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Limiting Global Carbon Emissions

Singapore Energy Marketing Authority
Meeting with
Sandia National Laboratories

B.D. Zak

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
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Questions:

- Why Limit Global Carbon Emissions?
- Why am I Speaking on This Subject?
- What's the Evidence for Global Climate Change?
- How Certain is it?
- What's the Relevance to Singapore?
- Information Resources?
- Take Away Points?

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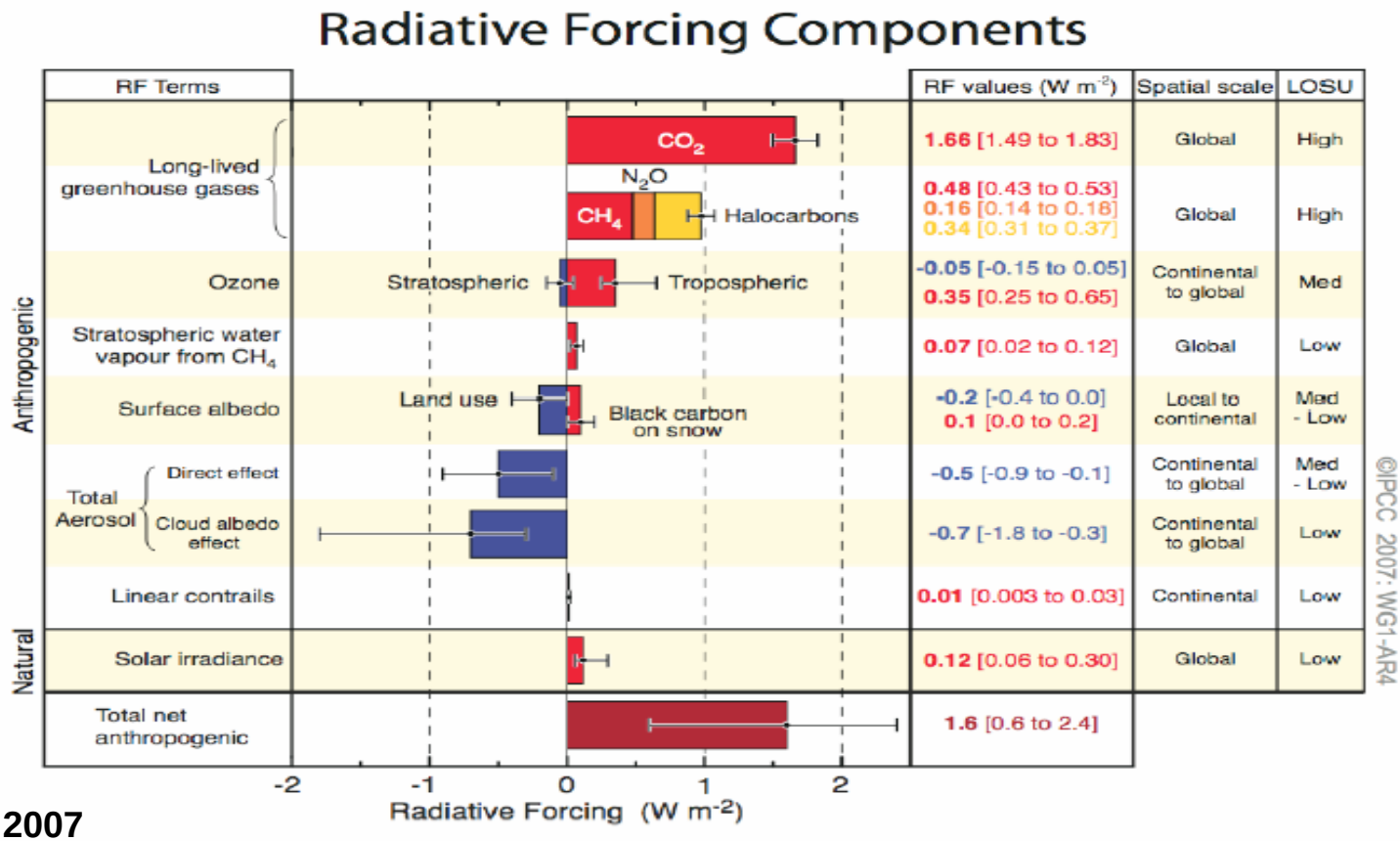
Why limit global carbon emissions?

Answer: Carbon dioxide from the burning of fossil fuels is the primary driver of current rapid global climate change.



IPCC 2007

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Why am I Speaking on This Subject?

Answer: My background; potential relevance to Singapore

- Involvement with climate issues since 1980s
- Since 1990, with U.S. Department of Energy principal global climate change research effort: Atmospheric Radiation Measurement (ARM) program
- Since early 2007, also responsible for internal Sandia planning study on Energy Technology for Reducing Carbon Emissions

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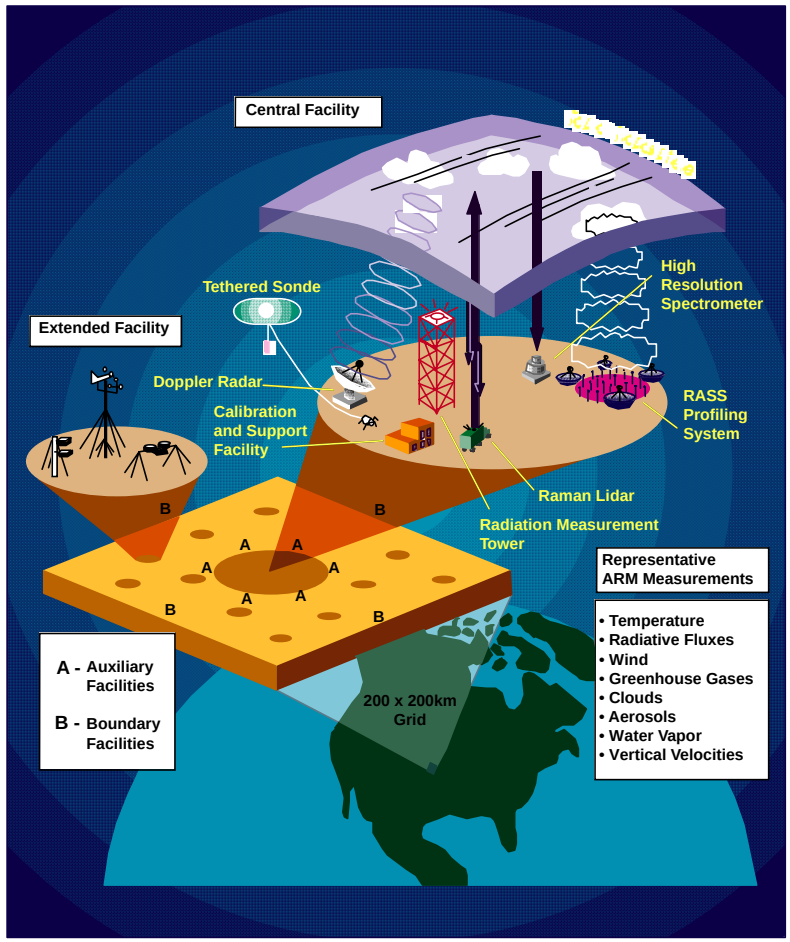
ARM Overview: Goals

Improve Climate Predictions

Improve Global Climate Models

- **Radiative Transfer w/Clouds**
- **Treatment of Clouds**



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ARM Mobile Facility Locations: Year 1: Coastal California Year 2: Sub Saharan Africa
Currently: Germany Next Year: China?

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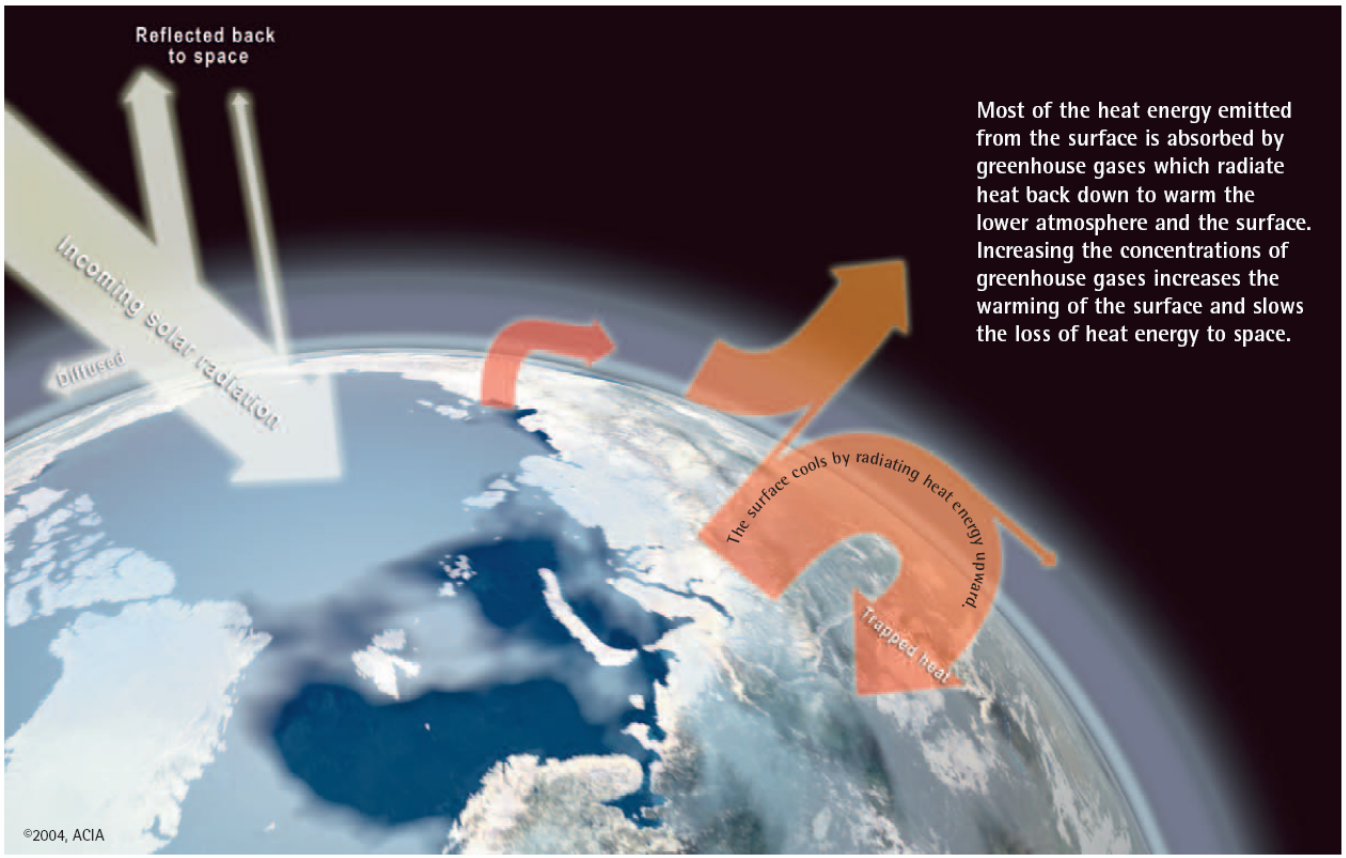
What's the Evidence for Global Climate Change as a Result of Carbon Dioxide Emissions?

Answer: **Lots; both theoretical and observational.**



Greenhouse Effect:

Gases that absorb radiation in the infra-red portion of the spectrum (such as carbon dioxide) impede the the flow of radiant energy from the surface of the earth through the atmosphere to outer space. Greenhouse Gases (GHGs) act like a blanket, holding heat in.

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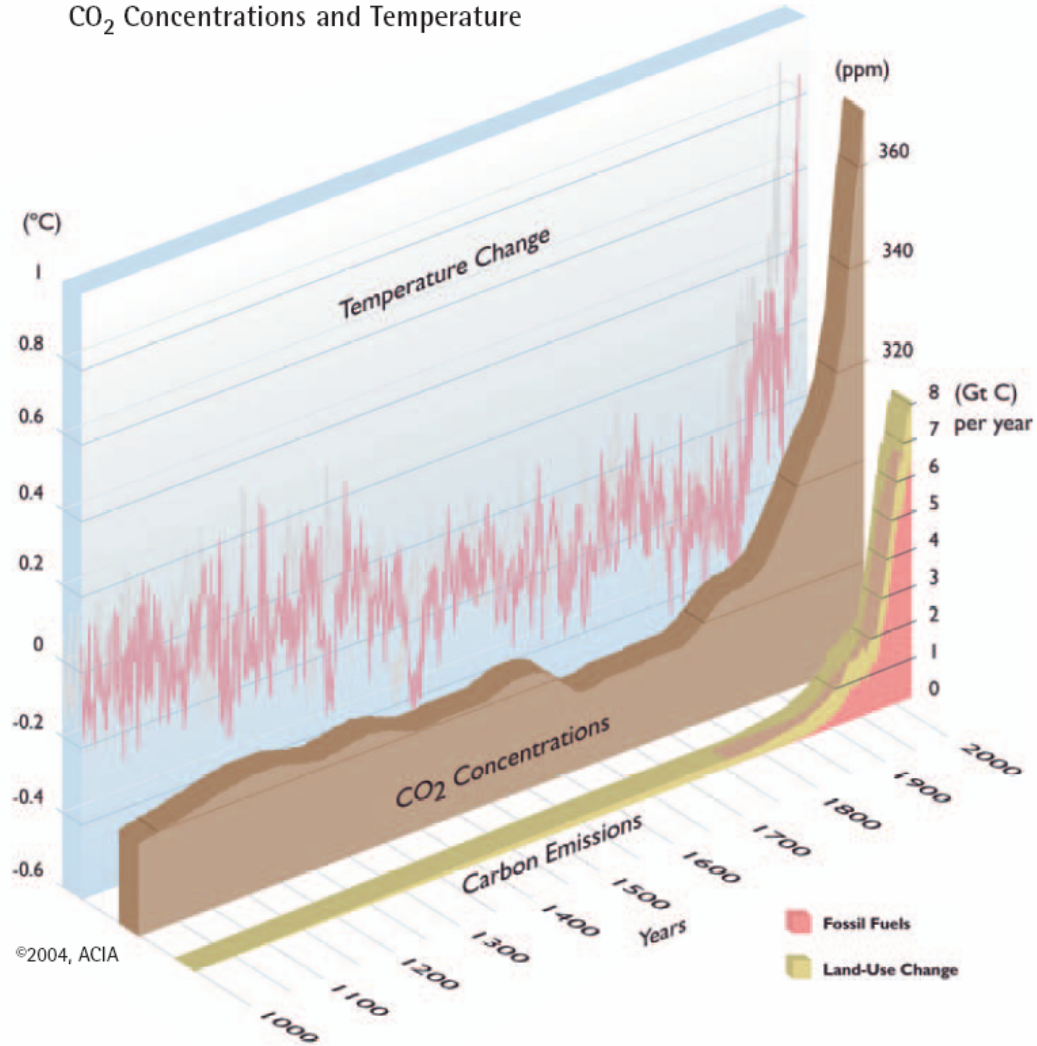
1000 Years of Changes in Carbon Emissions, CO_2 Concentrations and Temperature



This 1000-year record tracks the rise in carbon emissions due to human activities (fossil fuel burning and land clearing) and the subsequent increase in atmospheric carbon dioxide concentrations, and air temperatures. The earlier parts of this Northern Hemisphere temperature reconstruction are derived from historical data, tree rings, and corals, while the later parts were directly measured. Measurements of carbon dioxide (CO_2) in air bubbles trapped in ice cores form the earlier part of the CO_2 record; direct atmospheric measurements of CO_2 concentration began in 1957.

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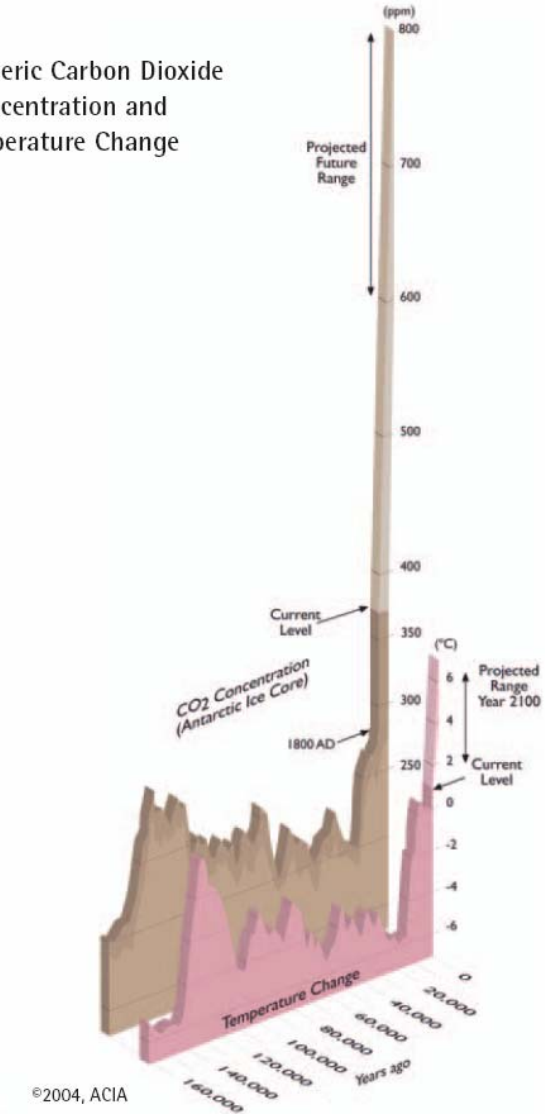
Atmospheric Carbon Dioxide Concentration and Temperature Change



This record illustrates the relationship between temperature and atmospheric carbon dioxide concentrations over the past 160 000 years and the next 100 years. Historical data are derived from ice cores, recent data were directly measured, and model projections are used for the next 100 years.

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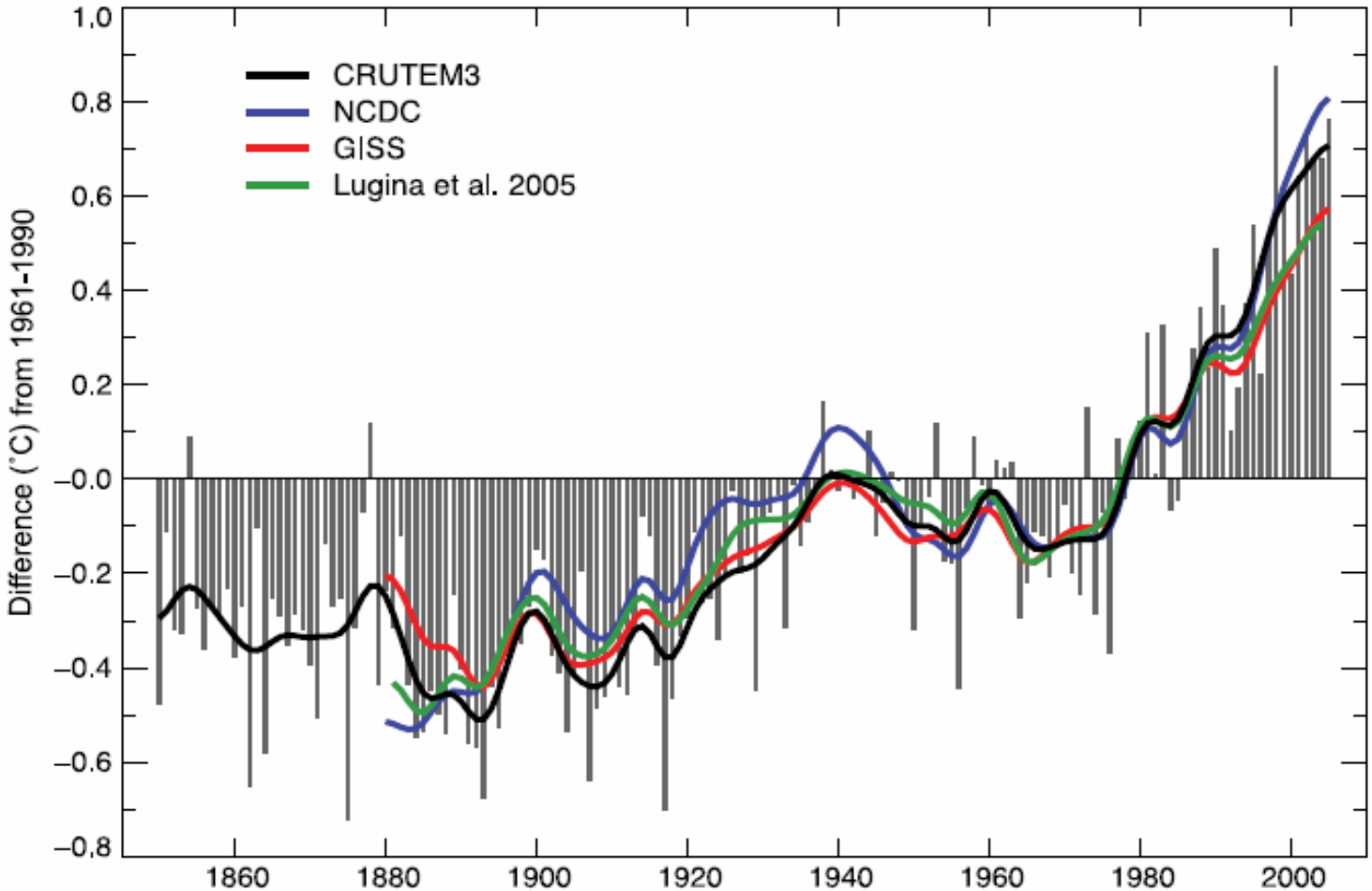
Globally: "Most of the observed increase in globally averaged air temperature since the mid-20th century is *very likely* [>90%] due to the observed increase in anthropogenic greenhouse gas concentrations." -- IPCC



Good agreement between global average temperature record and models obtained only if greenhouse effect of increasing atmospheric concentrations of CO_2 included.

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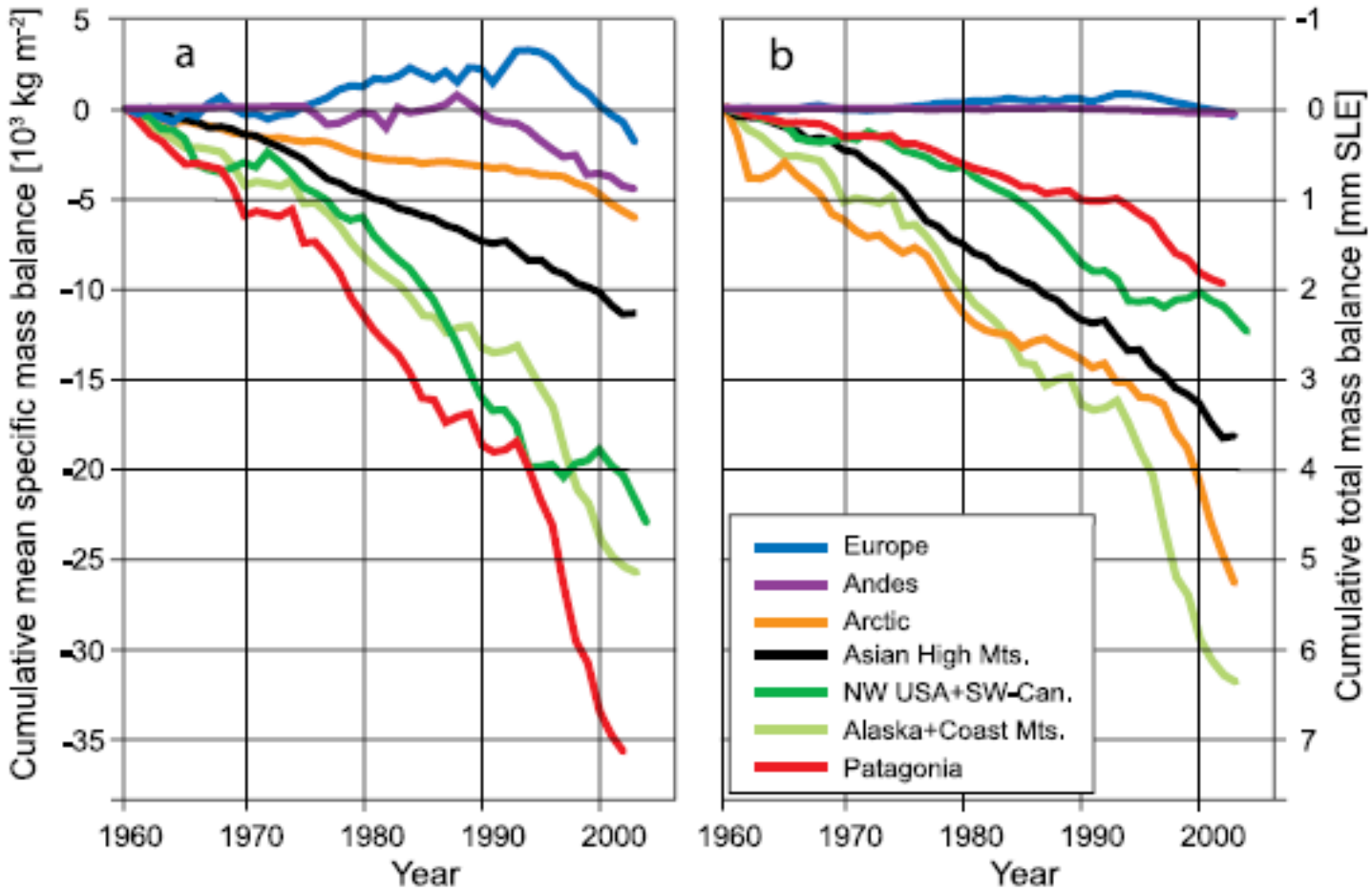
Mass Balance of Glaciers and Ice Caps

Dyurgerov and Meier
as cited by J. Walsh, 2007



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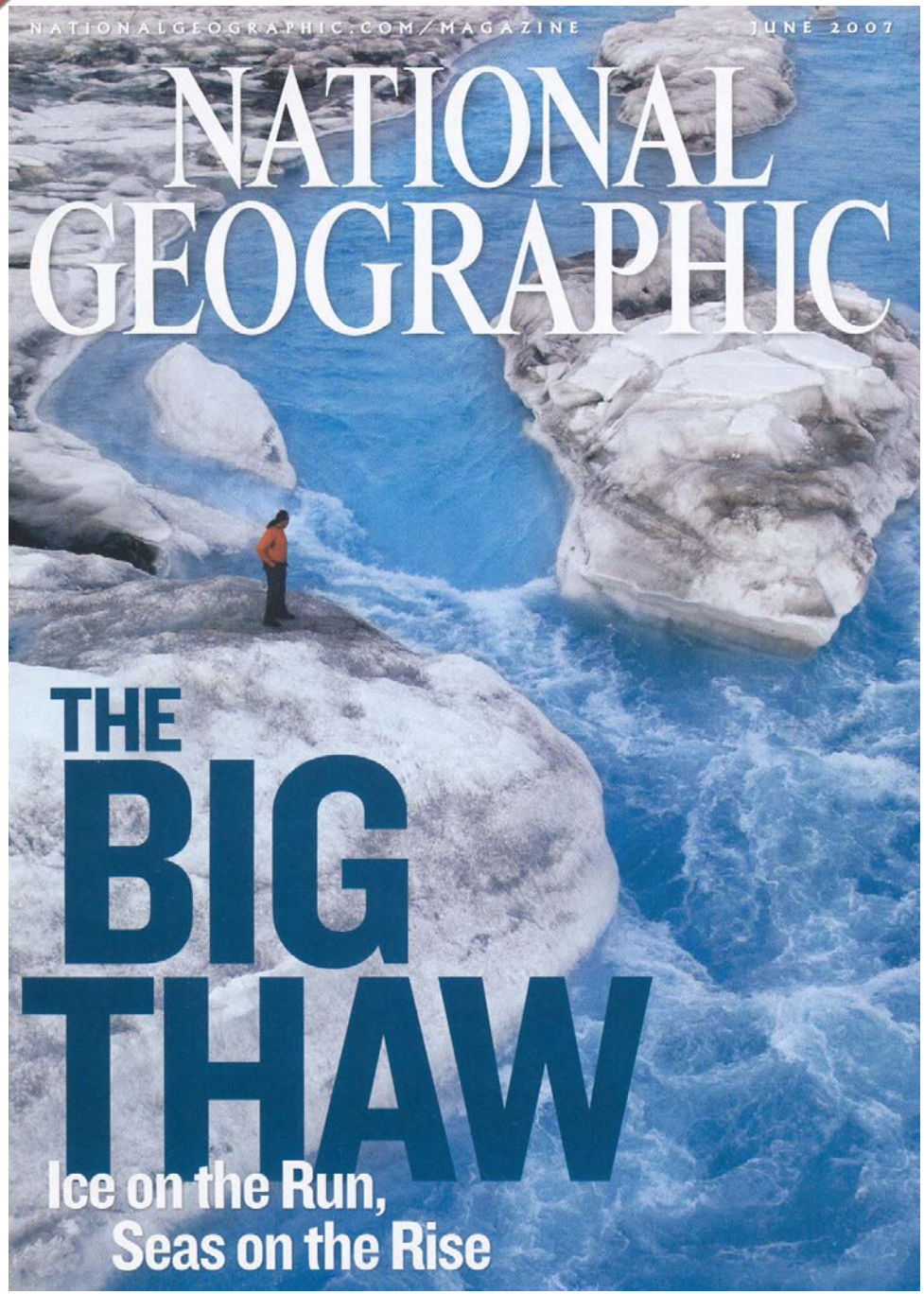

Photo by James Balog: Meltwater drains from Greenland ice sheet.

Subtitle of article: "It's no surprise that a warming climate is melting the world's glaciers and polar ice. **But no one expected it to happen this fast."**

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How Certain is It?

Answer: **Probability greater than 90% according to the Intergovernmental Panel on Climate Change (IPCC*) report that came out within the last few months. IPCC conclusions backed up by U.S. National Academy of Sciences and similar prestigious institutions in other countries. Accepted by G8 Summit 2007 Declaration dated 6/7/07.**

*IPCC was created in 1988 by the World Meteorological Organization and the United Nations Environmental Program to assess human-induced climate change, its impacts, and options for adaptation and mitigation. The current report is the fourth in a series that started in 1990, each report reaching much the same conclusion based on the evidence available at the time, but with continually increasing confidence.

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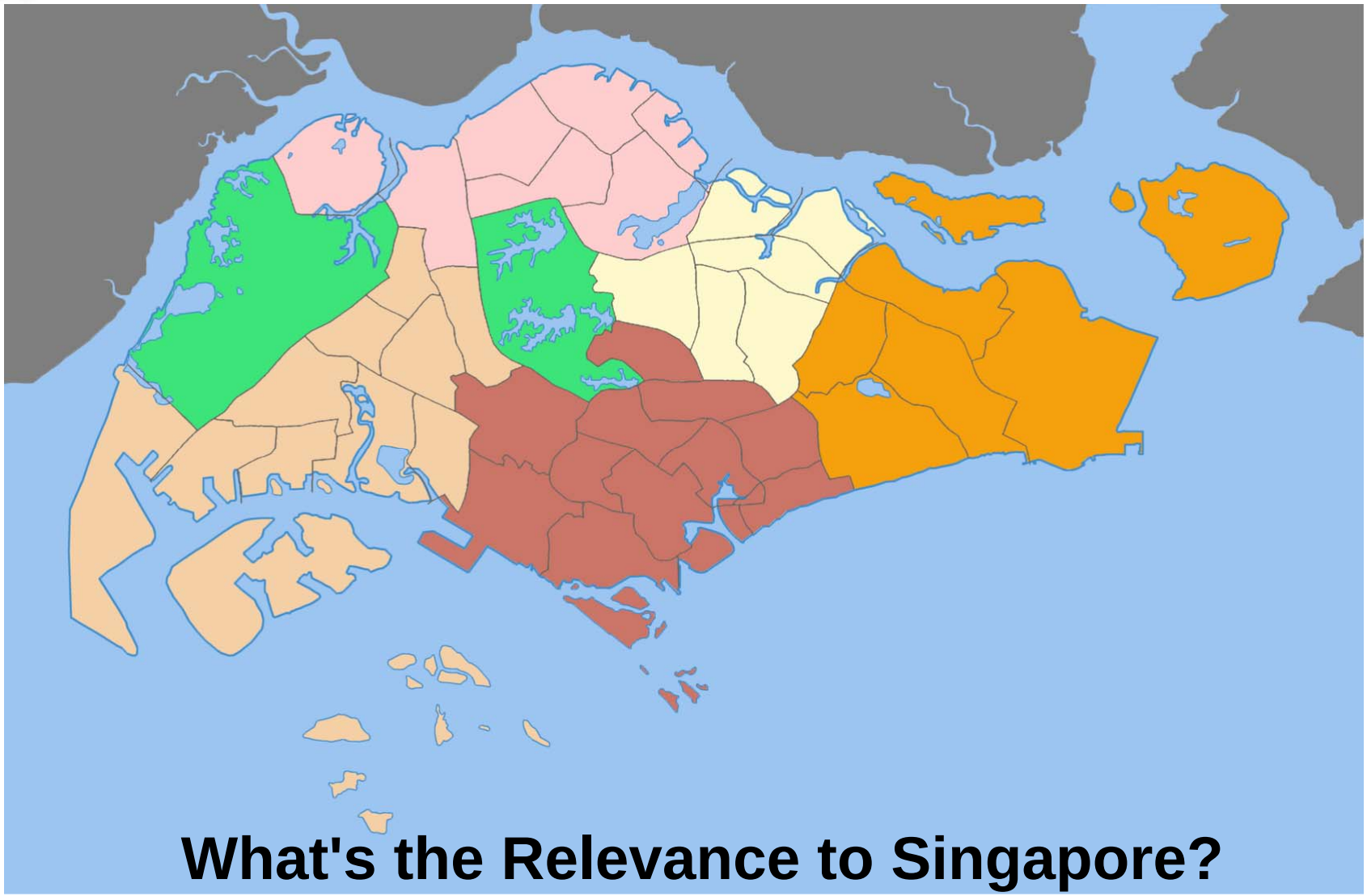

What's the Relevance to Singapore?

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Likely Physical Impacts (among others)

Sea Level Rise resulting in:

- **Inundation of areas currently near sea level**
- **Increased rate of coastal erosion**
- **Increased probability of damage from storm surge**

Anticipated increase in severity of tropical storms

Impact of 1 meter sea level rise on Florida provides some idea of effect of a sea level rise of this size on coastal regions around the world. Note that population and supporting infrastructure are heavily concentrated in coastal areas. 1 meter sea level rise is now considered by some climate scientists to be within the range of possibility for this century. The IPCC consensus is about 0.3 m. Context: Sea level has risen about 120 m since the end of the last ice age, but has been fairly stable for last 2000 years except for recent past.

Areas in Florida Subject to Inundation with 100 Centimeter Sea Level Rise

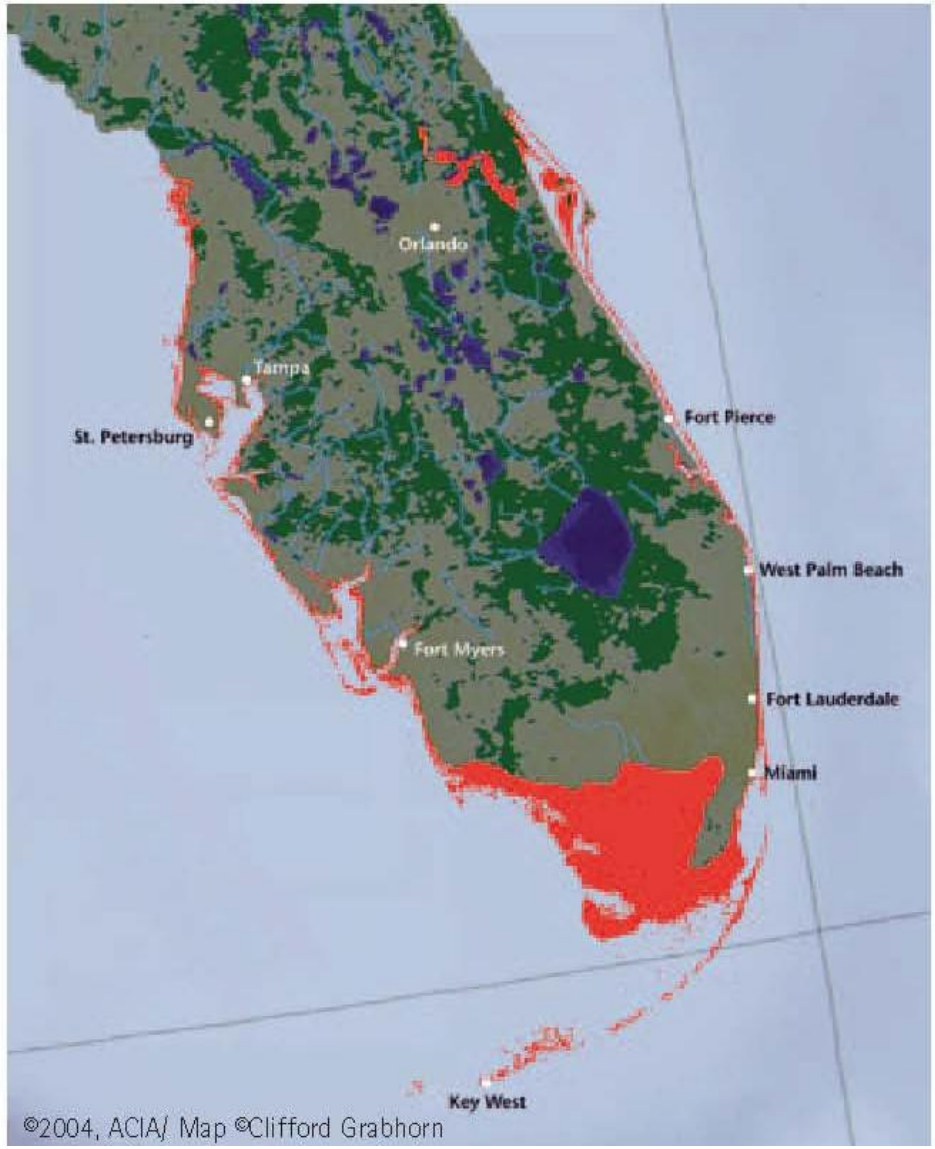

Figure from Arctic Climate Impact Assessment (2004)

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Coastal erosion of cliffs on California coast at Pacifica. House in picture did not survive the following storm season. It's not just low-lying areas that are at risk. (Wikipedia, coastal erosion)

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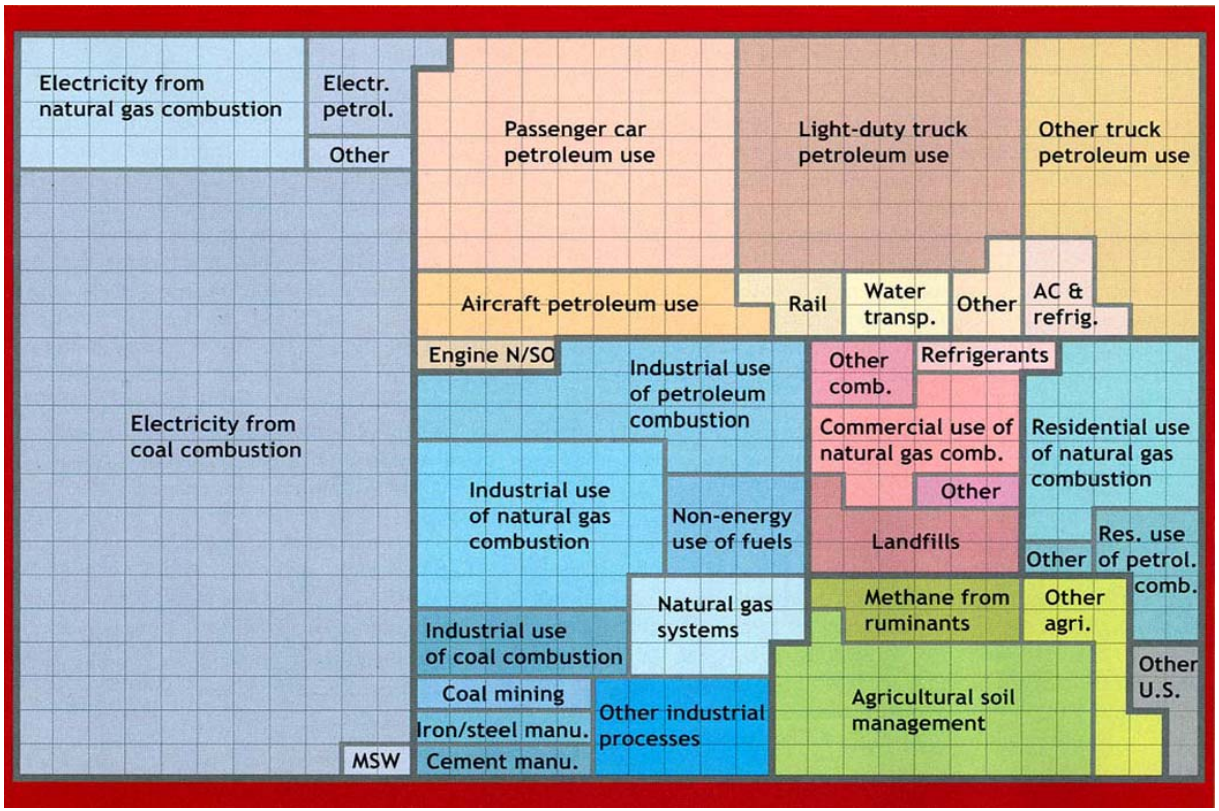
Likely Political Impact (among others)

- **Greatly increased global pressure to reduce carbon, other GHG emissions.**

U.S. anthropogenic GHG emissions suggests where cuts are possible



Shaded areas represent fractions of all US anthropogenic greenhouse gases from various sources based on carbon dioxide equivalence (takes into account specific radiative forcing and atmospheric lifetimes). Electricity accounts for roughly 34% of these; transportation accounts for about 27%. *Mechanical Engineering*, 2007, 129 , No. 4. Based on a draft USEPA report.

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Carbon Emission Reduction Themes Currently Receiving Attention at Sandia:

- Low Carbon Energy Sources
- Decarbonization of Fossil Fuels
- Deriving Value from Carbon Dioxide
- Energy Efficiency

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Information Resources?

- **IPCC Fourth Assessment Report, WG I, *Climate Change 2007: The Physical Science Basis, Summary for Policy Makers* (February, 2007) http://www.ipcc.ch/WG1_SPM_17Apr07.pdf**
- **IPCC Fourth Assessment Report, WG I, *Climate Change 2007: The Physical Science Basis,* Prepublication Copy of the Full Report http://ipcc-wg1.ucar.edu/wg1/wg1-report.html**
- **IPCC Fourth Assessment Report, WG II, *Climate Change 2007: Impacts, Adaptation and Vulnerability, Summary for Policy Makers* (April, 2007) http://www.ipcc.ch/SPM13apr07.pdf**
- **IPCC Fourth Assessment Report, WG III, *Climate Change 2007: Mitigation of Climate Change, Summary for Policy Makers* (May, 2007) http://www.ipcc.ch/SPM040507.pdf**
- **IPCC Fourth Assessment Report, WG III, *Climate Change 2007: Mitigation of Climate Change,* Prepublication Copy of the Full Report http://www.mnp.nl/ipcc/pages_media/AR4-chapters.html**
- **Coastal Ocean Institute, Woods Hole Oceanographic Institution http://www.whoi.edu/page.do?pid=7397**
- **European Sea Level Service. http://www.eseas.org/**

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Take Away Points

The International Consensus* is:

- **Global Climate Change is both Real and Serious**
- **If the International Community Doesn't Get a Handle on Carbon and Other GHG Emissions Soon, Low-Lying and Some Other Coastal Areas Around the World will Likely be at Serious Risk**
- **Even Under Optimistic Assumptions, Hardship is Likely in Some Areas**
- **What is Likely to Happen Depends Importantly upon the Political Will of the International Community**

***From recent IPCC reports and the G8 2007 Summit Declaration**

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Pt. Barrow Alaska, on the Arctic Ocean near the ARM Climate Research Facility. A single storm can erode tens of meters from this shoreline.

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