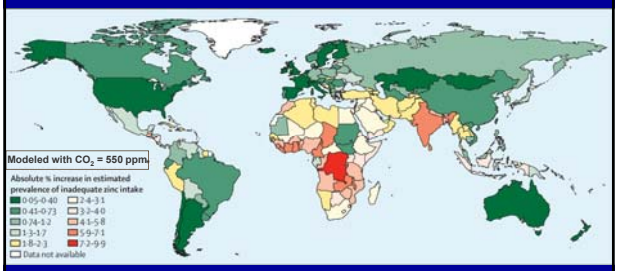
Samuel S. Myers[1,2], Antonella Zanobetti[1], Itai Kloog[3], Peter Huybers[4], Andrew D. B. Leakey[5], Arnold J. Bloom[6], Eli Carlisle[6], Lee H. Dietterich[7], Glenn Fitzgerald[8], Toshihiro Hasegawa[9], N. Michele Holbrook[10], Randall L. Nelson[11], Michael J. Ottman[12], Victor Raboy[13], Hidemitsu Sakai[9], Karla A. Sartor[14], Joel Schwartz[1], Saman Seneweera[15], Michael Tausz[16] & Yasuhiro Usui[9]



Percentage change in nutrients at elevated [CO_2] relative to ambient [CO_2].

Myers *et al.* Increasing CO_2 threatens human nutrition. *Nature* 2014;510:139-142.

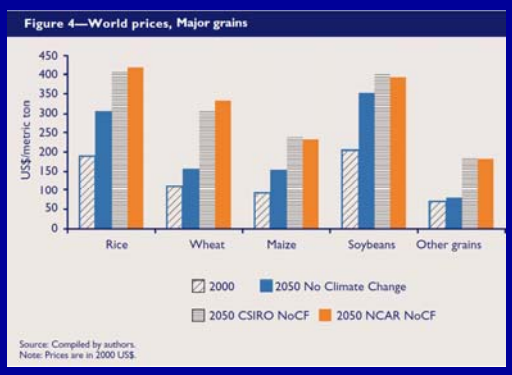
↑ CO_2 → ↑ dietary Zn deficiency



Estimated 138 million people at new risk of zinc deficiency by 2050, most in Africa and South Asia (including 48 million in India alone)

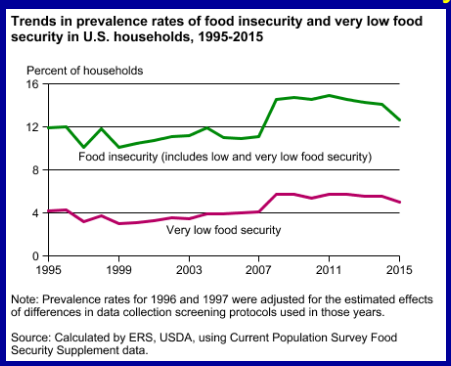
Myers et al. Effect of increased concentrations of atmospheric carbon dioxide on the global threat of zinc deficiency: a modelling study. *The Lancet Global Health*, 2015;3(10):e639-e645.

Projected rise in food prices



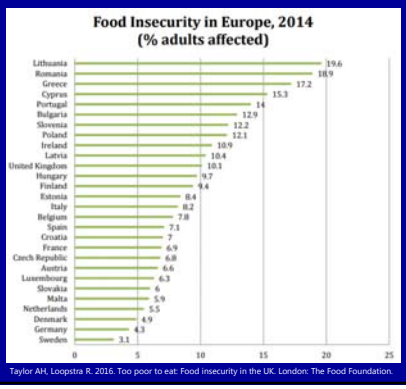
Source: Nelson et al. *Climate Change Impact on Agriculture and Costs of Adaptation*. International Food Policy Research Institute, 2009.

A baseline of food insecurity



USDA, Economic Research Service, 2016. https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics.aspx

A baseline of food insecutiry



Taylor AH, Loopstra R. 2016. Too poor to eat: Food insecurity in the UK. London: The Food Foundation.

Food prices, nutrition, and health

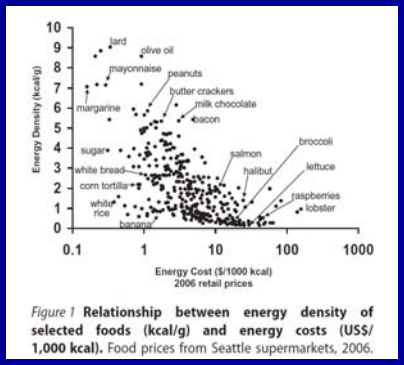
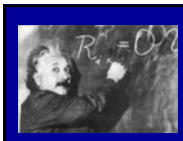


Figure 1 **Relationship between energy density of selected foods (kcal/g) and energy costs (US$/1,000 kcal).** Food prices from Seattle supermarkets, 2006.

Source: Drewnowski A. The cost of US foods as related to their nutritive value. *Am J Clin Nutr* 2010 92: 1181-88.

Consequences of drought and hunger

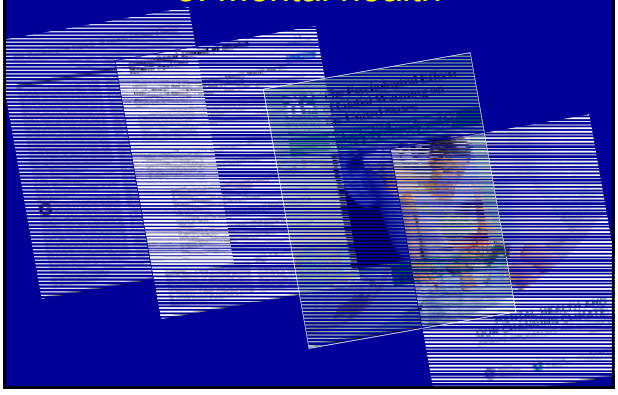
Source: Thomson Reuters Foundation - 21 Nov 2015 http://www.trust.org/item/20151121175335-b2zm1/?source=jt

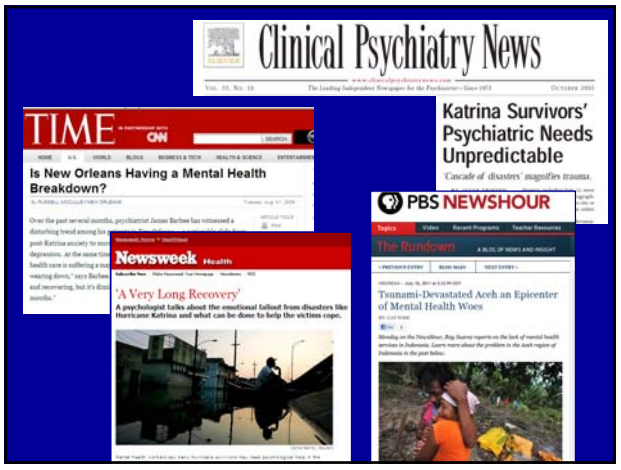


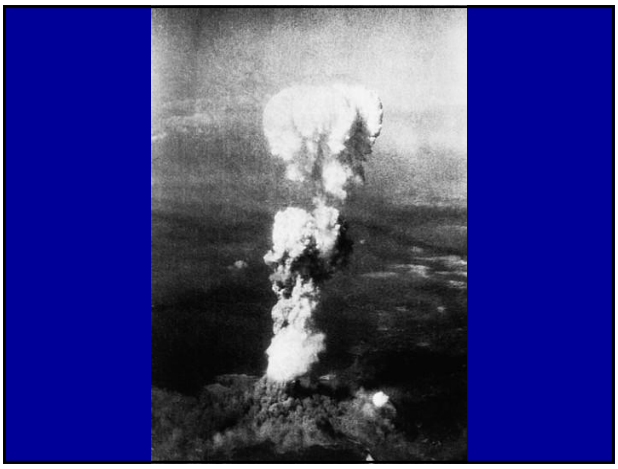
Food: Lessons learned

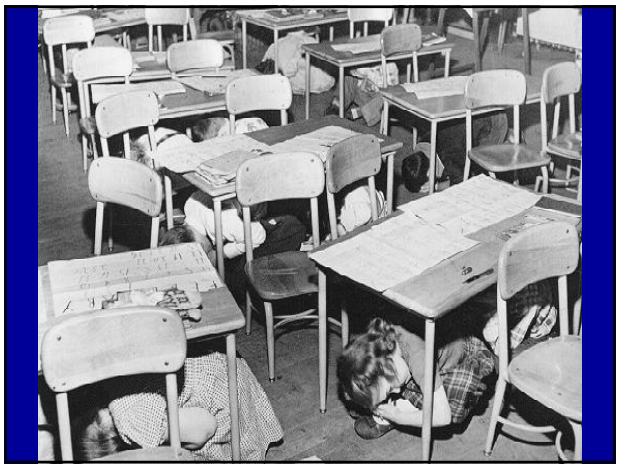
- Climate change aggravates existing problems: food production, nutritional content, and potentially chemical contaminants
- Need for complex, systems analyses
- Disproportionate impacts on the food insecure, in both wealthy and poor countries
- Very large potential impacts; 1 billion people food insecure
- Adaptation will require many innovations

8. Mental health







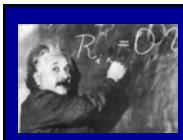



KOREN
"This past summer, I got deeply depressed about our planet—as if I didn't have enough problems of my own."


Solastalgia: the distress caused by environmental change
Glenn Albrecht, Gina-Maree Sartore, Linda Connor, Nick Higginbotham, Sonia Freeman, Brian Kelly, Helen Stain, Anne Tonna and Georgia Pollard
Objective: Solastalgia is a new concept developed to give greater meaning and clarity to environmentally induced distress. As opposed to nostalgia – the melancholia or homesickness experienced by individuals when separated from a loved home – solastalgia is the distress that is produced by environmental change impacting on people while they are directly connected to their home environment. The paper will focus on two

Heat and severe mental illness

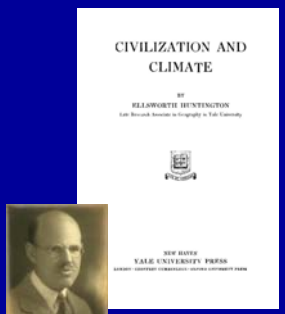
- Heat regulation
- Medication effects
- ↓ Awareness of danger
- ↓ Judgment to protect self



Mental health: Lessons learned

- Large existing baseline of mental illness
- Climate change may aggravate it in several ways

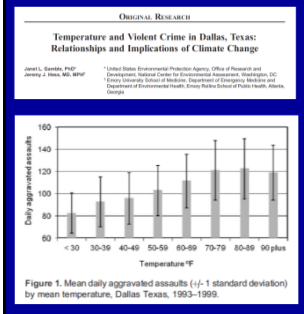
9. Conflict

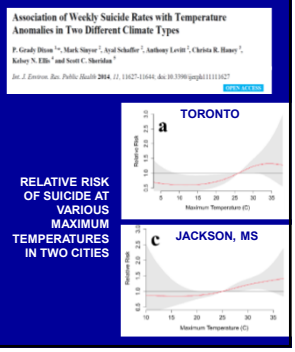


"Almost any American or European who has travelled or resided within the tropics will confess that he has occasionally flown into a passion, and perhaps used physical violence, under circumstances which at home would merely have made him vexed."

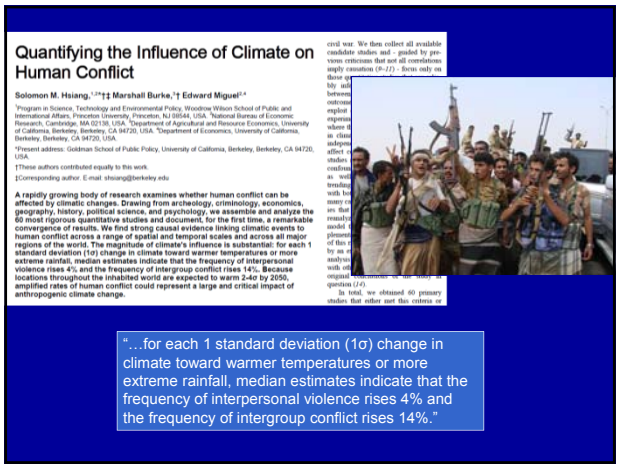
Ellsworth Huntington, *Civilization and Climate* (1924)

Temperature and violence



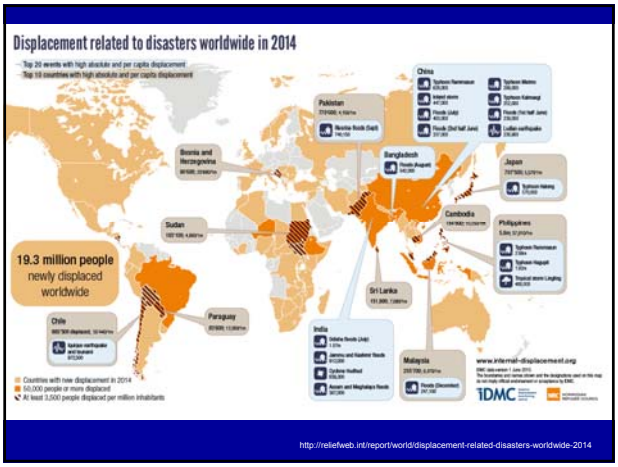


RELATIVE RISK OF SUICIDE AT VARIOUS MAXIMUM TEMPERATURES IN TWO CITIES



"…for each 1 standard deviation (1σ) change in climate toward warmer temperatures or more extreme rainfall, median estimates indicate that the frequency of interpersonal violence rises 4% and the frequency of intergroup conflict rises 14%."

10. Migration



http://reliefweb.int/report/world/displacement-related-disasters-worldwide-2014

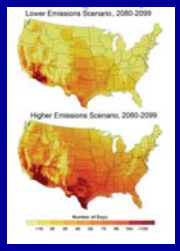
Managed retreat

Abandoned house in Shishmaref, Alaska. Residents voted in 2016 to relocate the community.

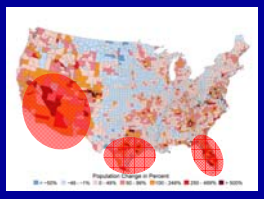
Photo: Diana Haecker/AP. www.nytimes.com/2016/08/20/us/shishmaref-alaska-elocate-vote-climate-change.html

www.theguardian.com/environment/2017/may/08/australia-and-nz-should-allow-open-migration-for-pacific-islanders-threatened-by-climate-says-report; www.independent.co.uk/environment/climate-change/global-warming-thousands-flee-pacific-islands-on-front-line-of-climate-change-a6757796.html

Potential internal relocation, U.S.



Number of days likely to exceed 100°F by late 21st century



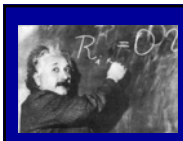
Percent change in population across the U.S., 1970-2008.

Projected net migration (in-migrants minus out-migrants) due to sea level rise (SLR)

(1.8 m SLR scenario, no adaptation)

Core based statistical areas (showing only counties located in CBSAs)
(Locations without expected SLR in-migration shown in white.)

Hauer ME. 2017. Migration induced by sea-level rise could reshape the US population landscape. *Nature Clim Change* 7:321-325.



Displacement and war: Lessons learned

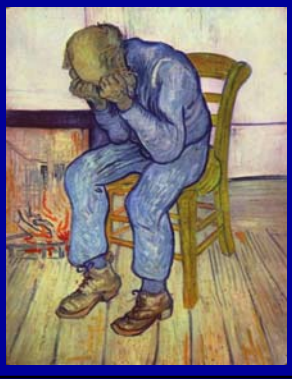
- Large, under-recognized potential for suffering
- Preparedness and service delivery essential

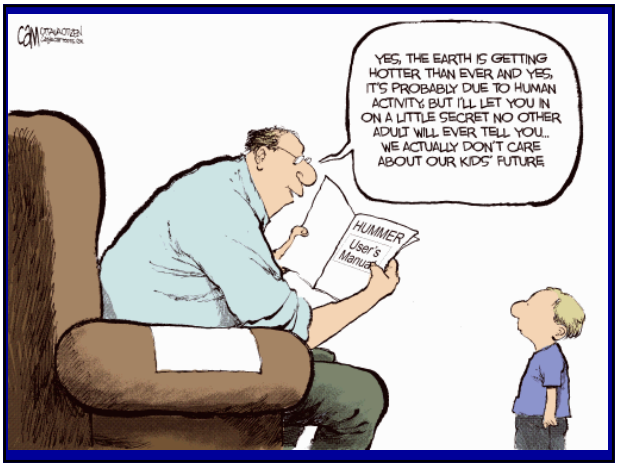
Climate impacts on health

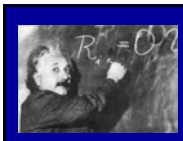
Climate change:
- ↑ temperature
- Sea level rise
- Extreme weather

HEAT	Heat stress, cardiovascular failure, ↓ work capacity
SEA LEVEL RISE AND SEVERE WEATHER	Injuries, fatalities
AIR POLLUTION	Asthma, cardiovascular disease
ALLERGIES	Resp allergies, poison ivy
VECTOR-BORNE DISEASES	Malaria, dengue, hantavirus, encephalitis, Rift Valley fever
WATER-BORNE DISEASES	Cholera, cryptosporidiosis, campylobacter, leptospirosis
WATER AND FOOD SUPPLY	Malnutrition, diarrhea, harmful algal blooms
MENTAL HEALTH	Anxiety, post-traumatic stress, depression, despair
RESOURCE SCARCITY AND COMPETITION	Forced migration, civil conflict

I know how you must feel now.







Health effects of climate change: Summary lessons learned

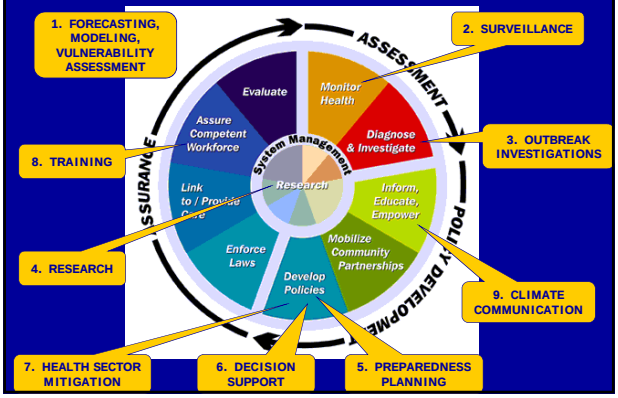
Implications for:
- What we think about
- How we think
- The methods we use
- How we protect health

Framing Climate Change and Health

Mitigation → Prevention

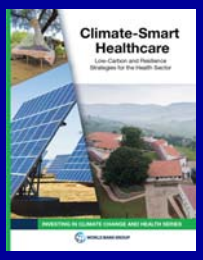
Adaptation → Preparedness

Public Health Action on Climate Change



Climate-Smart Health Care

- Mitigation
  - ↓ energy use
  - ↓ material use
  - ↓ waste generation
  - ↑ active transportation
  - local food sourcing
- Resilience and adaptation
  - operational adaptation
  - disaster preparedness



Innovation: Transportation

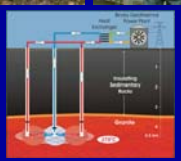


Innovation: Transportation
Finding the new in the old



Innovation: Energy




Innovation: Buildings


Innovation: Neighborhoods
Finding the new in the old




Innovation: Food
Finding the new in the old

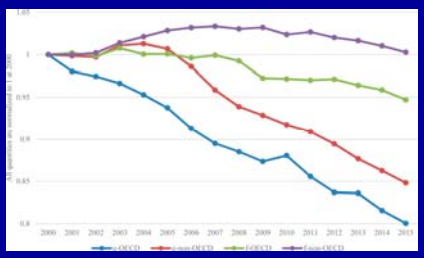


Innovation: Communication

skype
join me
Google Hangouts
WhatsApp

zoom
GoToMeeting by CITRIX
webex

The result: Decoupling economic growth from carbon emissions



Energy consumption per unit of GDP (red and blue lines and **carbon emission per unit of energy consumption** (purple and green lines) in OECD and non-OECD countries, 2000-2015.

Notes: Energy is total primary energy consumption measured in tons of oil equivalent. Carbon dioxide emissions are those from fuel combustion, measured in tons of carbon dioxide.

Source: Wang et al. Toward decoupling: Growing GDP without growing carbon emissions. *Environ. Sci. Technol.* 2016;50:11435-436.

Tracking progress on health and climate change: the Lancet Commission (2016)

1: Health impacts of climate hazards
- 1.1 Exposure to temperature change
- 1.2 Exposure to heatwaves
- 1.3 Changes in labor productivity
- 1.4 Exposure to flood
- 1.5 Exposure to drought
- 1.6 Changes in incidence and geographical range of climate-sensitive infectious diseases (sentinel sites)
- 1.7 Food security and undernutrition

2: Health resilience and adaptation
- 2.1 Integration of health into national adaptation plans
- 2.2 Climate services for health
- 2.3 Adaptation of finance for health

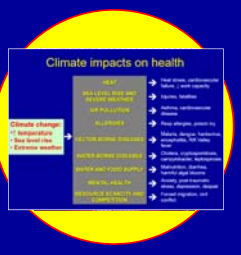
3: Health co-benefits of climate change mitigation
- 3.1 Coal phase-out
- 3.2 Growth in renewable energy
- 3.3 Access to clean energy
- 3.4 Energy access for health facilities
- 3.5 Exposure to ambient air pollution
- 3.6 Deployment of low-emission vehicles and access to public transport
- 3.7 Active travel infrastructure and uptake

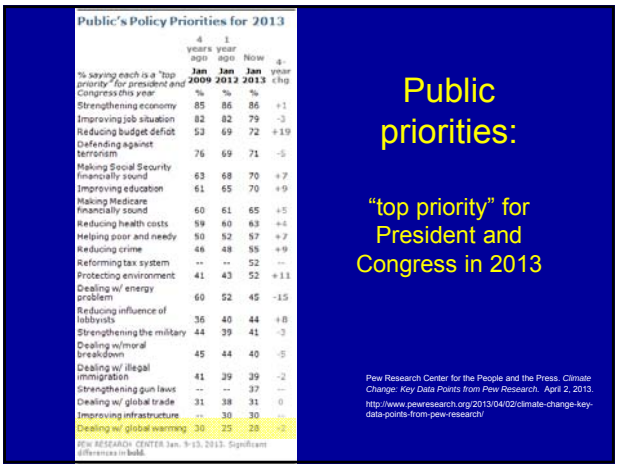
3: Health co-benefits of climate change mitigation
- 3.8 GHG emissions from the food system and healthy diets
- 3.9 GHG emissions of health-care systems

4: Economics and finance
- 4.1 Change in annual investment in renewable energy
- 4.2 Change in annual investment in energy efficiency
- 4.3 Low-carbon technology patent generation and innovation
- 4.4 Valuing the health co-benefits of climate change mitigation
- 4.5 Direct and indirect fossil fuel subsidies
- 4.6 Coverage and strength of carbon pricing
- 4.7 Equity of the low-carbon transition

5: Political and broader engagement
- 5.1 Public engagement with health and climate change
- 5.2 Academic publications on health and climate change
- 5.3 Inclusion of health and climate change within medical and public health curricula
- 5.4 Health and climate change in high-level statements of the UNFCCC and UNGA
- 5.5 Implementation and estimated health benefits of the nationally determined contributions (NDCs)

Climate communication

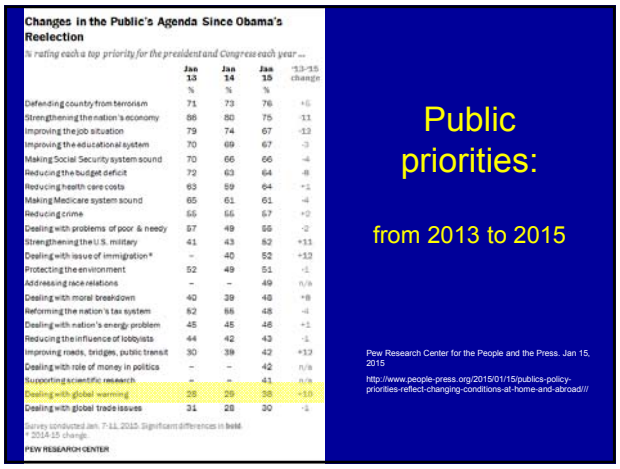





Public priorities:

"top priority" for President and Congress in 2013

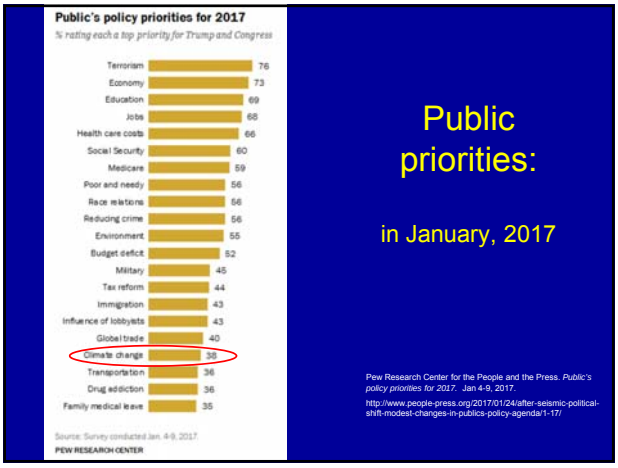
Pew Research Center for the People and the Press. *Climate Change: Key Data Points from Pew Research.* April 2, 2013.
http://www.pewresearch.org/2013/04/02/climate-change-key-data-points-from-pew-research/



Public priorities:

from 2013 to 2015

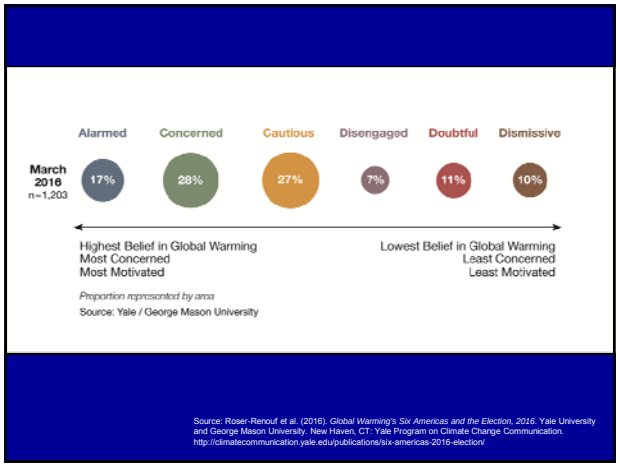
Pew Research Center for the People and the Press. Jan 15, 2015
http://www.people-press.org/2015/01/15/publics-policy-priorities-reflect-changing-conditions-at-home-and-abroad///



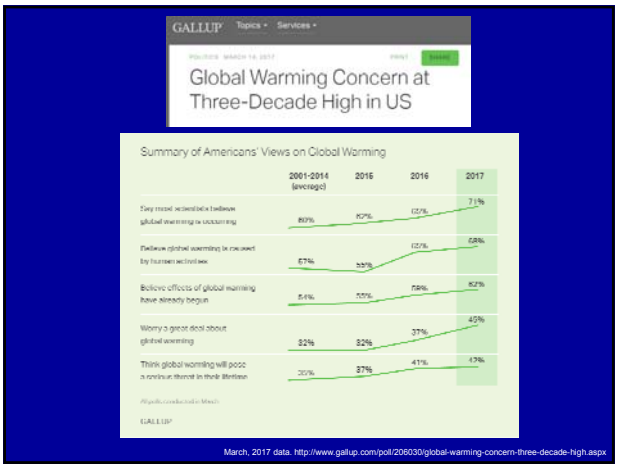
Public priorities:

in January, 2017

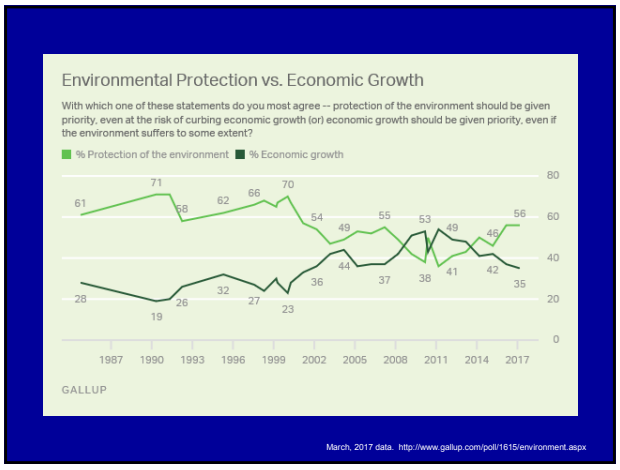
Pew Research Center for the People and the Press. *Public's policy priorities for 2017.* Jan 4-9, 2017.
http://www.people-press.org/2017/01/24/after-seismic-political-shift-modest-changes-in-publics-policy-agenda/1-17/



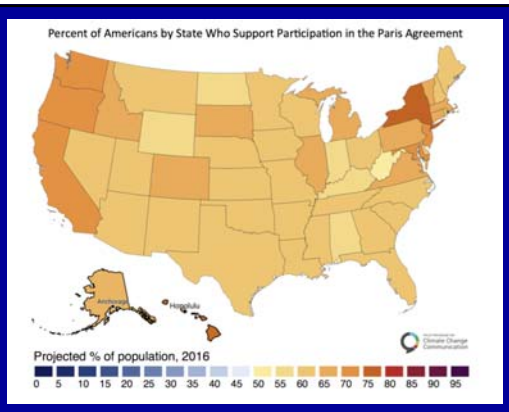
Source: Roser-Renouf et al. (2016). *Global Warming's Six Americas and the Election, 2016.* Yale University and George Mason University. New Haven, CT: Yale Program on Climate Change Communication.
http://climatecommunication.yale.edu/publications/six-americas-2016-election/



March, 2017 data. http://www.gallup.com/poll/206030/global-warming-concern-three-decade-high.aspx

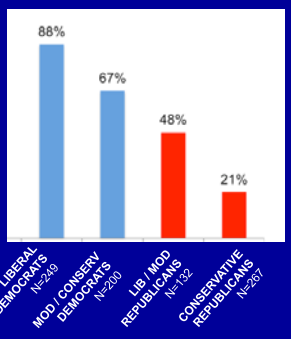


March, 2017 data. http://www.gallup.com/poll/1615/environment.aspx



Marlon, J.R., Fine, E., and Leiserowitz, A. (2017). A majority of Americans in every state say the U.S. should participate in the Paris Climate Agreement. Yale University. New Haven, CT: Yale Program on Climate Change Communication. http://climatecommunication.yale.edu/publications/paris_agreement_by_state/.

Deep partisan divides persist.



Leiserowitz et al. (2016). *Politics and global warming, Spring 2016.* Yale University and George Mason University. New Haven: Yale Program on Climate Change Communication.

Proportion of registered American voters saying they are "very" or "somewhat" worried about global warming.

Global variation in level of concern

How serious of a threat is global warming to you and your family?

% saying "very" or "somewhat" serious threat

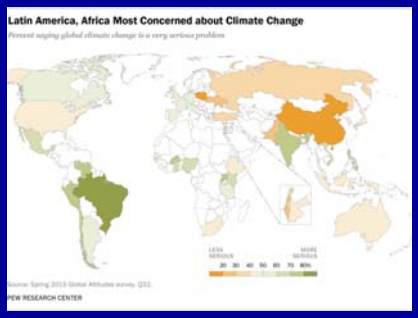
	2007-2008	2010	Change (pct. pts.)
World	41%	42%	+1
Western Europe	66%	56%	-10
Eastern/Southern Europe	67%	60%	-7
Commonwealth of Independent States	42%	44%	+2
Latin America	67%	73%	+6
United States	63%	53%	-10
Canada	74%	71%	-3
Developing Asia	31%	31%	--
Developed Asia	79%	74%	-5
Sub-Saharan Africa	29%	34%	+5
Middle East and North Africa	42%	37%	-5

Figures projected to the entire adult population.

GALLUP

Gallup. Fewer Americans, Europeans view global warming as a threat. April 20, 2011. http://www.gallup.com/poll/147203/Fewer-Americans-Europeans-View-Global-Warming-Threat.aspx

Majorities in all 40 nations polled say climate change is a serious problem, and a global median of 54% believe it is a *very* serious problem

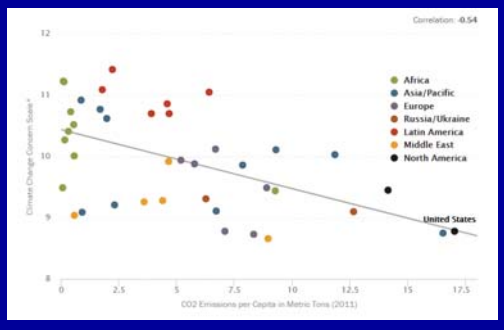


Nations surveyed

U.S.A., Canada, France, Germany, Italy, Poland, Spain, U.K., Russia, Ukraine, Turkey, Jordan, Lebanon, Palest. ter., Israel, Australia, China, India, Indonesia, Japan, Malaysia, Pakistan, Philippines, South Korea, Vietnam, Argentina, Brazil, Chile, Mexico, Peru, Venezuela, Burkina Faso, Ethiopia, Ghana, Kenya, Nigeria, Senegal, South Africa, Tanzania, Uganda

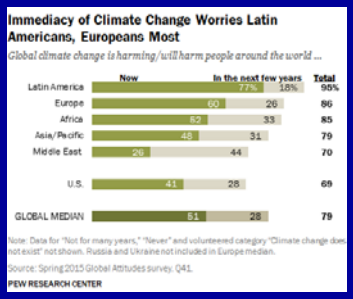
Wike R. What the world thinks about climate change in 7 charts. Pew Research Center. April, 2016. http://www.pewresearch.org/fact-tank/2016/04/18/what-the-world-thinks-about-climate-change-in-7-charts/

Less intense concern among high CO_2 emitters.



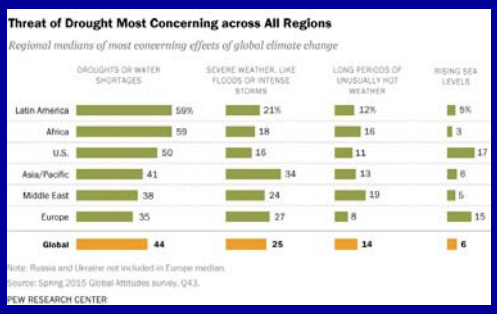
Wike R. What the world thinks about climate change in 7 charts. Pew Research Center. April, 2016. http://www.pewresearch.org/fact-tank/2016/04/18/what-the-world-thinks-about-climate-change-in-7-charts/

Climate change is not seen as a distant threat. A global median of 51% say climate change is already harming people around the world, while another 28% believe it will do so in the next few years.



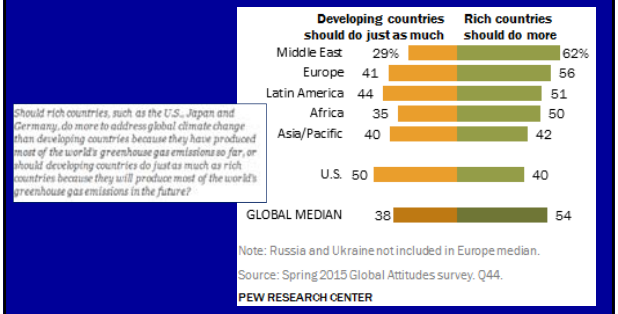
Wike R. What the world thinks about climate change in 7 charts. Pew Research Center. April, 2016. http://www.pewresearch.org/fact-tank/2016/04/18/what-the-world-thinks-about-climate-change-in-7-charts/

Drought is the top climate change concern.



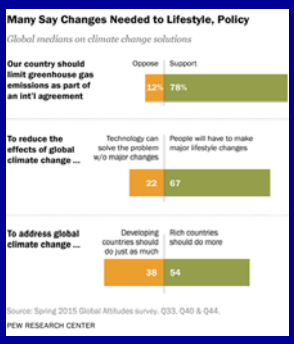
Wike R. What the world thinks about climate change in 7 charts. Pew Research Center. April, 2016. http://www.pewresearch.org/fact-tank/2016/04/18/what-the-world-thinks-about-climate-change-in-7-charts/

Most people say rich nations should do more than developing nations to address climate change.



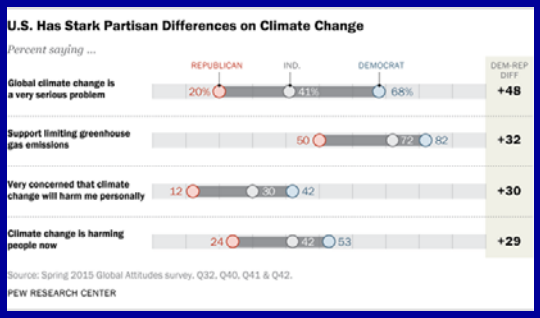
Wike R. What the world thinks about climate change in 7 charts. Pew Research Center. April, 2016. http://www.pewresearch.org/fact-tank/2016/04/18/what-the-world-thinks-about-climate-change-in-7-charts/

To deal with climate change, most people think both policy and lifestyle changes will be needed.



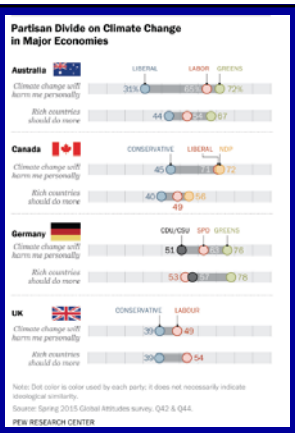
Wike R. What the world thinks about climate change in 7 charts. Pew Research Center. April, 2016. http://www.pewresearch.org/fact-tank/2016/04/18/what-the-world-thinks-about-climate-change-in-7-charts/

Americans' views about climate issues divide sharply along partisan lines.



Wike R. What the world thinks about climate change in 7 charts. Pew Research Center. April, 2016. http://www.pewresearch.org/fact-tank/2016/04/18/what-the-world-thinks-about-climate-change-in-7-charts/

Partisan divides are also present, although less stark, in other wealthy nations.



Stokes B, Wike R, Carle J. November 2015. Global Concern about Climate Change, Broad Support for Limiting Emissions. Pew Research Center. http://www.pewglobal.org/2015/11/05/global-concern-about-climate-change-broad-support-for-limiting-emissions/

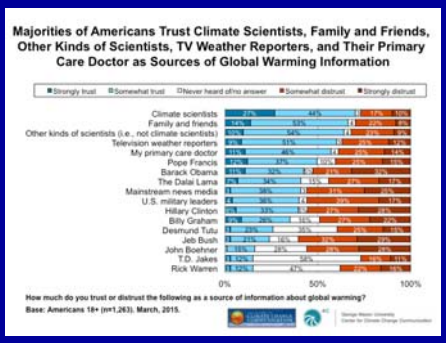
Psychological barriers

- Climate change is unprecedented
- Climate change is complicated
- People discount risks
- Daily experience doesn't confirm climate change
- Climate change is frightening
- People mistrust information sources and authorities
- People don't like the needed behavioral changes
- Climate change has been hitched to ideology

Undermining climate science

- Manufacturing uncertainty by raising doubts about even indisputable science
- Seemingly independent front organizations
- Phony grass-roots voices
- Funding and promoting fringe scientist spokespersons
- Harassing climate scientists
- Equating climate action with financial ruin

Trusted sources of information



Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G., & Rosenthal, S. (2015). *Climate change in the American mind: March, 2015.* Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication.
http://environment.yale.edu/climate-communication/files/Global-Warming-CCAM-March-2015.pdf

Climate communication strategies

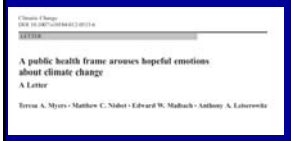
Cross et al. (2015). News Media and Climate Politics: Civic Engagement and Political Efficacy in a Climate of Reluctant Cynicism. Canadian Centre for Policy Alternatives.

- **Success stories** about climate politics have a positive impact.
- People are especially excited by stories of **entrepreneurial activism and everyday heroism**.
- As people increase their **awareness and understanding of political successes**, they are more likely to contradict others' cynicism by bringing up these success stories.
- People engage more strongly with **localized information** about the causes and consequences of climate change, as well as solutions.
- **Descriptive communication** is more powerful than prescriptive (which increase feelings of guilt and frustration).
- Information about **how to engage politically**, and the effects of political engagement, is just as important as information about climate change science.

3 Messages That Win

Breakthrough Strategies and Solutions, 2014

Framing climate change as a health issue

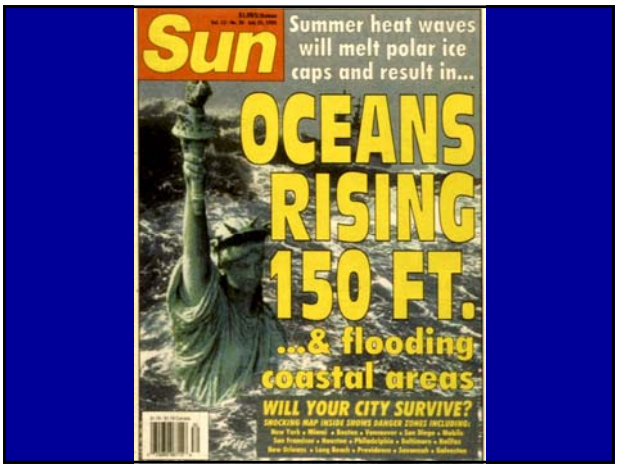


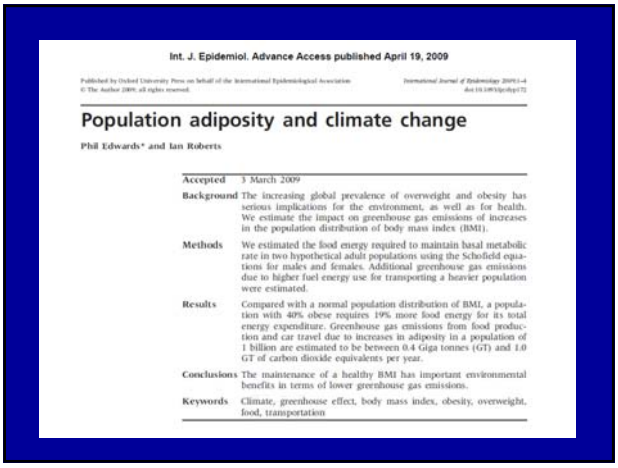
- Three possible frames:
  - National security
  - Health
  - Environment
- The health frame elicited more hope, and less anger, than the others, in the most skeptical respondents

Communication theory

"There's a simple rule: You say it again, and you say it again, and you say it again, and you say it again, and you say it again, and then again and again and again and again, and about the time that you're absolutely sick of saying it is about the time that your target audience has heard it for the first time."

Frank Luntz
Republican political strategist





Int. J. Epidemiol. Advance Access published April 19, 2009

Population adiposity and climate change

Phil Edwards* and Ian Roberts

Accepted 3 March 2009

Background The increasing global prevalence of overweight and obesity has serious implications for the environment, as well as for health. We estimate the impact on greenhouse gas emissions of increases in the population distribution of body mass index (BMI).

Methods We estimated the food energy required to maintain basal metabolic rate in two hypothetical adult populations using the Schofield equations for males and females. Additional greenhouse gas emissions due to higher fuel energy use for transporting a heavier population were estimated.

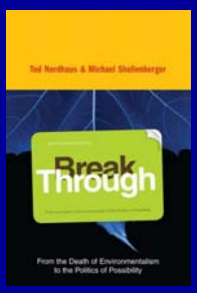
Results Compared with a normal population distribution of BMI, a population with 40% obese requires 19% more food energy for its total energy expenditure. Greenhouse gas emissions from food production and car travel due to increases in adiposity in a population of 1 billion are estimated to be between 0.4 Giga tonnes (GT) and 1.0 GT of carbon dioxide equivalents per year.

Conclusions The maintenance of a healthy BMI has important environmental benefits in terms of lower greenhouse gas emissions.

Keywords Climate, greenhouse effect, body mass index, obesity, overweight, food, transportation

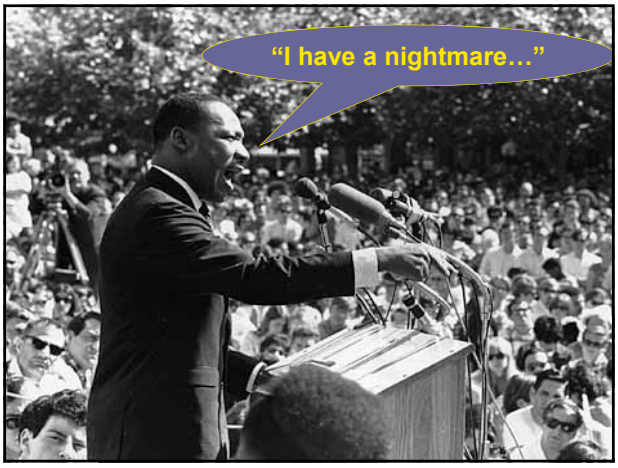
Image courtesy of Jonathan Patz.

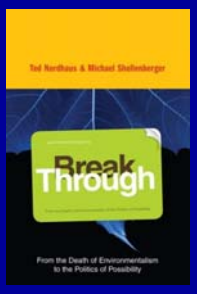
Edvard Munch does Climate Change



"Think of the verbs associated with environmentalism and conservation: 'stop,' 'restrict,' 'reverse,' prevent,' 'regulate,' and 'constrain.' All of them direct our thinking to stopping the bad, not creating the good."

⇨ The need for positive, aspirational messages.



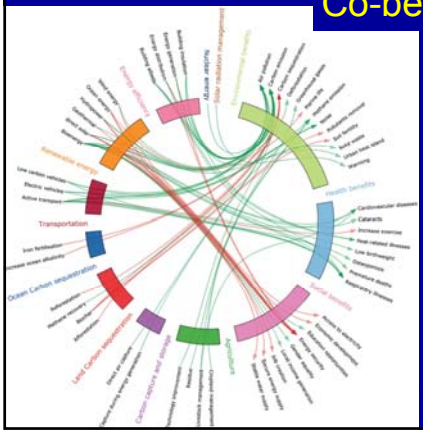


"The challenge of climate change is so massive, so global, and so complex that it can only be overcome if we look beyond the issue categories of the past and embrace a grand new vision for the future."

⇨ The need for bold, cross-cutting thinking.

Promoting co-benefits

Co-benefits



Red arrows: a mitigation technology will **increase** the effect;
Green arrows: a mitigation technology will **decrease** the effect.

Watts et al. (2015). Health and climate change: policy responses to protect public health. *The Lancet*, 386, 1861-1914.

Co-benefits: Cycling


Research

Air Quality and Exercise-Related Health Benefits from Reduced Car Travel in the Midwestern United States

Study of the Day: Biking to Work Could Save 1,100 Midwesterners

Swapping Tail Pipes For Pedals: Small Changes Could Pay Huge Dividends For Public Health And Economy

↑ Air quality
↑ Physical activity

Co-benefits: Electric vehicles

50% replacement of cars with electric cars in Rotterdam predicted to yield:

⇩ carbon emissions ⇩ particulate matter ⇩ noise	⇩ annoyance ⇩ sleep disturbance Minimal benefits from ⇩ IHD, ⇩ cancer because emissions reduction already underway

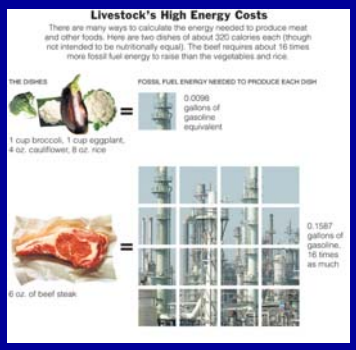
Tobollik et al. 2016. Health impact assessment of transport policies in Rotterdam: Decrease of total traffic and increase of electric car use. *Environ Res* 146:350-58.

Co-benefits: Food

To produce 320 calories:

Carbon footprint: **0.4 pounds**

Carbon footprint: **9.75 pounds**


Livestock's High Energy Costs

There are many ways to calculate the energy needed to produce meat and other foods. Here are two dishes of about 320 calories each (though not intended to be nutritionally equal). The beef requires about 16 times more fossil fuel energy to raise than the vegetables and rice.

THE DISHES

FOSSIL FUEL ENERGY NEEDED TO PRODUCE EACH DISH

0.0098 gallons of gasoline equivalent

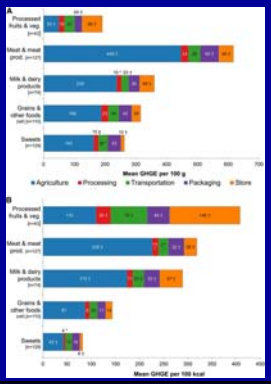
1 cup broccoli, 1 cup eggplant, 4 oz. cauliflower, 8 oz. rice

0.1587 gallons of gasoline, 16 times as much

6 oz. of beef steak

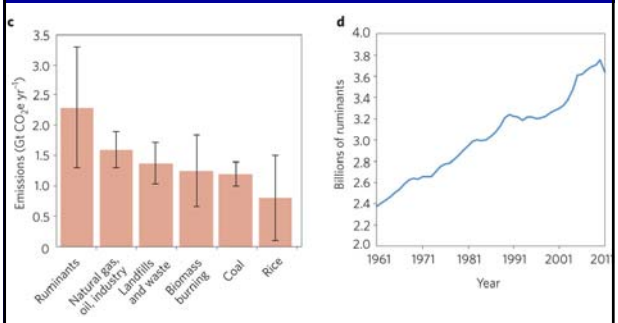
New York Times, 27 January 2008. Based on Eshel G, Martin PA. Diet, energy, and global warming. *Earth Interactions* 2006;10:1-17.

GHG emissions for broad food groups



Drewnowski et al. 2015. Energy and nutrient density of foods in relation to their carbon footprint. *Am J Clin Nutr* 101:184-191.

Ruminants are a major methane source



Estimated annual anthropogenic emissions from major sources of methane in recent years.

Global ruminant numbers from 1961 to 2011.

Ripple WJ et al. Ruminants, climate change and climate policy. *Nature Climate Change* 2014;4:2-5


ORIGINAL INVESTIGATION

Meat Intake and Mortality

A Prospective Study of Over Half a Million People

Rashmi Sinha, PhD; Amanda J. Cross, PhD; Barry I. Graubard, PhD; Michael F. Leitzmann, MD, DrPH; Arthur Schatzkin, MD, DrPH

EDITORIAL

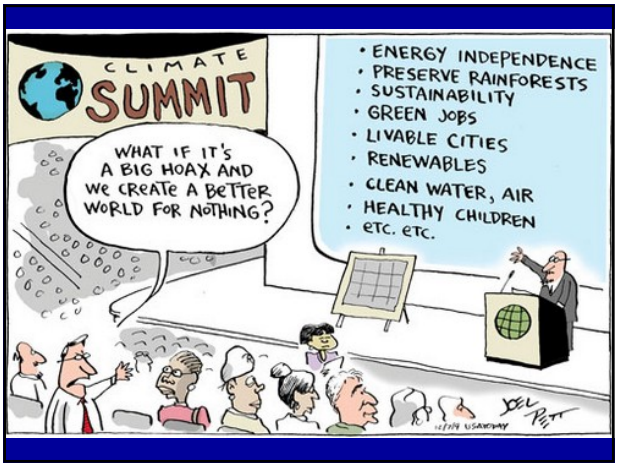
Reducing Meat Consumption Has Multiple Benefits for the World's Health

Co-benefits: Short-lived climate pollutants

Scovronick N, Dora C, Fletcher E, Haines A, Shindell D. 2015. Reduce short-lived climate pollutants for multiple benefits. *Lancet* 386:e28-31.

Co-benefits: Street trees

- Cooler temperatures
- Storm water management
- Promoting physical activity
- Cleaner air
- Beauty
- Mental health
- Other benefits



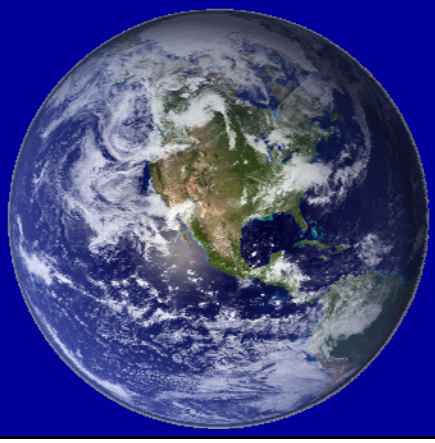
Five reasons for hope

1. Public perception is changing
2. Climate change is no longer "just" an environmental problem
3. China is working toward an efficient and low-carbon society
4. Renewable energy is growing exponentially
5. Carbon pricing is here

Source: Josh Laughton, WWF Canada Climate and Energy Program. http://blog.wwf.ca/blog/2013/03/14/climate-change-five-reasons-for-hope/

Summary

- Climate change is a public health priority.
- Climate mitigation and adaptation are public health strategies.
- There is much we can do, using established tools and strategies of public health and prevention.
- We need to:
  - Innovate
  - Communicate effectively
  - Celebrate co-benefits
  - Hope



Thank you!