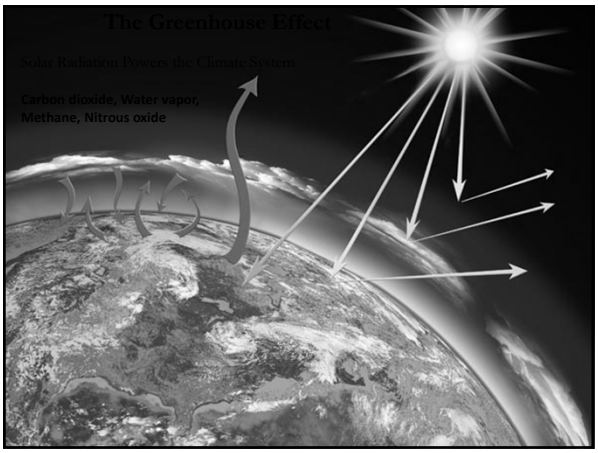
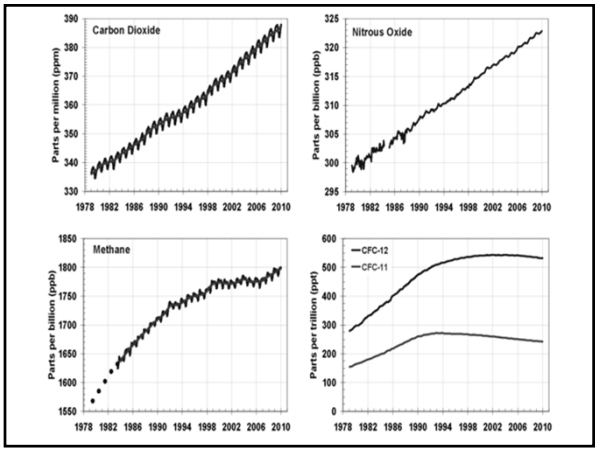
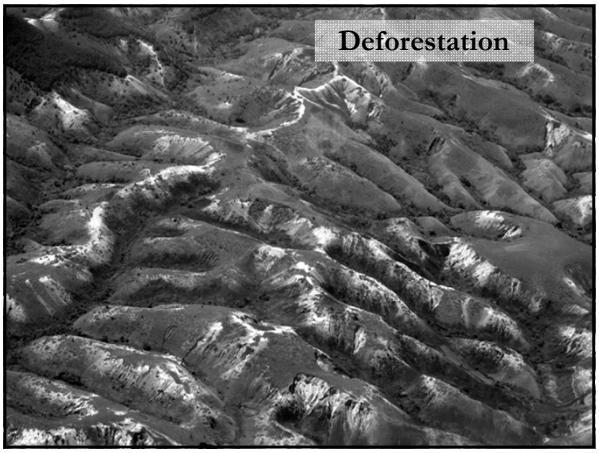
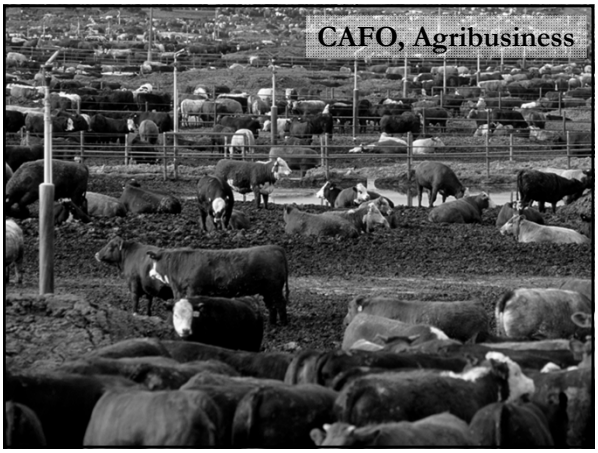
Global Warming and
Climate Change


The Greenhouse Effect
Solar Radiation Powers the Climate System
Carbon dioxide, Water vapor,
Methane, Nitrous oxide


Carbon Dioxide
Parts per million (ppm)
Nitrous Oxide
Parts per billion (ppb)
Methane
Parts per billion (ppb)
CFC-12
CFC-11
Parts per trillion (ppt)
1978 1982 1986 1990 1994 1998 2002 2006 2010

Industrial Pollution


Deforestation


CAFO, Agribusiness

U.S. National Academy of Science and Engineering

May 29, 2011

Some scientific conclusions have been so thoroughly examined and tested, and supported by so many independent observations and results, that their likelihood of being found wrong is vanishingly small. Such conclusions are then regarded as **settled facts**. This is the case for the conclusions that the Earth system is warming and that much of this warming is very likely due to human activities.

very likely = 90-99% probability

…strong evidence on climate change underscores the need for actions to reduce emissions and begin adapting to impacts.

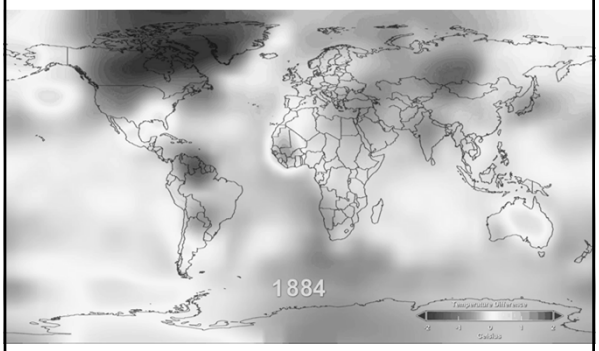
Advancing the Science of Climate Change – National Academies: http://americasclimatechoices.org/

"…the debate on the authenticity of global warming and the role played by human activity is largely nonexistent among those who understand the nuances and scientific basis of long-term climate processes. The challenge, rather, appears to be how to effectively communicate this fact to policy makers and to a public that continues to mistakenly perceive debate among scientists."

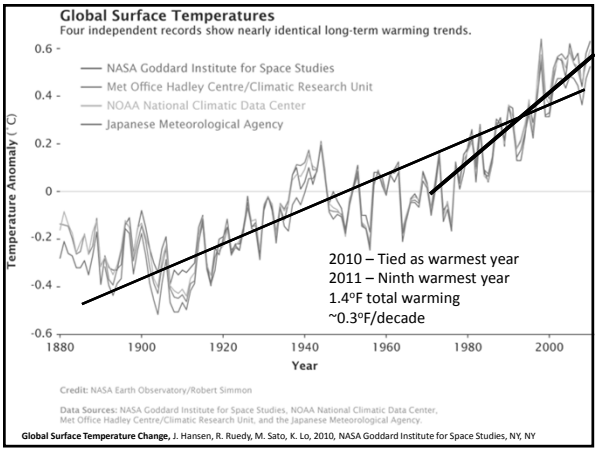
97 out of 100 climate experts think humans are changing global temperature

Doran et al 2009, Anderegg et al 2010

Doran, P.T., Zimmerman, M.K., 2009 Examining the scientific consensus on climate change, EOS, v.90, no.3.

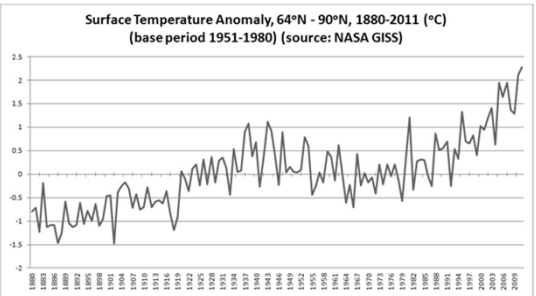


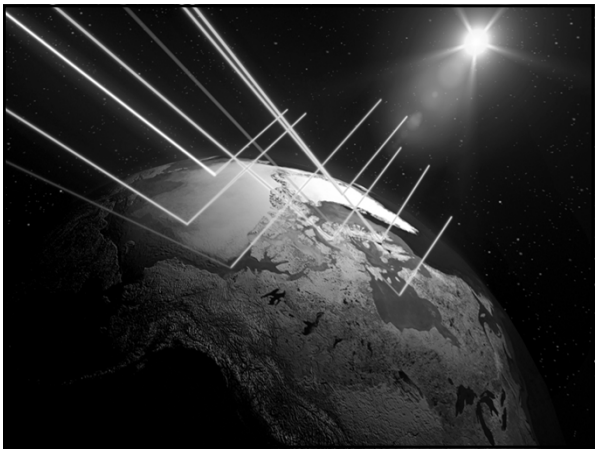
NASA Goddard Institute for Space Studies, NY, NY http://data.giss.nasa.gov/gistemp/

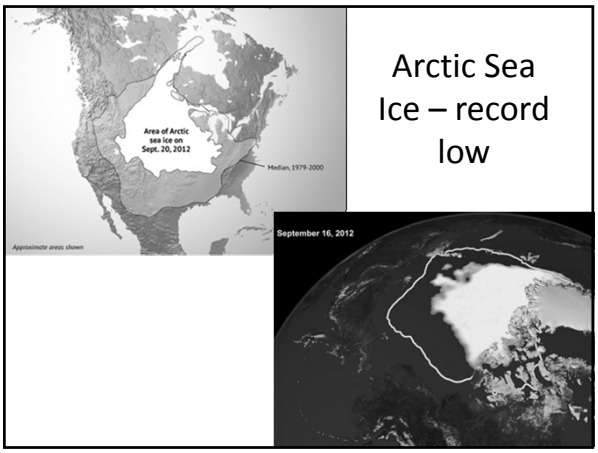


Global Surface Temperature Change, J. Hansen, R. Ruedy, M. Sato, K. Lo, 2010, NASA Goddard Institute for Space Studies, NY, NY

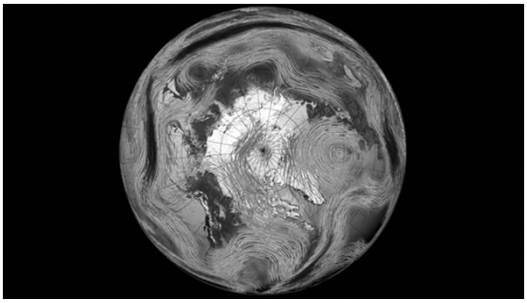
New record in the Arctic – 2nd year in a row "Arctic Amplification"



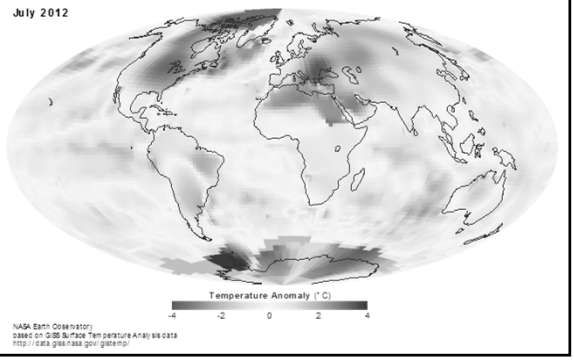




Weird weather-added heat in the Arctic (sea ice retreat) influences the jet stream and may make extreme weather and climate events more likely.

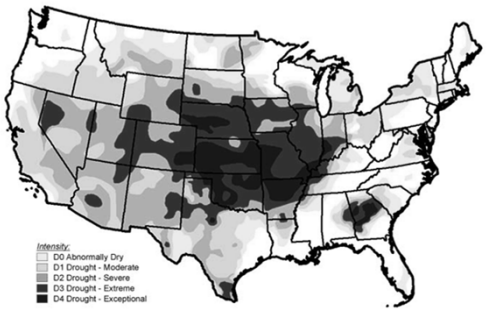


July, 2012 was the hottest month on record in the contiguous U.S.
June-August hottest global land temperature ever recorded



Drought of historic proportions – 4/5ths of U.S.

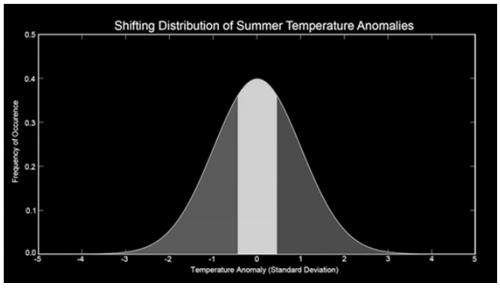
On July 11, 2012 the U.S. Department of Agriculture announced more than 1000 counties in 26 states qualified as natural disaster areas – largest natural disaster in U.S. history.



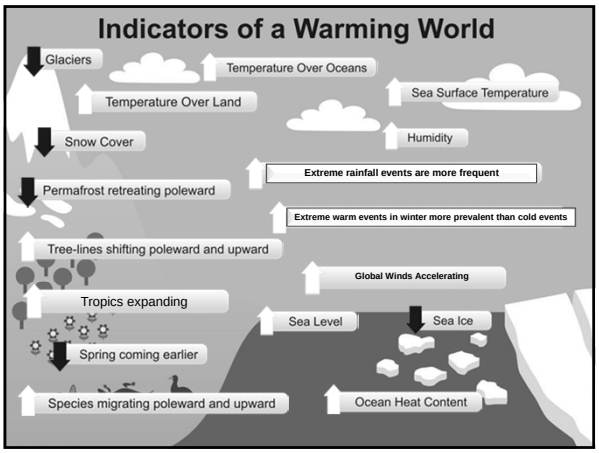
Northern Hemisphere Temperature Anomalies, 1951-2011

"Extremely hot" summer temperatures have gone from occurring on 1% of the land area, to 10% of the land area; 75% of land area experienced summers in the "hot" category during the past decade, compared to only 33% during the 1951 to 1980 base period

- Seasonal mean temperature 1951-1980 plotted at top of the curve. Decreasing in frequency to the right are "hot" anomalies (1-2 σ), "very hot" (2-3 σ), "extremely hot" (>3 σ).

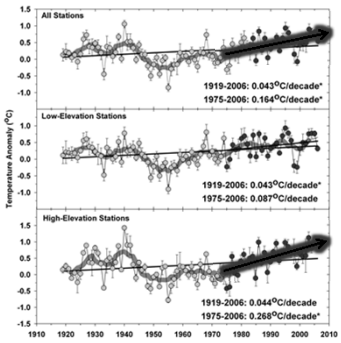


Hansen, J., Mki. Sato, and R. Ruedy, 2012: Perception of Climate Change, *Proc. Natl. Acad. Sci.*, **109**, 14726-14727, E2415-E2423, doi:10.1073/pnas.1205276109.



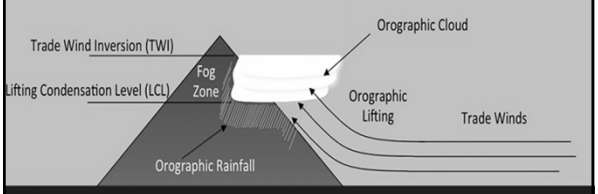
http://www.cfr.org/climate-change/crisis-guide-climate-change/p17088

Hawai'i Temperature Index

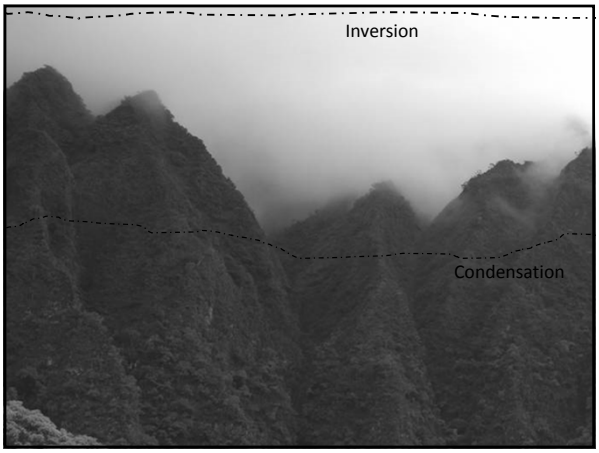


Giambelluca, T.W., Diaz, H.F., and Luke, M.S.A. 2008. Secular temperature changes in Hawai'i. *Geophysical Research Letters* 35, L12702, doi:10.1029/2008GL034377.

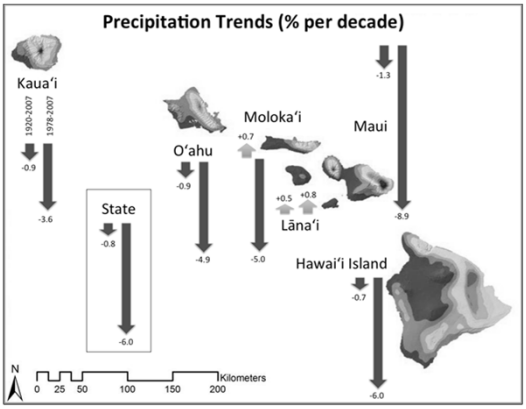
The Orographic Cloud



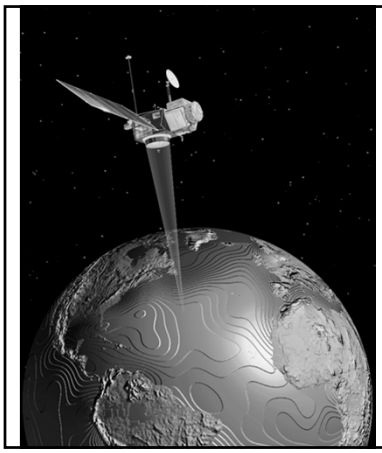
Giambelluca et al. 2011. The Rainfall Atlas of Hawai'i. http://rainfall.geography.hawaii.edu



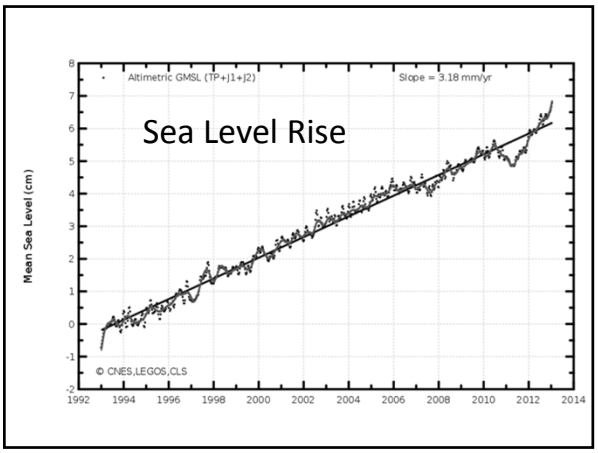
Precipitation Trends (% per decade)



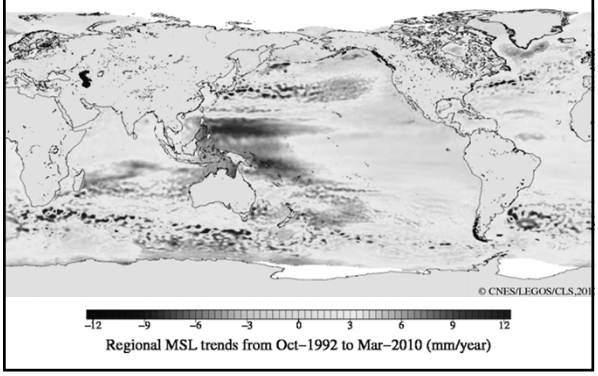
Giambelluca et al. 2011. Regional climate trends in Hawai'i. American Geophysical Union Fall Meeting, Abstract GC21B-0898.

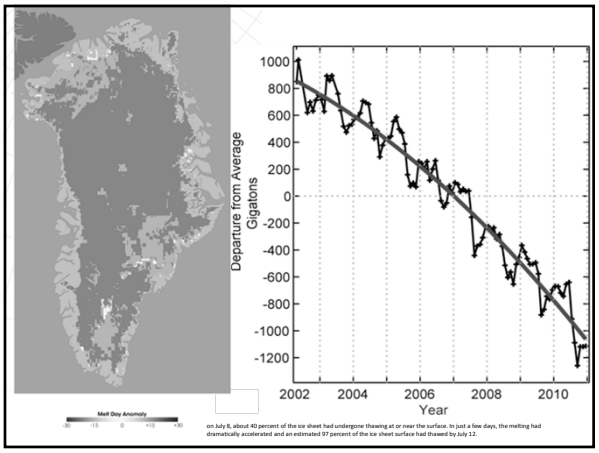


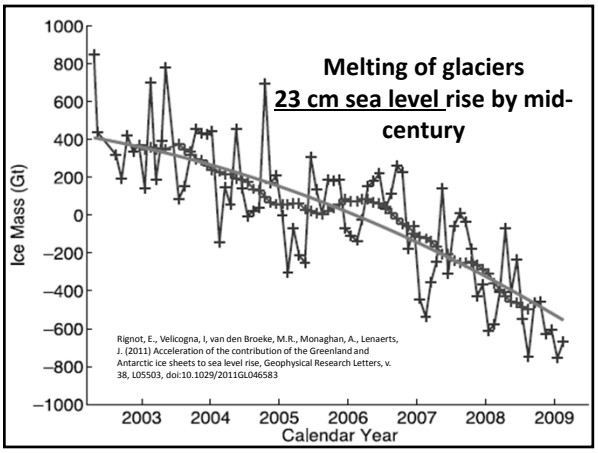
http://www.youtube.com/watch?v=VEuEqgdJXHg



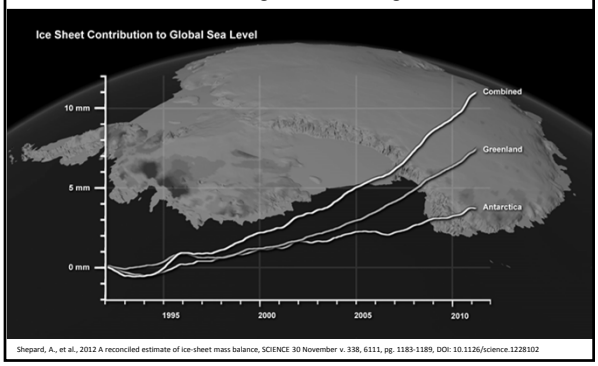
Satellite Altimetry – global average 3.2 mm/yr





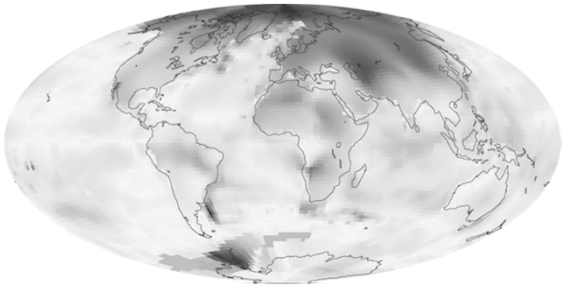


Greenland is losing mass at about five times the rate today as it was in the early 1990s.
Antarctica losing mass at 50% higher rate

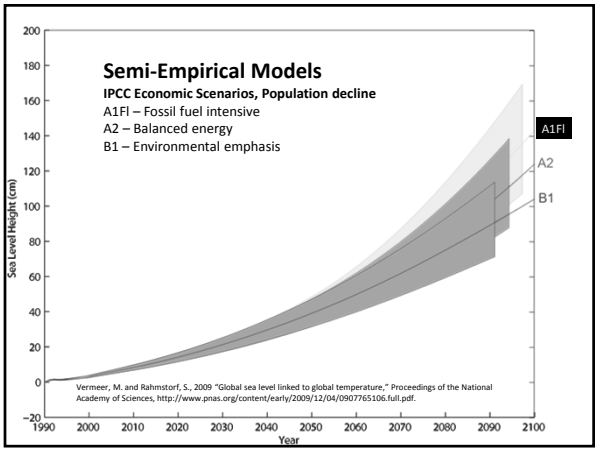


Shepard, A., et al., 2012 A reconciled estimate of ice-sheet mass balance, SCIENCE 30 November v. 338, 6111, pg. 1183-1189, DOI: 10.1126/science.1228102

Thermal expansion of shallow ocean
TOTAL = 32 cm of sea level rise by mid-century
9 cm sea level rise by mid-century



Rignot, E., Velicogna, I, van den Broeke, M.R., Monaghan, A., Lenaerts, J. (2011) Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise, Geophysical Research Letters, v. 38, L05503, doi:10.1029/2011GL046583

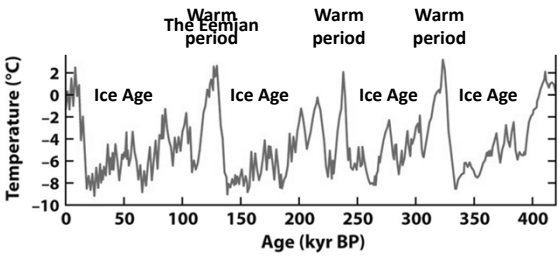


National Research Council, 2012

- 8-23 cm (6 in) by 2030
- 18-48 cm (1 ft) by 2050
- 50-140 cm (3 ft) by 2100

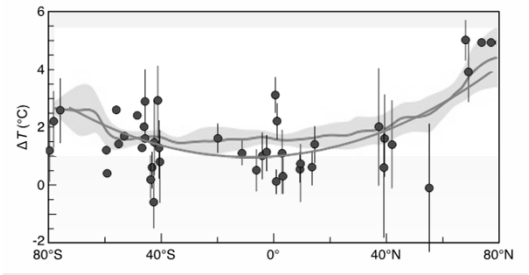
http://www.nap.edu/catalog.php?record_id=13389

Last interglacial was warmer than today and Greenland partially melted

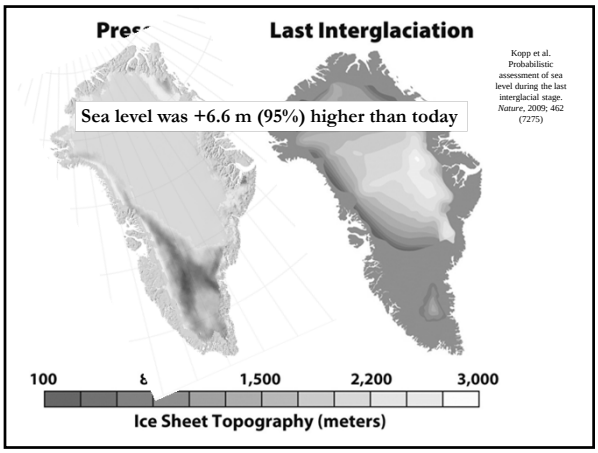


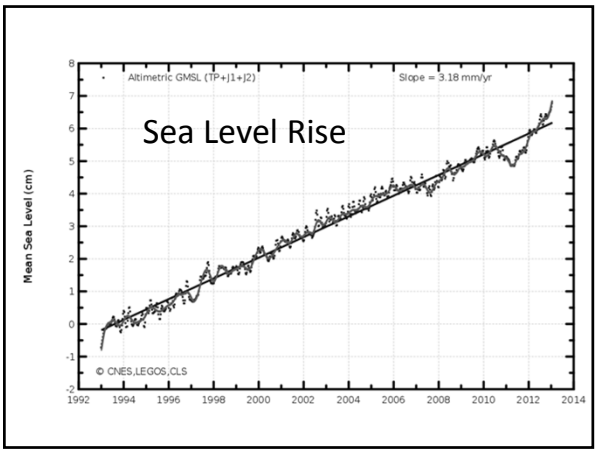
Eemian
Temperature and Sea Level

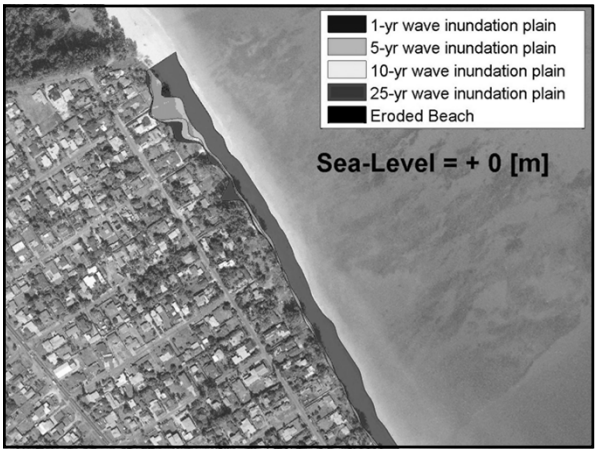
Red dots – temperature (sea surface, ice cores, pollen)
Green line – model of temperature data
Blue – B1, 2100 scenario



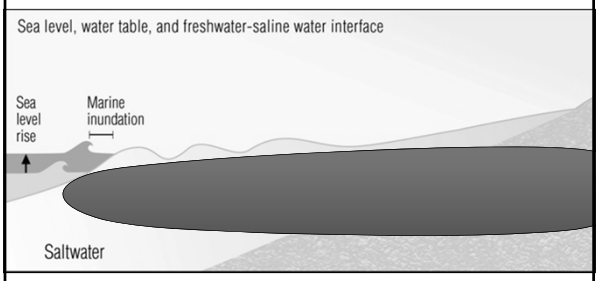
Clark, P.U., and Huybers, P., 2009, Interglacial and future sea level: Nature, v. 462, p. 856-857.


Last Interglaciation
Sea level was +6.6 m (95%) higher than today
Kopp et al. Probabilistic assessment of sea level during the last interglacial stage. *Nature*, 2009; 462 (7275)
100
1,500
2,200
3,000
Ice Sheet Topography (meters)


Sea Level Rise
Altimetric GMSL (TP+J1+J2)
Slope = 3.18 mm/yr
Mean Sea Level (cm)
© CNES,LEGOS,CLS
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


1-yr wave inundation plain
5-yr wave inundation plain
10-yr wave inundation plain
25-yr wave inundation plain
Eroded Beach
Sea-Level = + 0 [m]

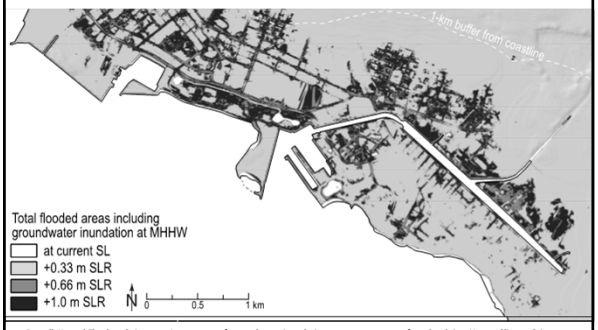
Groundwater Inundation



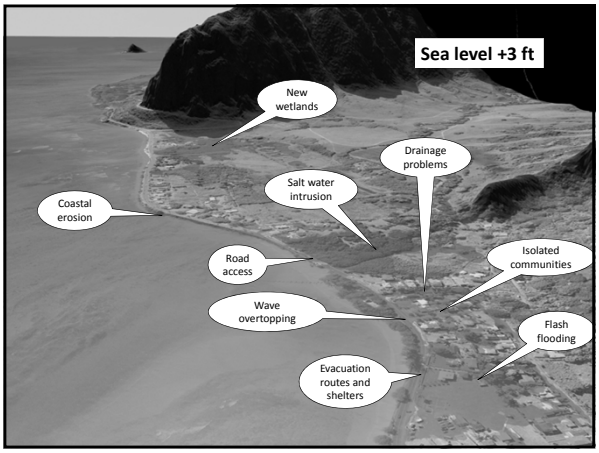
Rotzoll, K., and Fletcher, C. *in press*, Assessment of groundwater inundation as a consequence of sea-level rise. Nature Climate Science

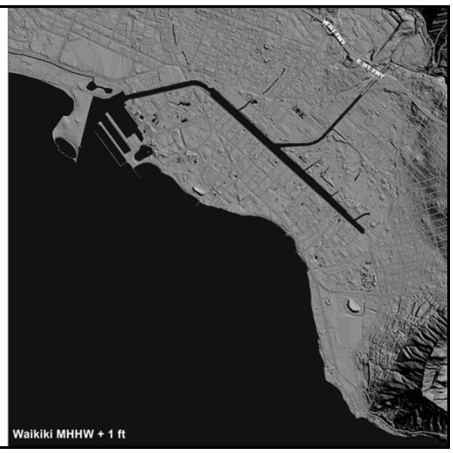
Marine and Groundwater Inundation

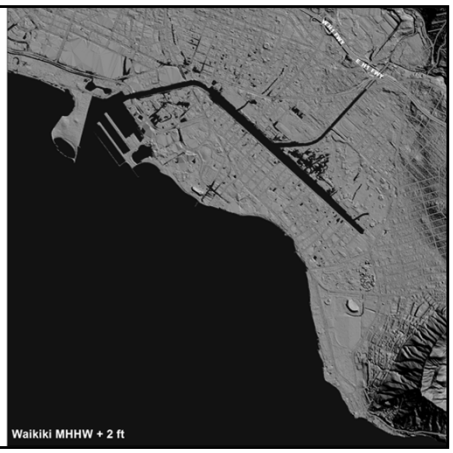
At 0.66 m, 69% of total flooded area is due to groundwater inundation

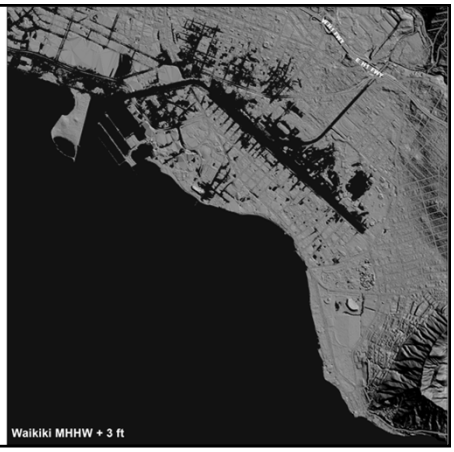


Rotzoll, K., and Fletcher, C. *in press*, Assessment of groundwater inundation as a consequence of sea-level rise. Nature Climate Science







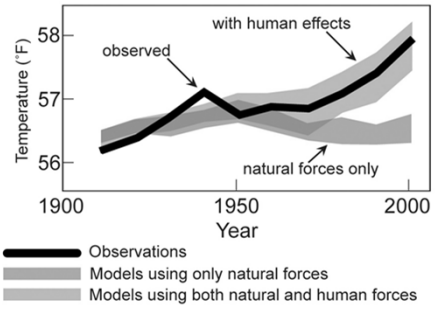


http://blogs.agu.org/sciencecommunication/2013/02/25/agu-video-speak-up-about-climate-change-science-communicators-say/

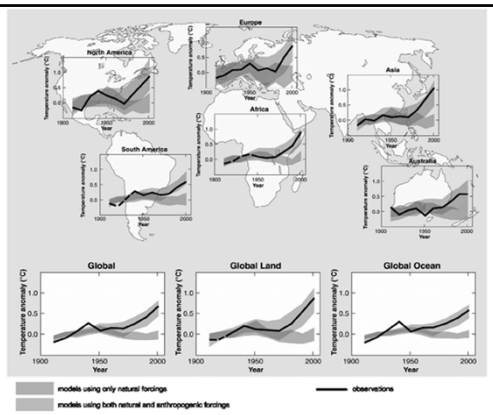
http://www.ted.com/talks/james_hansen_why_i_must_speak_out_about_climate_change.html

Intergovernmental Panel on Climate Change

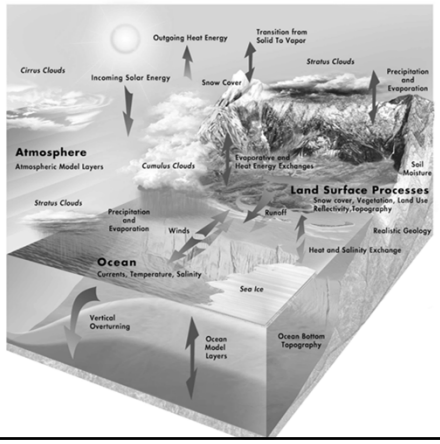
1990
1995
2001
2007
2014

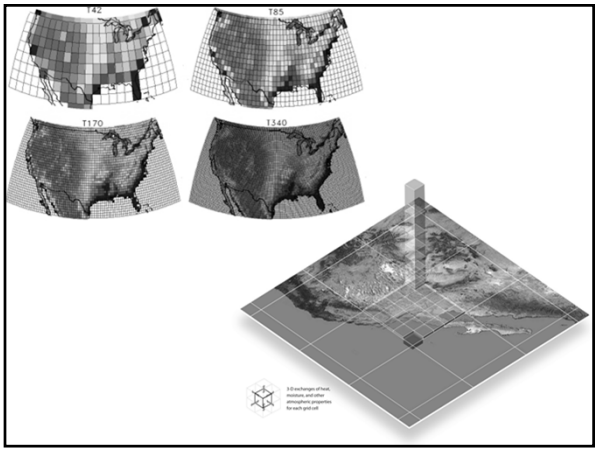


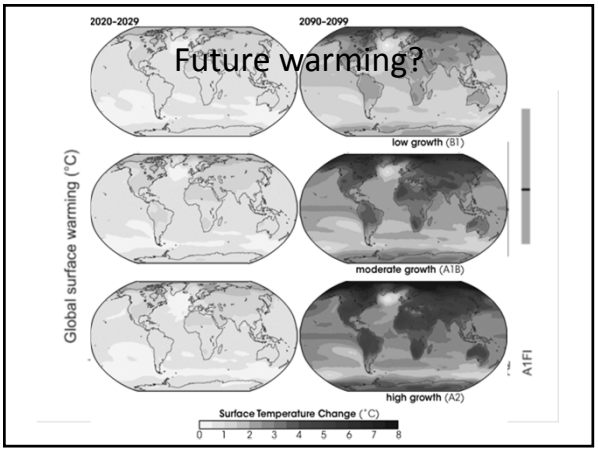
The blue band shows how global average temperatures would have changed due to natural forces only, as simulated by climate models. The red band shows model projections of the effects of human and natural forces combined. The black line shows actual observed global average temperatures. As the blue band indicates, without human influences, temperature over the past century would actually have first warmed and then cooled slightly over recent decades.



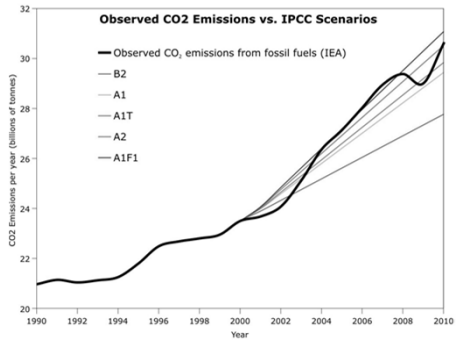
IPCC, 2007 – Intergovernmental Panel on Climate Change

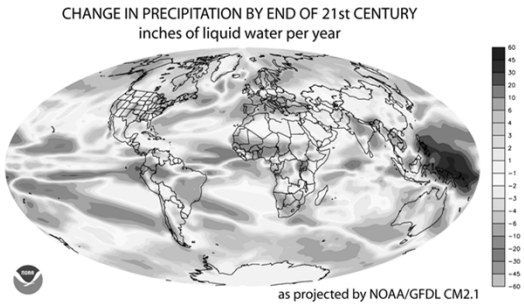






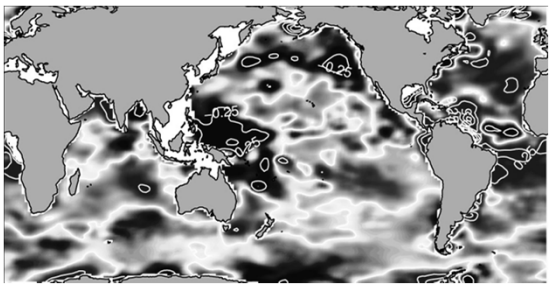
CO_2 Production

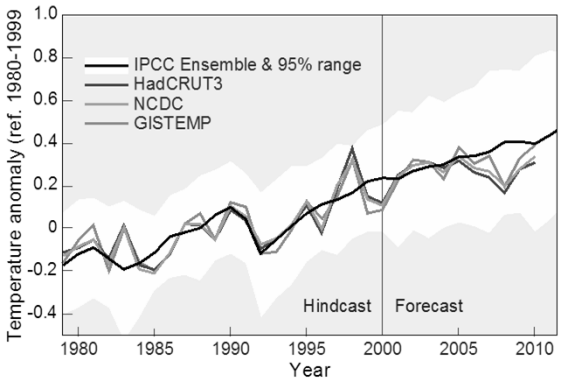


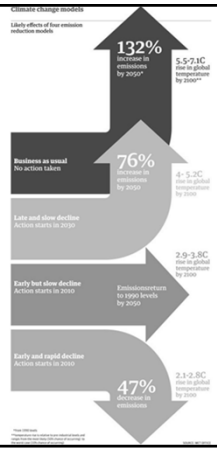


Surface salinity change over the period 1950–2000.

Rainfall and evaporation changes are making the oceans less salty in vast regions (blue) and more salty elsewhere (red). Research shows that while the surface warmed 0.5°C, the water cycle has sped up roughly 4%, twice as fast as predicted by most climate models. These results also indicate that in general, wet areas got wetter and dry areas got drier.





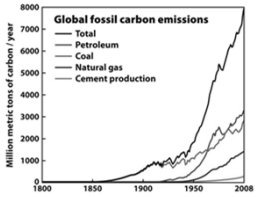


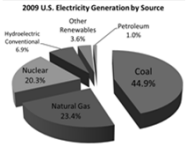
Red and Orange Arrows

- Hundreds of millions of people exposed to increased water stress
- 30–40% of species at risk of extinction around the globe
- About 30% of global coastal wetlands lost
- Increased damage from floods and storms
- Widespread coral mortality
- Many ecosystems severely damaged
- Reduction in food production
- Increased mortality from heat waves, floods and droughts

Mitigation – human intervention to reduce the sources or enhance the sinks of greenhouse gases

- Alternative energy sources
  - Renewable
- Energy efficiency and conservation
  - Transportation/Urban Design
  - Reforestation (land preservation)
  - Mass transit
- Geoengineering
  - Bio energy
  - Carbon capture and storage
  - Radiation management





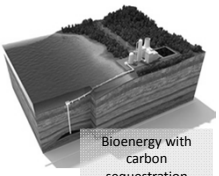
Alternative energy sources

Renewable, Electric/Hybrid mass transit

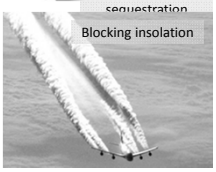
Electric/hybrid Mass transit <1/4 cost of gasoline, emissions -40%

Geoengineering

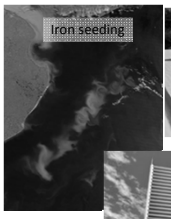
Bio energy with carbon capture and storage, Carbon Air capture, Carbon capture and storage, Radiation management



Bioenergy with carbon sequestration

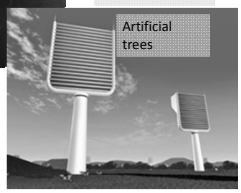


Blocking insolation



Iron seeding

Reflective surfaces



Artificial trees

Adaptation – actions to tolerate the effects of warming

- Enhancing adaptive capacity
  - Improving access to resources
  - Improving education
  - Improving infrastructure
  - Community-based planning
- Agriculture during drought
  - Improve emergency response
  - Drought tolerant crops
  - Rainwater storage
- Coastal communities
  - Retreat and abandon
  - Stay and defend
  - Combination, phased adaptation

King Tides

Pacific Islands have special needs and important skills