



ARCUS Arctic Research Seminar

Why the Arctic Matters at All?

May 3, 2017



Welcome

ARCUS Arctic Research Seminar Series

“Why the Arctic Matters at All?”

3 May 2017



Presented by Robert Corell
Global Environment Technology Foundation



#arcuswebinar

Why the Arctic Matters at All?

Exploring the Implications of the Accelerating Changes in the Arctic for the Rest of the World



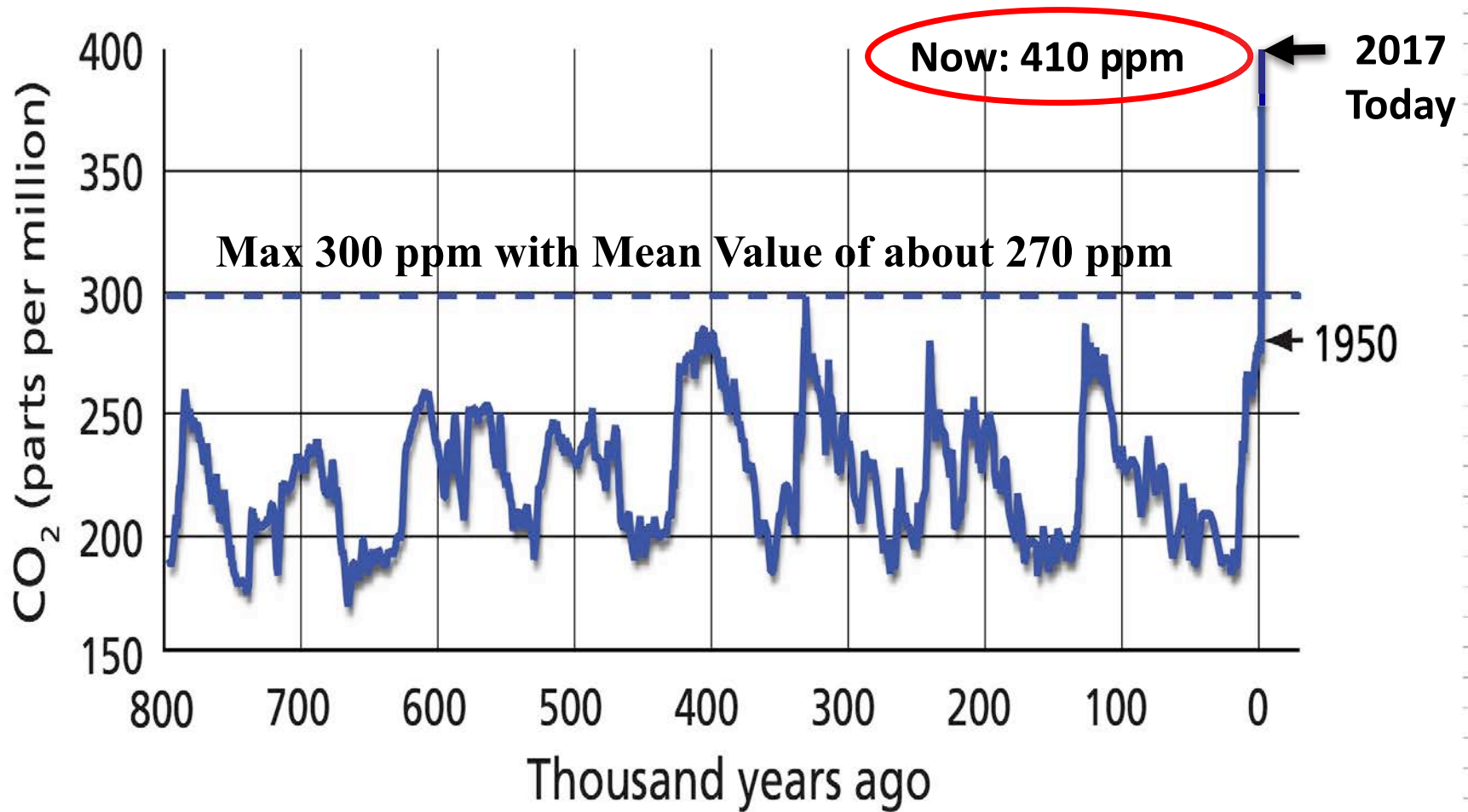
How did we get here?

An ARCUS Arctic Research Seminar

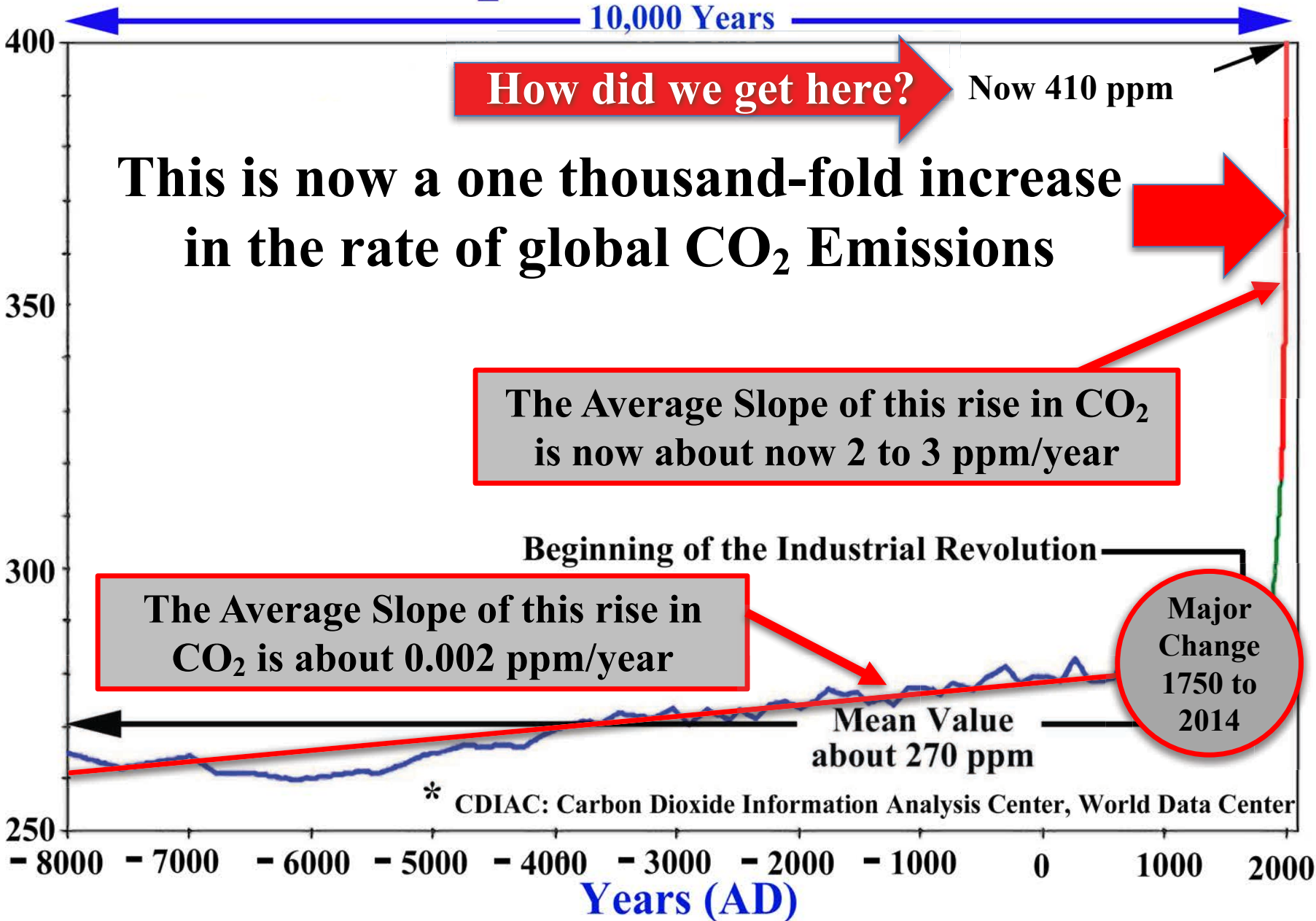
Dr. Robert W. Corell Professor, University of the Arctic, Adjunct Professor, University of Miami, and Principal, Global Environment and Technology Foundation

Video Source: Howard Ruby at http://www.howardruby.com/index_original.html

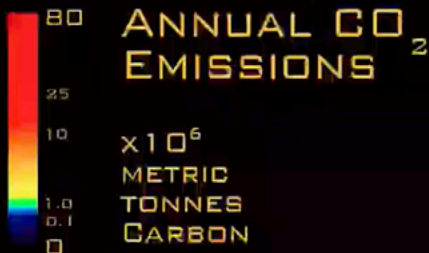
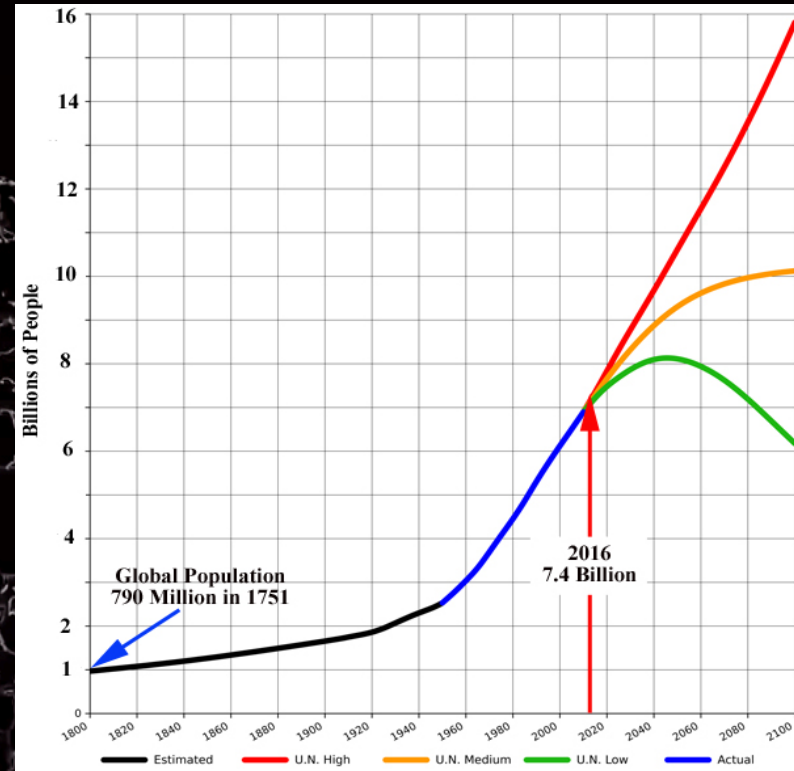
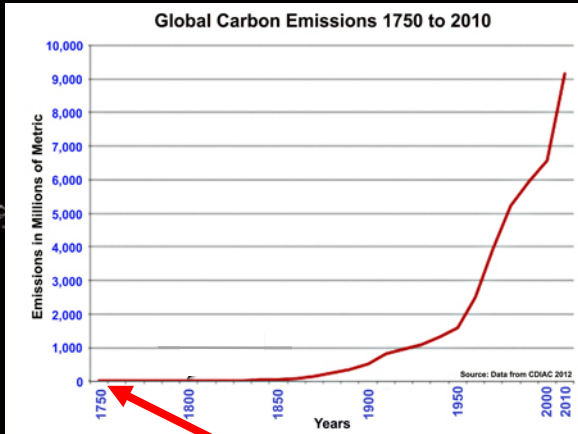
The “Language” of Climate Change is to Measure the Effects of Global Changes in Carbon Dioxide by Stating: *parts per million or simply ppm,*



Atmospheric CO₂ levels over the last 10,000 years



Annual Global CO₂ Emissions 1751



YEAR
1751

TOTAL ANNUAL EMISSION
2 x 10⁶ METRIC TONNES

Global Population: ~ 790 Million

A short movie starts in 1751, the beginning of the industrial revolution, to depict the annual global CO₂ emissions to 2014 as the world adopted fossil fuels as it's primary energy source, beginning with coal, then to oil, and ultimately natural gas.



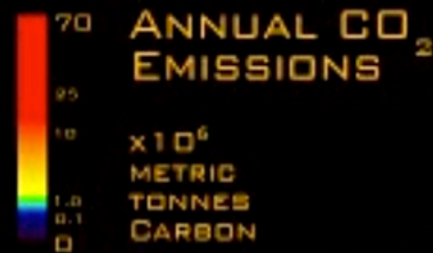
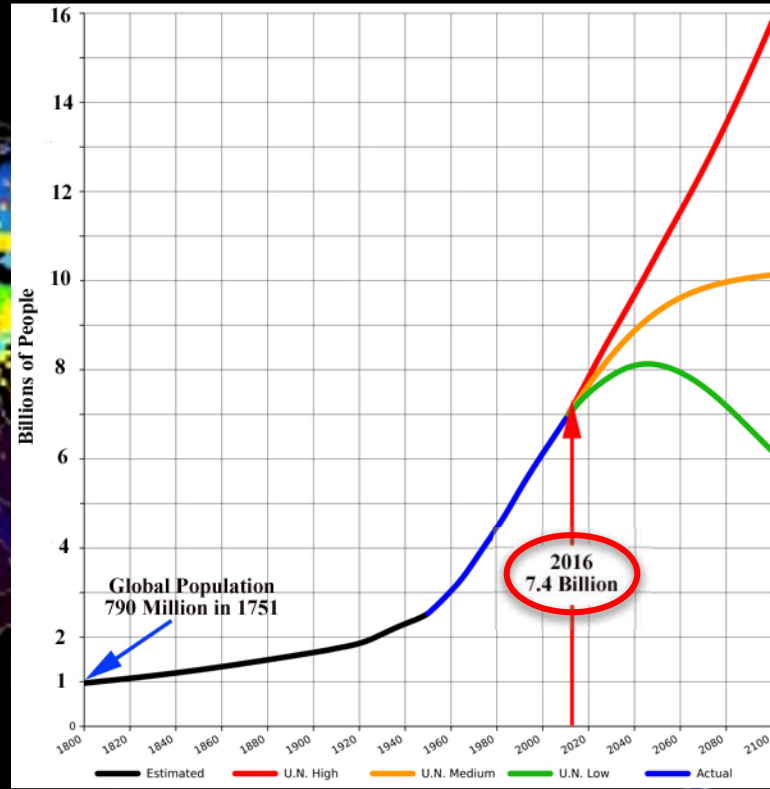
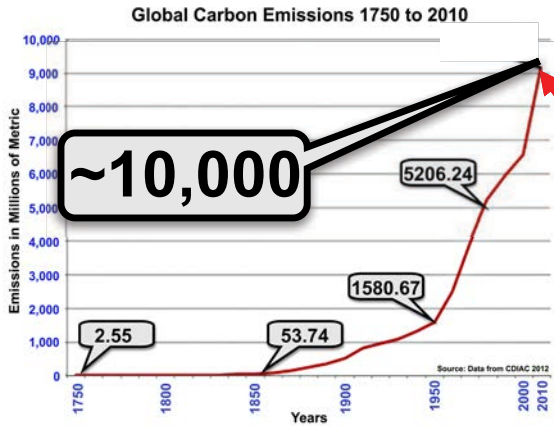
Annual Global CO₂ Emissions 1751 to 2010

Note beginning in England



Source: 2014 Global Carbon Project

Annual Global CO₂ Emissions 2015



YEAR
2016

TOTAL ANNUAL EMISSION
~10,000 $\times 10^6$ METRIC TONNES

By 2016, the 2015 emissions are globally mixed!

2016 Global Population: ~ 7.5 Billion (Today)

Source: CO₂ Data is from the Global Carbon Project; population data is from United Nations Department of Economic and Social Affairs Population Division

Fate of Anthropogenic CO₂ Emissions (2016 Data)

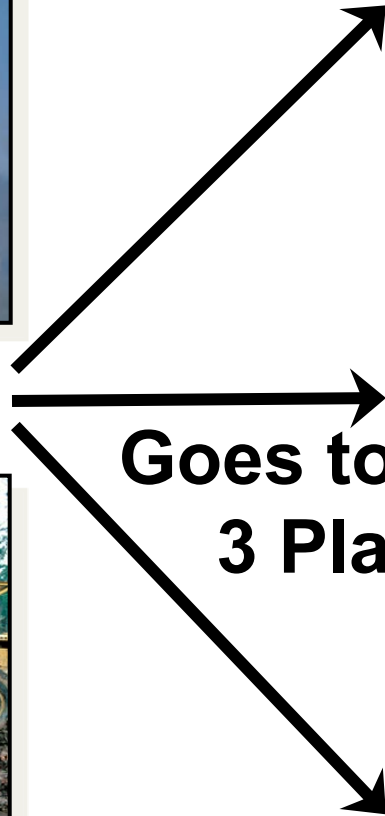
~91%



~9% +



Sources



44%



30%



26%



WHAT HAPPENS IN THE ARCTIC.....

Even if you don't live there, don't do business there, and will never travel there, the Arctic is closer than you think. Rapid climatic and other changes in the region are having profound effects, not only in the Arctic but on the rest of the planet.



Arctic Matters

THE GLOBAL CONNECTION TO CHANGES IN THE ARCTIC

..... DOESN'T STAY IN THE ARCTIC

Scientific study continues to illuminate the changes that are underway and their global connections.

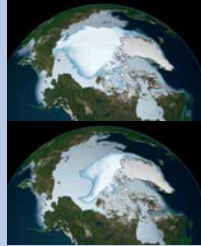
Arctic Matters



Source: Stratux Consulting/University of Colorado; NOAA Climate.gov

PERMAFROST IS THAWING
Permafrost (a frozen layer of soil found in the Arctic) derives its name from the word "permanent," but it is becoming markedly less so. When permafrost thaws, it can have significant impacts on landscapes, ecosystems, hydrology, and infrastructure—for example, by causing the erosion of coastlines and the collapse of roads, bridges, runways, and buildings.

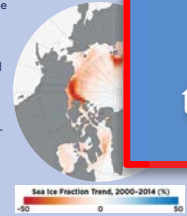
SEA ICE IS MELTING



If you were to stand at the North Pole, the sea ice under your boots might extend as far as you could see. But over the past several decades, warmer temperatures have meant there is less sea ice left at the end of the summer. These visualizations show the decrease in sea ice coverage, especially older "multi-year ice" (shown in bright white) from 1980 (left) to 2012 (right). Source: NASA Earth Observatory

GLOBAL CLIMATE GETS WARMER

Many of the shifts underway in the Arctic are likely to contribute to further climate changes, both in the Arctic and around the globe. For example, as the area covered by reflective, white Arctic snow and ice shrinks, darker surfaces like tundra and water—which absorb more of the Sun's energy—emerge. As a result, the reflectivity, or albedo, of the region decreases, causing temperatures to rise and more snow and ice to melt.



The percentage change in sea ice cover from 2000 to 2014 shows a decrease (in red) in many areas. Source: NASA Earth Observatory.

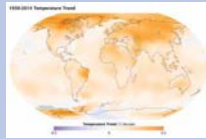
Why do changes in the Arctic matter to the rest of the world?

ECOSYSTEMS ARE CHANGING

Many Arctic species are highly specialized, having evolved in response to the unique Arctic environment over millions of years. As ice melts and temperatures change, these species face mounting challenges—including the possibility of extinction.



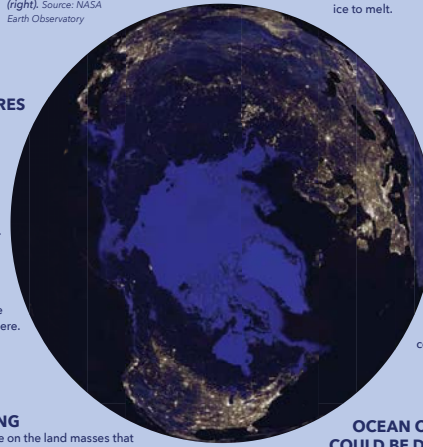
Source: US Fish and Wildlife Service/Dean Biggins



A much warmer Arctic is evident in this map of the temperature trend from 1950 to 2014. Source: NASA Earth Observatory/NASA Goddard Institute for Space Studies (GISS)/Kevin Ward

TEMPERATURES ARE RISING

Temperatures are rising twice as fast in the Arctic as compared to the average global temperature rise. Warming temperatures are a driver of Arctic change and also may be affecting weather patterns across the Northern Hemisphere.



GLOBAL SEA LEVEL RISES

Much of the Arctic's melting land ice and glaciers ultimately flows into the sea, adding volume to the world's oceans. Sea-level rise (and associated storm surges) poses significant threats to human lives and infrastructure, especially in vulnerable and densely populated coastal areas.



During Superstorm Sandy in 2012, storm surges brought water inland and flooded the coastline of New Jersey. Source: U.S. Air Force/Master Sgt Mark C. Olsen.

SHIPPING & TOURISM INCREASE

In the past, few ships ventured into the frigid waters of the Arctic or its narrow straits and channels. As temperatures rise, the Arctic and surrounding waters are becoming more navigable, and research missions, trade routes, and other commodities, and tourism.



Research mission in the Arctic. Source: U.S. A Grenier

ARCTIC CHANGES

ARCTIC LIFE IS CHANGING

Changes in the Arctic environment—combined with broad political, economic, and cultural shifts—are putting new strains on ancient traditions. For example, melting snow and ice pose problems for subsistence hunters who typically rely on sleds or snow mobiles to reach seals, walrus, and caribou.



A family with a traditional qamutik (sled) in Cape Dorset, an Inuit hamlet in Nunavut, Canada. Source: Angsar Walk.

RESOURCES ARE BEING DEVELOPED

An estimated 30 billion barrels of undiscovered oil remain in the U.S. Arctic alone, and the Arctic also contains valuable mineral deposits, including some rare minerals critical to making electronics. Rising demand for these raw materials and the Arctic's increasing accessibility will likely increase development in the region as reserves are explored.



Source: Shutterstock/vitstudio

LAND ICE IS MELTING

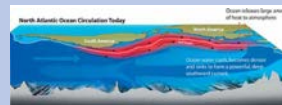
Ice is melting at a rapid pace on the land masses that encircle the Arctic Ocean. Glaciers, many of which have endured since the last Ice Age or longer, are becoming smaller. Those that border bodies of water are increasingly breaking off into icebergs that float away and gradually melt into the sea.



Photographs show how the Muir Glacier in Glacier Bay National Park and Preserve, Alaska, has changed from 1976 (top) to 2003 (bottom). Source: USGS/Bruce F. Molnia

OCEAN CIRCULATION COULD BE DISRUPTED

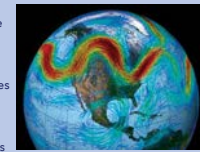
As Arctic ice melts, the Arctic Ocean is being flooded with fresh water. Because the circulation of ocean water is acutely affected by water temperature and salinity (saltiness), scientists believe this freshwater influx could have profound impacts on global ocean circulation, which, in turn, can alter weather patterns around the world.



North Atlantic Ocean circulation. Source: E. Paul Oberlander, Woods Hole Oceanographic Institution

NEW WEATHER PATTERNS EMERGE

Weather in the Northern Hemisphere is strongly influenced by the jet stream, an air current generated when colder air masses from the Arctic meet warmer air masses from the tropics. Because temperatures are rising faster in the Arctic than at the tropics, the forces that drive the jet stream are becoming less intense. This could result in longer droughts, heat waves, heavy rain events, and cold snaps in North America and Europe.



Weather and climate observations are used to model 30 days of the jet stream's journey over North America. Source: NASA's MERRA dataset

GEOPOLITICS SHIFT

Growing interest in the Arctic is bringing an influx of new people, cultures, ideas, and opportunities from all over the world. Many Arctic indigenous groups are experiencing greater political influence and are increasingly involved in decision making—for example, reviewing proposed developments such as mines or oil drilling operations.



Chief Kristina Kane speaks at an Arctic Council meeting. Source: Arctic Council



About Arctic Matters

Arctic Matters is an initiative by the Polar Research Board (PRB) of the National Academies of Sciences, Engineering, and Medicine to raise awareness of scientific findings on Arctic change and its impacts around the globe.

Additional support was provided by the U.S. Arctic Research Commission. The National Academy of Sciences was established under President Lincoln to honor top scientists and provide scientific and technical advice to the nation.

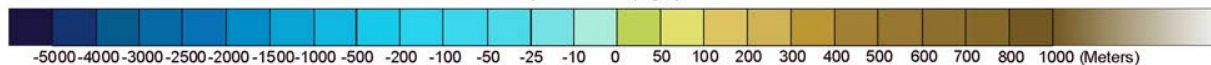




*What is happening
With in the Arctic that is
so important for the
Rest of the World?*

- **Sea Level Rise**
- **Opening of the Seaway**
- **Weather Extremes**
- **Ocean Acidification**
- **Thawing Permafrost**
- **Global Trends**

Bathymetric and topographic tints





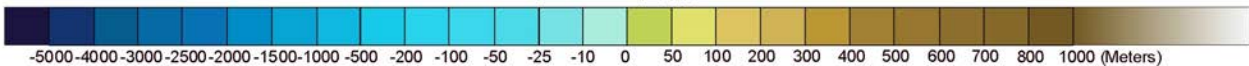
*What is happening in
the Arctic that is so
important **within** the Arctic
and for the **rest of the world?***

Sea Level Rise




Why Sea Level?

Bathymetric and topographic tints



The Changes in Local Sea Levels are Composed of Four Factors:

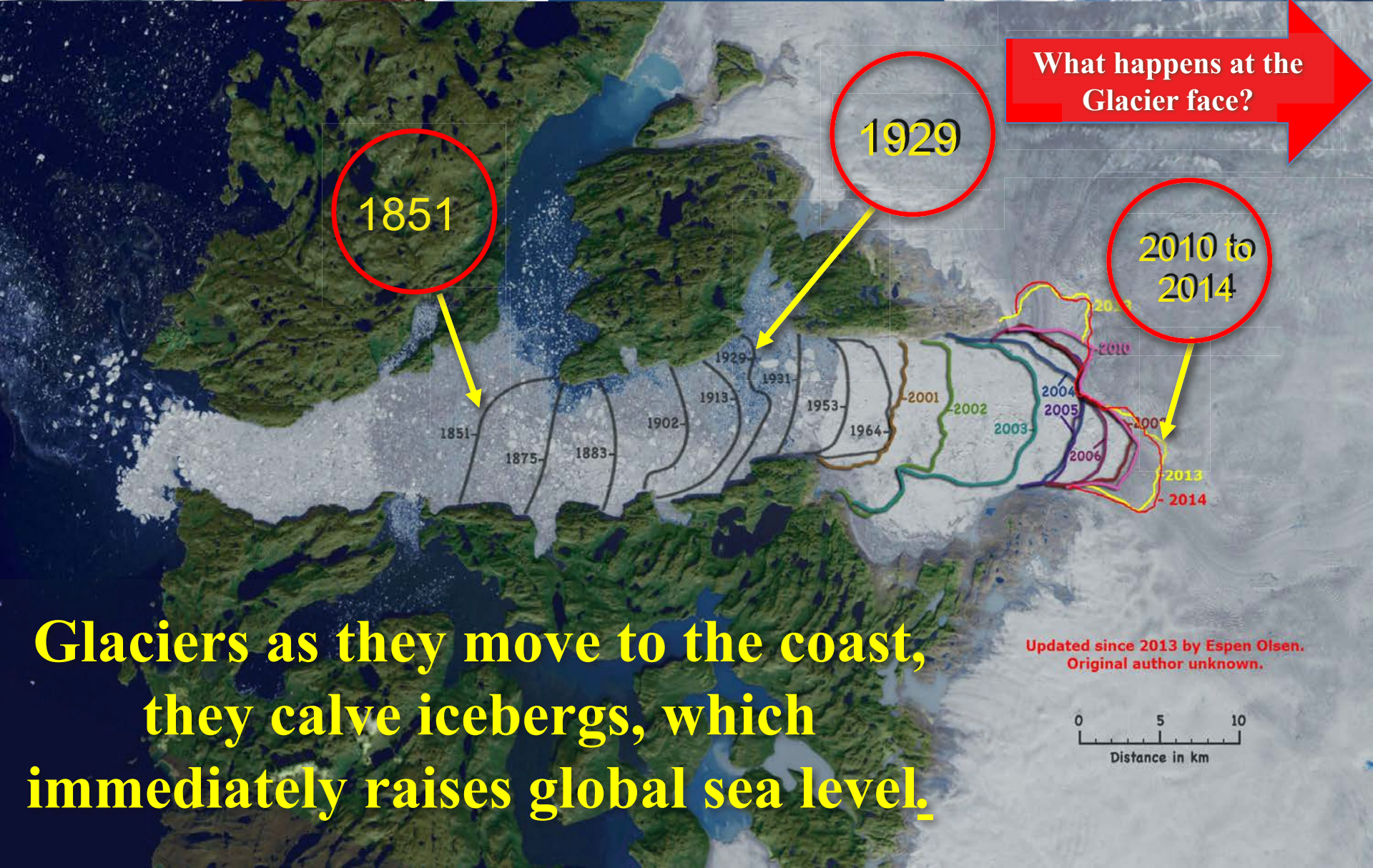
- 1. Thermal Expansion of Seawater:** As the water gets warmer, the ocean surface moves upward.
- 2. The Melting of Land-Based Glaciers:** glacial melt water runs off, the sea will rise accordingly. 
- 3. Landmass Subsidence;** The local upward or or downward movement of landmasses that are responding to release of the heavy weight from past ice age glaciers melting.
- 4. Changes in the Local Ocean Currents Impacts Local Sea Level:** As the Gulf Stream or other local ocean currents past the coastline, it will change the local sea level, particularly upward as the current slows.



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What happens at the Glacier face?

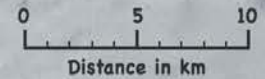
1851

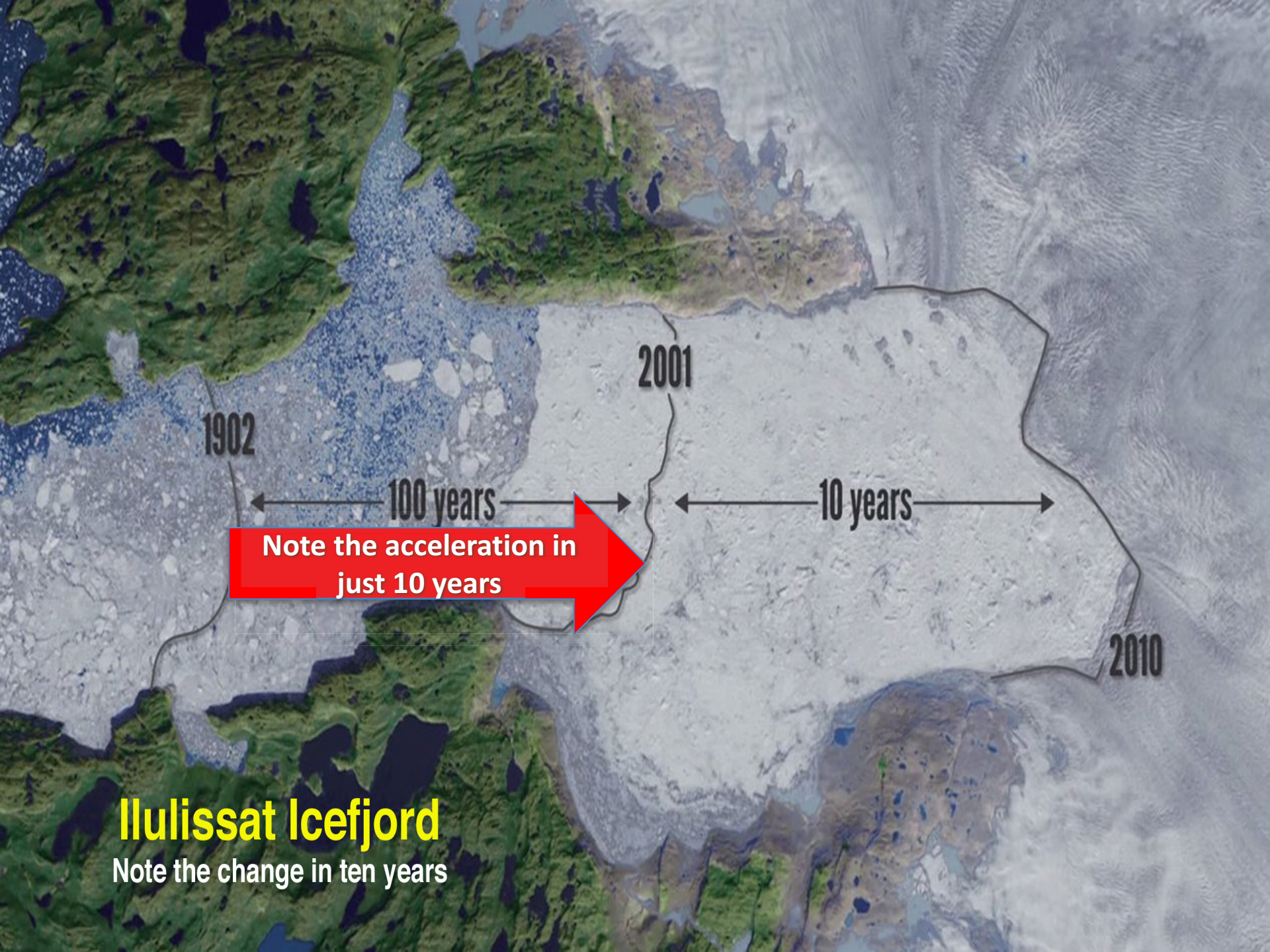
1929

2010 to 2014

Glaciers as they move to the coast, they calve icebergs, which immediately raises global sea level.

Updated since 2013 by Espen Oisen. Original author unknown.





1902

2001

2010

100 years

10 years

Note the acceleration in just 10 years

Ilulissat Icefjord

Note the change in ten years

Face of the Ilulissat Glacier



Ilulissat Glacier: Scale is ~ kilometer across the face and ~800 meters high



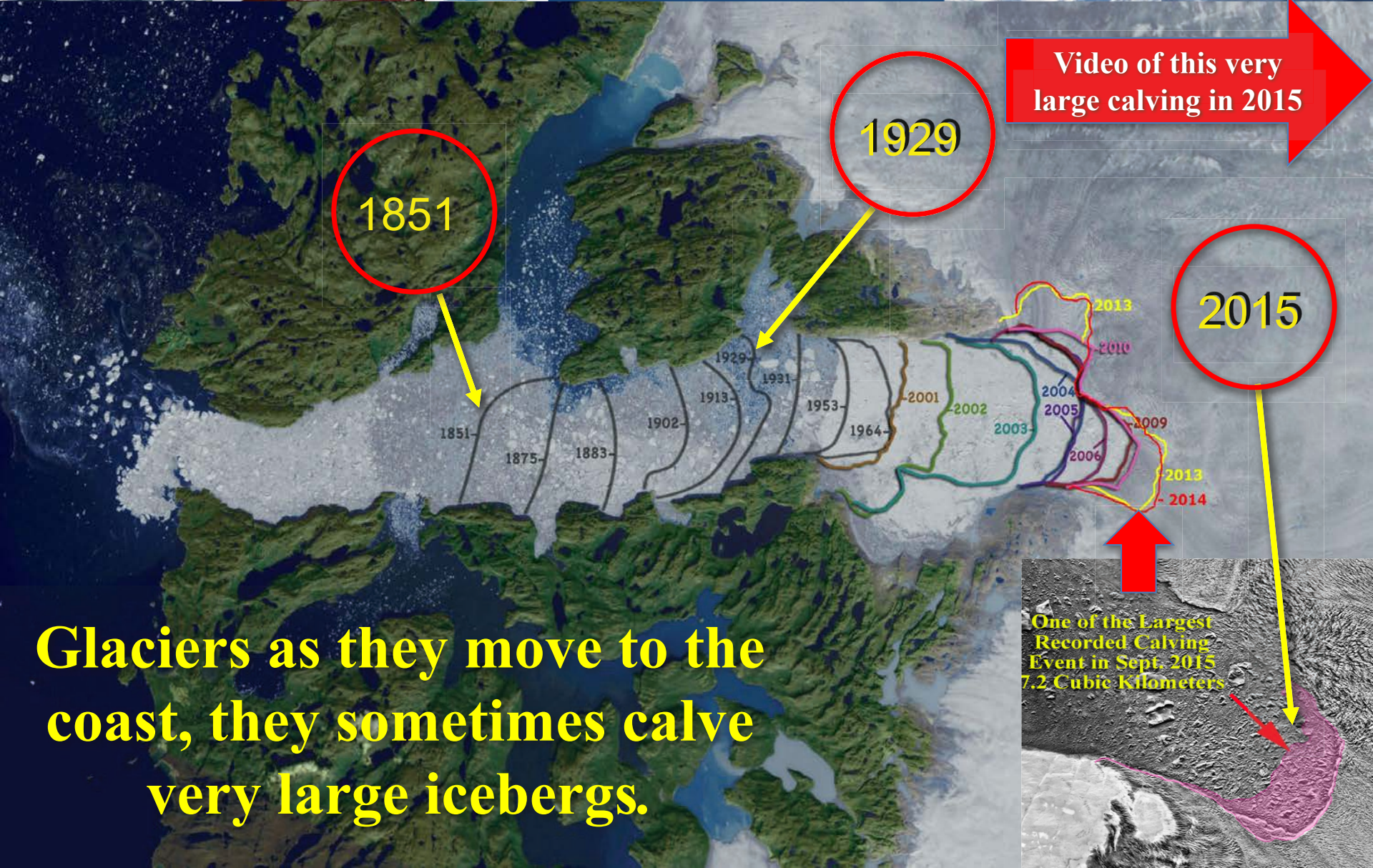
September 2015, the largest calving of a glacier was recorded



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1851

1929

Video of this very large calving in 2015

2015

Glaciers as they move to the coast, they sometimes calve very large icebergs.

One of the Largest Recorded Calving Event in Sept, 2015
7.2 Cubic Kilometers



The Extreme Ice Survey (EIS) team filmed the largest ice calving event ever recorded, which took place in September of 2015 in the Ilulissat Icefjord



Another way the melting glacier feeds sea level.



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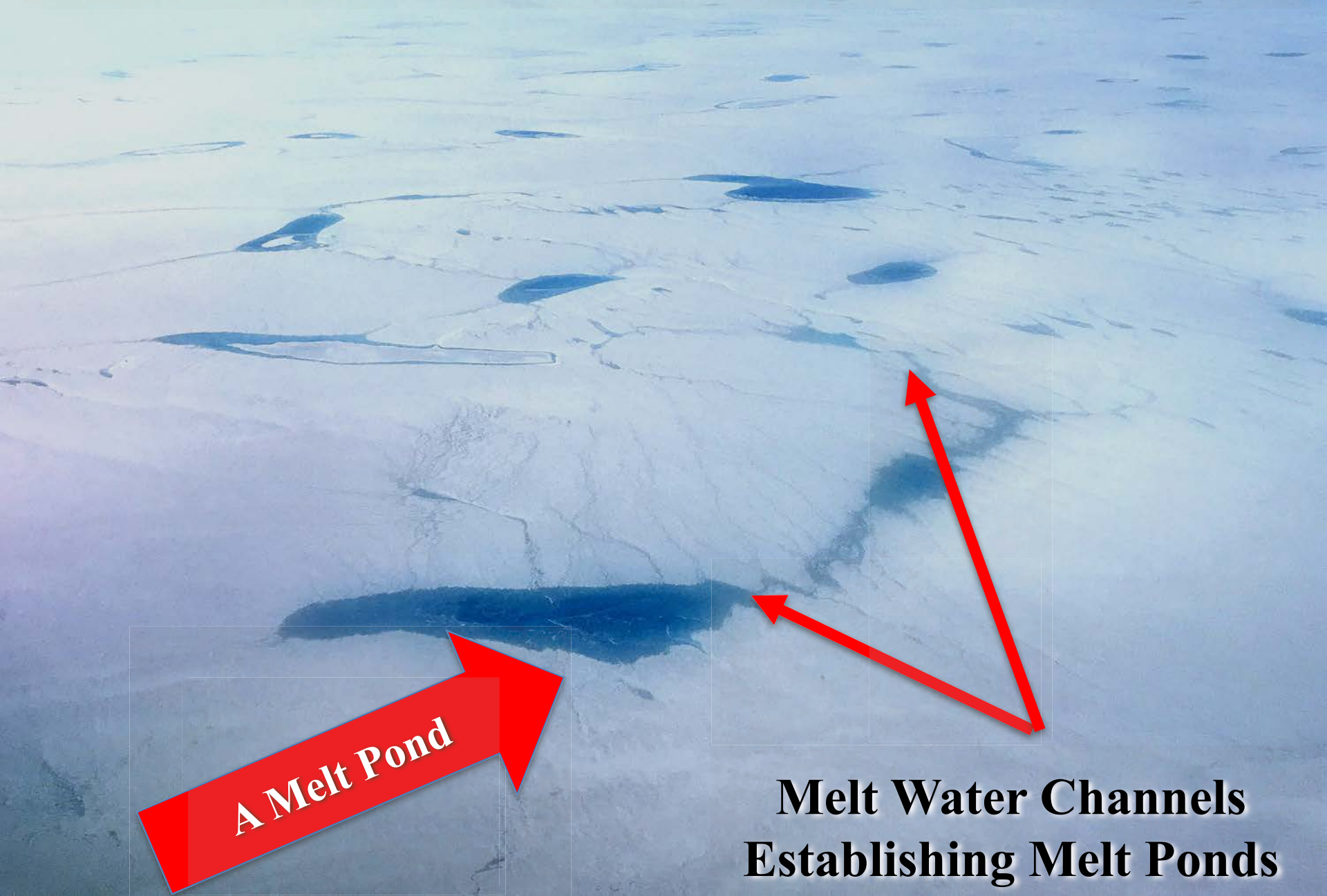
This very large iceberg is very likely an iceberg from the major calving event of September 2015!



Over 1 Km

About 100 Meters

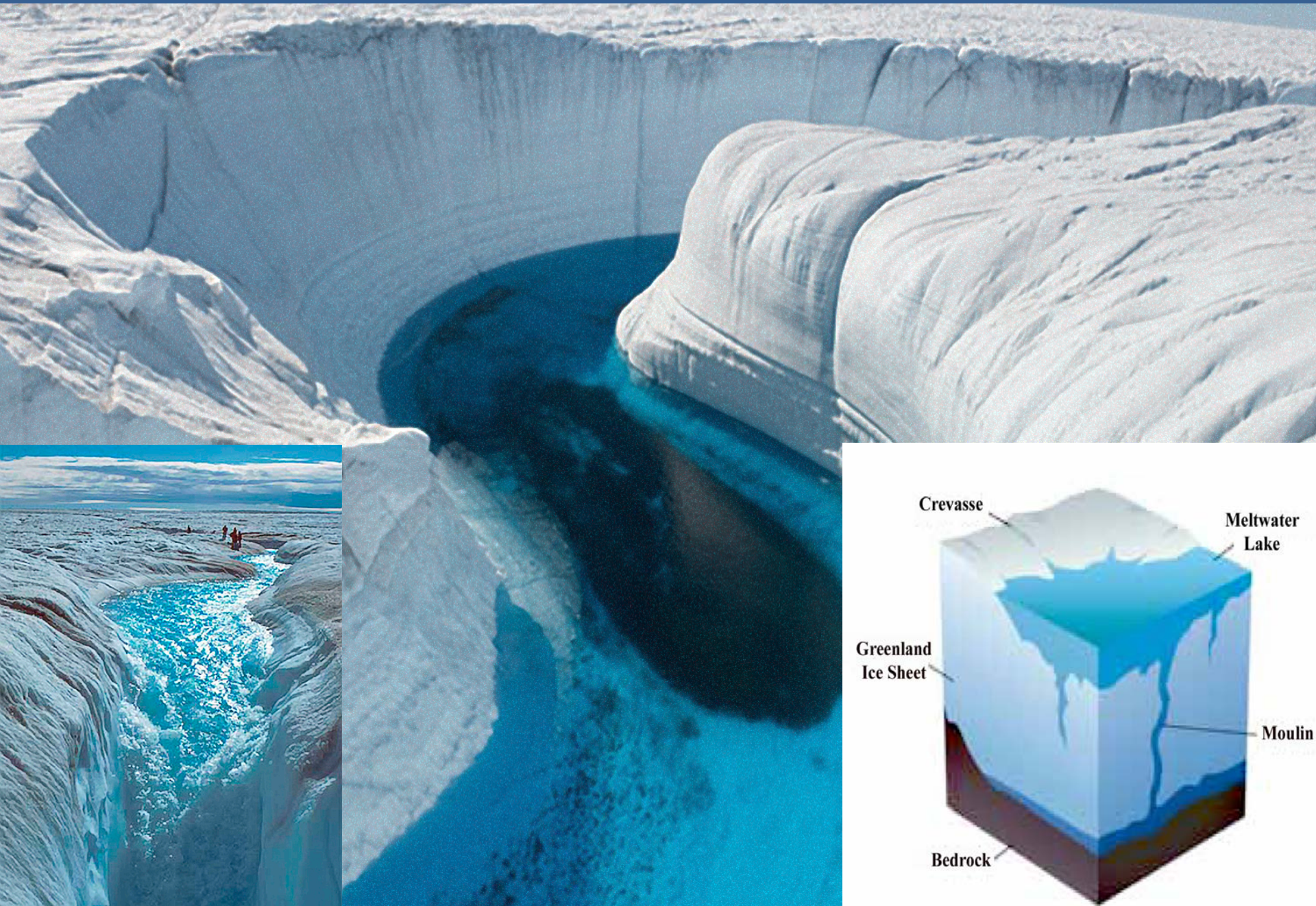
Melt Water Ponds and Channels: Greenland Glacier August 2016



A Melt Pond

**Melt Water Channels
Establishing Melt Ponds**

Moulins Channel Surface Melt Water to the Sea



Crevasse

Meltwater
Lake

Greenland
Ice Sheet

Moulin

Bedrock



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Melt Water Channels

The Moulin surface hole is often 10's of meters wide

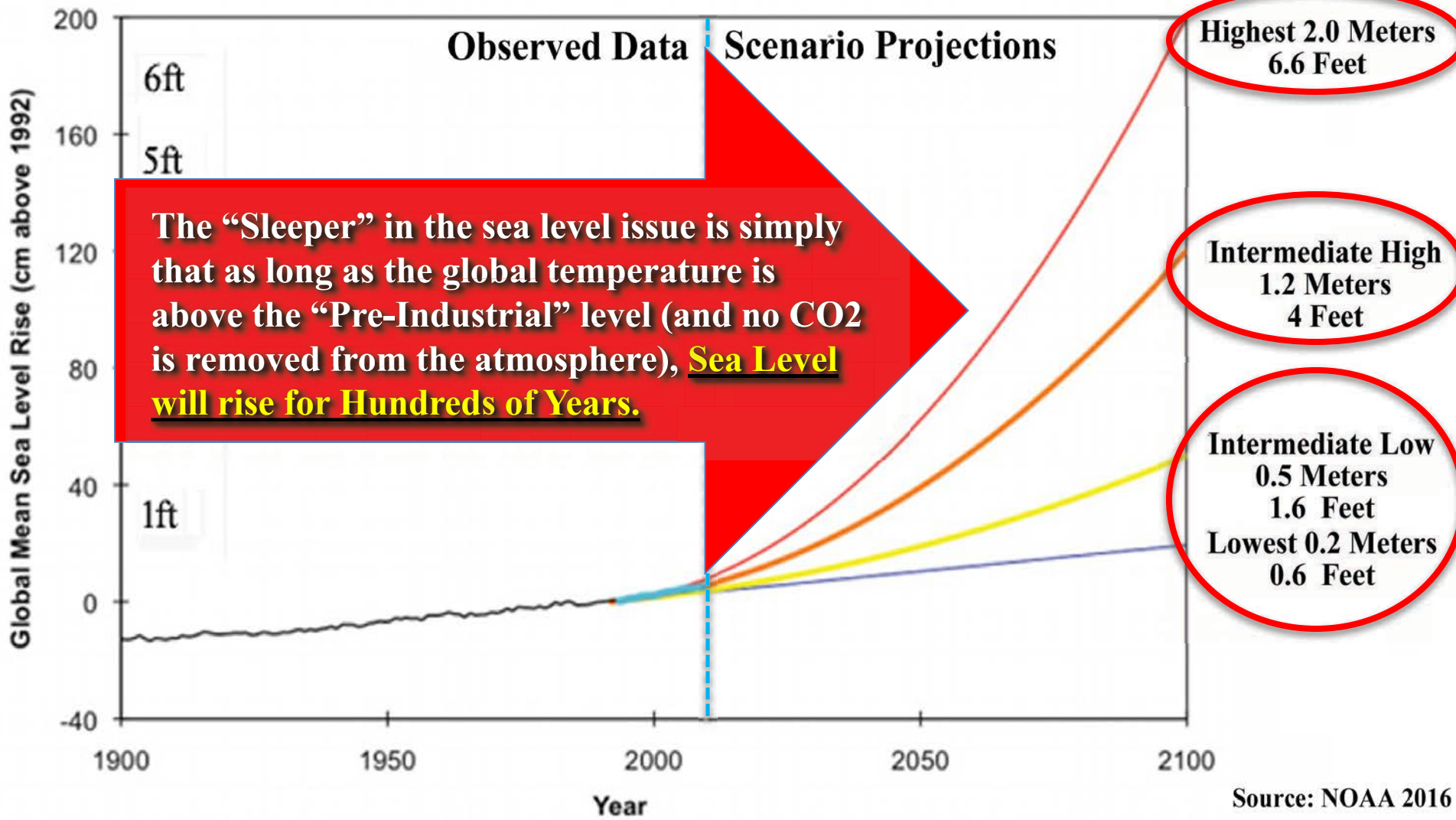
Melt Water and Moulin on the 2017 Greenland Glacier



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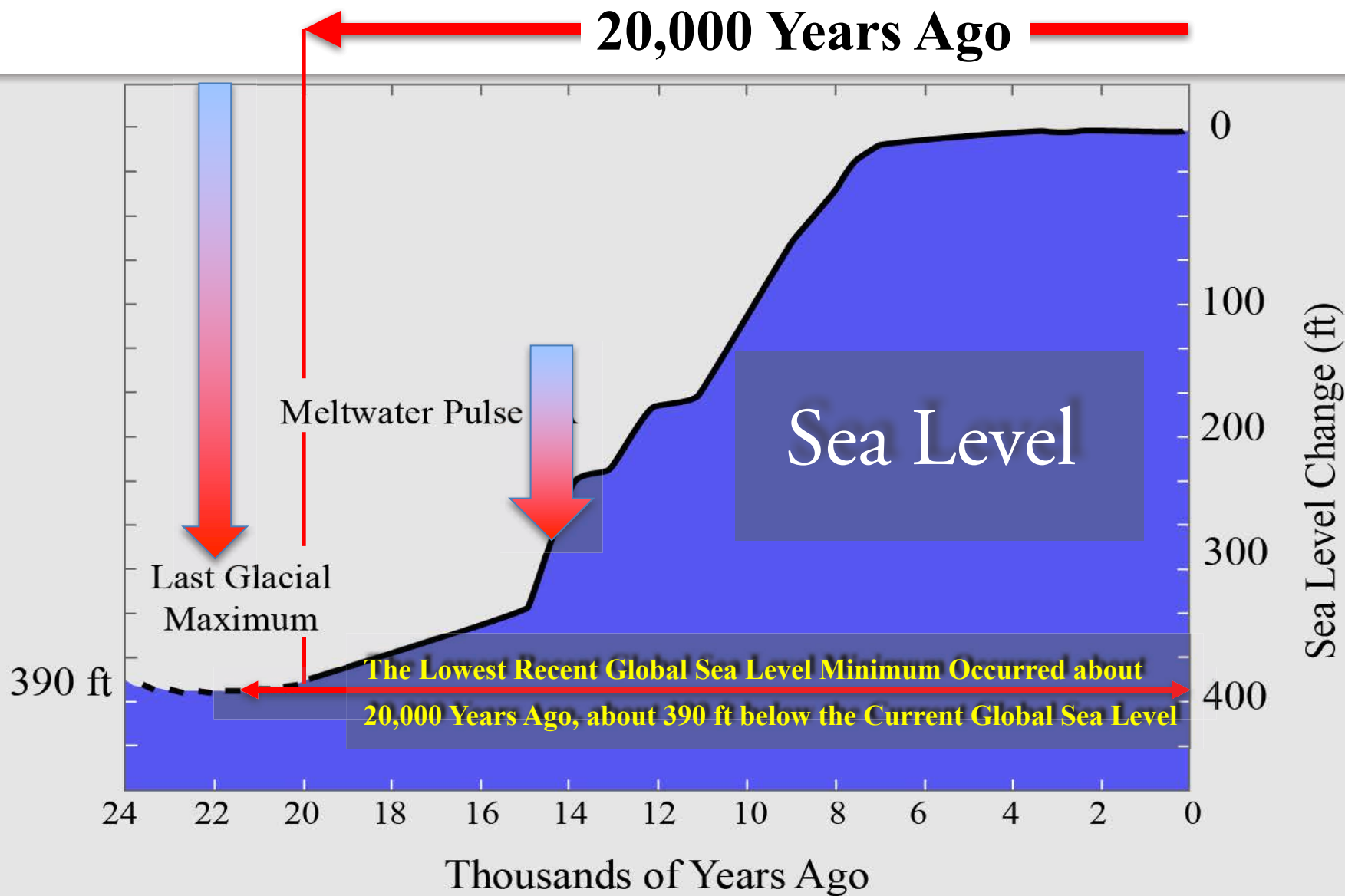


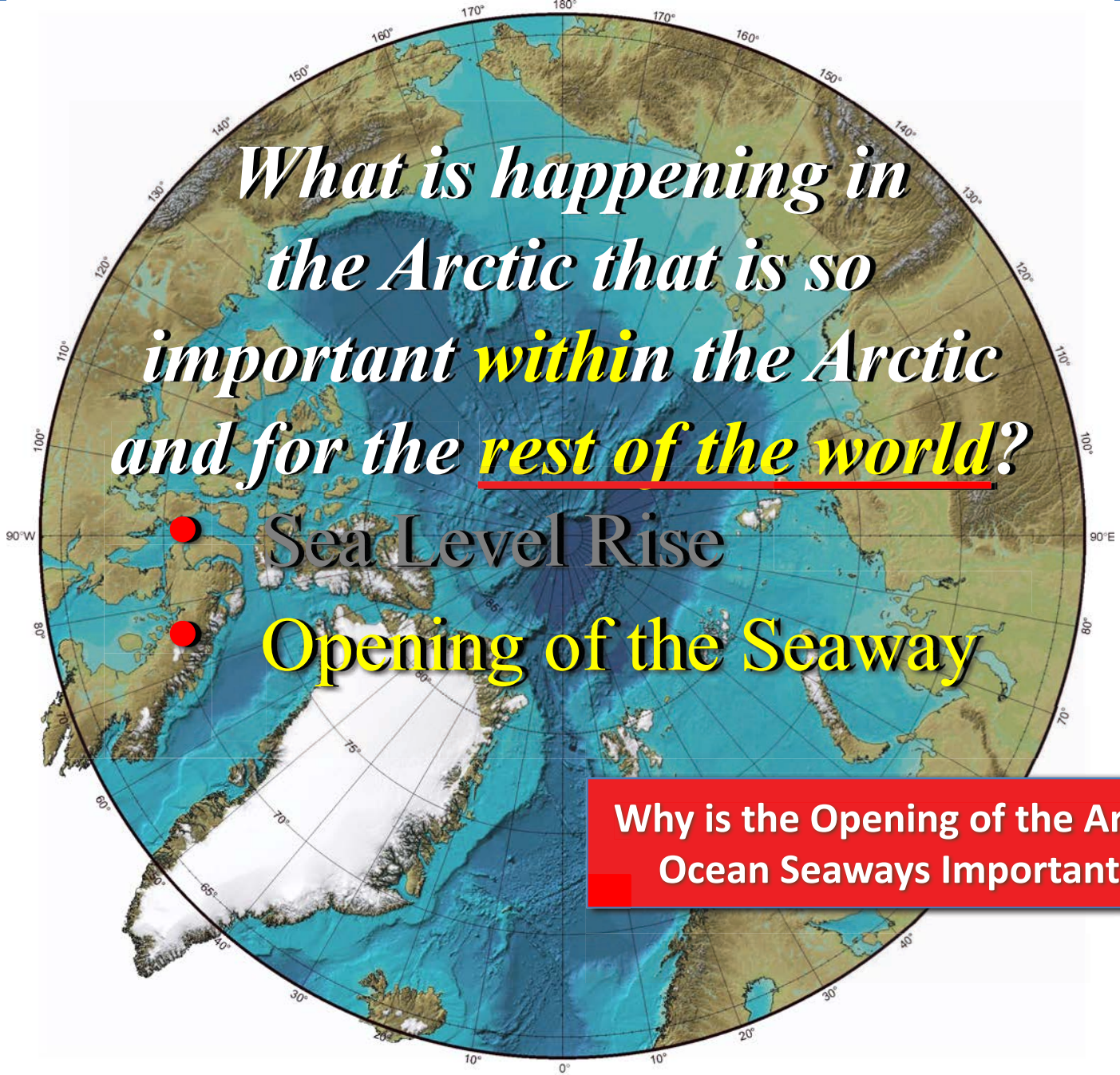
Global Sea Level Projection Scenarios



The "Sleeper" in the sea level issue is simply that as long as the global temperature is above the "Pre-Industrial" level (and no CO2 is removed from the atmosphere), **Sea Level will rise for Hundreds of Years.**

An Overview of the Last Ice Age

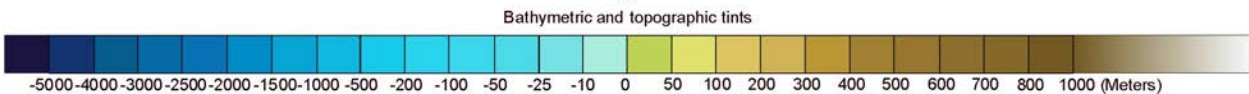




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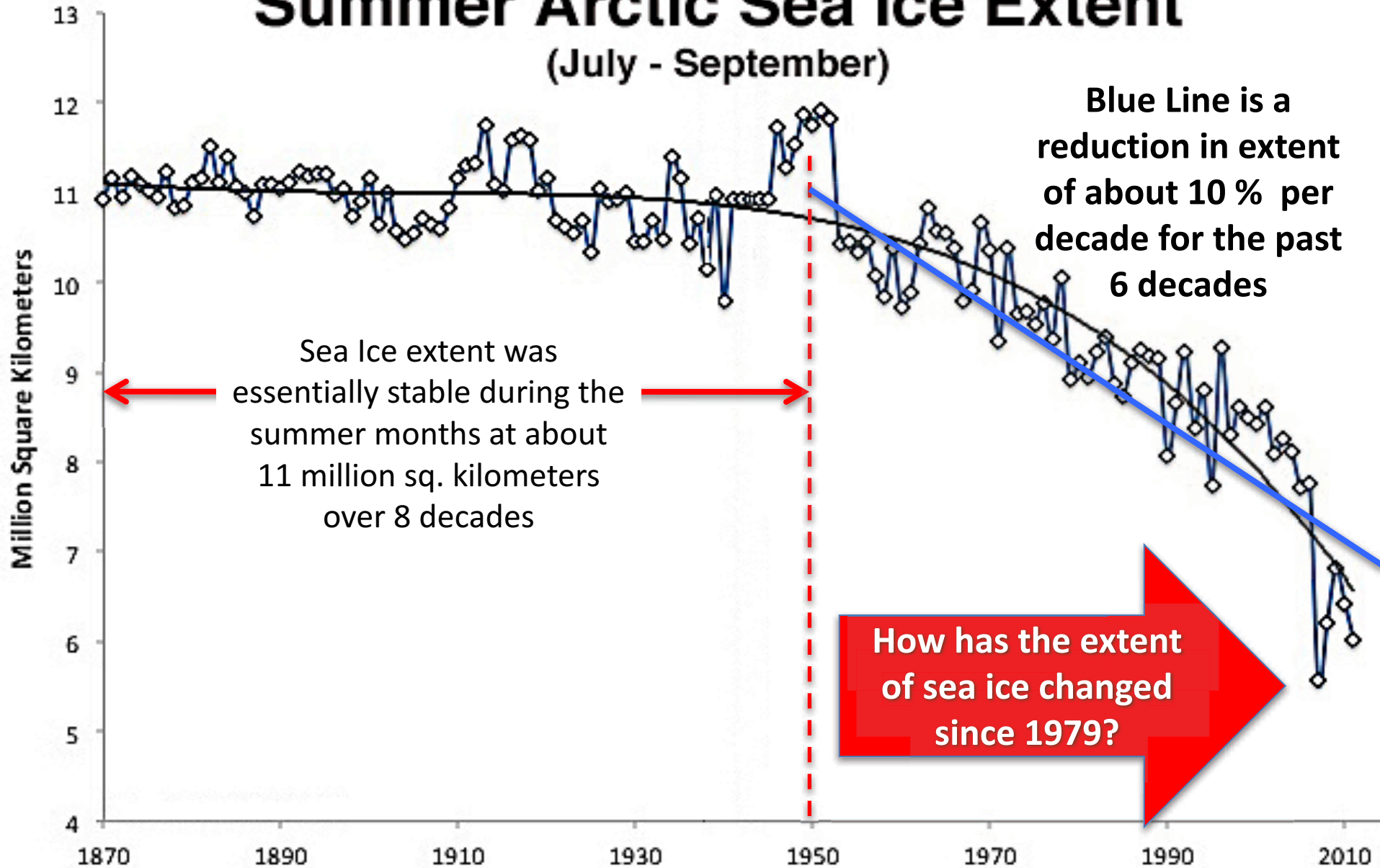
- Sea Level Rise
- Opening of the Seaway

Why is the Opening of the Arctic Ocean Seaways Important?

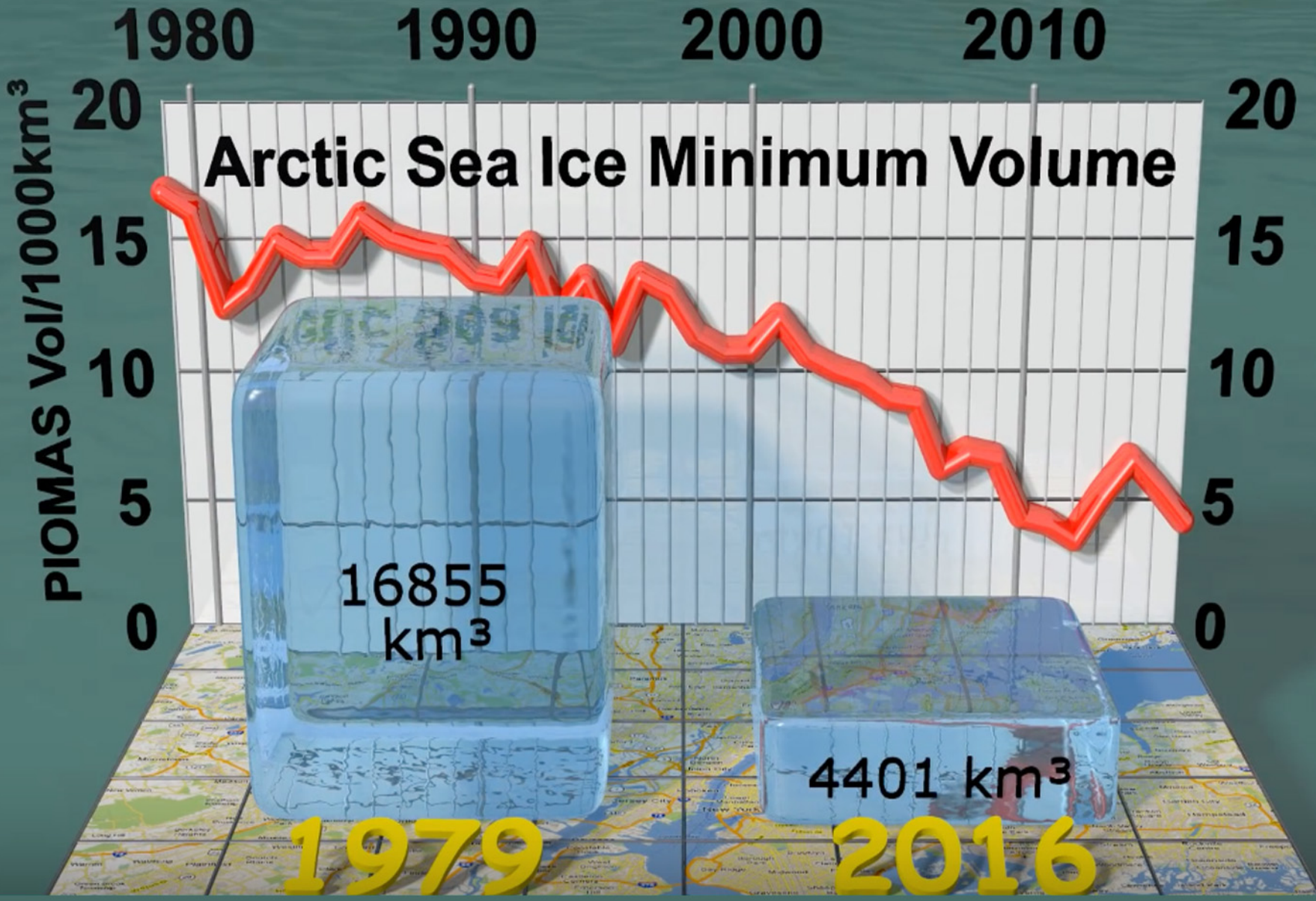


Summer Arctic Sea Ice Extent

(July - September)



Sources: Data for 1870-2008 from the University of Illinois (Walsh & Chapman 2001 updated to 2008) and observational data from NSIDC for 2009-2011. Graphic adapted from <http://www.skepticalscience.com>



Source: <http://psc.apl.washington.edu/wordpress/research/projects/arctic-sea-ice-volume-anomaly/>
Created by: Andy Lee Robinson <http://youtube.com/ahaveland> Oct 2015

74% of sea ice volume has been lost since 1979 by the September 2016



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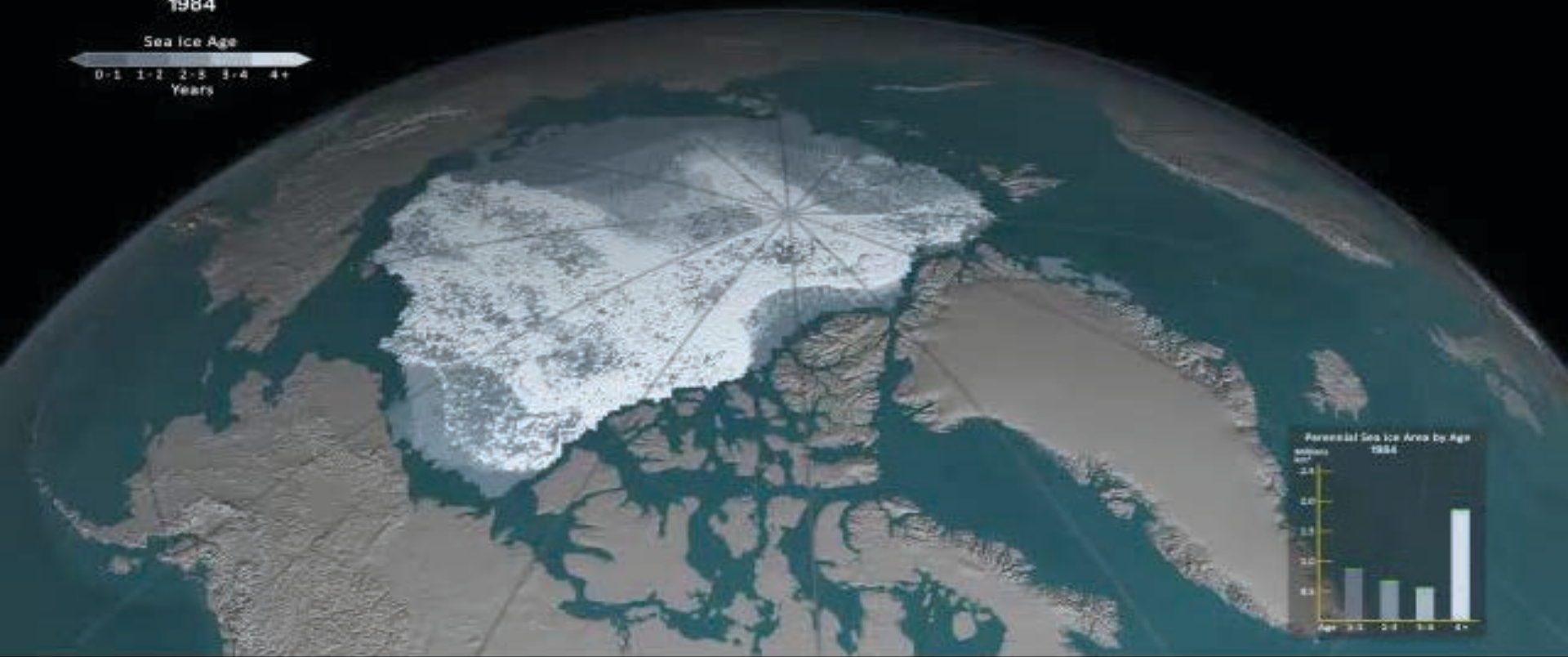
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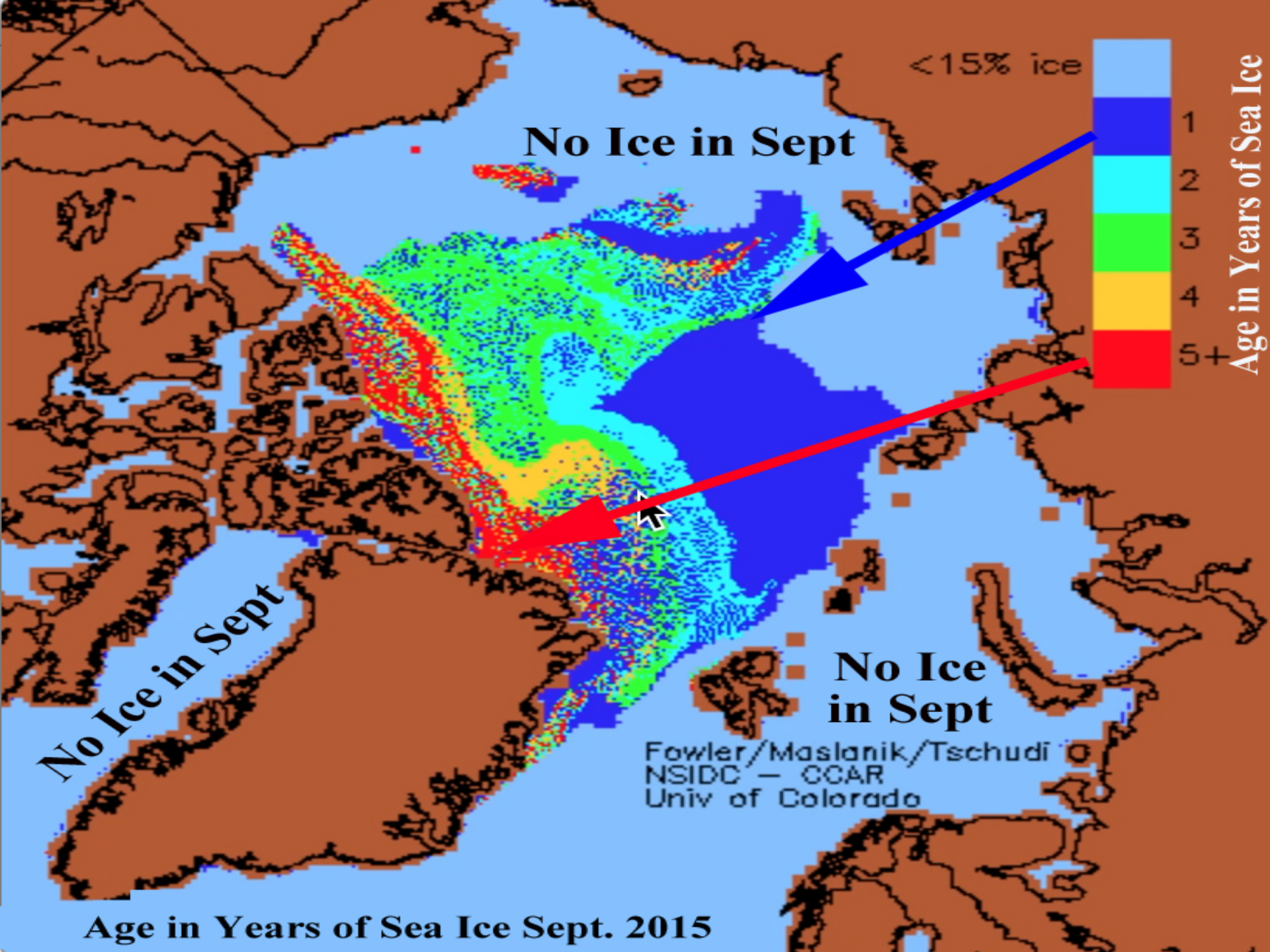


1984

Sea Ice Age

0-1 1-2 2-3 3-4 4+
Years







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Arctic Sea Ice Extent

The opening of these seaways has caused a dramatic shift in interests in natural resource development along with the prospect of international marine shipping routes within and across the Arctic Ocean basin. Korea, China and Japan have increased substantially their interest in these issues.

In 2015 a total of 5.4 million tons of goods and project cargo were transported on the NSR, up from about 4.0 million tons in 2014 and 3.9 million tons in 2013.

Opening of the Arctic Ocean Seaways

The increased Interest In the Arctic by Countries such as Korea, China, Japan and Singapore is a Consequence of the Opening of the Seaways in the Arctic Oceans.

There have been modest increases in shipping in recent years!



Source: Arctic Council AMSA Report

The Prospects of Trans-Arctic Ocean Shipping and Access to Ports has Driven these nation's Interests in being Players in the Arctic Council and other International Bodies

The Potentials for an Arctic Opening to the Global Economic System

- **Trade:** Trans-Arctic trade is seen as the most important prospect for socioeconomic development for the Arctic.
- **Estimated Arctic Hydrocarbons:** Natural Gas (30% of global) & Oil (13% of global).
- **Hard Minerals:** Palladium (40% of global), Nickel (22% of global), Diamonds (20% of global), Platinum (15% of global), Zinc (10% of global).
- **Rare Minerals:** Rare Earths (25% of global),
- **Commercial Fishing** (10% of global).
- **Marine Tourism:** The industry is growing and will have substantial potential with socio-economic consequences.

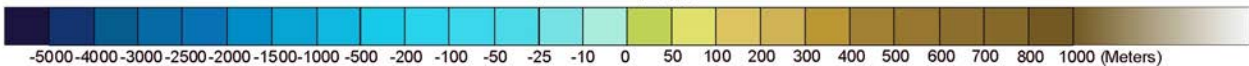




*What is happening in the Arctic that is so important **within the Arctic** and for the **rest of the world?***

- Sea Level Rise
- Opening of the Seaway
- **Weather Extremes**

Why Weather Extremes





Some Weather Trends with Global Implications

- **Stronger Hydrological Cycle:** A stronger hydrological cycle will lead to more water per storm across the globe. *US has seen a 30% increase in intense rain storms over the past few decades, even though the total increase in precipitation is only a 2%-3%.*
- **More Frequent Extremes:** Recent observations show more frequent extremes across the globe, what *were previously observed as 1-in-100 year events, now appear to be 1 in 20 year events or even more frequent.*
- **More Heat Extremes:** Heat extremes will have a significant effect on crop production has been well documented with the *likelihood of more hot days with record heat and less precipitation, hence crop yields are more vulnerable.*



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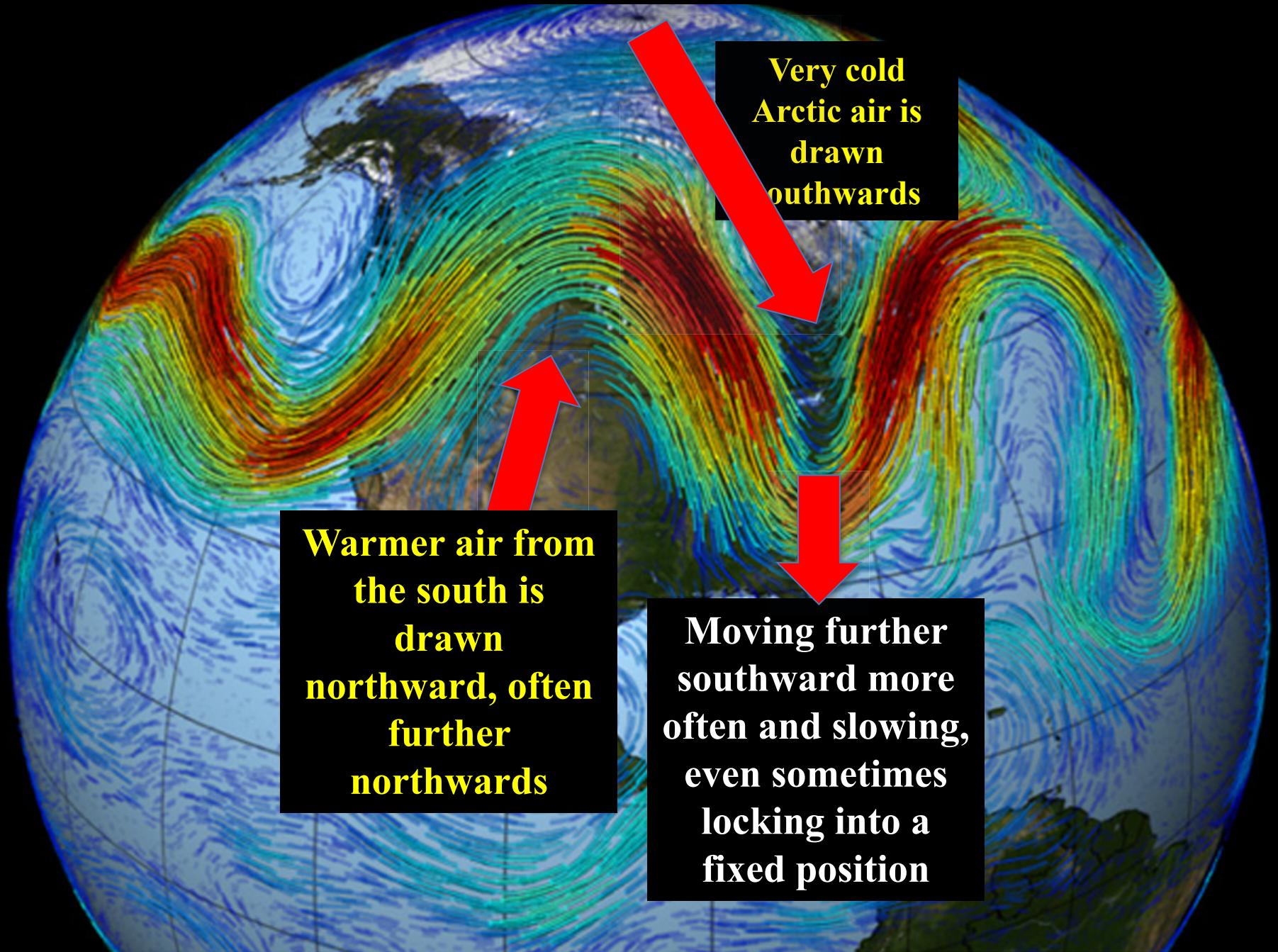
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Climate changes appears to increase the north-south range of the Jet Stream

Climate Changes Appears to Increase the North-south Range of the Jet Stream

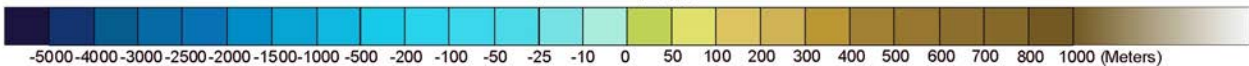




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- Sea Level Rise
- Opening of the Seaway
- Weather Extremes
- **Ocean Acidification**

Why Ocean Acidification?



Increases in Carbon Dioxide in the Atmosphere Acidifies the Oceans

The increase in CO₂ over ocean over the past 100 year has lead to a 30% increase in acid levels of seawater, a level that has not existed for over 65 million years!



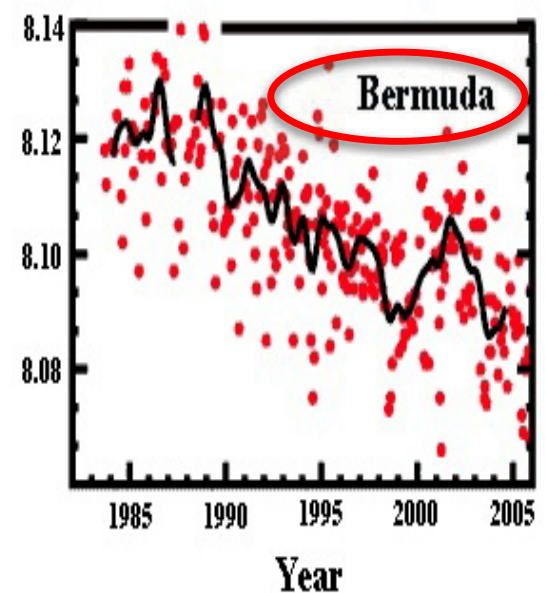
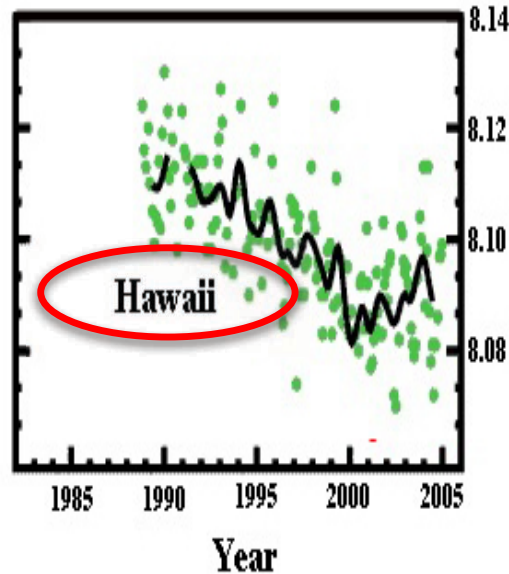
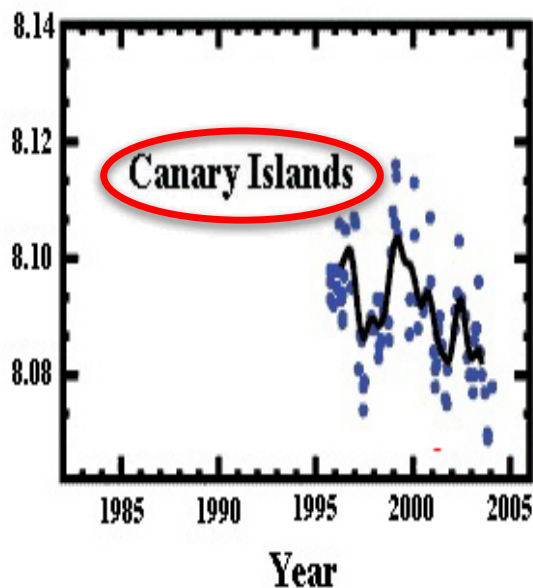
Simply, the oceans are becoming more acidic!

This reality can significantly modify and severely alter the marine biota and disrupt the oceanic food chain.

Ocean Acidification is Accelerating

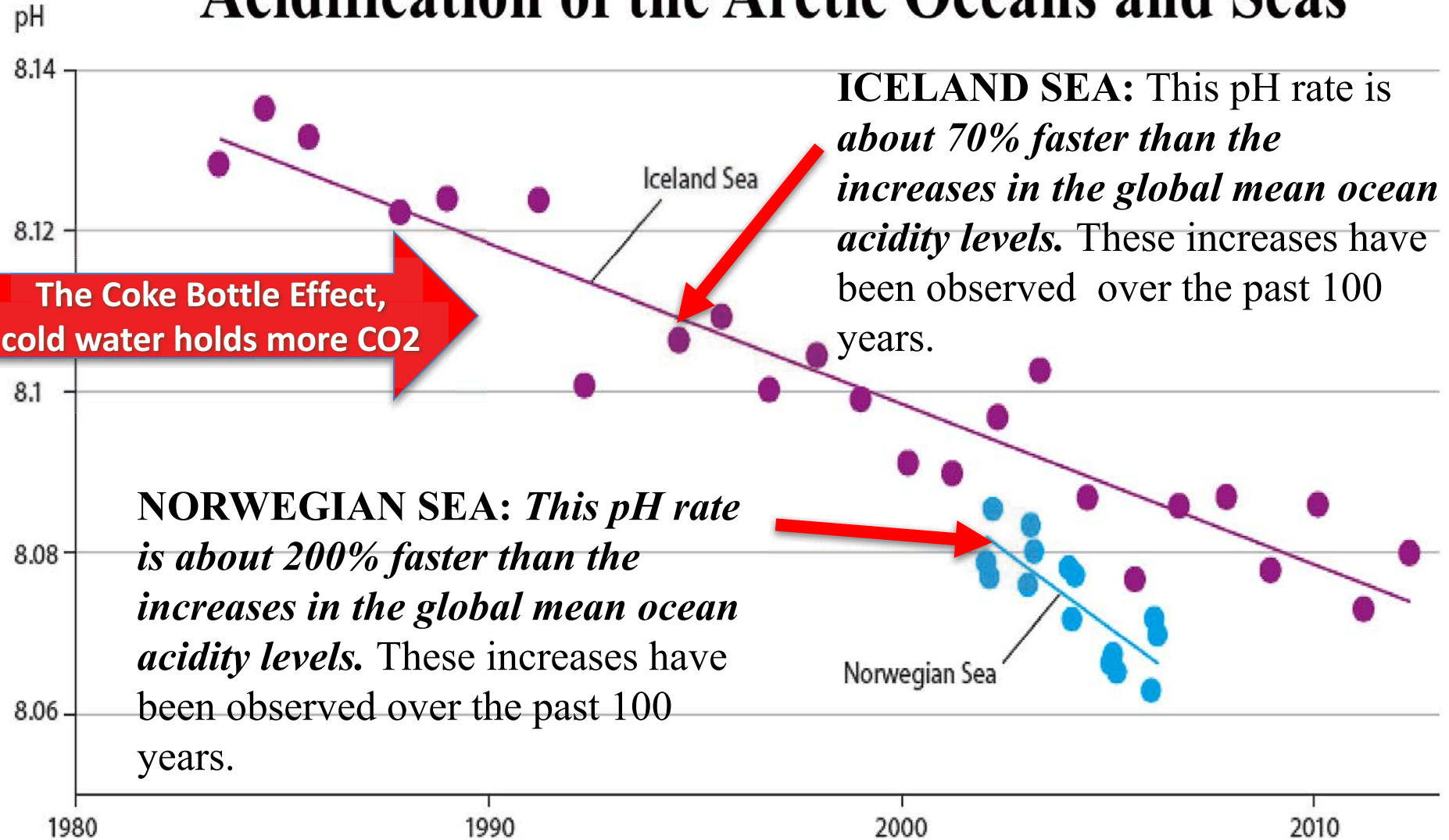
A recently published analysis projects that changes in the acidification of the deep ocean may exceed anything seen in the past 65 million years.

Andy Ridgwell, A. et al *Nature Geoscience*, 14 February 2010

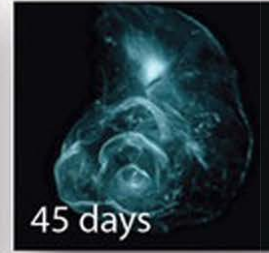




Acidification of the Arctic Oceans and Seas



Pteropods



Projected Acidified Levels later this Century will affect the Viability of this Species.

- Pteropods are abundant throughout the oceans that are sometimes referred to as the “potato chips of the sea” because of their importance as a food source for so many species, including salmon and other commercial and sport fisheries.
- Pteropods are very sensitive to the changes acidification levels projected for the decades ahead.
- North Pacific salmon depend heavily upon Pteropods for food. Pteropods are about 50% of the diet of juvenile pink salmon. The North Pacific salmon fisheries provided three billion dollars worth of personal income to fishermen and others in 2007, and supported 35 thousand jobs in just the harvesting and processing of the fish.
- Many commercially important fish species that feed on Pteropods, all of which are projected to risk collapse if Pteropod populations decline do to ocean acidification levels.

The Sea Butterfly, the pteropod, is increasingly affected by the Increases in Ocean Acidification

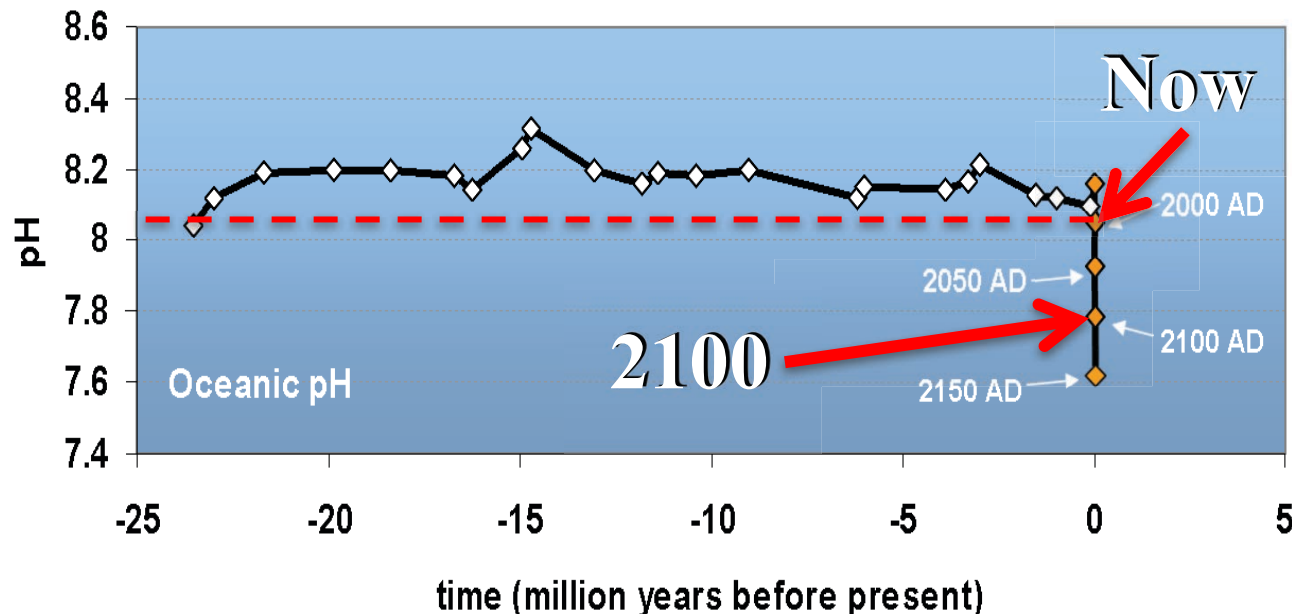
Ocean Acidification

“What are the Prospects for the the 21st Century?”

- **The Projected Drop in Ocean pH is Unprecedented:** Research projects that by 2100 the global ocean is likely to experience a 0.3 drop in pH, which will move the ocean toward levels in acidity that have not been documented for at least 65 million years.
- **Human Consequences of pH Change:** A drop of just 0.1 pH units in human blood pH can result in profound health consequences, including seizures, heart arrhythmia, or even coma.

Ocean Acidification

What are the prospects for the coming decades?

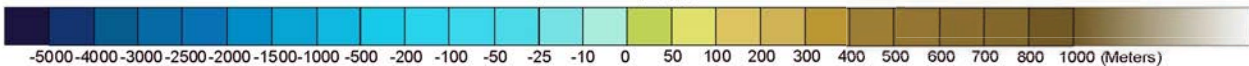




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- Opening of the Seaway
- Weather Extremes
- Ocean Acidification
- **Thawing Permafrost**

Is the Thawing of the Permafrost an Issue?





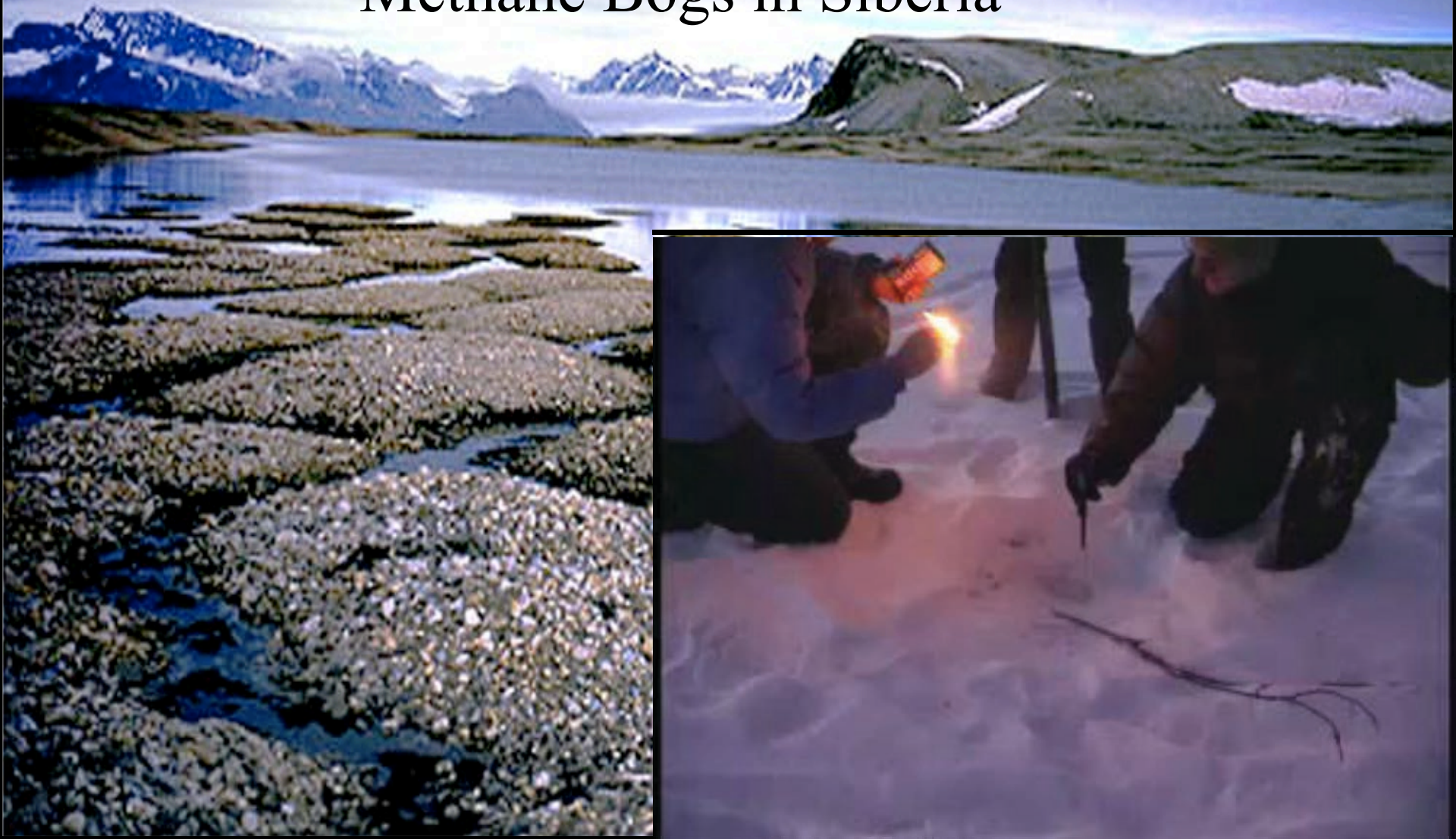
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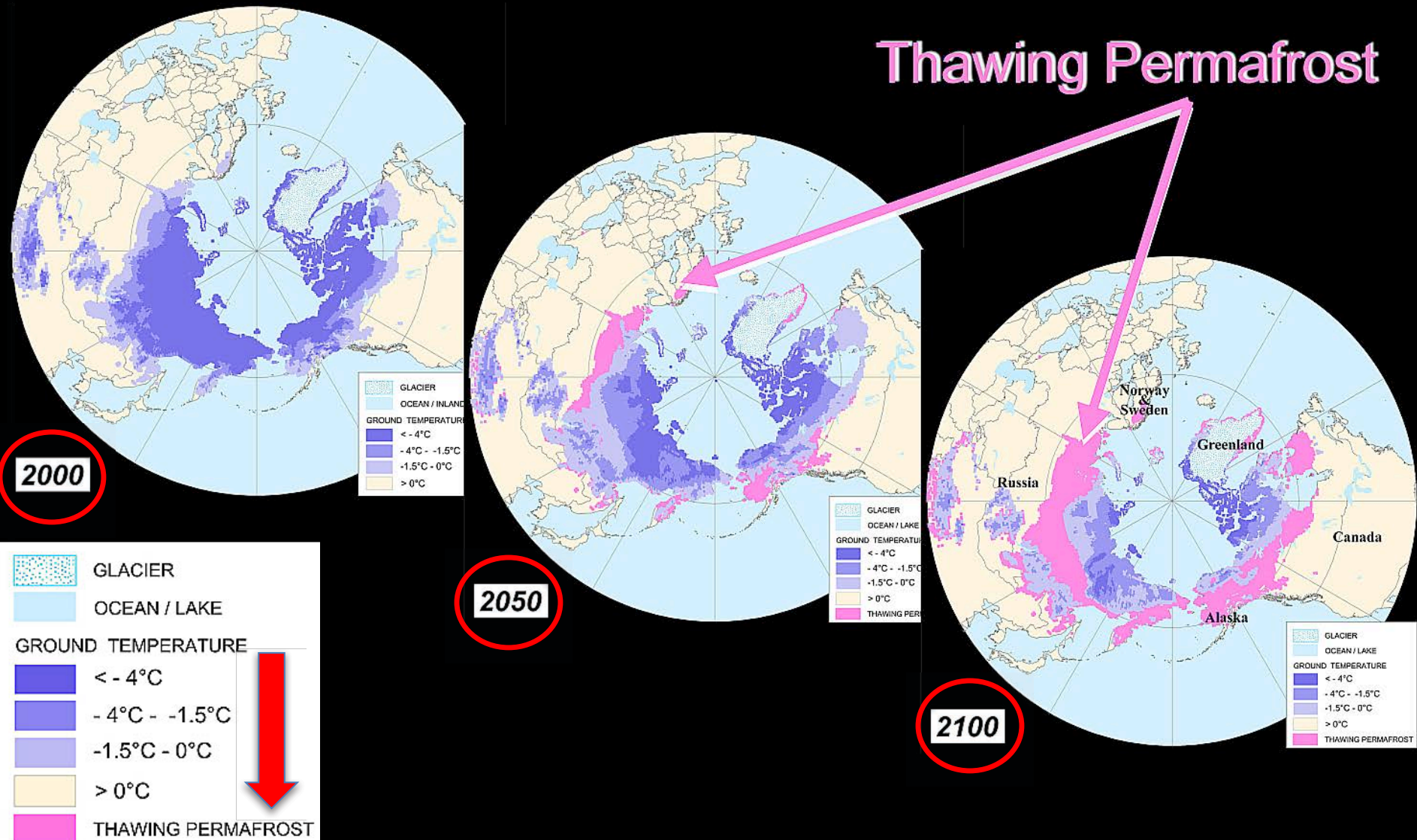


Methane Bogs in Siberia



Trends and Patterns of Permafrost Thawing in the Circumpolar Arctic

Thawing Permafrost





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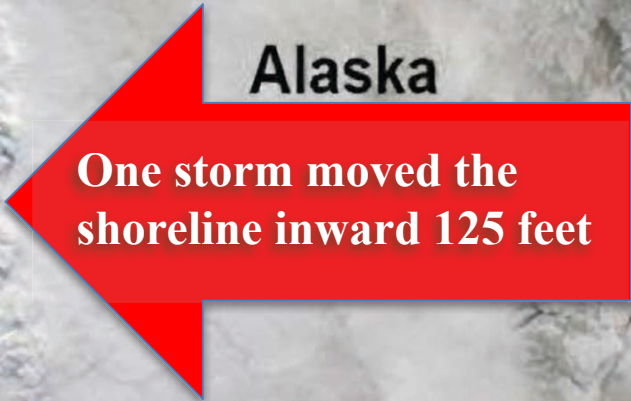
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**Thawing
Permafrost.**

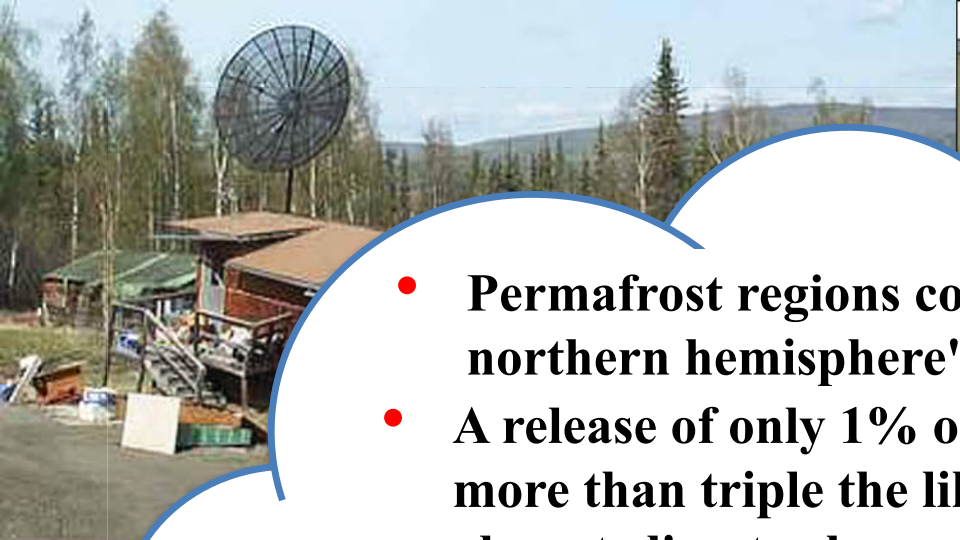
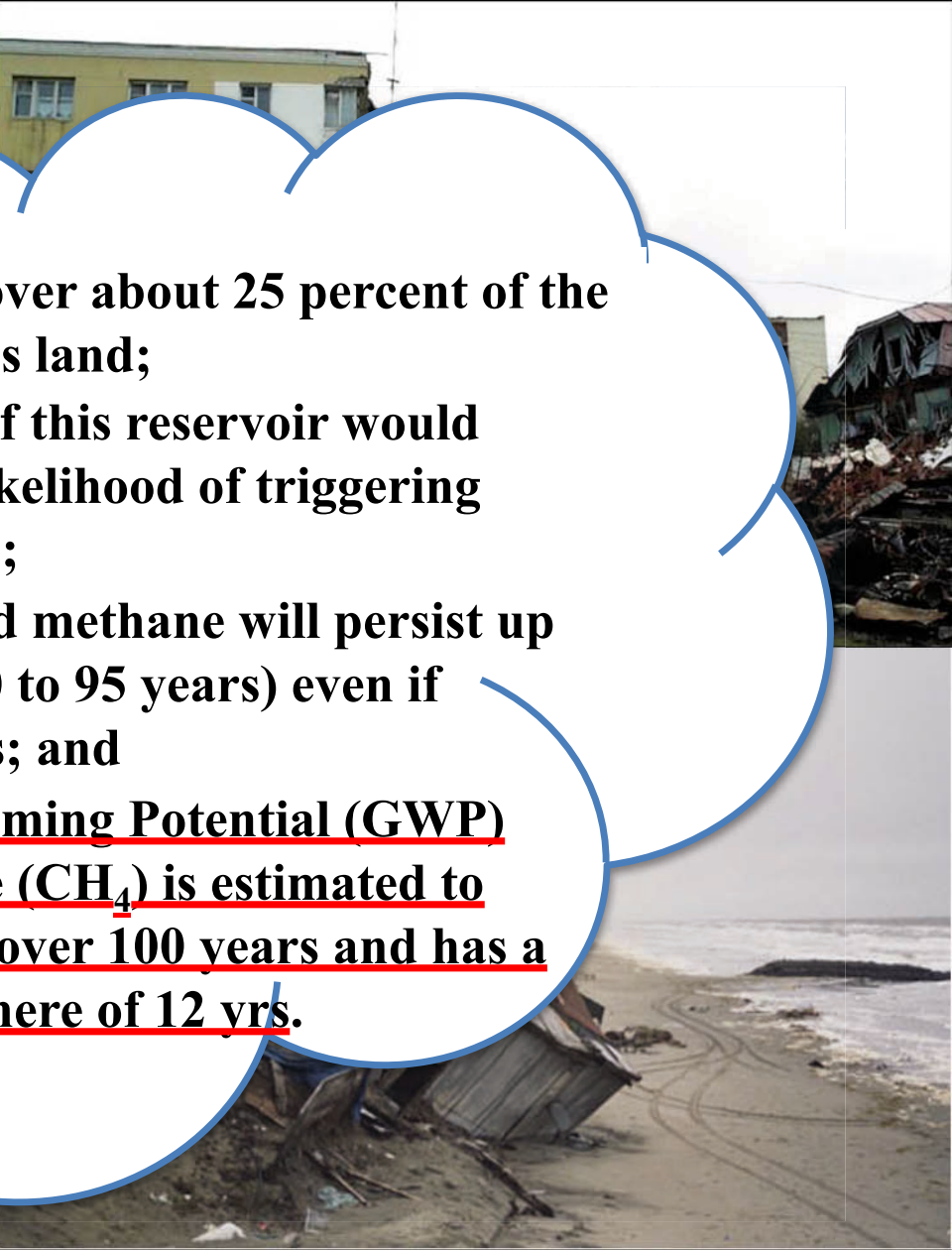
Shishmaref
Nome

Alaska



**One storm moved the
shoreline inward 125 feet**

**Intense North Pacific Storms off Shishmaref's Coast Reach and Erode the
Shoreline because the Sea Ice Barrier has melted by a Warming Arctic**

- 
- 
- Permafrost regions cover about 25 percent of the northern hemisphere's land;
 - A release of only 1% of this reservoir would more than triple the likelihood of triggering abrupt climate change;
 - The release of CO₂ and methane will persist up to a hundred years (30 to 95 years) even if emissions of CO₂ stops; and
 - CO₂ has a Global Warming Potential (GWP) of 1, whereas Methane (CH₄) is estimated to have a GWP of 28–84 over 100 years and has a lifetime in the atmosphere of 12 yrs.

Examples of the Consequences of the Thawing of Permafrost on Local Infrastructure where the Permafrost has been Frozen of Centuries

Arctic Amplification: Feedback Mechanisms in the Arctic that Accelerates the Climate System in High Latitudes

Melting sea ice
-albedo cooling
Replaced
by dark open
ocean warming

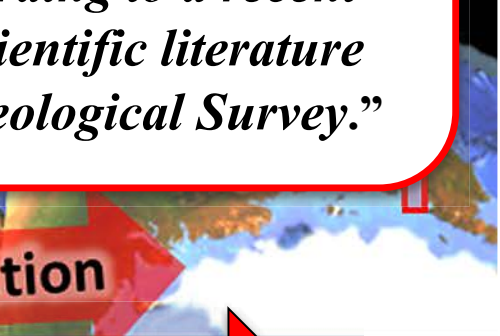
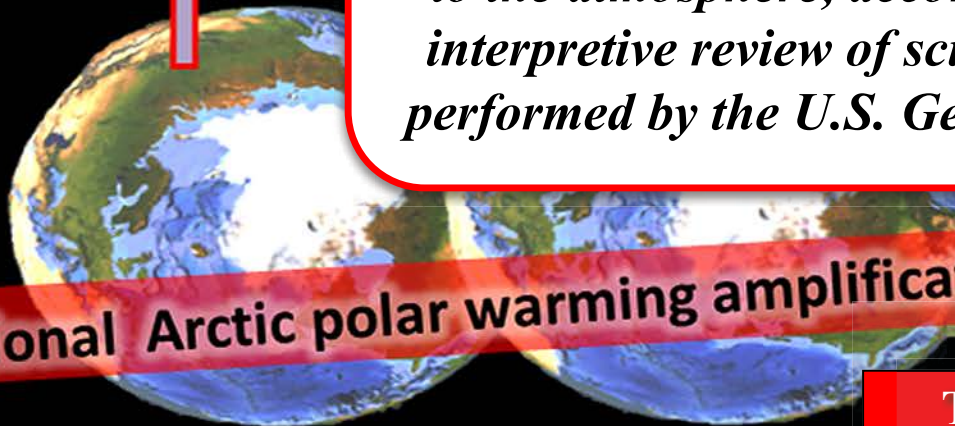
methane

“The breakdown of methane hydrates due to warming climate is unlikely to lead to massive amounts of methane being released to the atmosphere, according to a recent interpretive review of scientific literature performed by the U.S. Geological Survey.”

Warm
north
peat la

Regional Arctic polar warming amplification

The Arctic
Imperatives





**Global Trends
2030**

**International Conference on Arctic Science
"Bringing Knowledge to Action"**

***Beyond Assessments to take Science,
Knowledge and Consequences to Action***

April 26, 2017

Taking Knowledge to Action: An Opportunity to Build on the recent Study by the Council on Foreign Relations

The Council on Foreign Relations just released a report to the new Administration. An Independent Task Force Report titled:

Arctic Imperatives: Reinforcing U.S. Strategy on America's Fourth Coast

Co-Chairs:

Christine Todd Whitman

Admiral Thad Allen

COUNCIL on
FOREIGN
RELATIONS

Independent Task Force Report No. 75

Thad W. Allen and Christine Todd Whitman, Chairs
Esther Brimmer, Project Director

Arctic Imperatives

Reinforcing U.S. Strategy on America's Fourth Coast



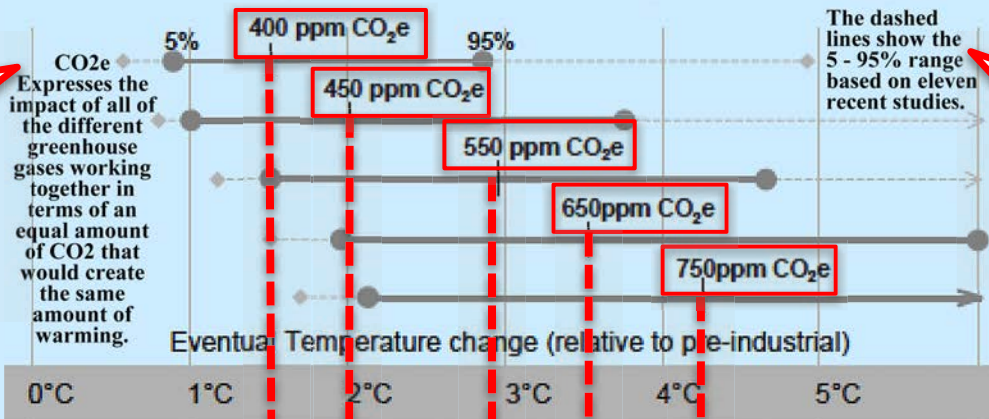
A Summary of the Global Consequences of a Rapidly Changing Arctic



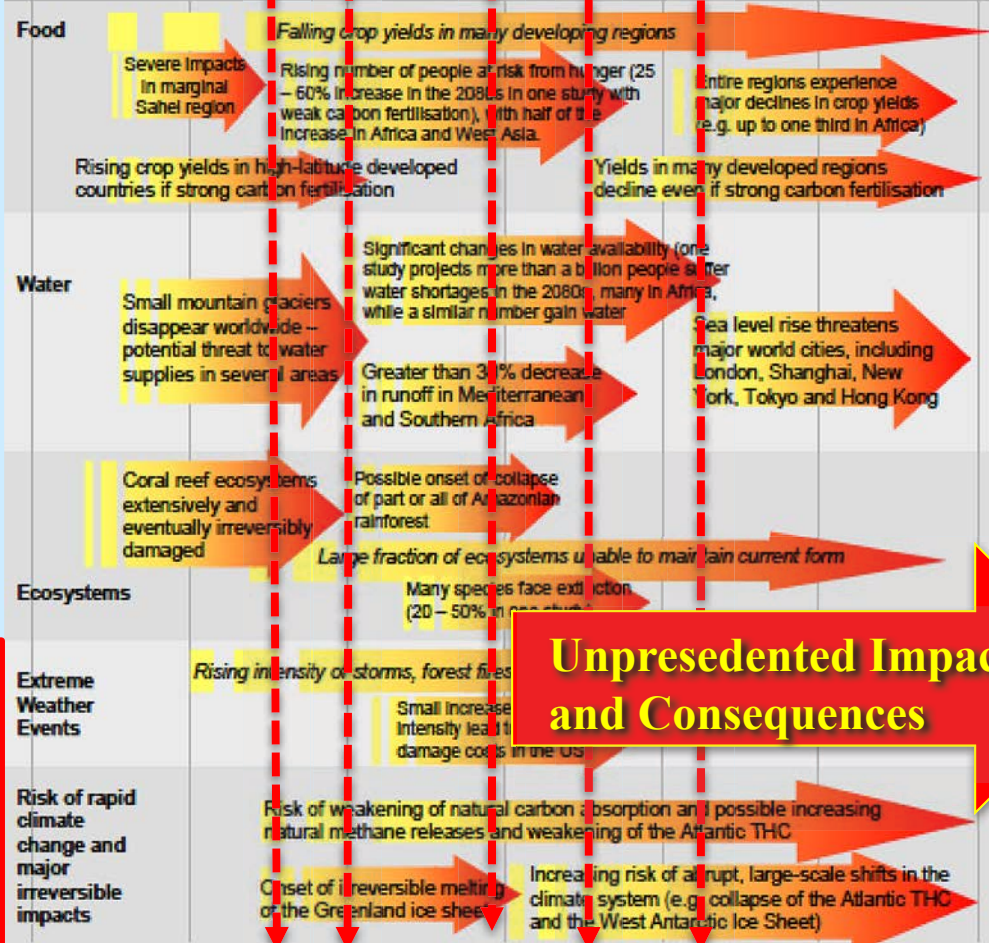
- Global Climate is Warmer,
- Fisheries are Likely to Change,
- Shipping & Tourism to Increase,
- Global Sea Level to Rises for Centuries,
- Ocean Circulation Appears to be Disrupted,
- New Weather Patterns are Emerging, and
- Geopolitics Shifts are Emerging.

Levels of Impacts and Probabilities for a Range of Temperature Increases (0 to 5 °C)
 The 2007 Stern Report: The Economics of Climate Change (UK Parliament Study)

CO₂e Concentration in the global atmosphere



The dashed lines show the 5 - 95% probabilistic range



At the current rate of 2-3 ppm/yr, the mean value of emission is likely to be in:

- 2050** about 500 ppm CO₂e
- 2075** about 550 ppm CO₂e
- 2100** about 625 ppm CO₂e

This is a mean global surface temperature of 3.5 Degree C

Levels of Impacts and Probabilities for a Range of Temperature Increases (0 to 5 °C)

Unprecedented Impacts and Consequences

Source: Stern Report 2007 for the UK Parliament



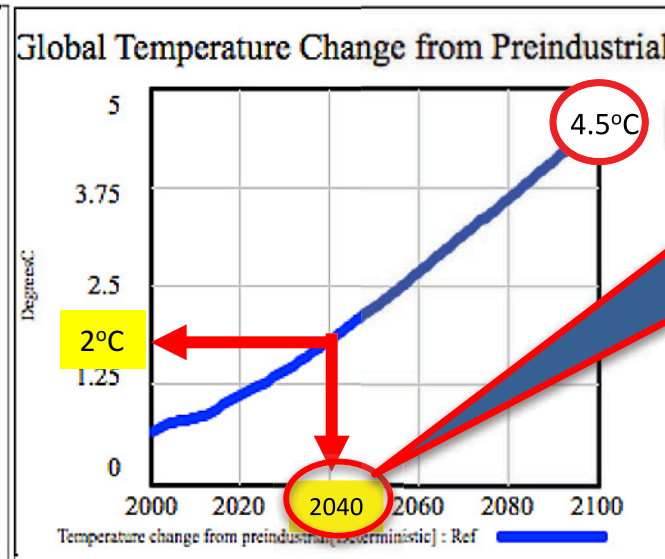
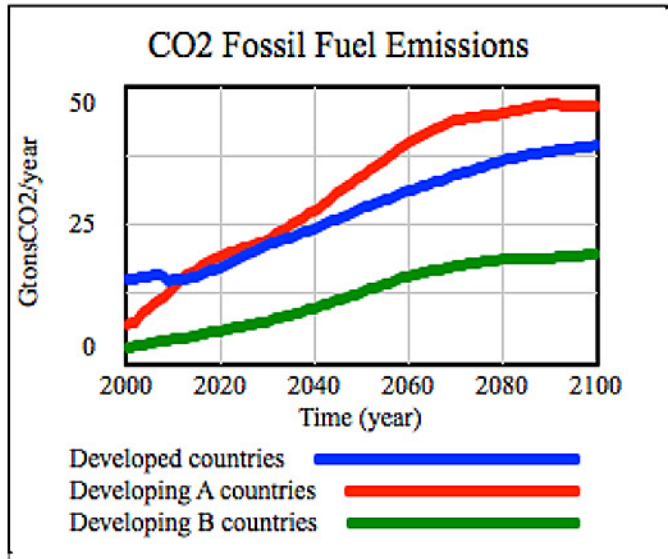
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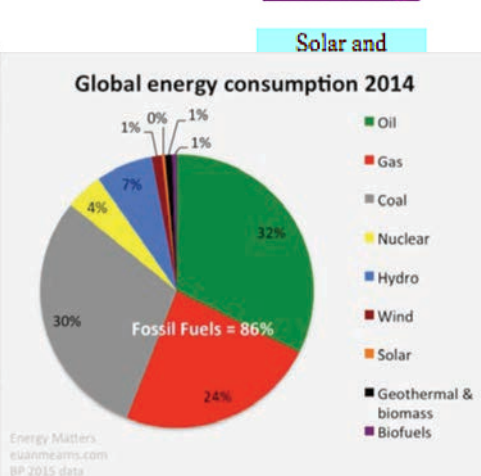
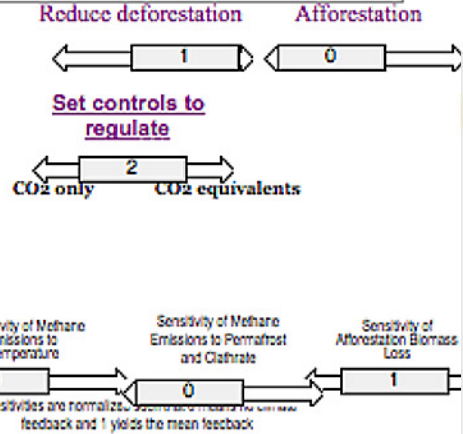
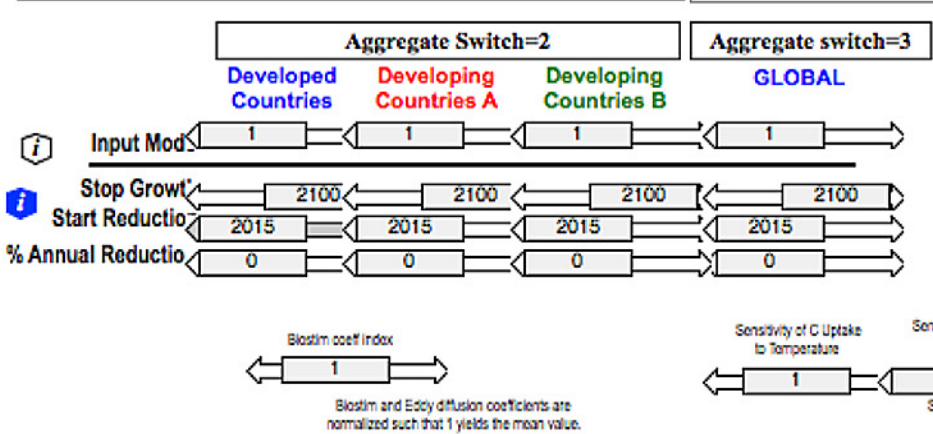
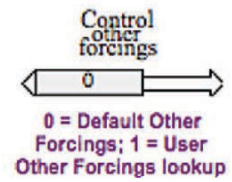
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The Business as Usual (An Estimate of the Projected Global Energy Demand)



Based on projected BAU demand for fossil fuel energy, it is projected that we will reach 2 degree C by about 2040



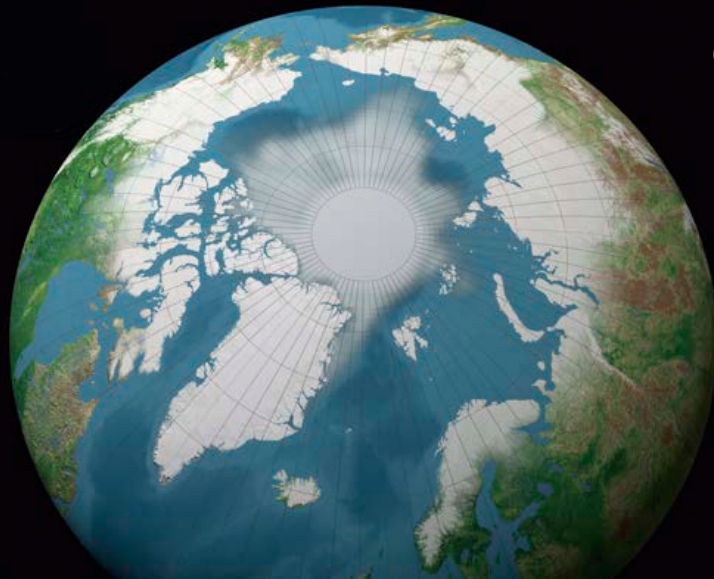


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We also will live in a remarkably different world



*Recent Global Trends
and Socio-Economic
Changes that are likely to
have Significant
Consequences for the
Arctic Region and the
World at Large!*

**Global Trends
2030**

GLOBAL TRENDS 2030:

ALTERNATIVE WORLDS

a publication of the National Intelligence Council



Available at:
<http://www.dni.gov/index.php/about/organization/national-intelligence-council-global-trends>

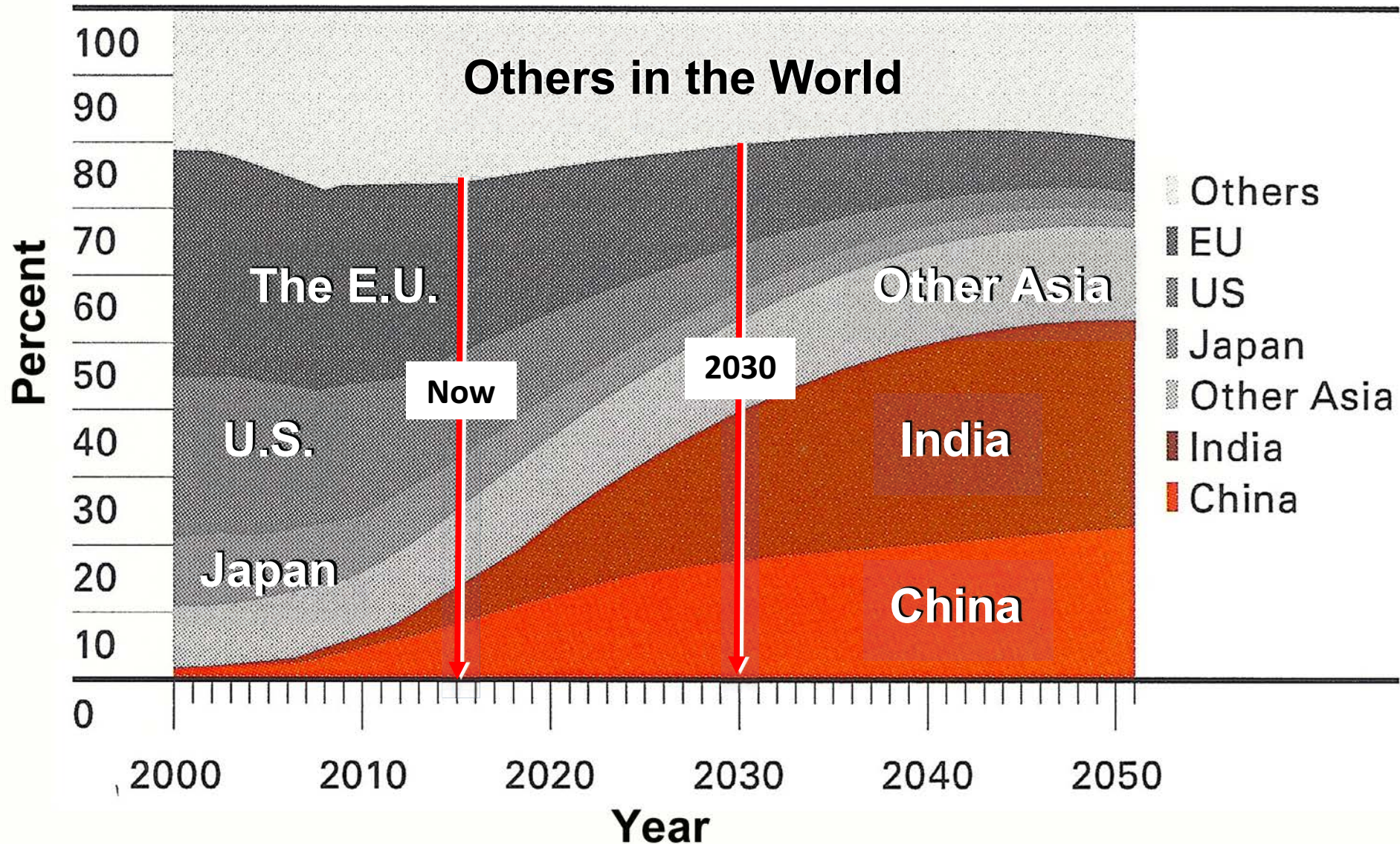
“Quadrennial Global Trends 2030 Report”

A report prepared every four years by the U.S. the intelligence community.

- **Majority of world's population won't be impoverished.**
- **Middle classes will expand in most countries.**
- **Individuals will move into the middle class as they seek and demand sociopolitical change and increase their demand for consumer goods.**

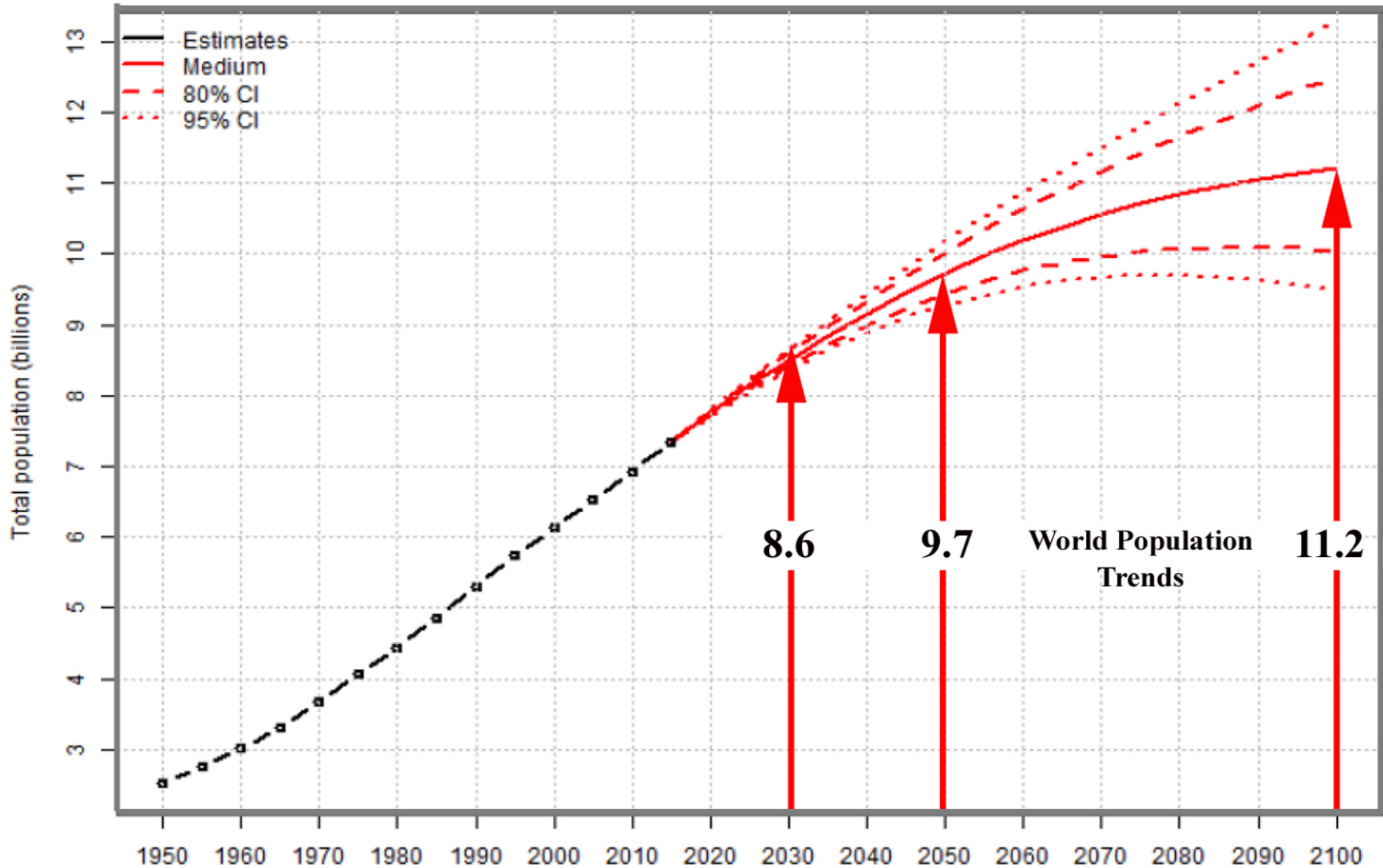
Shifts in the Global Middle-Class

Changes in Consumption Patterns 2000 - 2050 (Percentages)



Population of the World

Mean Global Projections to 2100



Source: World Population Prospects: The 2015 Revision, United Nations, Department of Economic and Social Affairs, Population Division (2015).

“Quadrennial Global Trends 2030 Report”

- **Demand for resources will increase owing to an increase in global population from 7.5 billion today to about 8.5 billion by 2030 and 9.7 billion by 2050 (UN Projections as of 2017).**
- **Demand for food projected to rise by ~ 50 percent and energy by ~ 45 percent over the next 15-20 years.**
- **Nearly half of the world’s population will live in areas with severe water stress.**
- **The main questions: will there be more effective management, broader technology access and use, and adequate governance mechanisms.**



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*Global Trends 2035 is a publication
of the National Intelligence
Council*

**Global Trends
2035**


GLOBAL TRENDS
PARADOX OF
PROGRESS
A publication of the National Intelligence Council

JANUARY 2017
NIC-2017-003
ISBN 978-1-6-08014-2
To view this report, visit
www.dia.gov/niic/publications

The National Intelligence Council (NIC) conducts a major assessment every four years for the U.S. President and Congress to identify the trends in the global geopolitical scene and to articulate the choices that are likely to shape the world over the next two decades or so.

Global Trends and Key Implications Through 2035

Perspectives from “*Global Trends 2035: The Paradox of Progress*”.

- **The rich are aging, the poor are not:** Working-age populations are shrinking in wealthy countries, China, and Russia, but growing in developing, poorer countries.
- **The global economy is shifting.** Weak economic growth will persist in the near term. The major economies will confront shrinking workforces and diminishing productivity gains.
- **Technology is accelerating progress but causing discontinuities.** Rapid technological advancements will increase the pace of change and create new opportunities but will aggravate divisions between winners and losers.
- **Ideas and Identities are driving a wave of exclusion.** Growing global connectivity amid weak growth will increase tensions within and between societies.



Trends are more
Paradoxical

Global Trends and Key Implications Through 2035

Perspectives from “*Global Trends 2035: The Paradox of Progress*”. (Continued)

- **Governing is getting harder.** Publics will demand governments deliver security and prosperity, but flat revenues, distrust and polarization will hamper government performance.
- **The nature of conflict is changing.** The risk of conflict will increase due to diverging interests among major powers, an expanding terror threat, continued instability in weak states, and the spread of lethal, disruptive technologies.
- **Climate change, environment, and health issues will attract attention by nations around the world.** A range of hazards pose imminent and longer-term threats that will require collective action.
- **The Bottomline: *These trends will converge at an unprecedented pace to make governing and cooperation harder and very likely to change the nature of power and fundamentally altering the global landscape.***



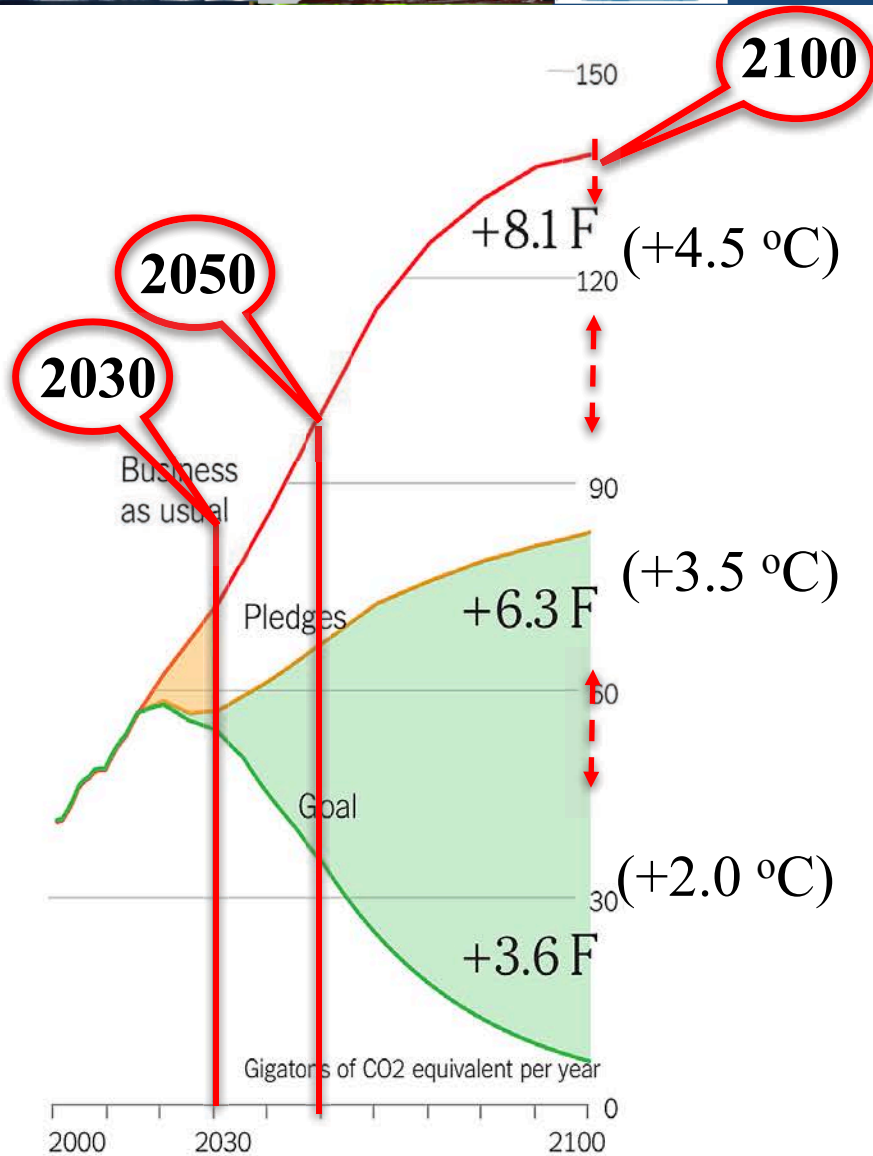
The 1992 Earth Summit Addressed Climate Change

The Key Goal of the UNFCCC:

- UNFCCC's Article 2 goal is in two key sentences:
 - *“Stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, and*
 - *Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.”*

The Central Purposes of the 2015 Paris Agreement

- **Strengthen Global Response and to Provide a Foundation for Future Actions:** Paris Agreement aims to strengthen global response to climate change.
- **Increase the Ability for all Nations and Societies to Adapt:** Paris Agreement aims to increase ability to adapt to the adverse impacts of climate change.
- **Enable Finance Flows Consistently:** Paris Agreement aims to make finance flows consistent with pathways toward lower greenhouse gas emissions and climate resilient development.
- **Reflect Equity and Enable Differentiated Responsibilities:** Paris Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities.



The delegates from these 188 UNFCCC nations meet in Paris in December of 2015 and signed an agreement to reduce their carbon emissions from fossil fuels and other sources by 2030, as depicted here, they are call: *Intended Nationally Determined Contribution (INDC)*



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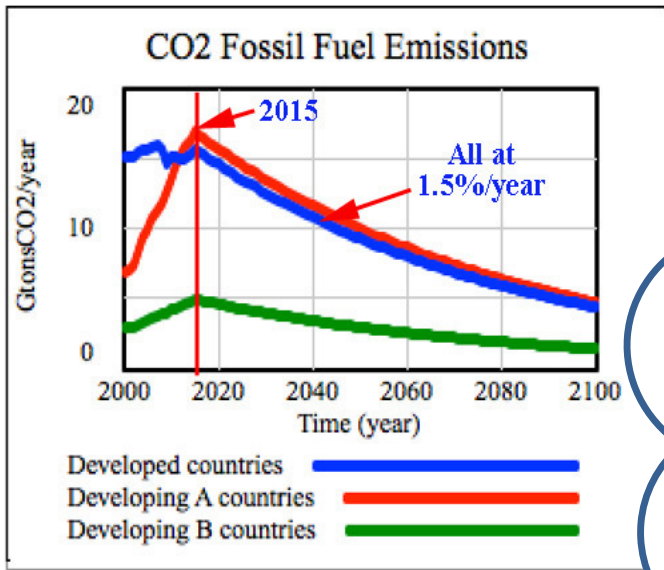
May 3, 2017



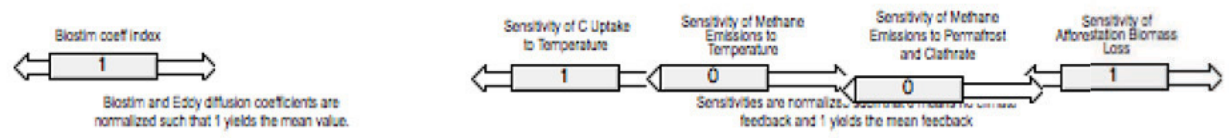
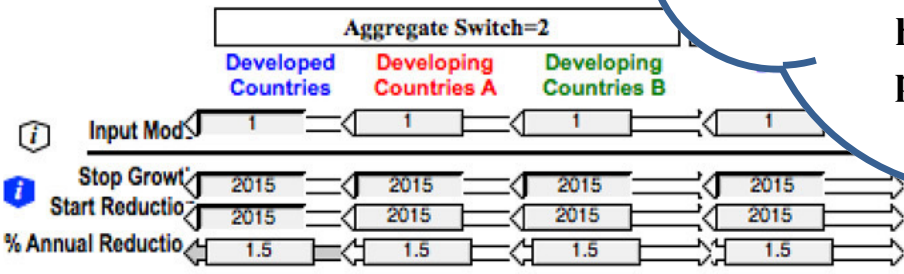
A few observations from an analysis and modeling of the global climate system to frame the global responses as we as a global family of nations implement three fossil fuel emission reduction strategies beginning in 2015, then 2030 and finally in the late 2030's.



An Estimates of about a 1.5%/year Rate at which Fossil Fuels will need to be replaced beginning in 2015 by Alternative Energy and/or by Increases in Energy Efficiency to Reach 2° C



- In 2015, Total Global Energy Demand from Fossil Fuels was ~14.5 Terawatts.
 - To meet the 2 degree target it is projected energy demand would need to be reduced by 1.5%/year for every year to 2100.
 - This means the equivalent of ~220 Gigawatts of capacity would need to be replaced annually by alternative energy or increases in energy efficiency.
 - A typical power plant is about 500 megawatts, hence the equivalent of 440 typical power plants would need to be replaced/year.
- Data Source: IEA



and
bedo forcings

Ozone precursor forcings

OC, BC, and bio aerosol forcings

\$350 Billion/yr to \$750 Billion/yr



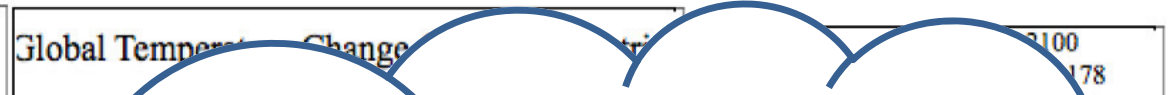
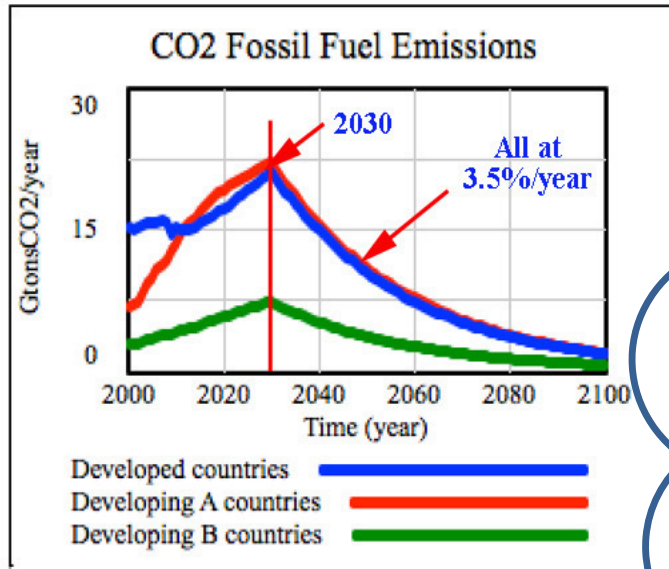
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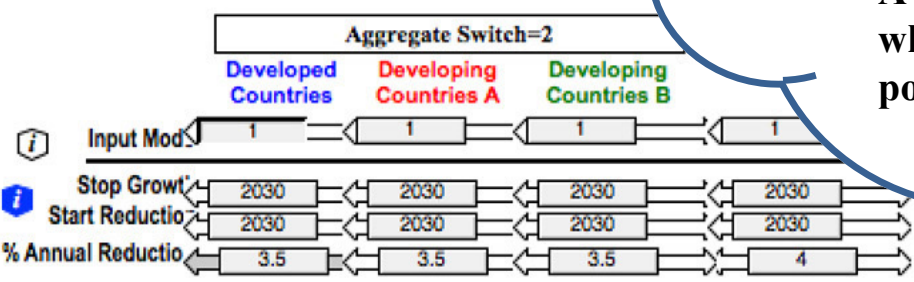
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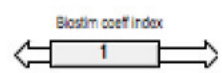
An Estimates of about a 3.5%/year rate at which Fossil Fuels will need to be replaced beginning in 2030 by Alternative Energy and/or by Increases in Energy Efficiency to Reach 2° C



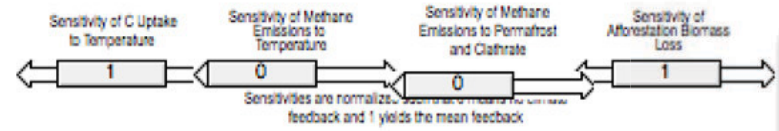
- In 2030, Total Global Energy Demand from Fossil Fuels is projected to be ~22.0 Terawatts;
- Hence, to meet the 2 degree target it is projected energy demand would need to be reduced by 3.5%/year;
- This means the equivalent of ~770 Gigawatts of capacity would need to be replaced annually by alternative energy or increases in energy efficiency; and
- A typical power plant is about 500 megawatts, which means the equivalent of 1540 typical power plants would need to be replaced/year.



Data Source: IEA



Bioslim and Eddy diffusion coefficients are normalized such that 1 yields the mean value.



\$1.2 Trillion/yr to \$2.4 Trillion/yr

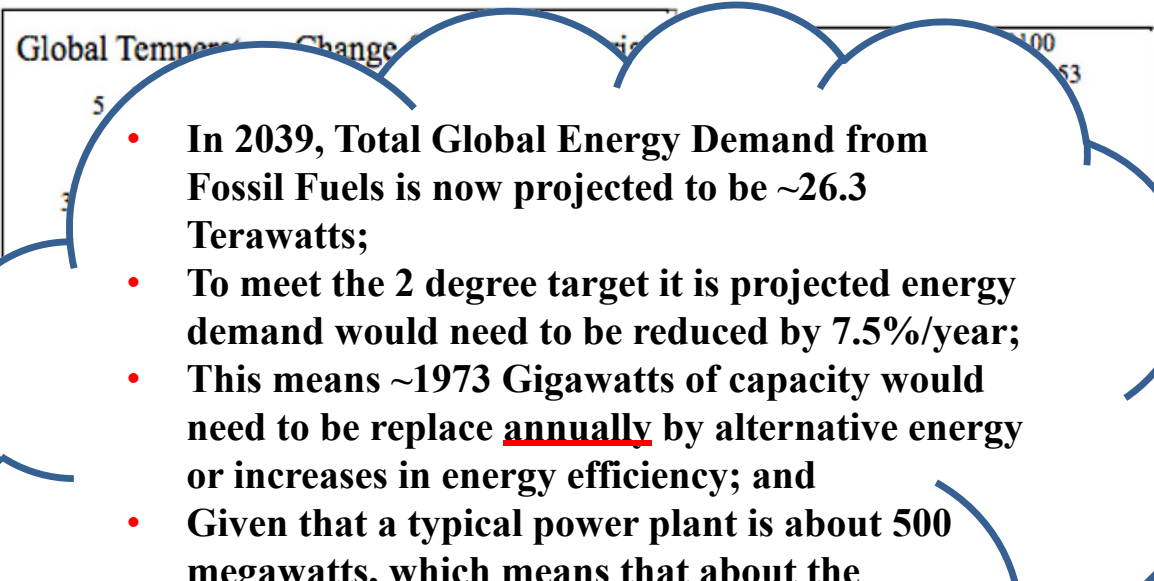
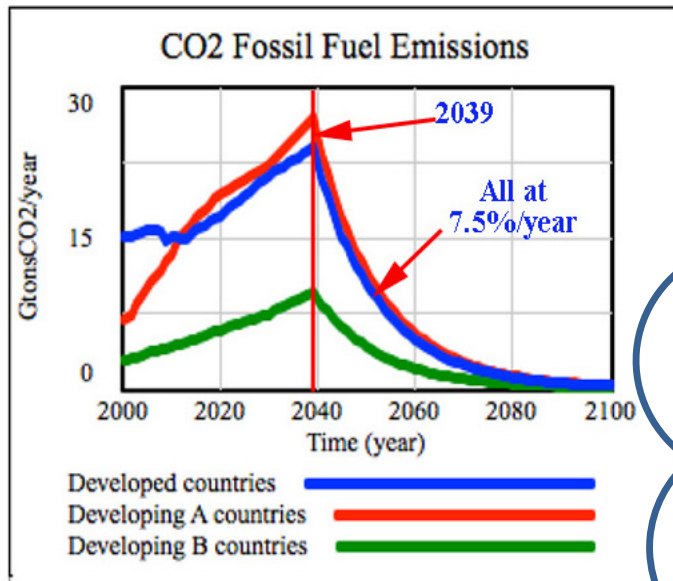
and bedo forcings

Ozone precursor forcings

OC, BC, and bio aerosol forcings

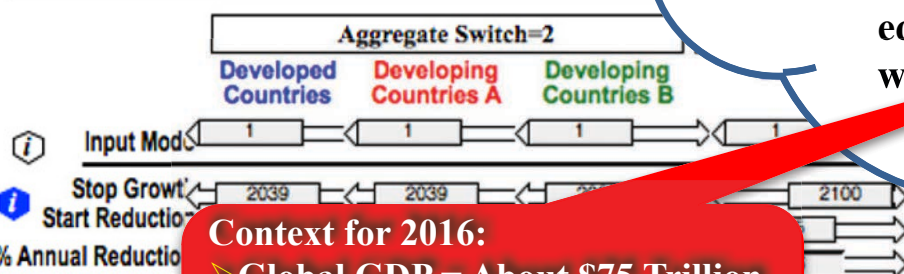


An Estimates of about a 7.5%/year Rate at which Fossil Fuels will need to be replaced beginning in 2039 by Alternative Energy and/or by Increases in Energy Efficiency to Reach 2° C



- In 2039, Total Global Energy Demand from Fossil Fuels is now projected to be ~26.3 Terawatts;
- To meet the 2 degree target it is projected energy demand would need to be reduced by 7.5%/year;
- This means ~1973 Gigawatts of capacity would need to be replaced annually by alternative energy or increases in energy efficiency; and
- Given that a typical power plant is about 500 megawatts, which means that about the equivalent of 3945 typical power plants globally would need to be replaced/year until 2100.

• Data Source: IEA



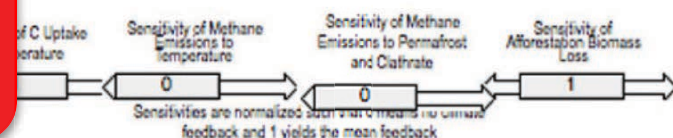
Context for 2016:

- Global GDP = About \$75 Trillion
- EU GDP = About \$ 16 Trillion
- U.S.A. GDP = About 18 Trillion
- China GDP = About 11 Trillion

• Solar andbedo forcings

• Ozone precursor forcings

• OC, BC, and bio aerosol forcings



Cost is about tens times more then by acting now!



Some Summary Thoughts Suggest from Paris Agreement:

- *If we do very little to change* our energy/economic system demand globally, and focus on seriously emission reductions, *humankind will reach 2 degrees C by 2040 and by 2045 to 2050 if the Paris Accord is fully implemented;*
- *Our scoping studies suggests* that *if we take global action with in a few years, the global costs of doing so are well within the global socio-economic systems of the 188 nations* of the UNFCCC; but
- *After about 2025 - 2030, this analysis suggests that the annual costs exceed these current investments global capabilities of the 188 nations substantially,* which suggests that it is ultimately *likely that dramatic upheavals in our global economic/energy collective security.*

So, what might this mean for us?

The rates of climate and global change are unprecedented will likely challenge our collective national and international governance strategies and our political capacities for years to come. These challenges are at the heart of “*Exploring the Implications of Bringing Knowledge to Action*”



Going Beyond Assessments to take Science, Knowledge and Consequences to Action

Developing the Knowledge to Understand the Earth's Systems

**This is the
world in
which we all
inevitably live!**

**Exploring Ideas to
“Move Knowledge to
Action”**

**This is our Science/Knowledge
Culture and Home**

**The Sources of Funding &
Essential Infrastructure**

Exploring of Science/Knowledge Home

A number of University Presidents are now suggesting:

“Our academic home will increasingly be marked by universities that deliberately aspire to effect a shift in outcomes through the seamless integration of cutting-edge science, technological innovation and adaptive management strategies focused on an institutional culture that is increasingly dedicated to the advancement of the academic enterprise and serving the public’s needs and interests”

The NAS has New Perspectives!

Exploring of Science/Knowledge Home

Our National Academy of Sciences, Engineering, and Medicine (NAS) concluded that our:

- *“The research enterprise should include and integrate disciplinary and interdisciplinary research across the physical, social, biological, health, and engineering sciences; focus on fundamental (i.e., basic), and*
- *use-inspired research that contributes to both improved understanding and more effective decision making; and be flexible in identifying and pursuing emerging research challenges*

Thoughts on ways to support policy actions.

Exploring of Science/Knowledge Home

Cultures all over the world have developed different views of nature throughout human history where indigenous people use it to understand and interpret their natural environment:

- **Indigenous people have a broad knowledge of how to live sustainably, which is an essential element to assessing knowledge and to exploring the implications of bringing knowledge to action.**

Thoughts on “Bringing Knowledge to Action”

Exploring of Science/Knowledge Home

- **Transformational Perspective:** Are we, in the science community, prepare to join a new epoch where expanded knowledge is more directly connected with the socio-economic and human well-being, and needs and interests globally and with relevance locally for decades ahead?

The challenges of moving knowledge to action

What might we do?

- 1. Intellectually and scientifically, all of us understand the potential for a future research agenda for our science and institutions.**
- 2. The discussion we need to undertake is to clearly articulate the community-wide realities and barriers that are likely to limit our future during the decade ahead, that become the foundation to move knowledge that supports action.**
- 3. We are not well structured within communities and among our institutions to address these realities .**
- 4. The ball is in our court. Can we, as a community, organize and manage our collective future in ways to meet the programmatic and funding challenges we face during the coming decades to a science culture that is increasingly dedicated to the advancement of the academic enterprise and to more directly serve the public's needs and interests”**



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A concluding thought from an 80 year old insightful thought:

“ . . . the idea of the future being different from the present is so repugnant to our conventional modes of thought and behavior that we, most of us, offer a great resistance to acting on it in practice.”

This pale blue dot is planet Earth taken from Saturn by NASA's Cassini spacecraft looking back toward the Earth on Sept. 27, 2006. Saturn is about 800 million miles from the Earth.



John Maynard Keynes, 1937



ARCUS Arctic Research Seminar
Why the Arctic Matters at All?
 May 3, 2017



“Beyond Assessments: Science, Knowledge, Consequences to Action”
Exploring the Implications of “Why the Arctic Matters at All?”



The North Polar Regions as Portrayed in the 1595
 Source: Helmink Antique Maps rom Gerardus Mercator, with addition of data from Willem Barentsz voyages

Source: Map of the Arctic region ©Hugobon Natural Earth version 1.3. Retrieved Feb 2017

A Treat while we move to a Q and A Session

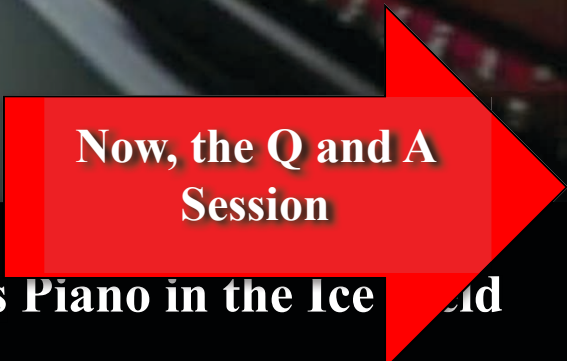
Thank You for inviting me to sharing this time with you!



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Now, the Q and A Session

Ludovico Einaudi: Italian Pianist and Composer with his Piano in the Ice World

Thank You!

- **Upcoming Arctic Research Seminar Speakers (Dates for next series TBA soon)**
 - Sandy Starkweather, NOAA
 - James Kendall, BOEM
 - Thomas Wagner, NASA
- **ARCUS Seminar Series recordings are available online at:**
<https://www.arcus.org/research-seminar-series>
- **Please consider becoming an ARCUS member!**
More info: <http://bit.ly/2ePsc5N>
- **Other Announcements**
The Smithsonian's "Narwhal: Revealing an Arctic Legend" exhibit opening in August



#arcuswebinar