

Climate in the Future AOSC 200

Tim Canty

Class Web Site: <http://www.atmos.umd.edu/~tcanty/aosc200>

Topics for today:

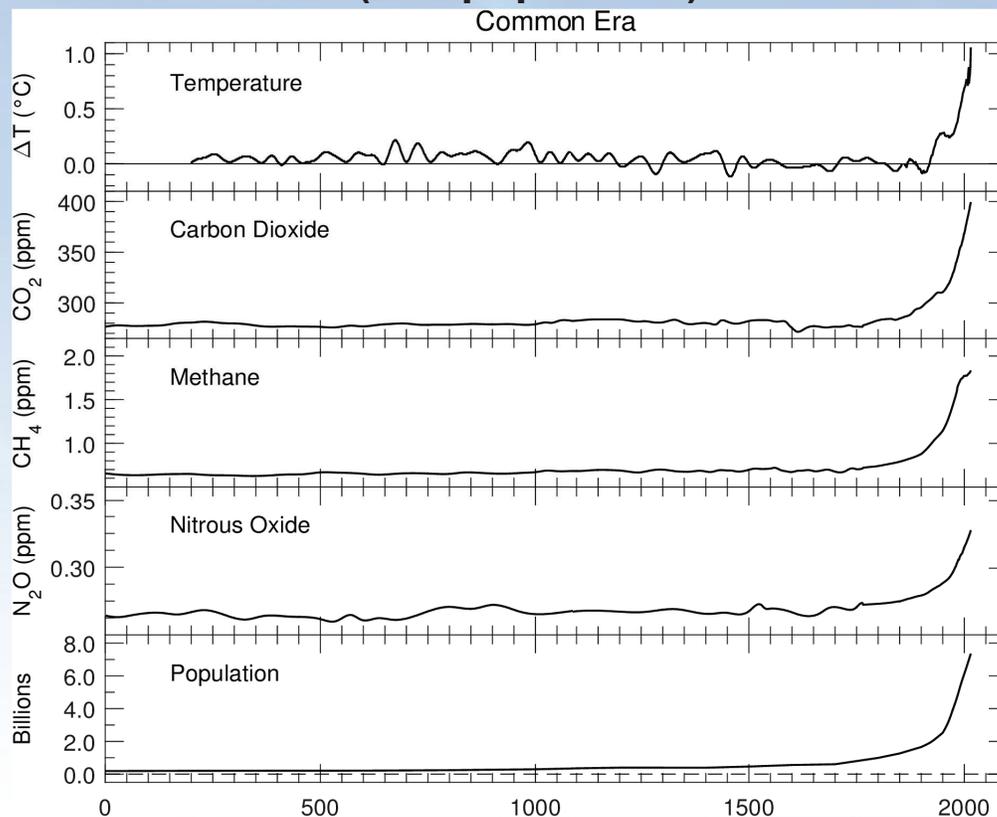
Evidence of a changing climate
Possible issues associated with a changing climate

Lecture 28
Dec 5 2019

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1

Increase in temperature is correlated with increase in GHGs (and population)



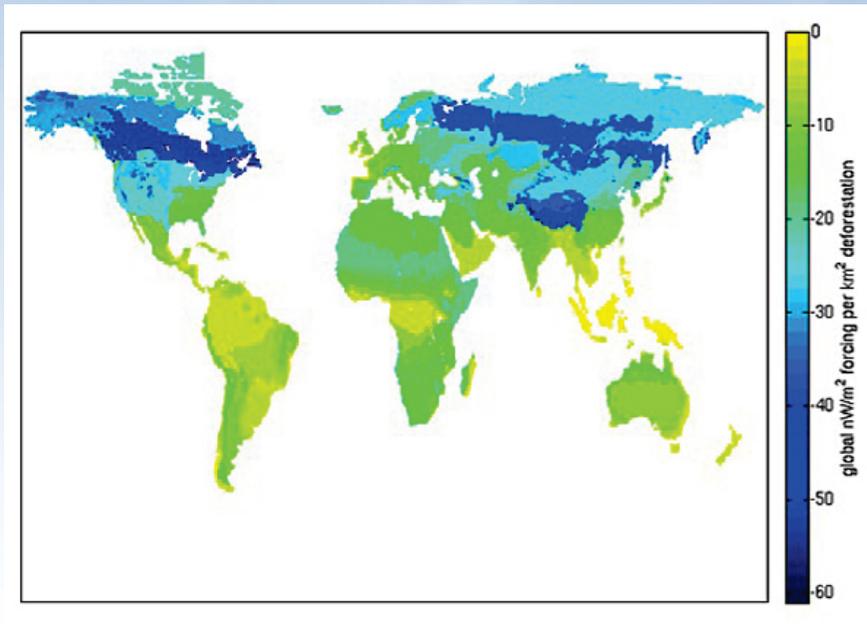
<http://www.parisbeaconofhope.org/index.htm>

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2

Land use change

Converting forests to land for agriculture may decrease radiative forcing (cooling). Albedo increases as snow on the ground is more reflective than snow on trees.



<http://esd.lbl.gov/radiative-forcing-albedo-in-land-use-scenarios/>

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Aerosol: Direct Climate Effect

Aerosols are often brighter than the surface and reflect incoming solar radiation. This leads to cooling.



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Aerosol: Direct Climate Effect

Some aerosols are darker and lead to regional warming. May explain retreat of Himalayan glaciers.



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<http://www.nature.com/climate/2007/0709/full/climate.2007.41.html>

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Aerosol: Direct Climate Effect

Dark aerosols on snow will decrease albedo and lead to increased absorption of solar energy and snow melt.



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<http://earthobservatory.nasa.gov/Features/Aerosols/page3.php>

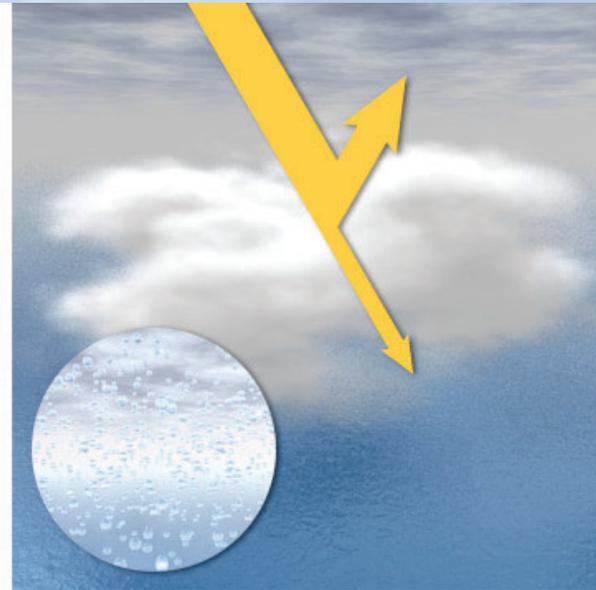
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Aerosol: Indirect Climate Effect

Aerosols = cloud condensation nuclei



Clean air: clouds made of fewer, larger drops. Cloud is darker



Dirty air: clouds made of many smaller drops. Cloud is brighter

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Influences on Climate

To try and predict future climate, we need to understand past climate

Understanding past climate allows us to separate natural changes in climate from human-made (anthropogenic)

Need to understand how changing climate can lead to further changes (feedback mechanisms)

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Climate Feedback

A climate feedback mechanism is a climate response to an initial change

Positive Feedback: amplifies the initial change

Negative Feedback: diminishes the initial change

Feedback mechanisms are one of the big “unknowns” in climate research

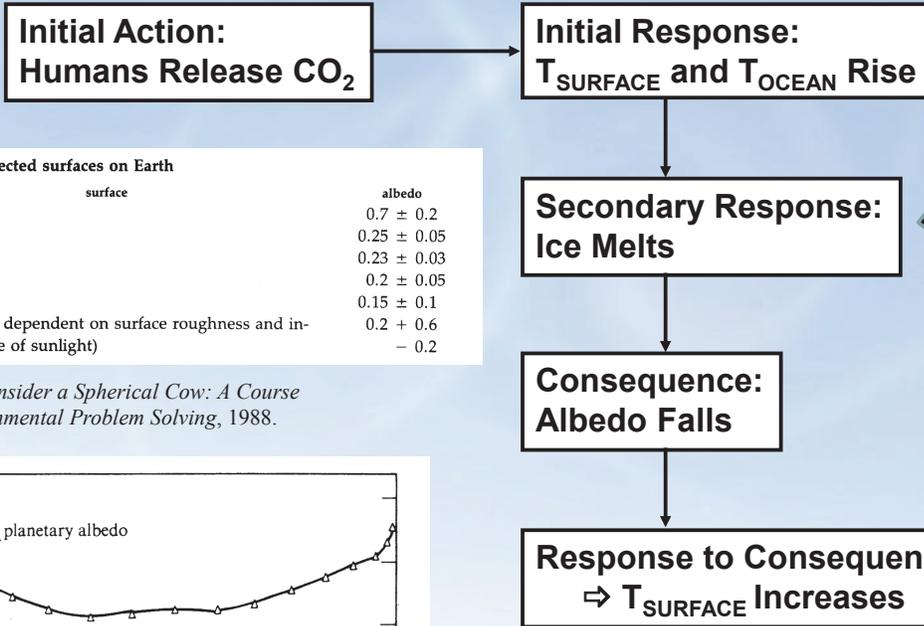
Understanding climate feedbacks vital to predicting climate trends.

Ice-Albedo Feedback

A rise in temperature, caused by increasing greenhouse gases like CO₂, will cause a further increase in temperature

How will this affect ice?

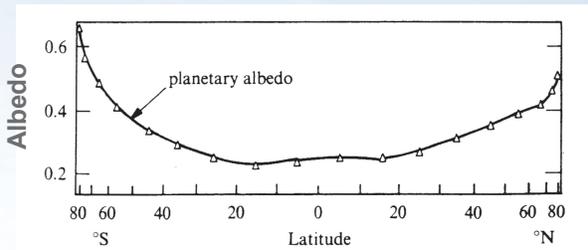
Ice-Albedo Feedback



2. Albedos of selected surfaces on Earth

surface	albedo
snow	0.7 ± 0.2
sand	0.25 ± 0.05
grasslands	0.23 ± 0.03
bare soil	0.2 ± 0.05
forest	0.15 ± 0.1
water (highly dependent on surface roughness and incident angle of sunlight)	0.2 ± 0.6 - 0.2

Harte, *Consider a Spherical Cow: A Course in Environmental Problem Solving*, 1988.

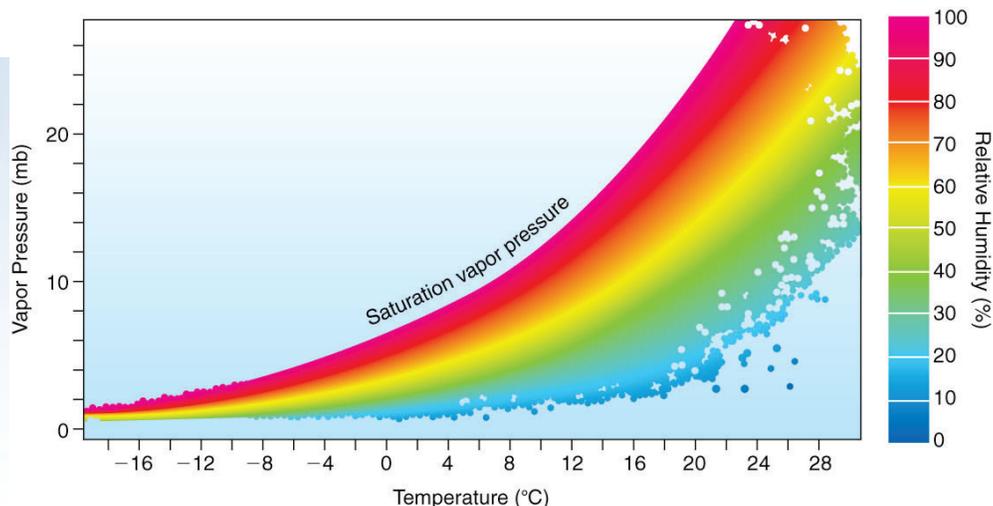


Houghton, *The Physics of Atmospheres*, 1991.

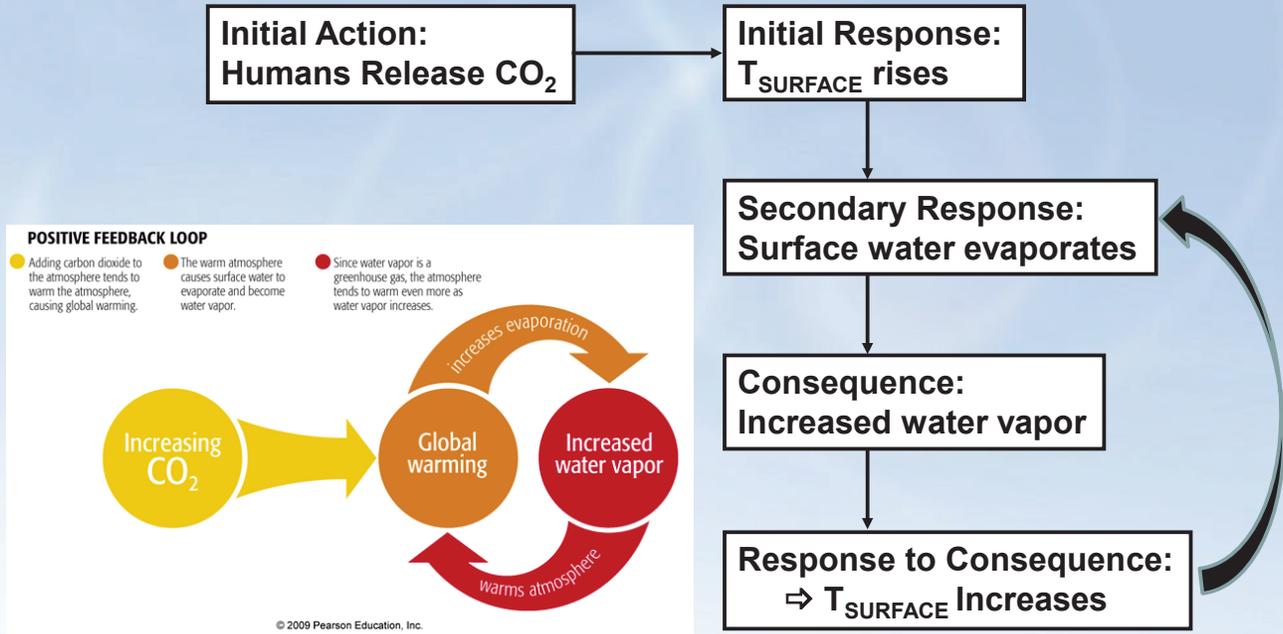
Water Vapor Feedback

A rise in temperature caused by increasing greenhouse gases, like CO₂, will cause an increase in temperature

How will this affect H₂O vapor?

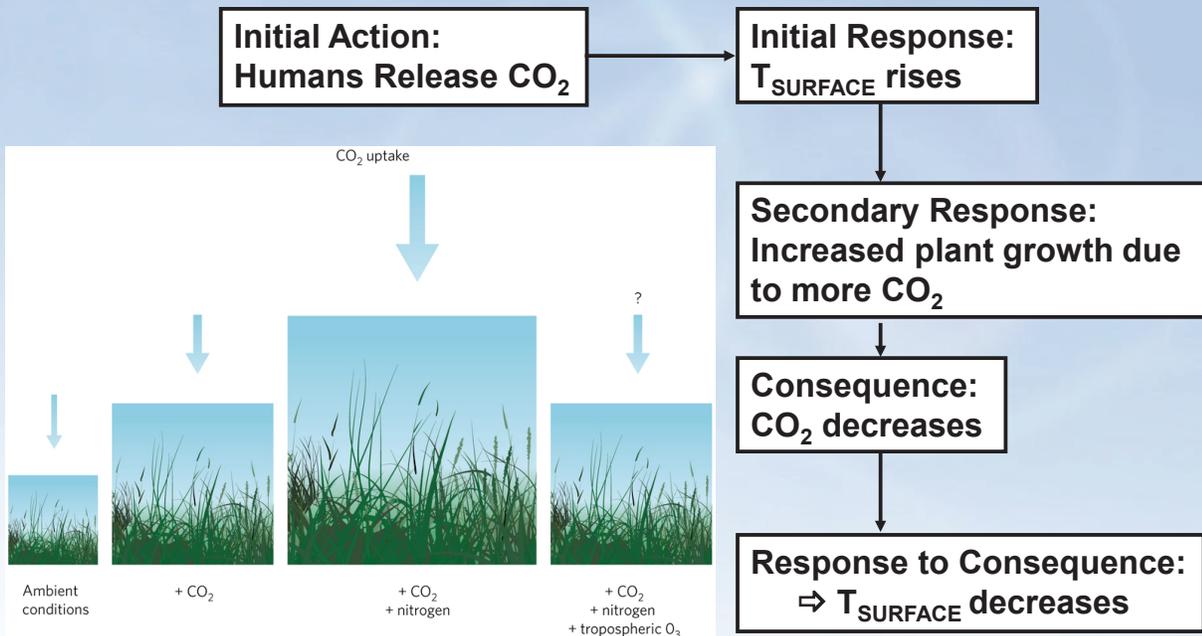


Water Vapor Feedback



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CO₂ Feedback: Plants



This is a negative feedback

<http://www.nature.com/nclimate/journal/v3/n3/full/nclimate1841.html>

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Cloud Feedback

Increased temperatures can increase the amount of water vapor which, in turn, can lead to an increase in clouds

How will clouds affect temperatures?



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Cloud Feedback

Increased temperatures can increase the amount of water vapor which, in turn, can lead to an increase in clouds

How will clouds affect temperatures?

This one's tricky?

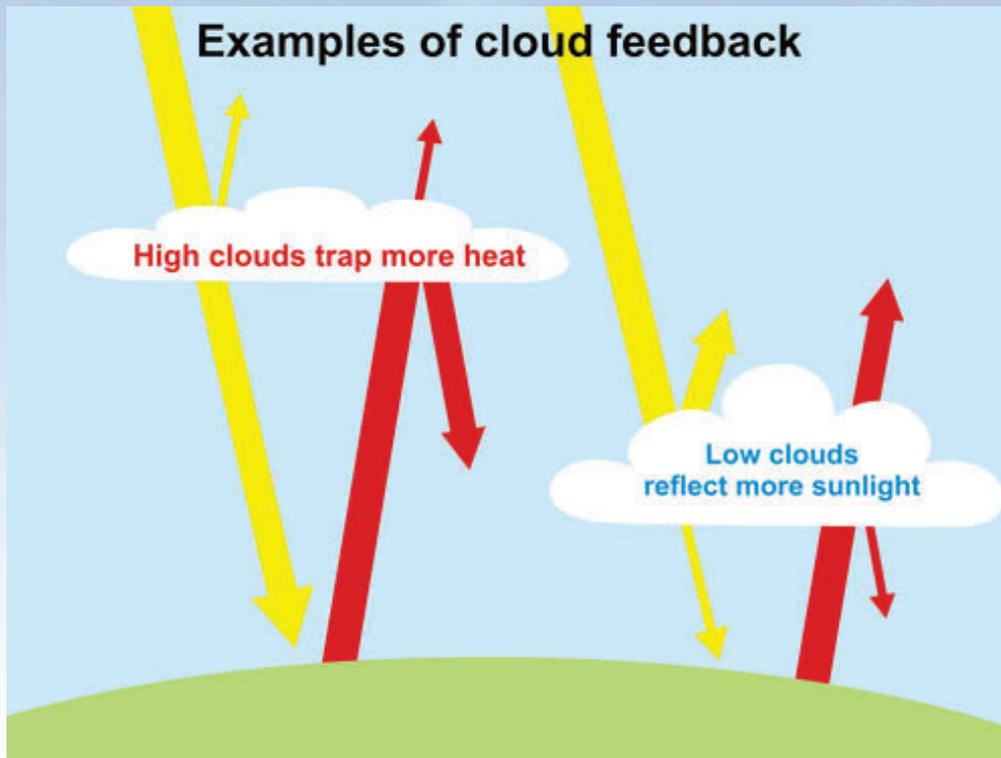
Clouds can either lead to more warming or more cooling

Cloud feedback is one of the largest uncertainties in climate science

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Cloud Feedback



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Climate Change

What is Climate Change?

“Any systematic change in the long-term statistics of climate elements (such as temperature, pressure, or winds) sustained over several decades or longer.”

http://glossary.ametsoc.org/wiki/Climate_change

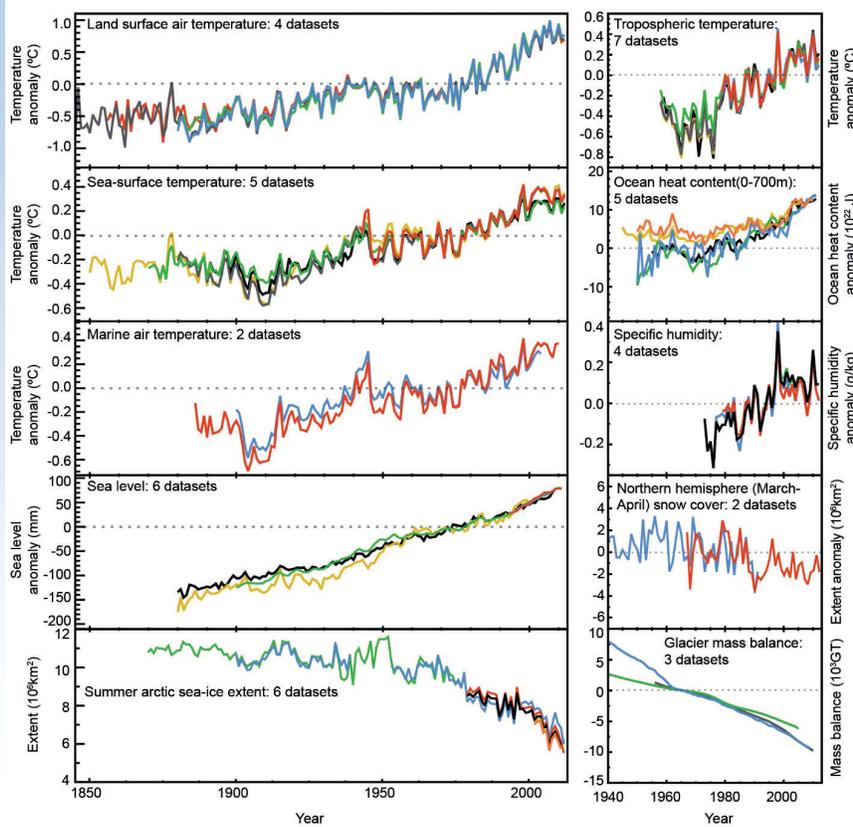
We’ve focused on temperature.

Are there other indications of a changing climate?

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Evidence that climate is changing?



Numerous data sets indicate long term changes in the Earth system.

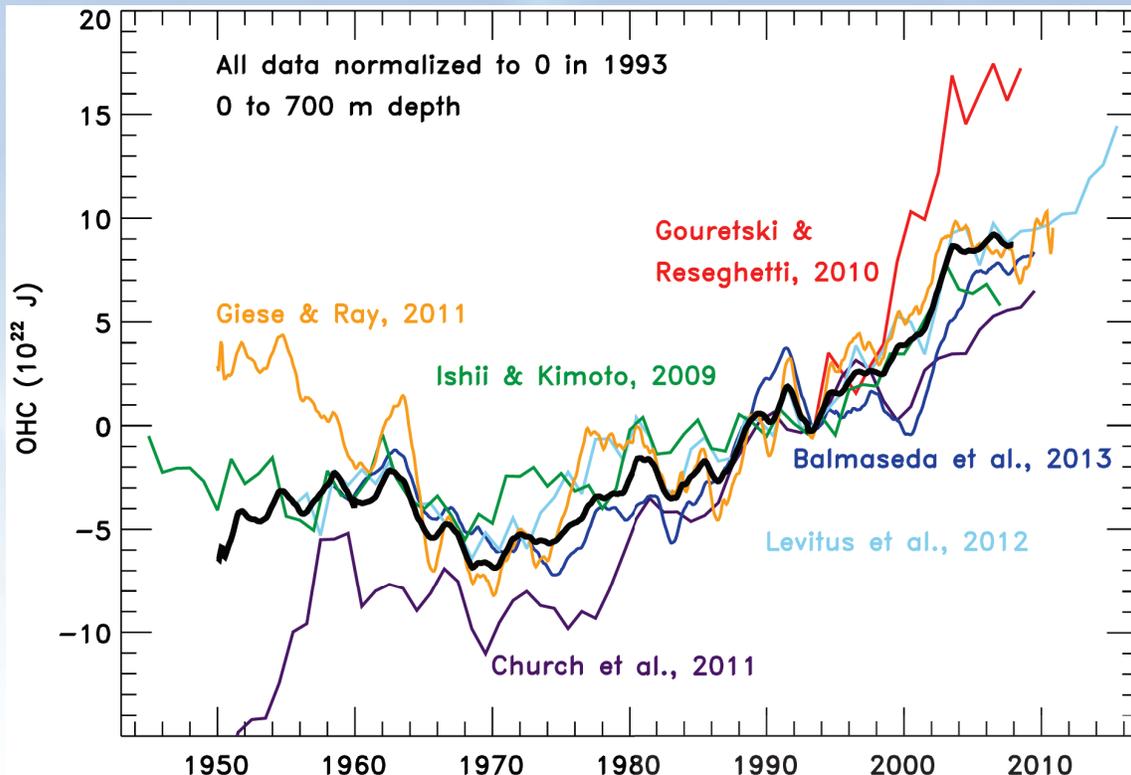
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http://www.climatechange2013.org/images/report/WG1AR5_TS_FINAL.pdf

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Increase in Energy in Oceans since 1970



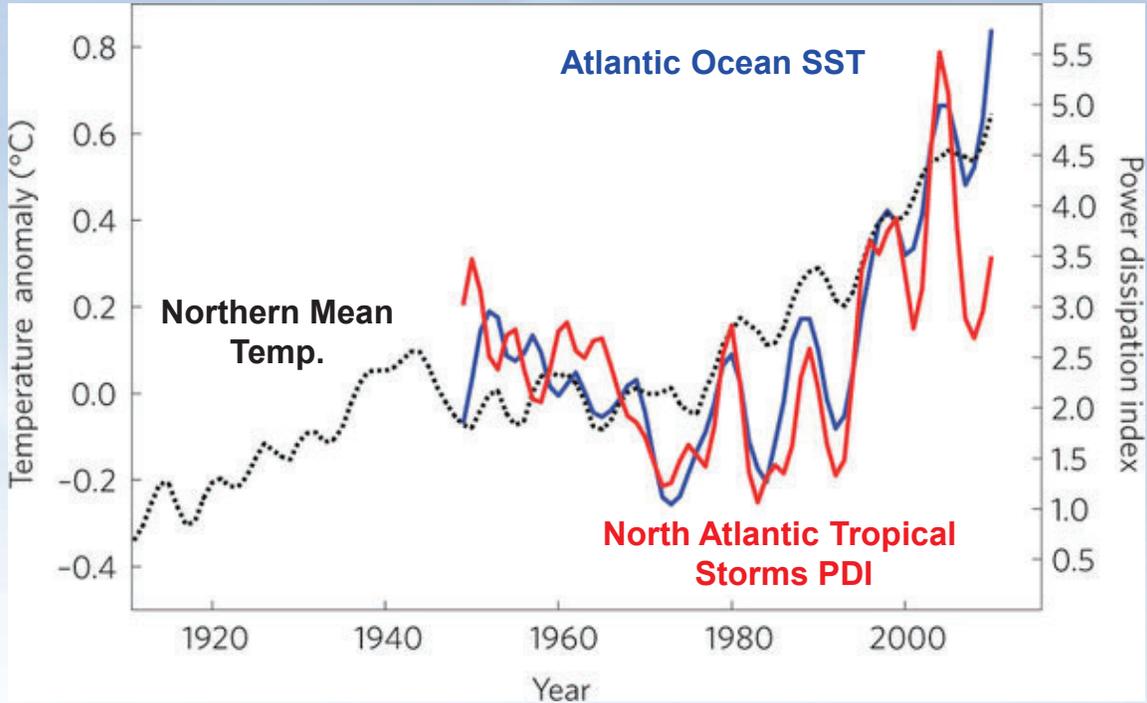
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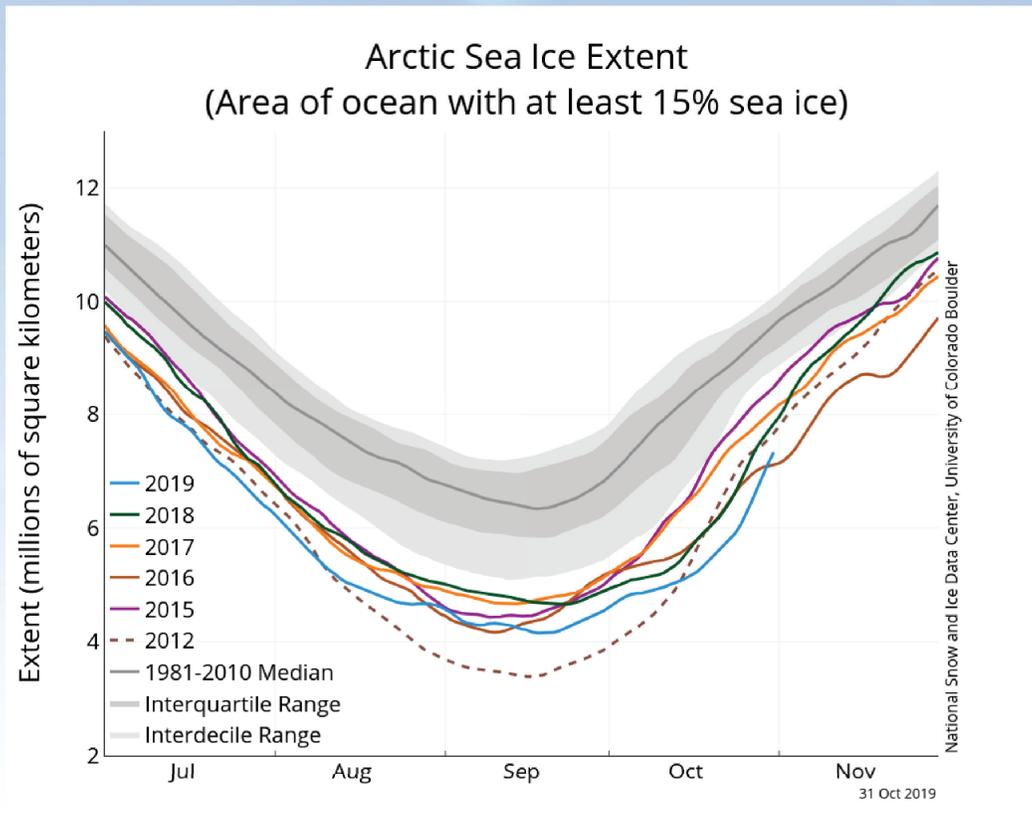
Atlantic Tropical Storms



Since the 1950's, the amount of energy (power dissipation) in tropical storms has been closely correlated with Atlantic Ocean temperature

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Arctic Sea Ice Loss

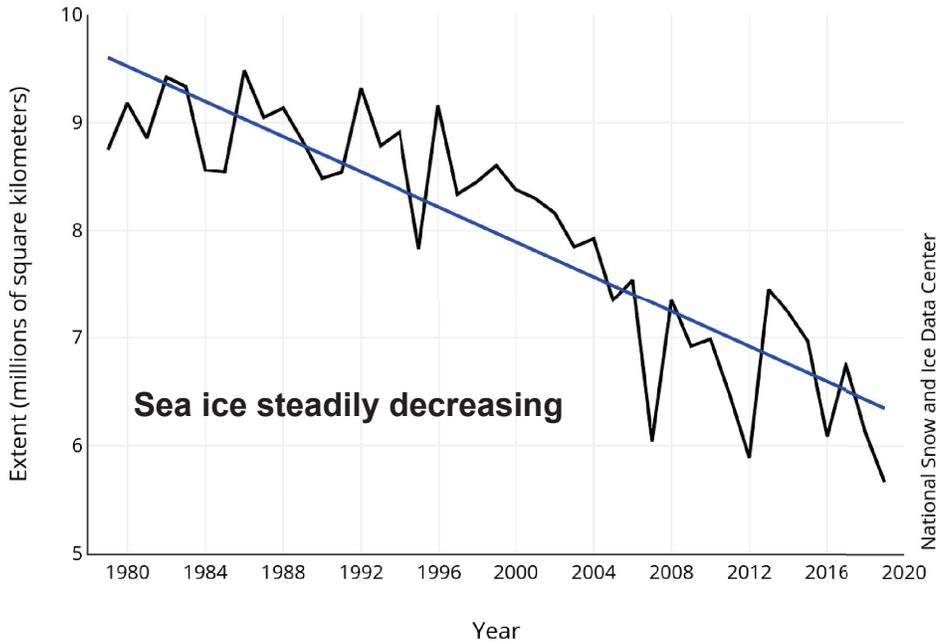


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<https://nsidc.org/arcticseaicenews/>

Arctic Sea Ice Loss

Average Monthly Arctic Sea Ice Extent
October 1979 - 2019



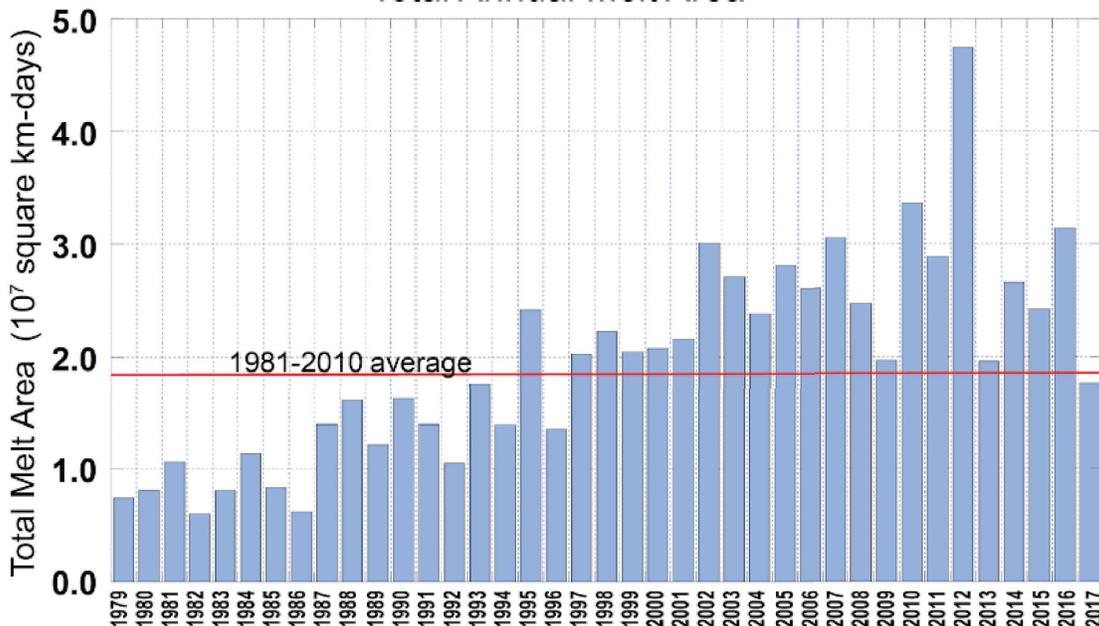
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<https://nsidc.org/arcticseaicenews/>

Greenland is melting...

Total Annual Melt Area



<https://nsidc.org/greenland-today/>

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Greenland is melting...faster

www.sciencemag.org/news/2017/02/great-greenland-meltdown

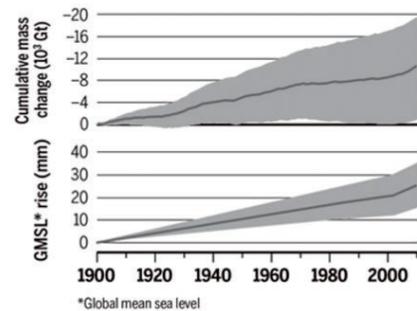
og in chicago | Emissions Inventory | Extreme Weather | National WeatherAssn

The great Greenland meltdown

By Eli Kintisch | Feb. 23, 2017, 8:00 AM

From a helicopter clattering over Greenland's interior on a bright July day, the ice sheet below tells a tale of disintegration. Long, roughly parallel cracks score the surface, formed by water and pressure; impossibly blue lakes of meltwater fill depressions; and veiny networks of azure streams meander west, flowing to the edge of the ice sheet and eventually out to sea.

Cumulative mass loss has risen in recent years, along with Greenland's contribution to sea level rise.



(Graphic) G. Grullón/Science;
(Data) Kjeldsen et al., *Nature*
(17 December 2015)

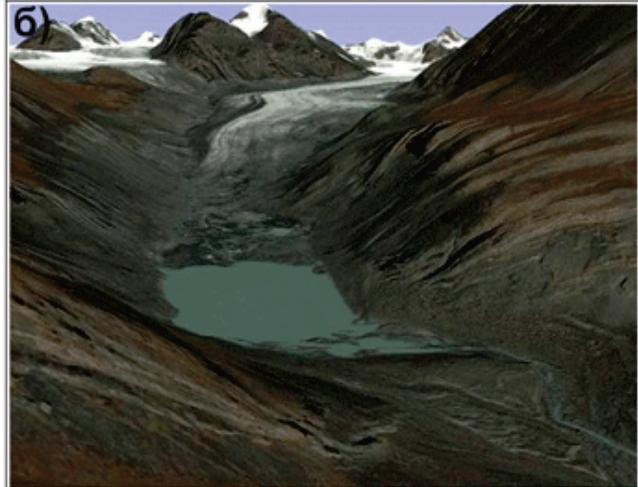
<http://www.sciencemag.org/news/2017/02/great-greenland-meltdown>

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Glacial Retreat

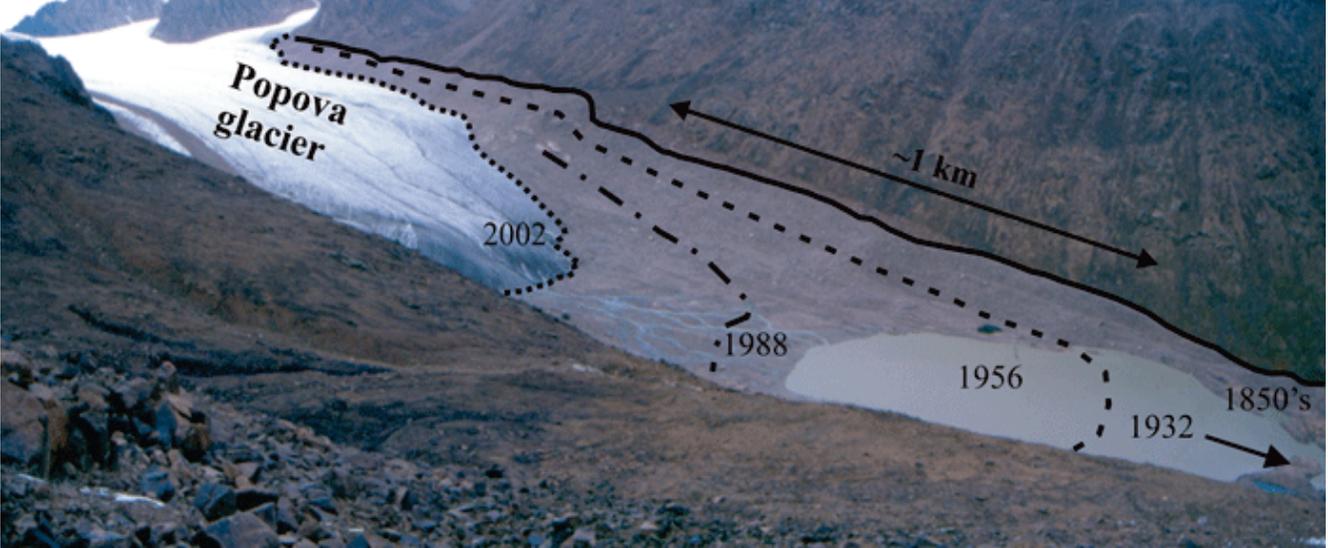


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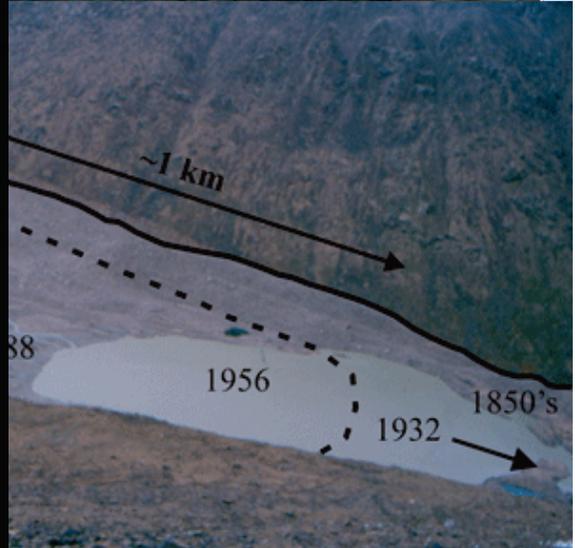
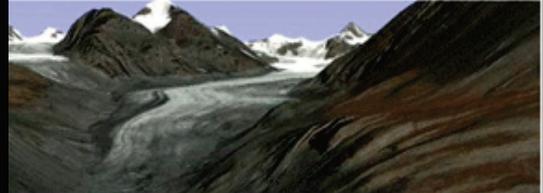
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Glacial Retreat



Pedersen Glacier Retreat



Pedersen

Muir and Riggs Glaciers

a)



2004



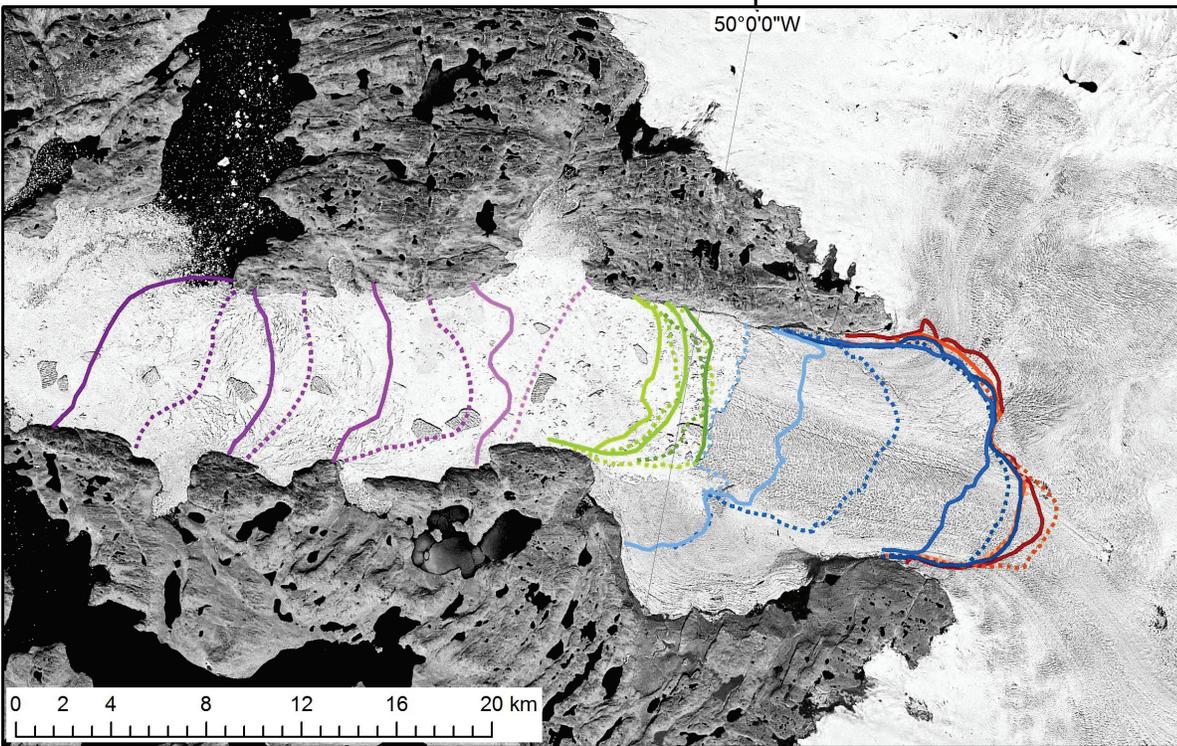
1941

Copy This

29

Pedersen

Muir and Riggs Glaciers



1941

Copy This

30

Glacial Retreat (?)

The screenshot shows the top portion of a Live Science article. At the top right is a dark blue button labeled 'EXPLORE NOW'. Below it is the Live Science logo, which consists of a stylized orange and black atom-like symbol followed by the text 'livescience' in white and orange. To the right of the logo are social media icons for Facebook and Twitter. Below the logo is a navigation menu with the words 'TECH HEALTH PLANET EARTH SPACE STRANGE' in white. Underneath that is a 'TRENDING:' section with several categories: 'Wearable Tech // Archaeology // Military & Spy Tech // 3D Printing // OurAmazingPlanet'. The main title of the article is 'Why Asia's Glaciers Are Mysteriously Expanding, Not Melting' in a large, grey font. Below the title is the author information: 'By Stephanie Pappas, Live Science Contributor | October 12, 2014 03:01pm ET'. To the left of the main image is a social sharing widget with buttons for '1016' (Facebook share count), 'Share' (Facebook icon), '93' (Twitter share count), and 'Tweet' (Twitter icon). The main image is a photograph of a snow-capped mountain peak. To the right of the image is a text box that says 'Updated on Oct. 13 at 11:33 a.m. ET.' and a paragraph of text starting with 'Glaciers around the world are melting, retreating and even vanishing altogether. But in the mountainous Karakoram region...'

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Shrinking glaciers are indicated in red Blue represents the glaciers that are increasing

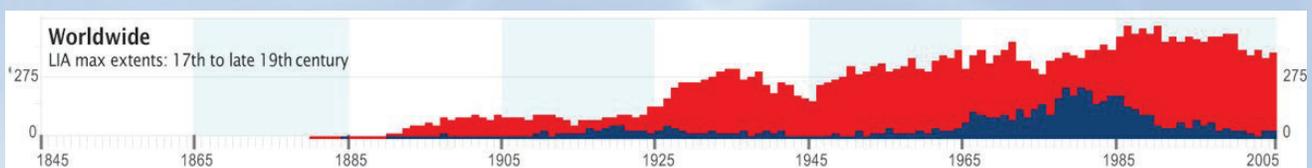


Fig. 5.1 Glacier length changes - Temporal overview on short-term glacier length changes. The number of advancing (blue) and retreating (red) glaciers are plotted as stacked columns in the corresponding survey year. This figure shows 30 420 length change observations with a time range of less than 4 years (between survey and reference year). This corresponds to almost 85 per cent of the reported data which in addition include observations covering a longer time scale and/or stationary conditions. The time period of glacier LIA maximum extents is given according to the regional information in Chapter 6. Note that the scaling of the number of glaciers on the y-axis changes between the regions. Source: figure based on data analysis by R. Prinz, University of Innsbruck, Austria; data from WGMS..

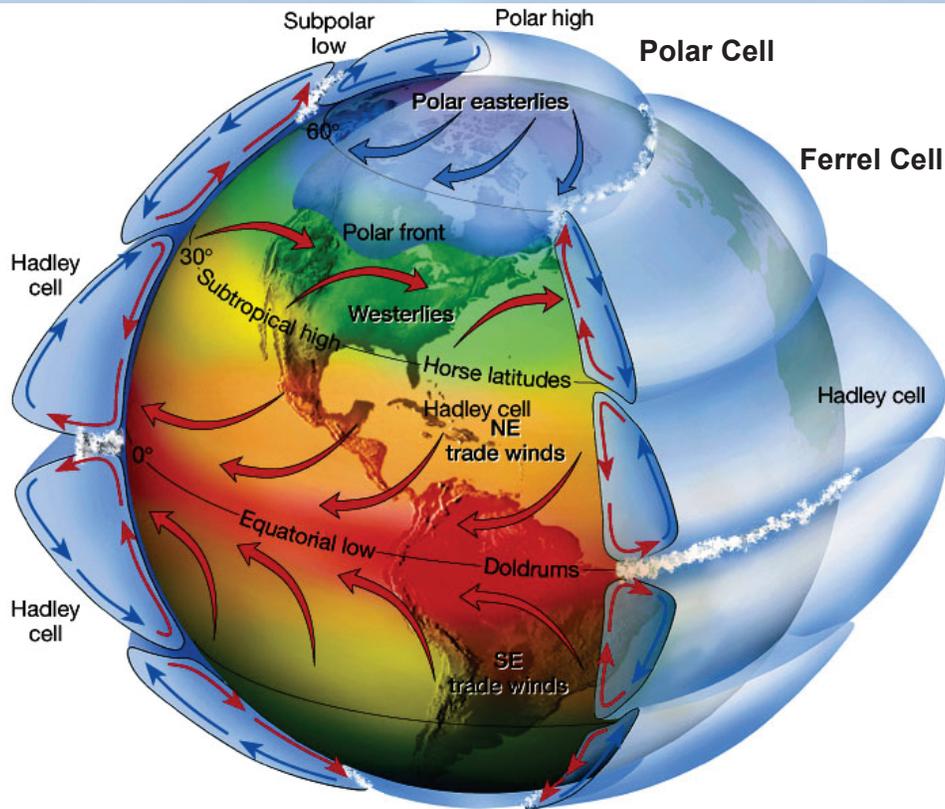
This figure shows the number of glaciers that are growing in blue and the number of glaciers that are shrinking in red.

If temperatures are warming, how can some glaciers be growing? Warmer air carries more moisture. As long as temperatures are cold enough, this can fall as snow and cause some glaciers to grow.

<http://www.livescience.com/48256-asia-karakoram-glaciers-stability.html>

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Conceptual Model



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<http://www.ux1.eiu.edu/~cfjps/1400/circulation.htm>

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Movement of the Sub-tropical Jet

From 1979– 2010, the subtropical jet moved poleward by:

3.7° in the Northern Hemisphere

6.5° in the Southern Hemisphere

The tropics are expanding.

Storms that follow the path of the jet stream will move poleward as well.

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Hudson, *ACP*, 2012

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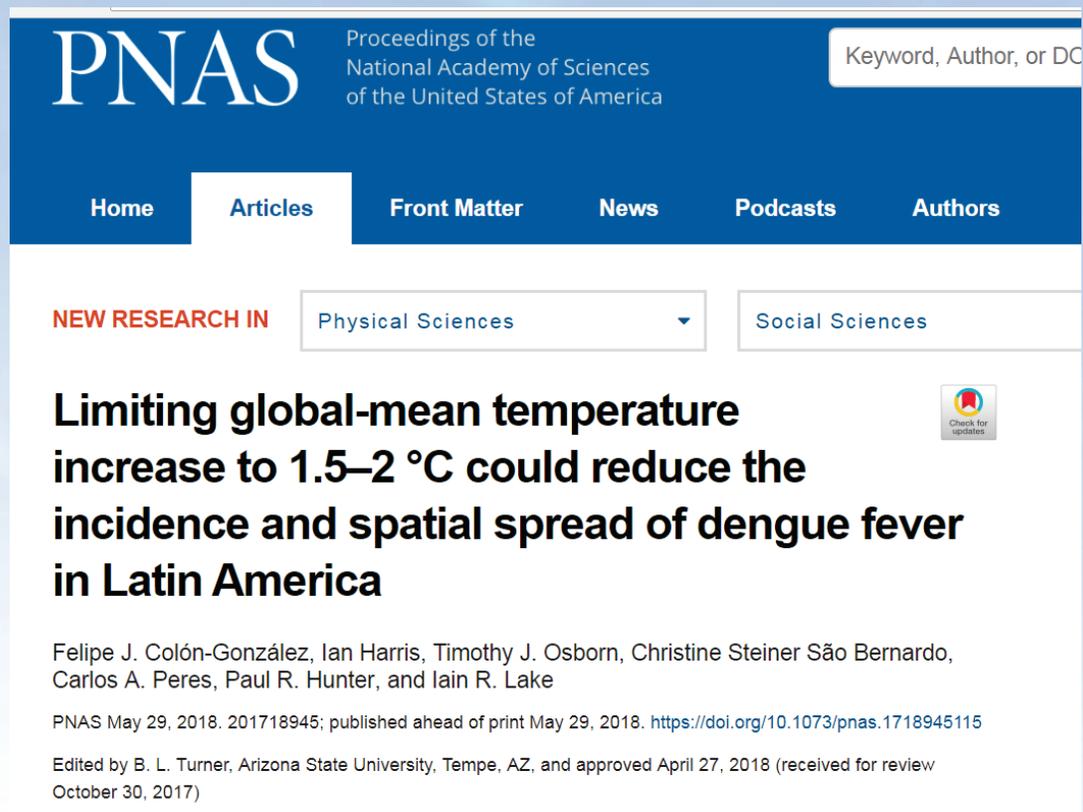
Climate Change and Health

Warmer temperatures promote the spread of warm climate diseases.

- **Dengue Fever (Maurens and Fauci, JAMA, 2008)**
 - fever, severe muscle and joint pain, may last week or more
 - Affect millions each year
 - Carried by mosquito, currently at Texas/Mexico border
- **Chikungunya Fever**
 - Symptoms similar to dengue fever, pain persists for weeks-months
 - Higher rates of death than dengue fever
 - Carried by mosquito, first cases in Italy, 2007 came from Africa
- **Zika Virus**
 - fever, rash, joint pain, or conjunctivitis (red eyes)
 - Usually mild with symptoms lasting for several days to a week
 - Remains in the blood of an infected person for about a week
 - Infection during pregnancy can cause microcephaly and other severe brain defects

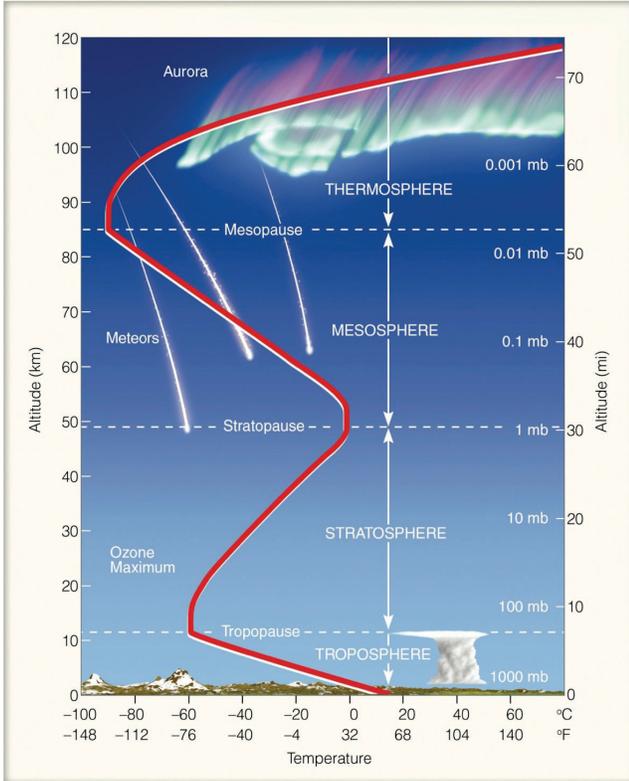
Cold temperatures kill off the mosquito species that carry these diseases

Poleward shift in the Tropics can impact human health



The image shows a screenshot of a PNAS (Proceedings of the National Academy of Sciences) article page. The header includes the PNAS logo and the text "Proceedings of the National Academy of Sciences of the United States of America". A search bar is visible with the placeholder text "Keyword, Author, or DOI". Below the header is a navigation menu with options: Home, Articles, Front Matter, News, Podcasts, and Authors. The "Articles" option is selected. Below the navigation menu, there is a section for "NEW RESEARCH IN" with two dropdown menus: "Physical Sciences" and "Social Sciences". The main title of the article is "Limiting global-mean temperature increase to 1.5–2 °C could reduce the incidence and spatial spread of dengue fever in Latin America". The authors listed are Felipe J. Colón-González, Ian Harris, Timothy J. Osborn, Christine Steiner São Bernardo, Carlos A. Peres, Paul R. Hunter, and Iain R. Lake. The publication date is May 29, 2018, and the DOI is <https://doi.org/10.1073/pnas.1718945115>. The article was edited by B. L. Turner, Arizona State University, Tempe, AZ, and approved for publication on April 27, 2018 (received for review October 30, 2017). A "Check for updates" button is located to the right of the title.

Have temperatures in other parts of the atmosphere exhibited changes?



The Sun provides the energy that warms the planet.

The rise in surface temperature must be caused by more heat at the surface

Some people say that increasing solar output is causing the rise in surface temperature

If this is the case then the entire atmosphere should be warming

Is this the case?

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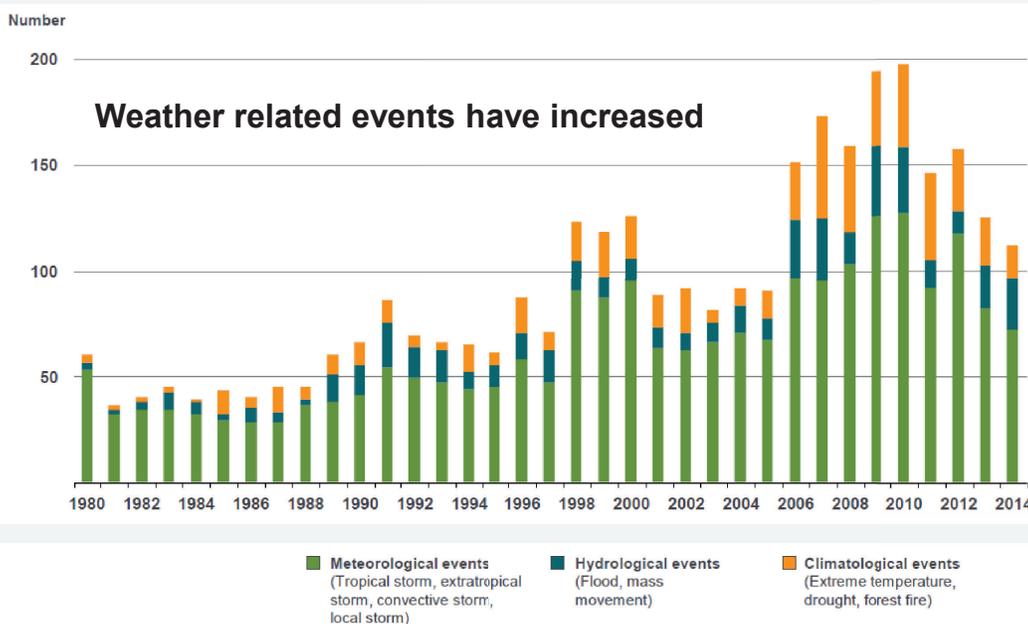
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Are extreme weather events getting more frequent?

NatCatSERVICE

Weather-related loss events in the U.S. 1980 – 2014

Number of events

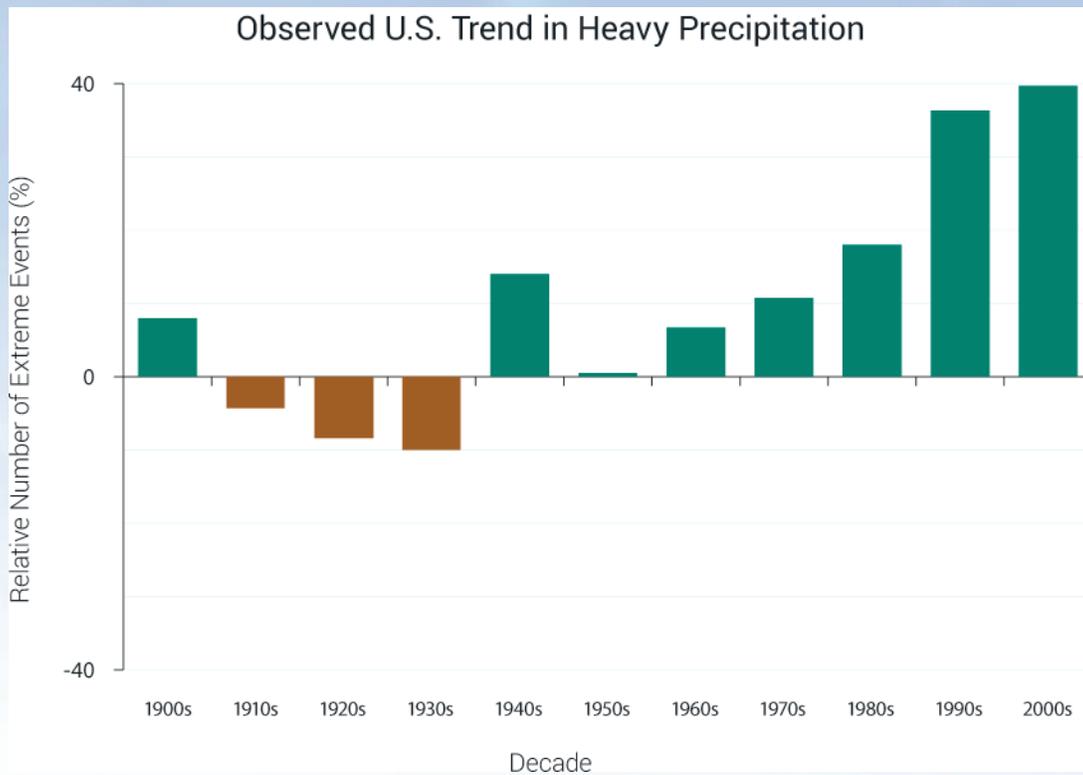


© 2015 Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE – As at January 2015

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In the United States, the number of extreme precipitation events has increased

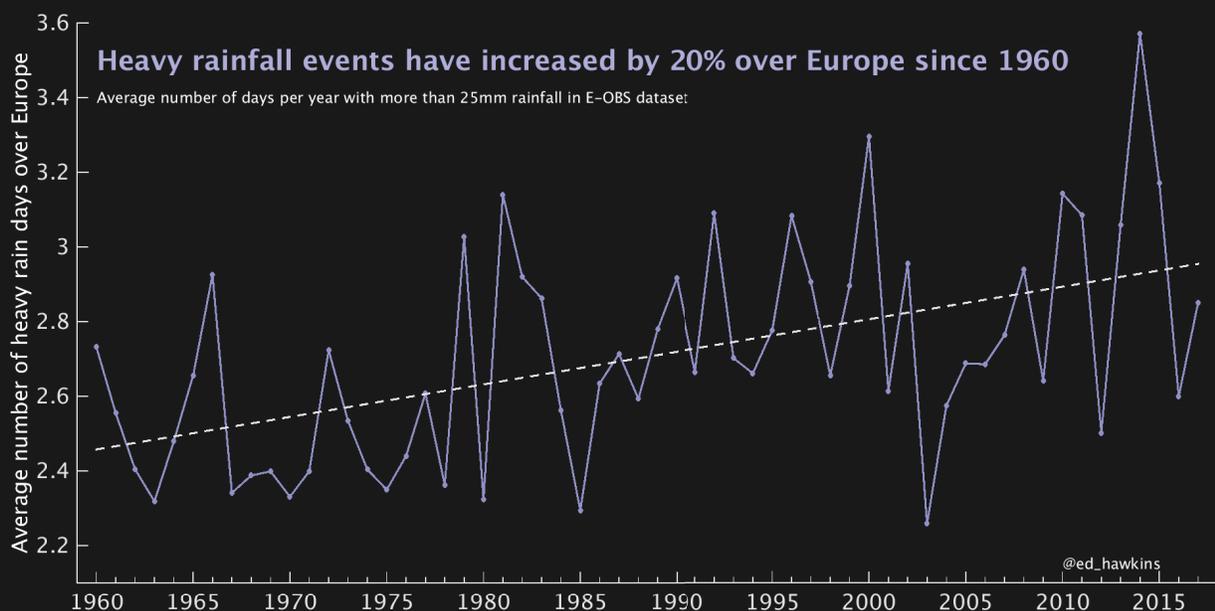


<http://nca2014.globalchange.gov/highlights/report-findings/extreme-weather#intro-section>

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Heavy rainfall events in Europe are increasing



<https://www.climate-lab-book.ac.uk/author/ehawkins/>

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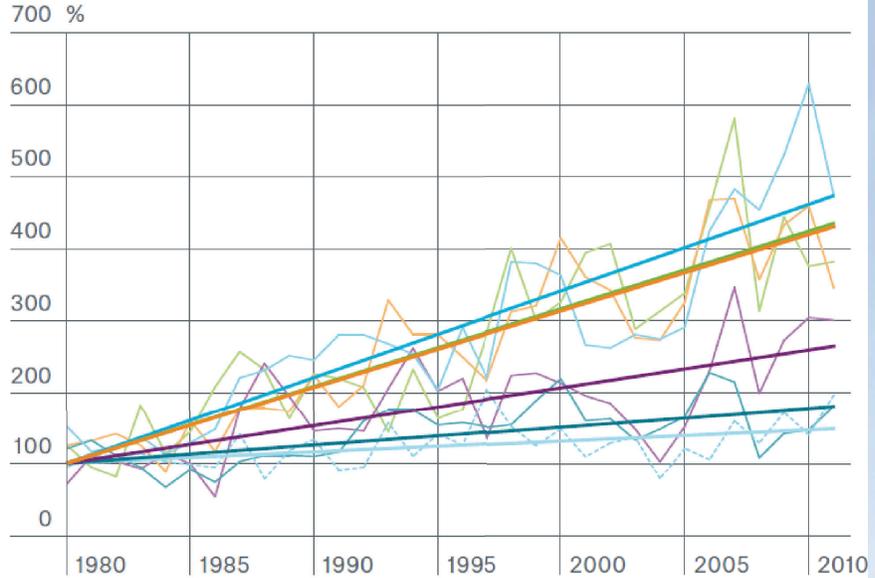
Globally, severe weather has increased

Upward trends in weather-related loss events per continent, 1980-2011

Remark: This analysis considers events in the United States, Canada, the Caribbean and Central America.

- North America
- Australia/Oceania
- Asia
- Africa
- Europe
- South America

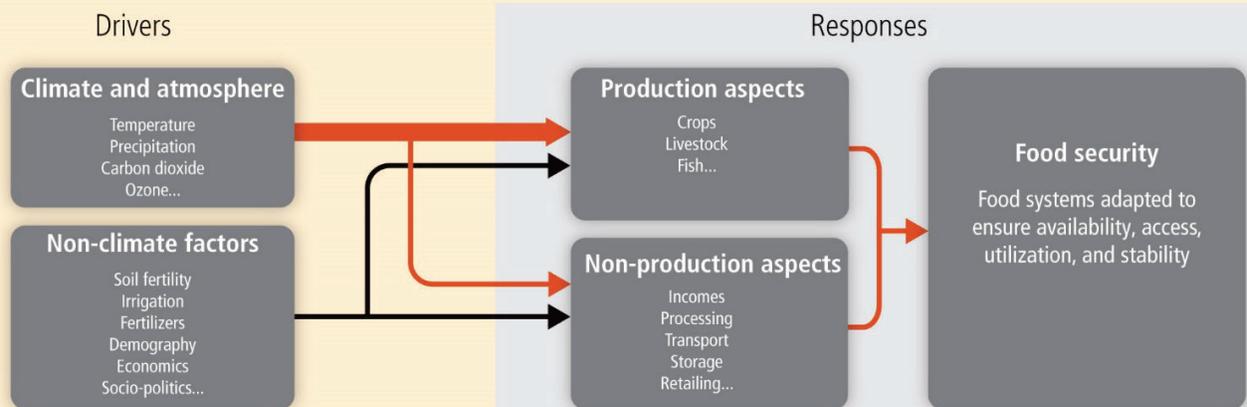
Source: Munich Re, NatCatSERVICE



Some regions of the world have experienced a greater increase in severe weather events

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What drives food production?



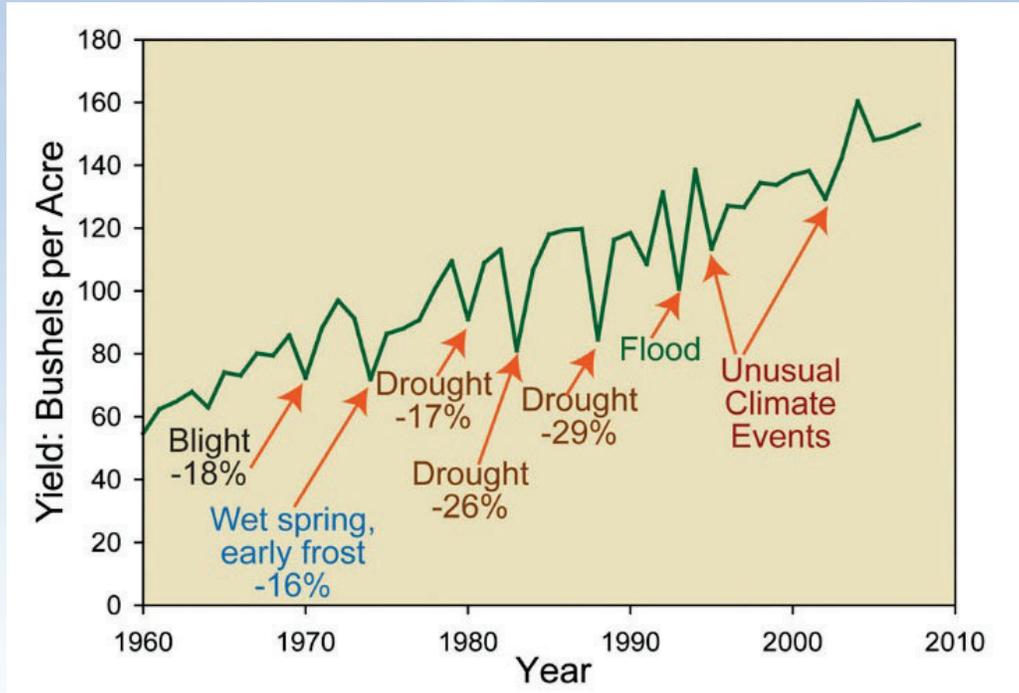
Food security: the supply of food and people's access to it.

Food security is driven by climate and non-climate factors and all must be accounted for.

https://ipcc-wg2.gov/AR5/images/uploads/WGIAR5-Chap7_FINAL.pdf

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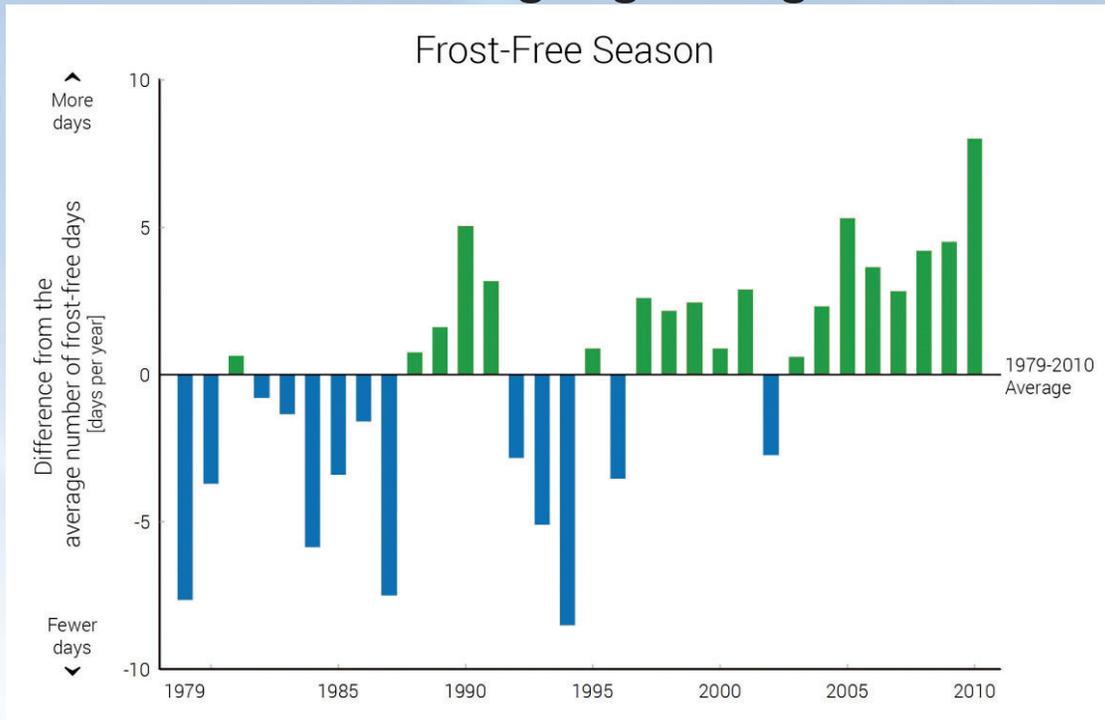
Too much rain or not enough will affect crop yields



Crop yields have been increasing due to better farming practices but nature can play a negative role at times.

<http://www3.epa.gov/climatechange/impacts/agriculture.html#impactscrops>

Less frost means a longer growing season but ...

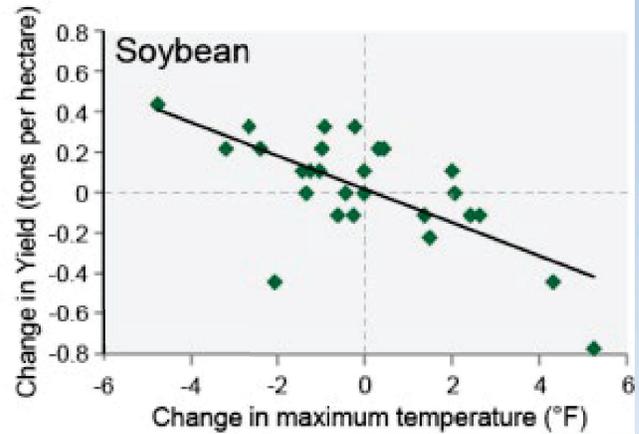
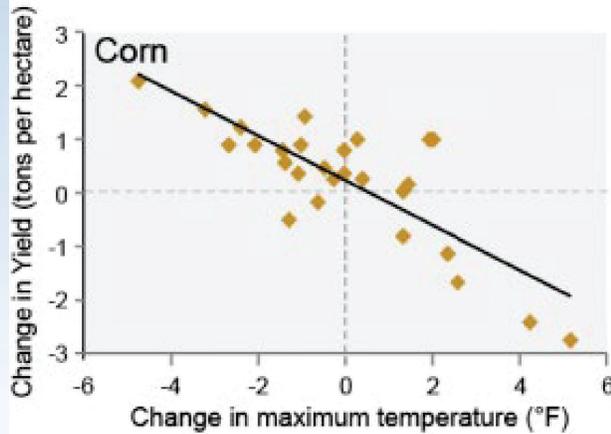


The number of frost free days has been increasing

<http://www.globalchange.gov/browse/indicators/indicator-frost-free-season>

...warmer temperatures can harm crop yields

Crop Yields Decline under Higher Temperatures



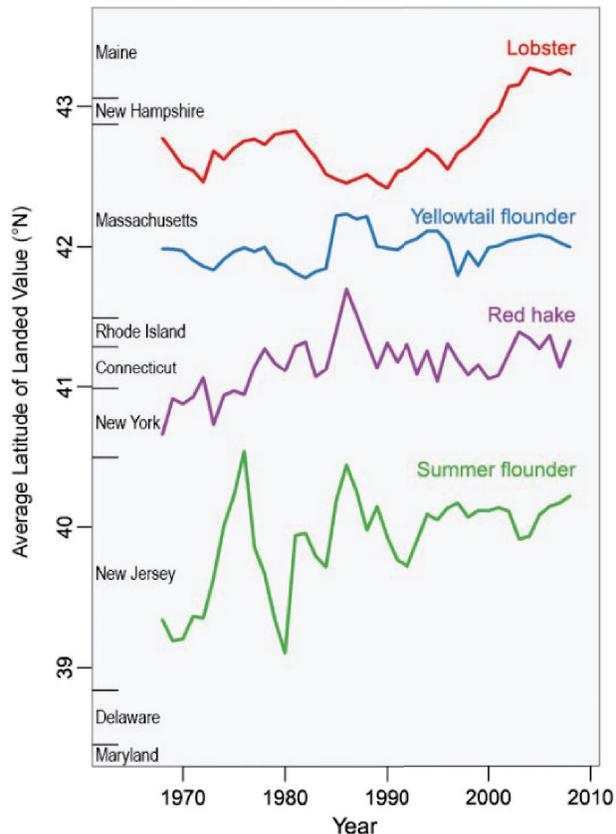
<http://www.globalchange.gov/browse/multimedia/crop-yields-decline-under-higher-temperatures>

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Fisheries Shifting North



As ocean waters warm, species move northward to stay in waters that are more comfortable for them.

This means that species more accustomed to warmer waters will move into the area.

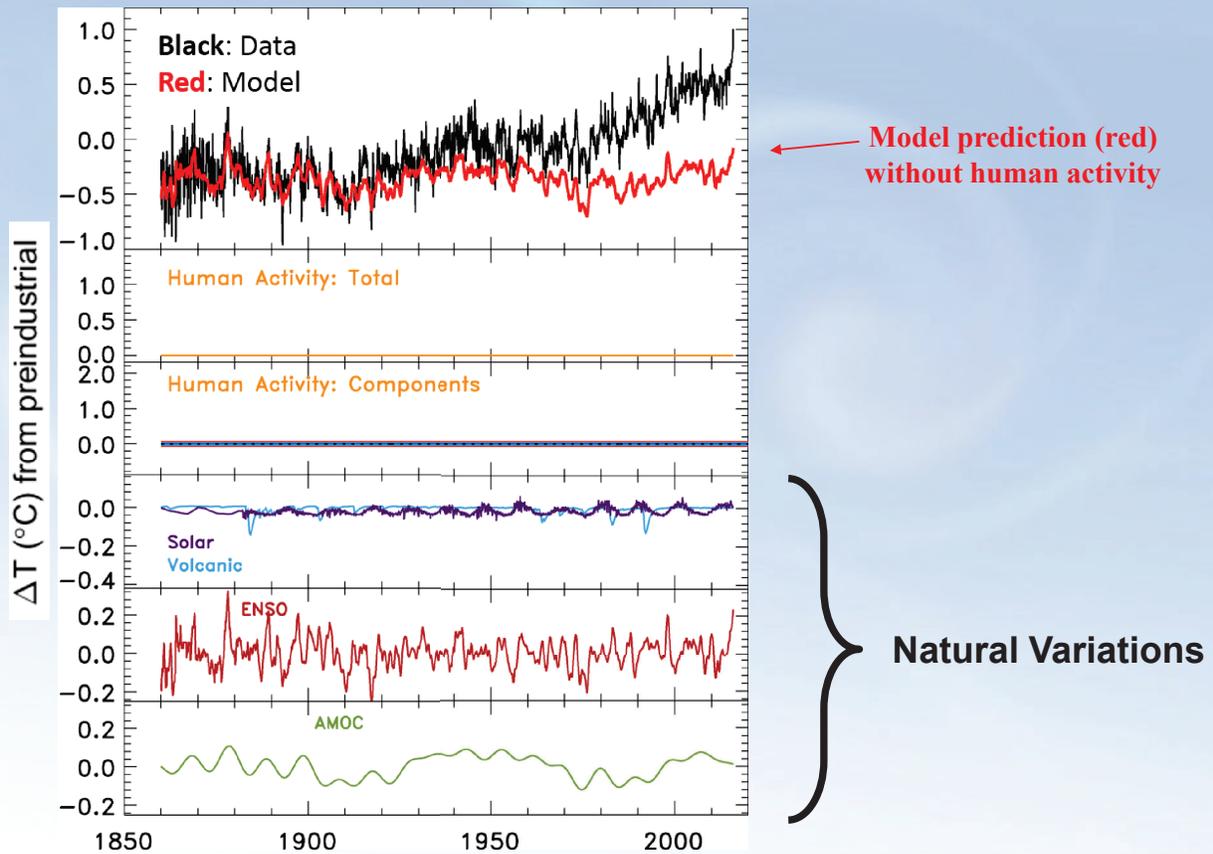
<http://www.globalchange.gov/browse/multimedia/fisheries-shifting-north>

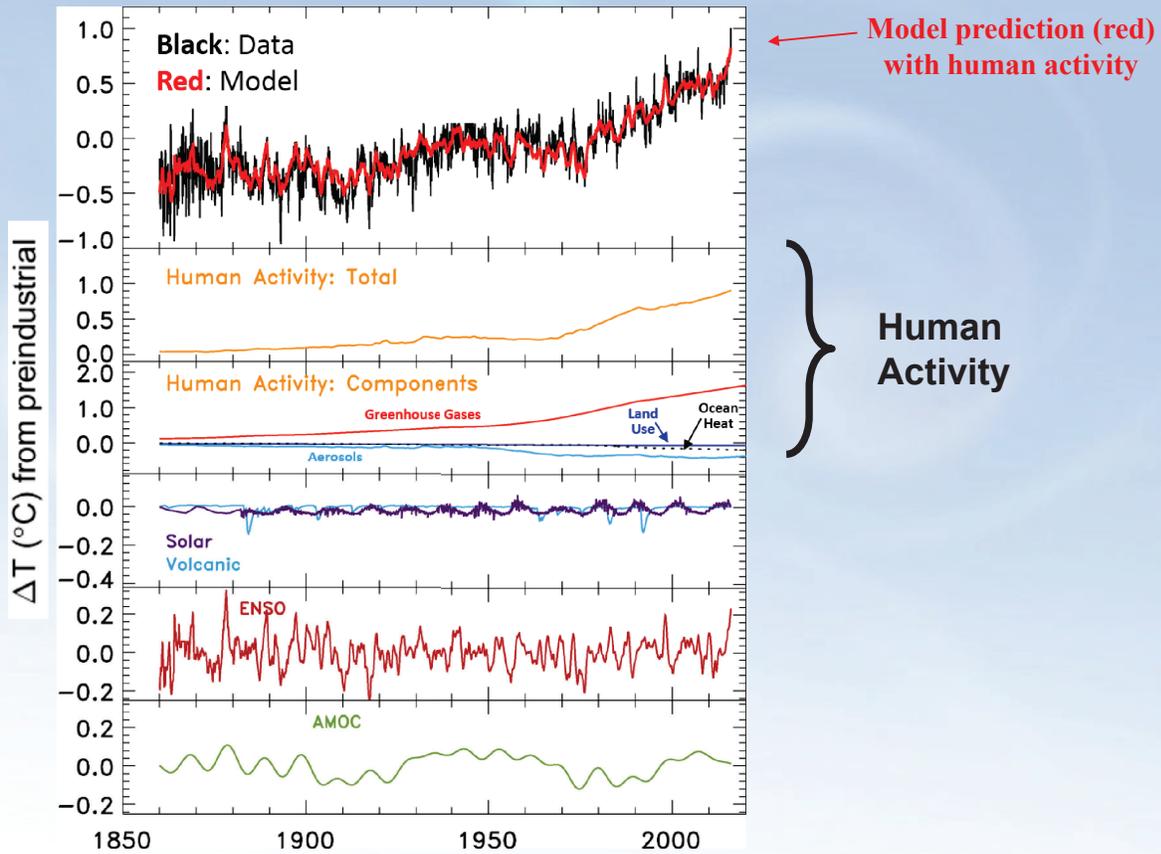
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Future Predictions





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Future Predictions

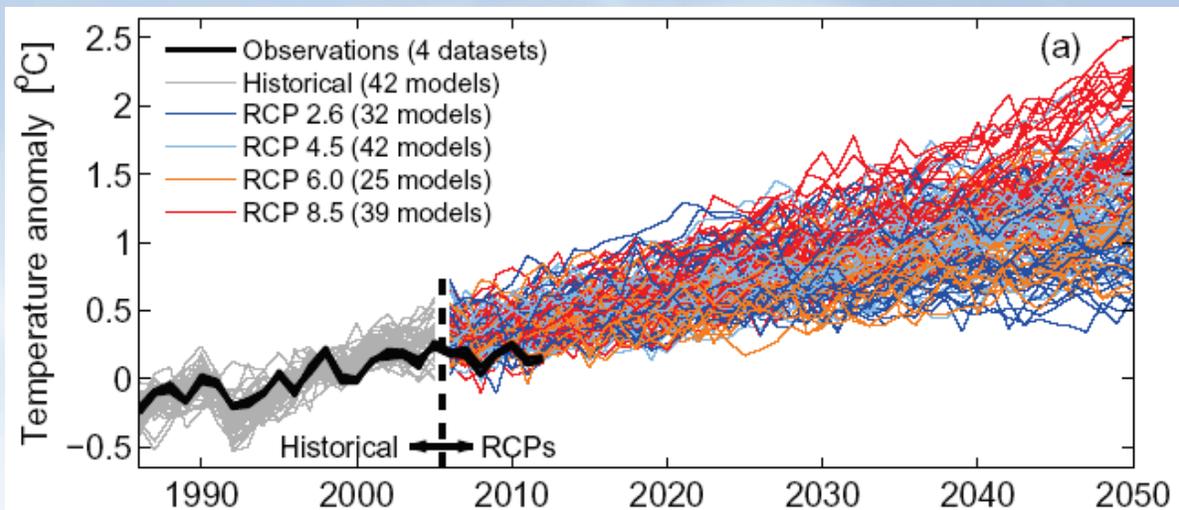
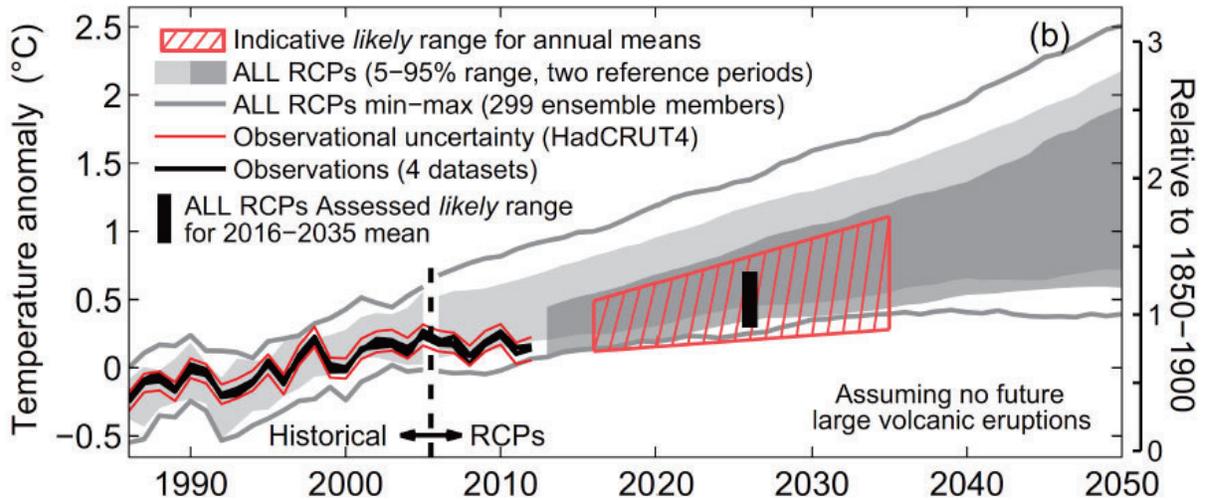


Fig 11.25, IPCC 2013

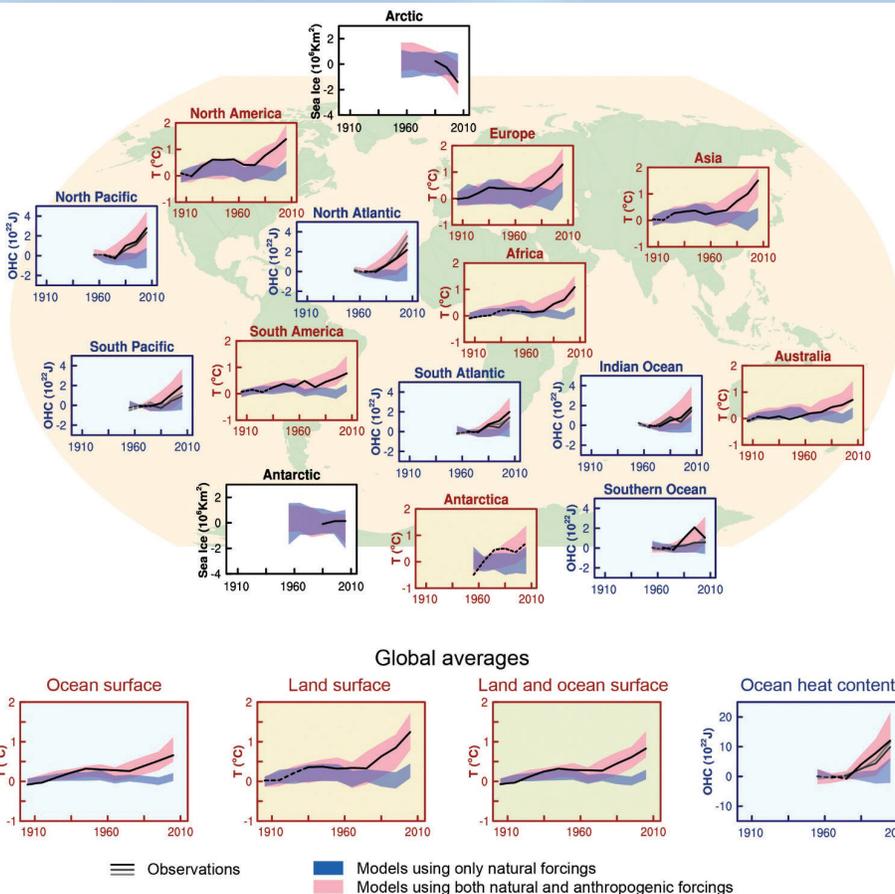
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Future Predictions: Corrected

Figure 11-25b, IPCC (2013)



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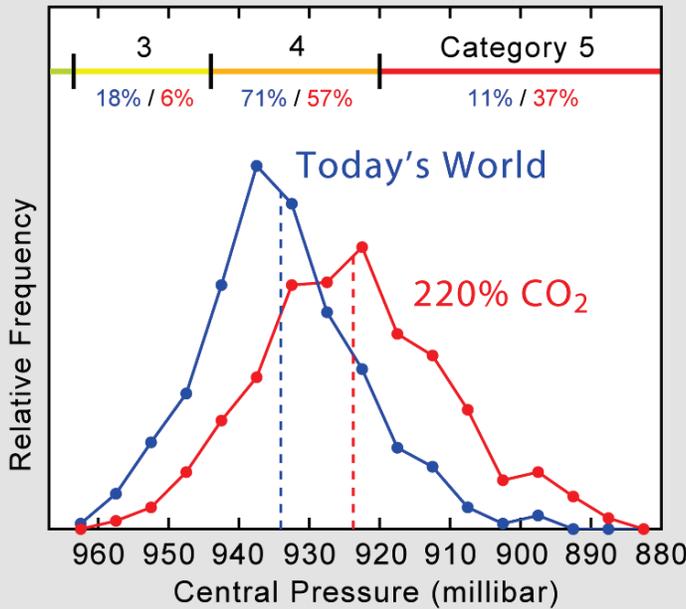


In some areas, human activity plays a larger role than in other areas

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Future Hurricanes

Achieved Storm Intensity Under Idealized Conditions



Hurricane prediction is very difficult. It is expected that ocean waters will warm. It is also expected that wind shear will increase.

In Today's World, 90% of major hurricanes are category 3 or 4.

Computer climate models that simulate a world where CO₂ is 220% greater than today and these results indicate over 90% of hurricanes will be category 4 or 5 but there will be fewer hurricanes overall.

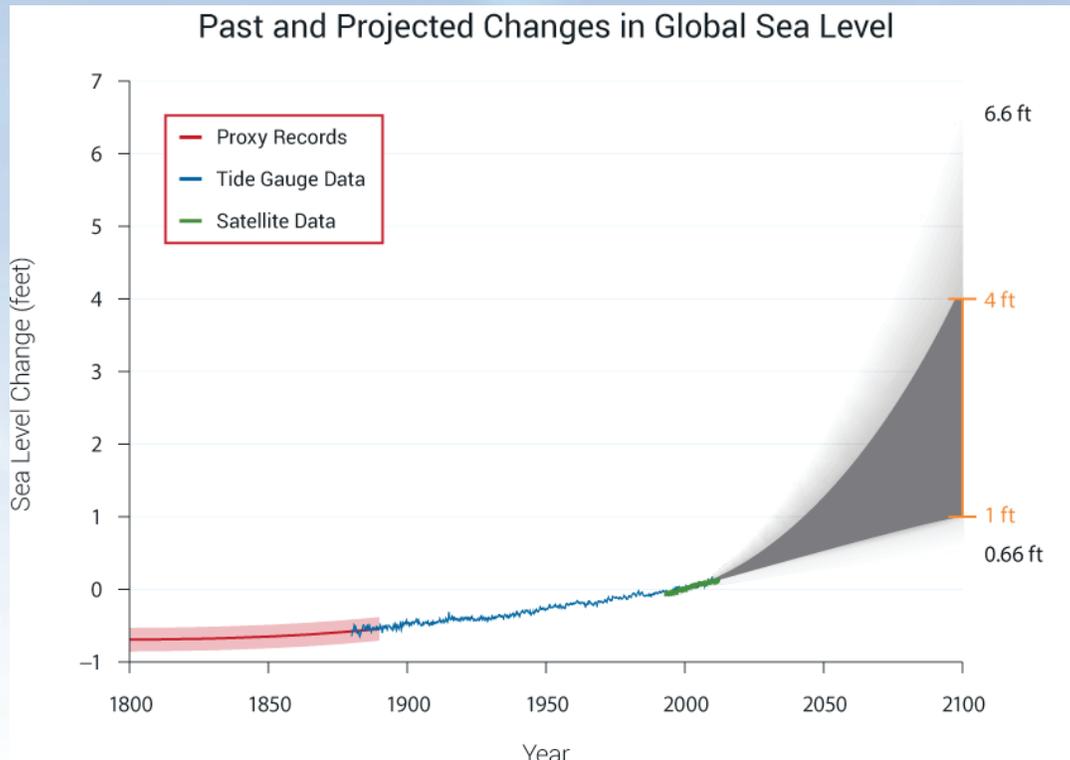
http://www.globalwarmingart.com/wiki/File:Hurricane_Intensity_Shift_png

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Future Sea Level Rise

Past and Projected Changes in Global Sea Level

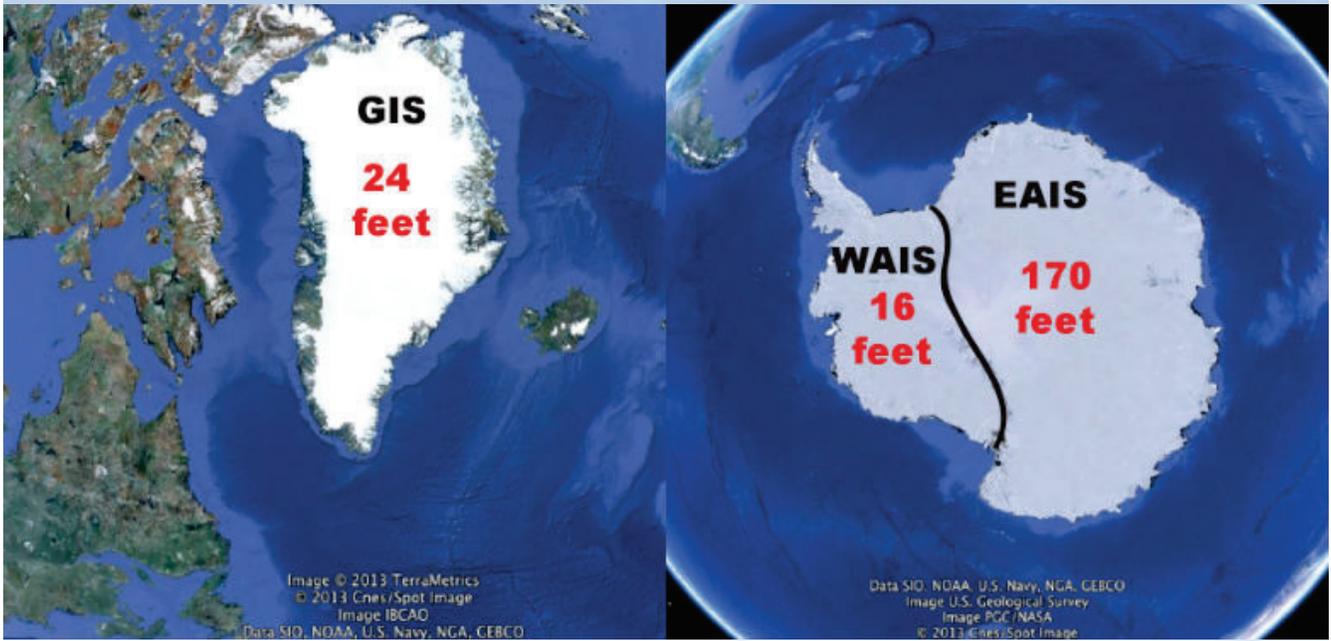


<http://nca2014.globalchange.gov/highlights/report-findings/future-climate#graphic-20997>

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How can melting ice sheets affect sea level?



<http://www.coastalreview.org/2013/06/rising-seas-come-with-rising-co2/>

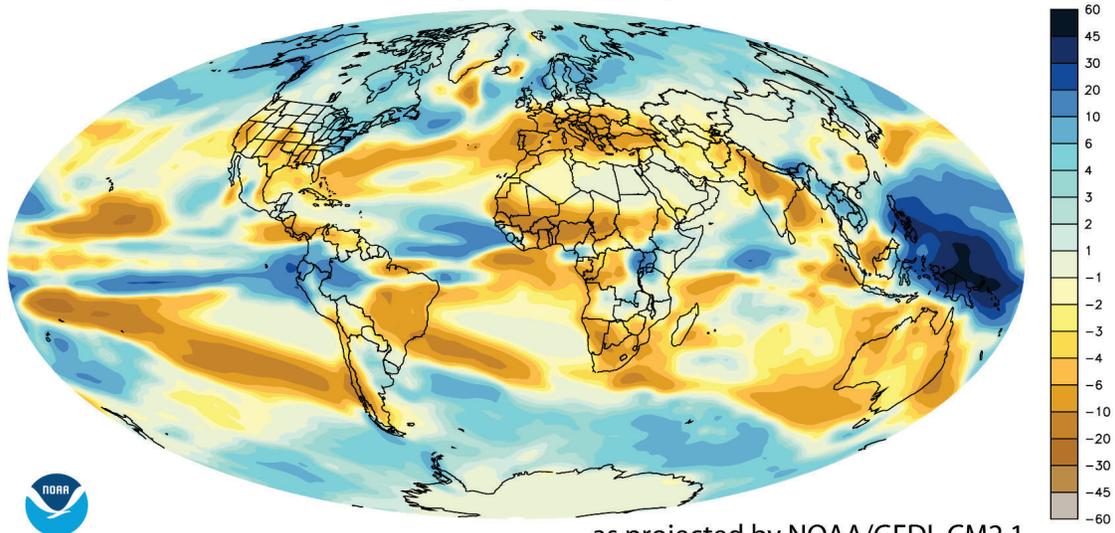
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The predictions are that dry areas will get drier and wet areas will get wetter

CHANGE IN PRECIPITATION BY END OF 21st CENTURY
inches of liquid water per year



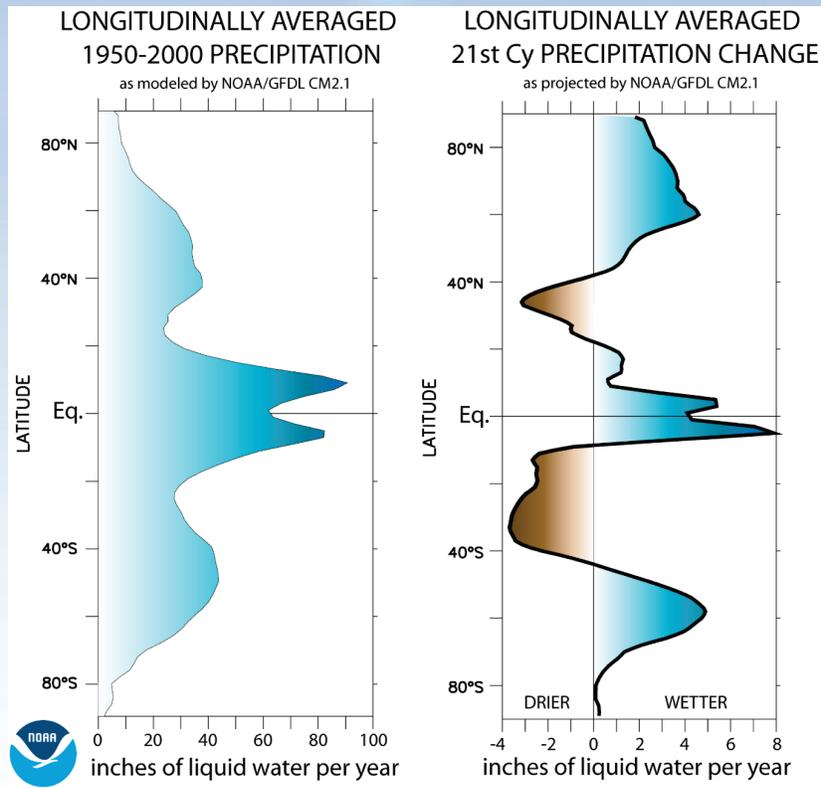
<https://www.gfdl.noaa.gov/will-the-wet-get-wetter-and-the-dry-drier/#movies>

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The predictions are that dry areas will get drier and wet areas will get wetter

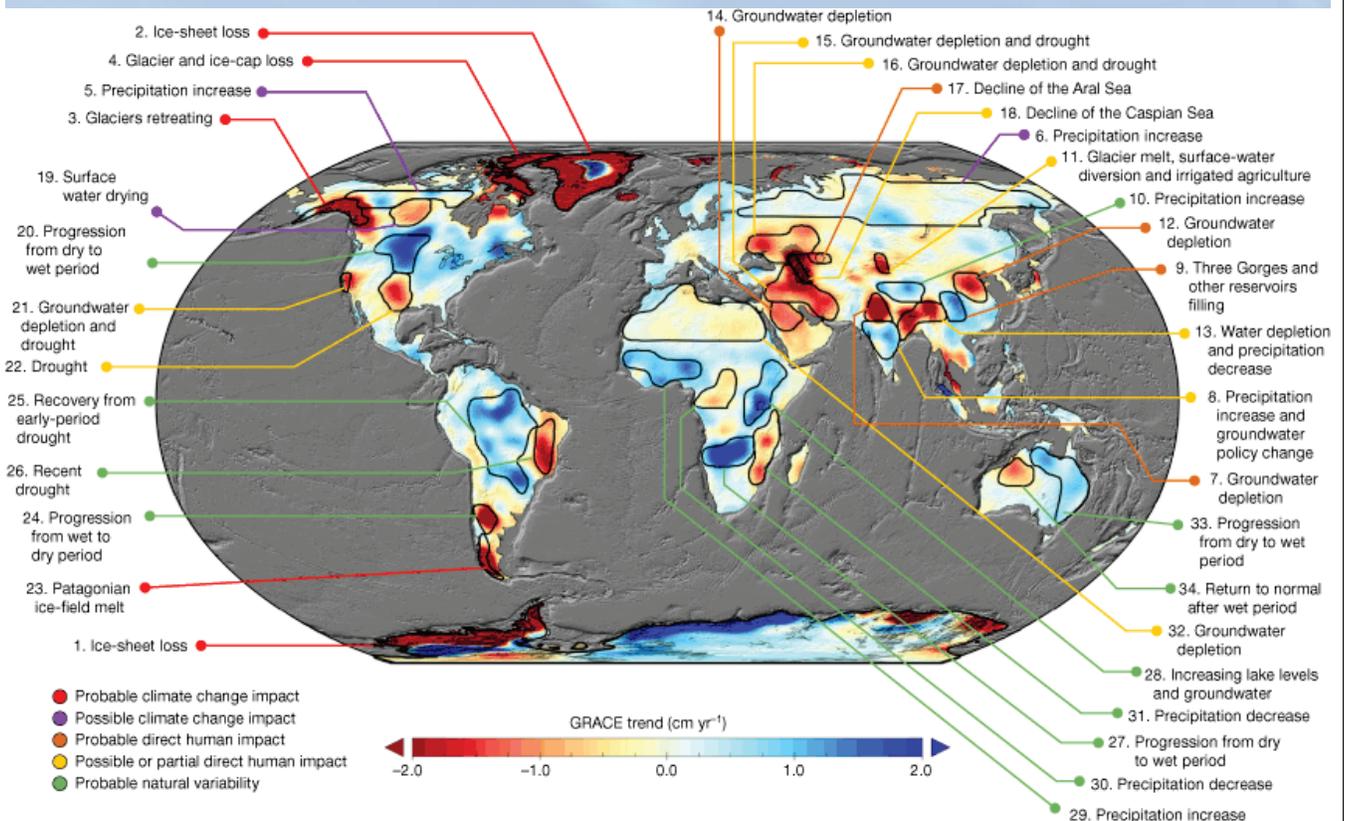


<https://www.gfdl.noaa.gov/will-the-wet-get-wetter-and-the-dry-drier/#movies>

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15 years of satellite observations (GRACE) indicate this is happening now



Rodell et al., Nature 2018

<https://www.nature.com/articles/s41586-018-0123-1#Fig1>

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Analysis:

- **Climate has warmed and most likely will continue to**
- **Recent warming due to human activity**
- **Warmer temperatures will affect weather**
- **Prediction is more extreme events; will cost more \$\$\$, risk more lives**
- **Yes, it can still snow (all you need is below 32°F)**
- ***But...*climate models seem to be warming too quickly**
- **If correct, this gives us more time to fix the problem**