

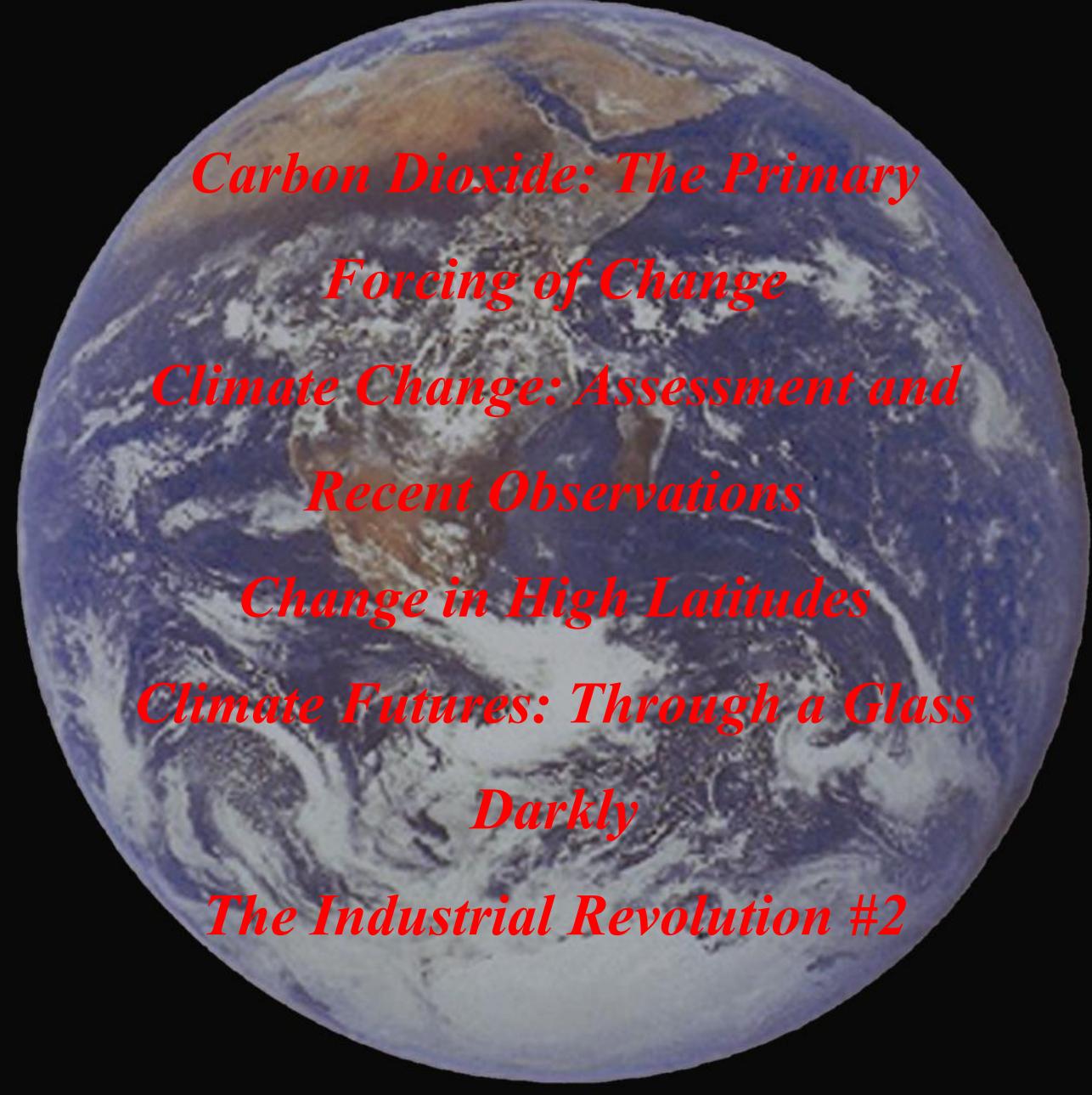
Climate Change and Earth Observations: Challenges and Responsibilities

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University of Oklahoma
Norman, Oklahoma



*Sharing the Adventure (and the Challenge) with the Public
Space Studies Board*
8-10 November 2010





*Carbon Dioxide: The Primary
Forcing of Change*

*Climate Change: Assessment and
Recent Observations*

Change in High Latitudes

*Climate Futures: Through a Glass
Darkly*

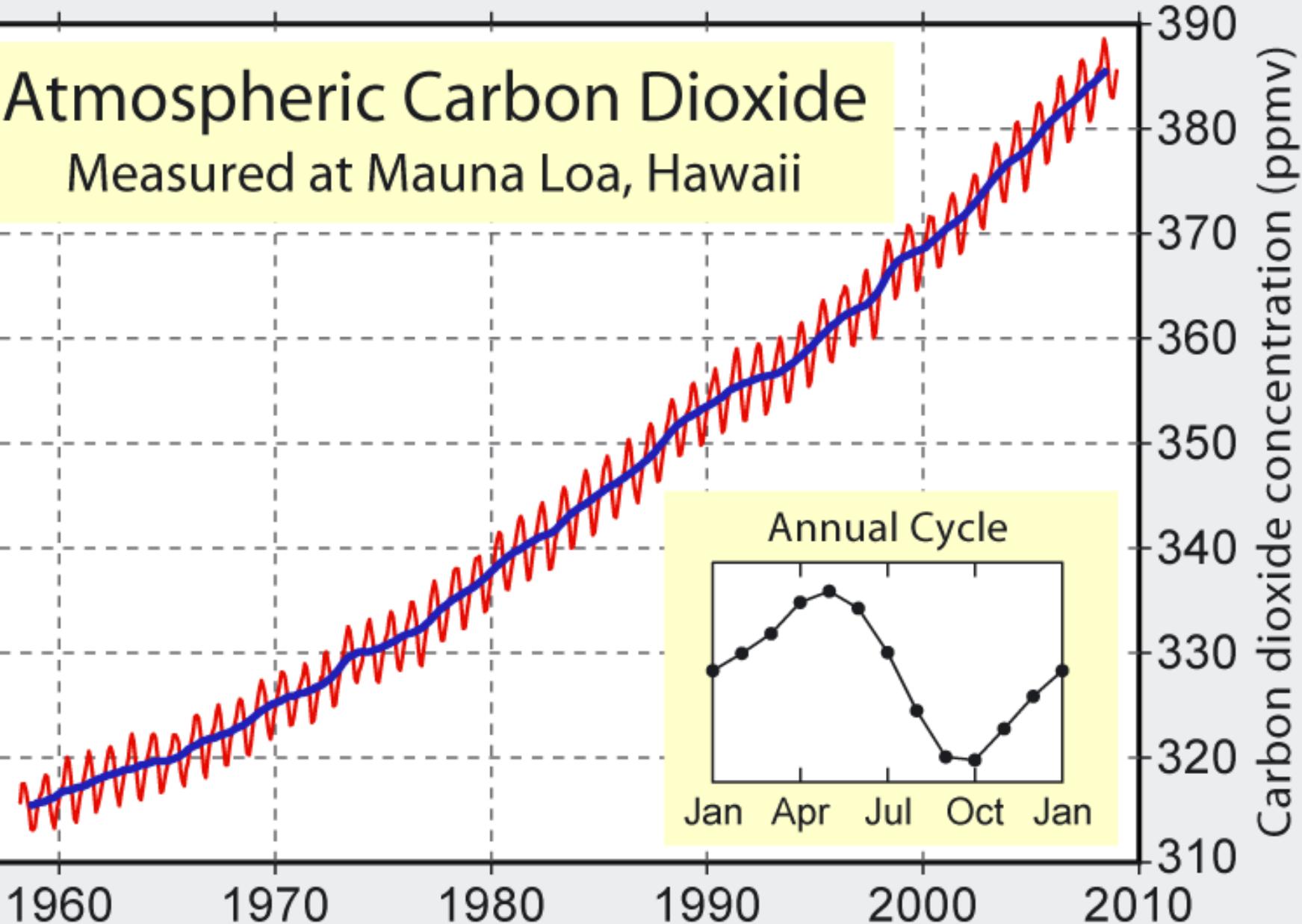
The Industrial Revolution #2



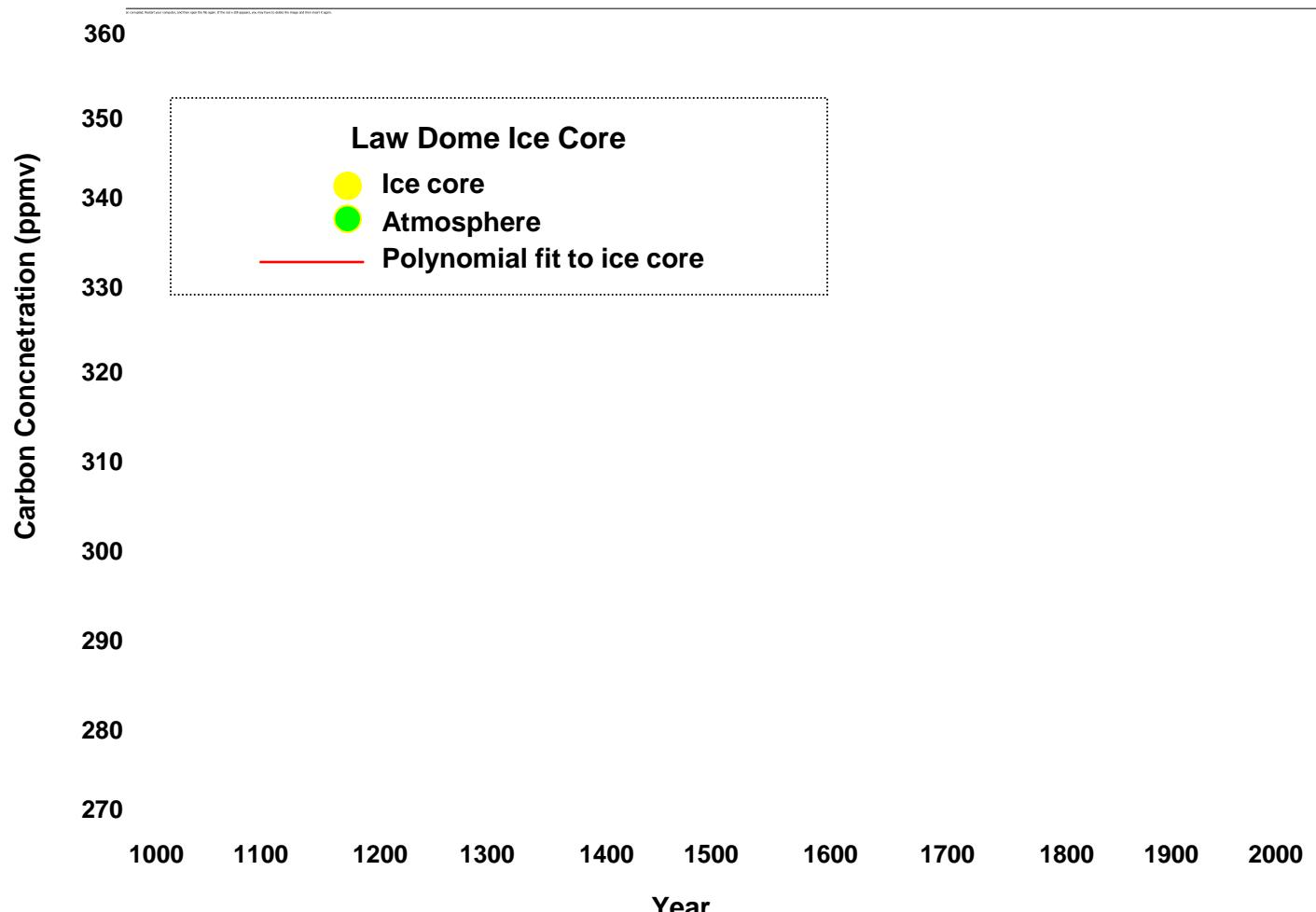
*Carbon Dioxide: The
Primary Forcing of Change*

Atmospheric Carbon Dioxide

Measured at Mauna Loa, Hawaii

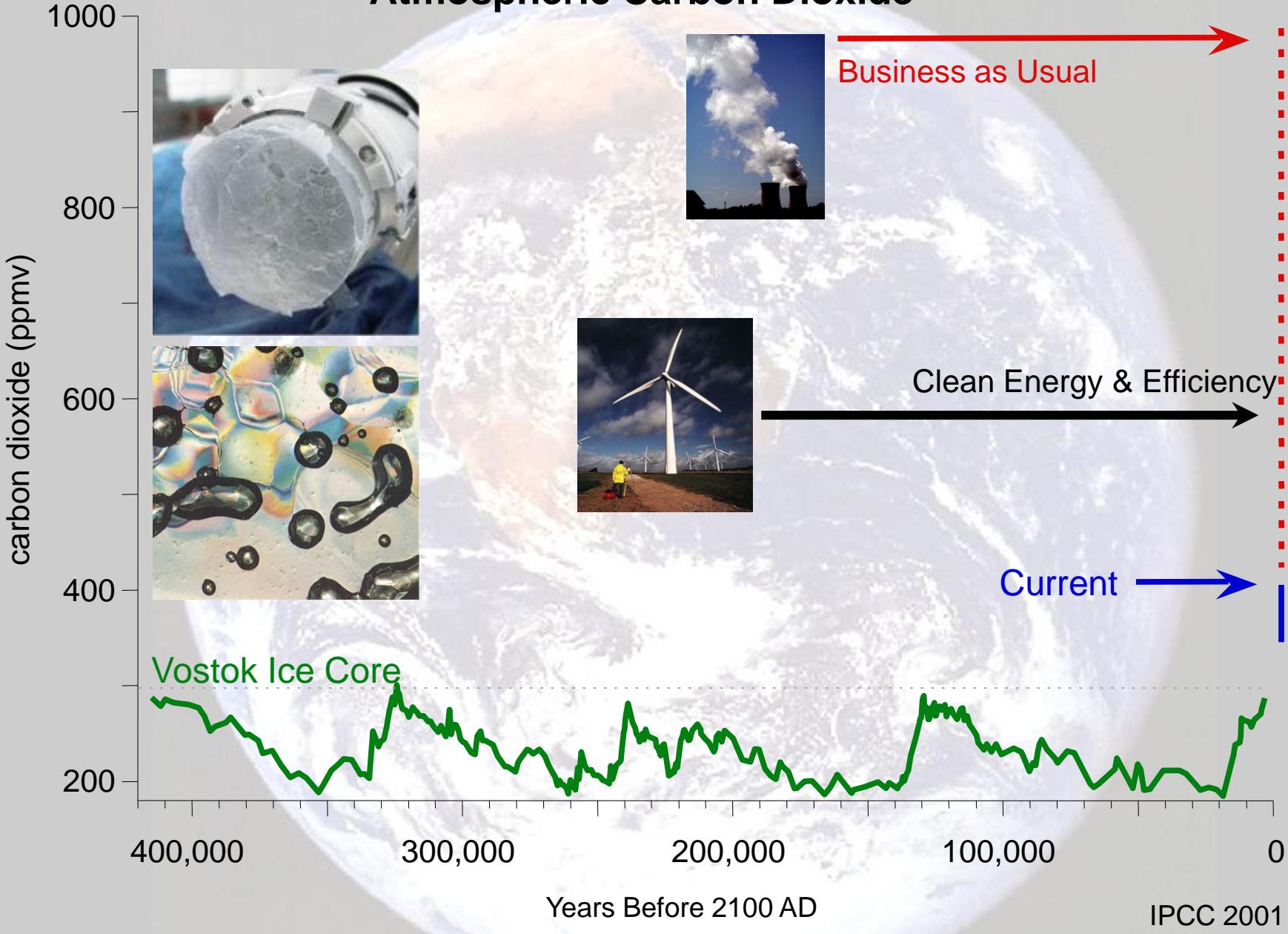


Historical Atmospheric Carbon Concentration for the Last 1000 Years Extracted from the Law Dome Ice Core



Etheridge, et.al., Petit, et.al.

Atmospheric Carbon Dioxide



Anthropogenic C Emissions: Fossil Fuel



2008 Fossil Fuel: 8.5 Pg C

[2008-Total Anthrop. Emissions: $8.5 + 1.5 = 10.0$ Pg]

1850 1870 1890 1910 1930 1950 1970 1990 2010

1990 - 1999: 0.9% y^{-1}

2000 - 2008: 3.5% y^{-1}

NOAA 2007, Canadell et al., 2007 and 2009, PNAS

The Current Airborne Fraction: 45/100

45% of all CO₂ emissions accumulated in the atmosphere



The Airborne Fraction

The fraction of the annual anthropogenic emissions that remains in the atmosphere

55% were removed by natural sinks

Ocean removes 25%



Land removes 30%

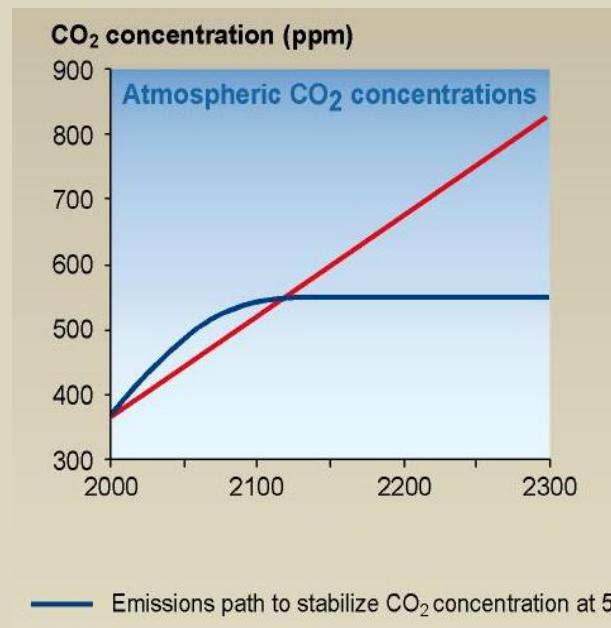
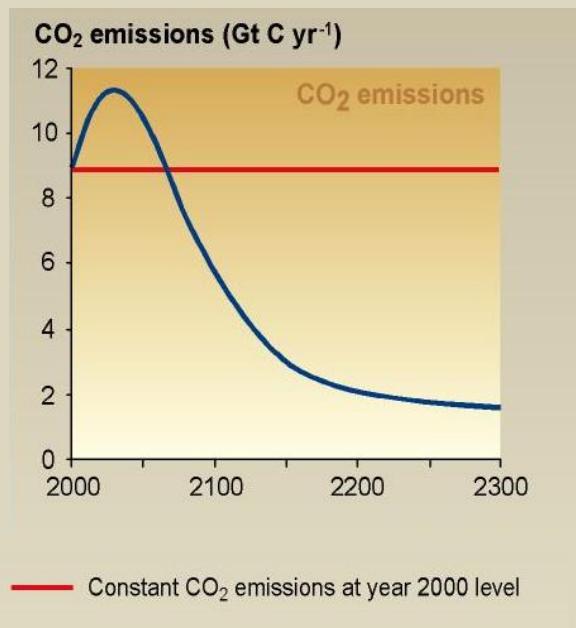


October 2010
Atmospheric CO₂
concentration:
387.18 ppm

Mauna Loa Hawaii
Nearly 40% above pre-industrial

Keeling Record; NOAA

Impact of Stabilizing Emissions versus Sabilizing Concentrations of CO₂



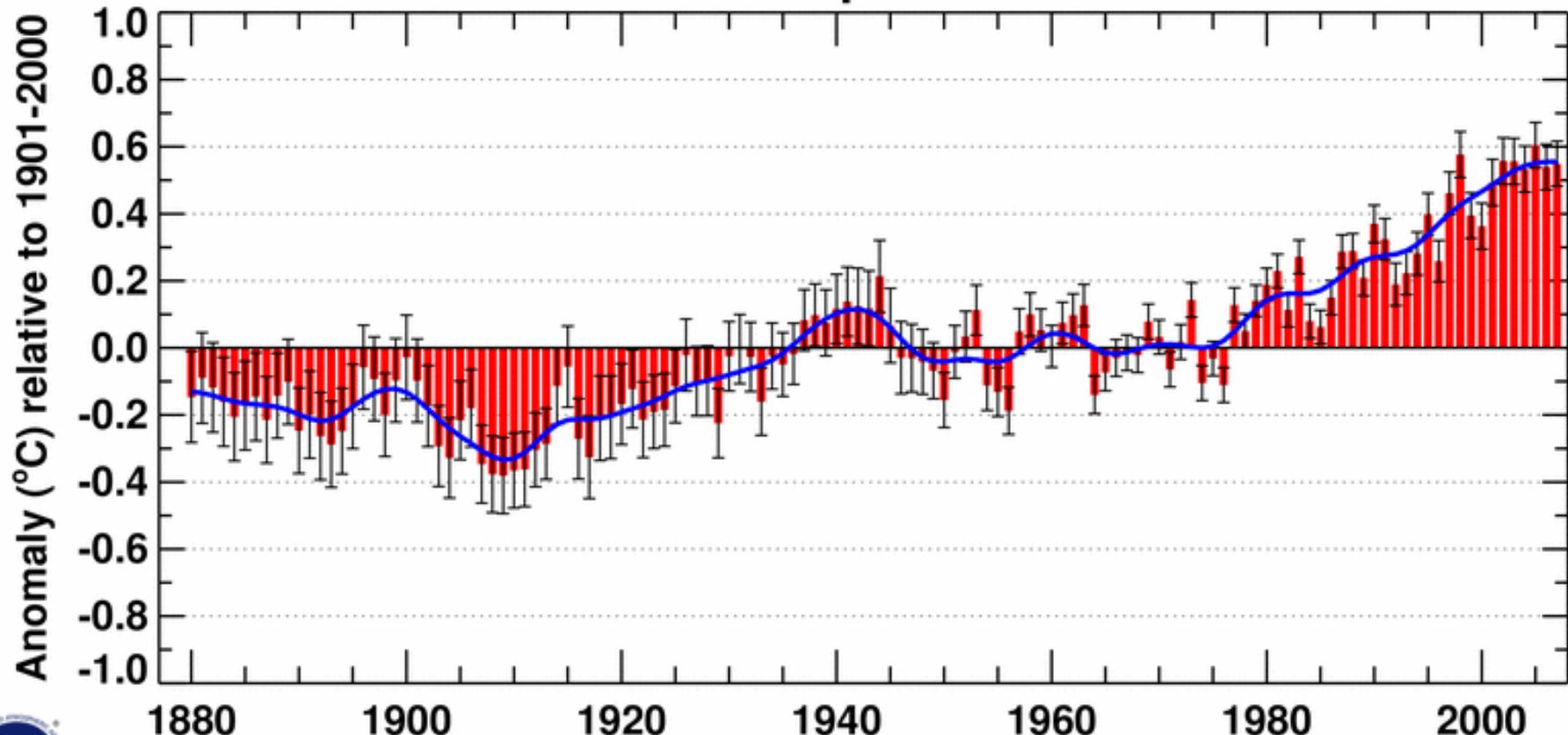
What We Know for SURE

- CO₂ is a greenhouse gas;
- The atmospheric concentration of CO₂ is increasing;
- The increase is being caused primarily by fossil fuel burning;
- Fossil fuel consumption is at the center of almost all economies;
- CO₂ is long-lived in the atmosphere (500+ years), and
- Stabilizing the atmospheric concentration of CO₂ will be difficult.



*Climate Change: Assessment
and Recent Observations*

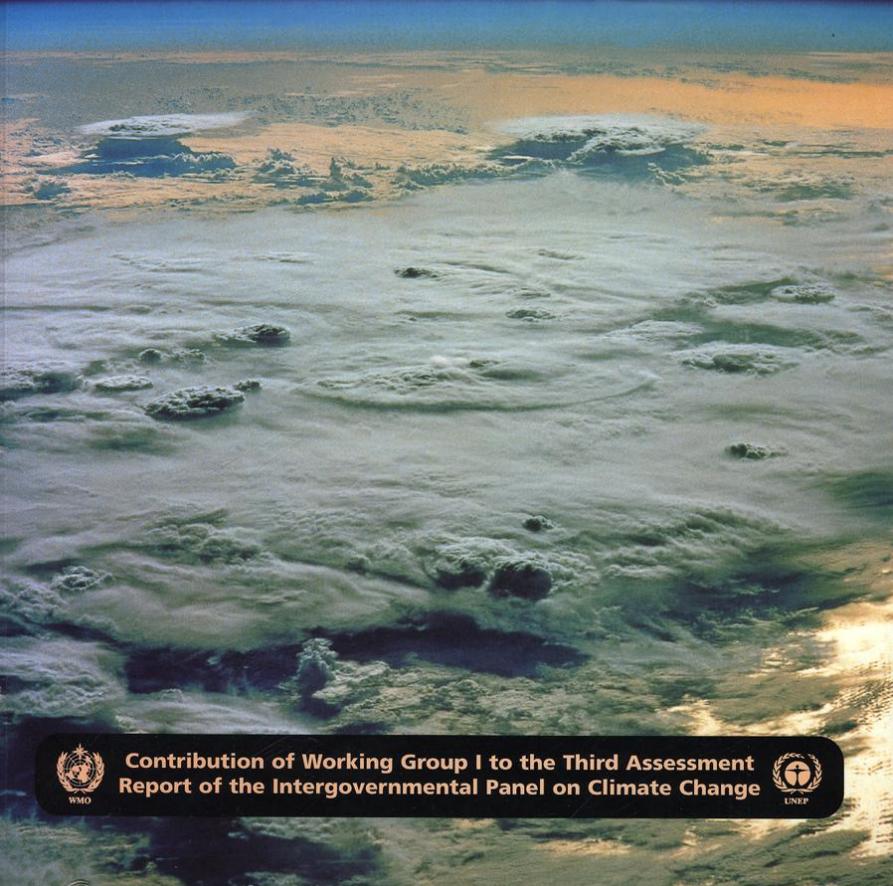
Jan-Dec Global Mean Temperature over Land & Ocean



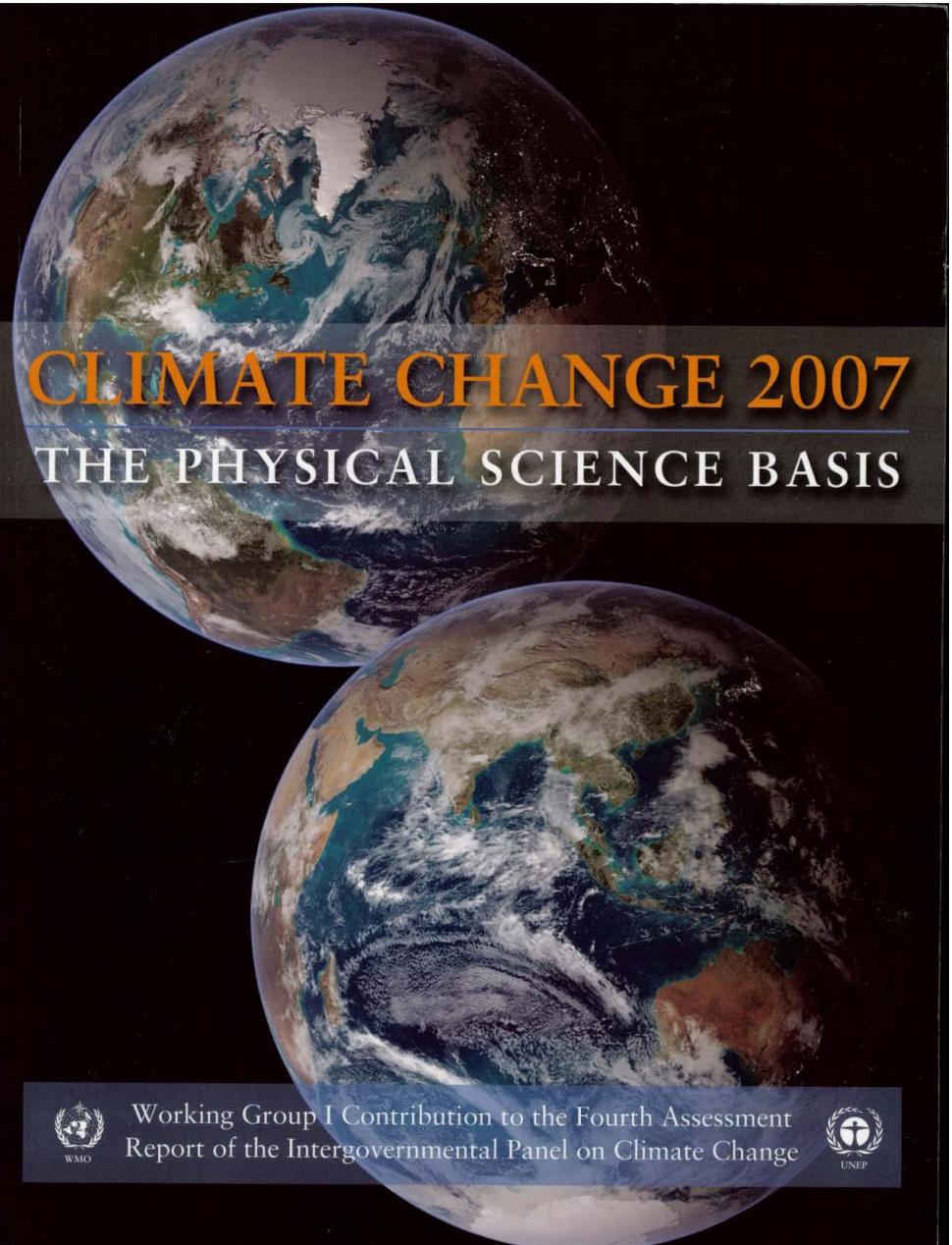
NCDC/NESDIS/NOAA

CLIMATE CHANGE 2001

The Scientific Basis



Contribution of Working Group I to the Third Assessment
Report of the Intergovernmental Panel on Climate Change



Working Group I Contribution to the Fourth Assessment
Report of the Intergovernmental Panel on Climate Change



An increasing body of observations of climatic and other changes in physical and ecological systems gives a collective picture of a warming world.



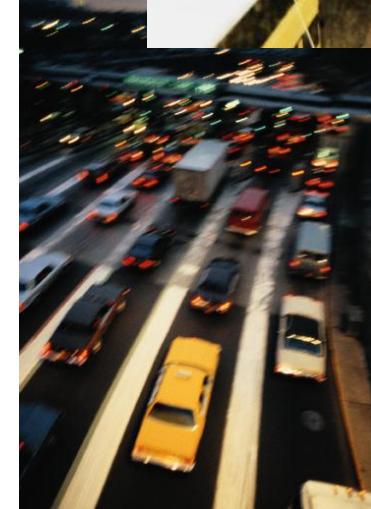
IPCC Third Assessment Report, WG1

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.

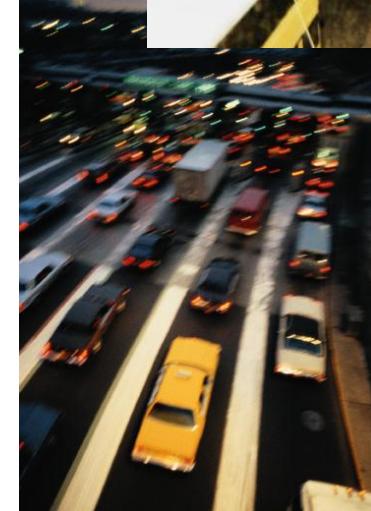


IPCC Fourth Assessment Report, WG1

There is new and stronger evidence that most of the warming
observed over the last 50 years
is *likely* attributable to human activities.



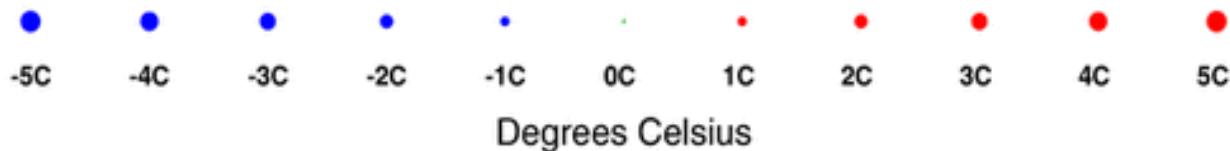
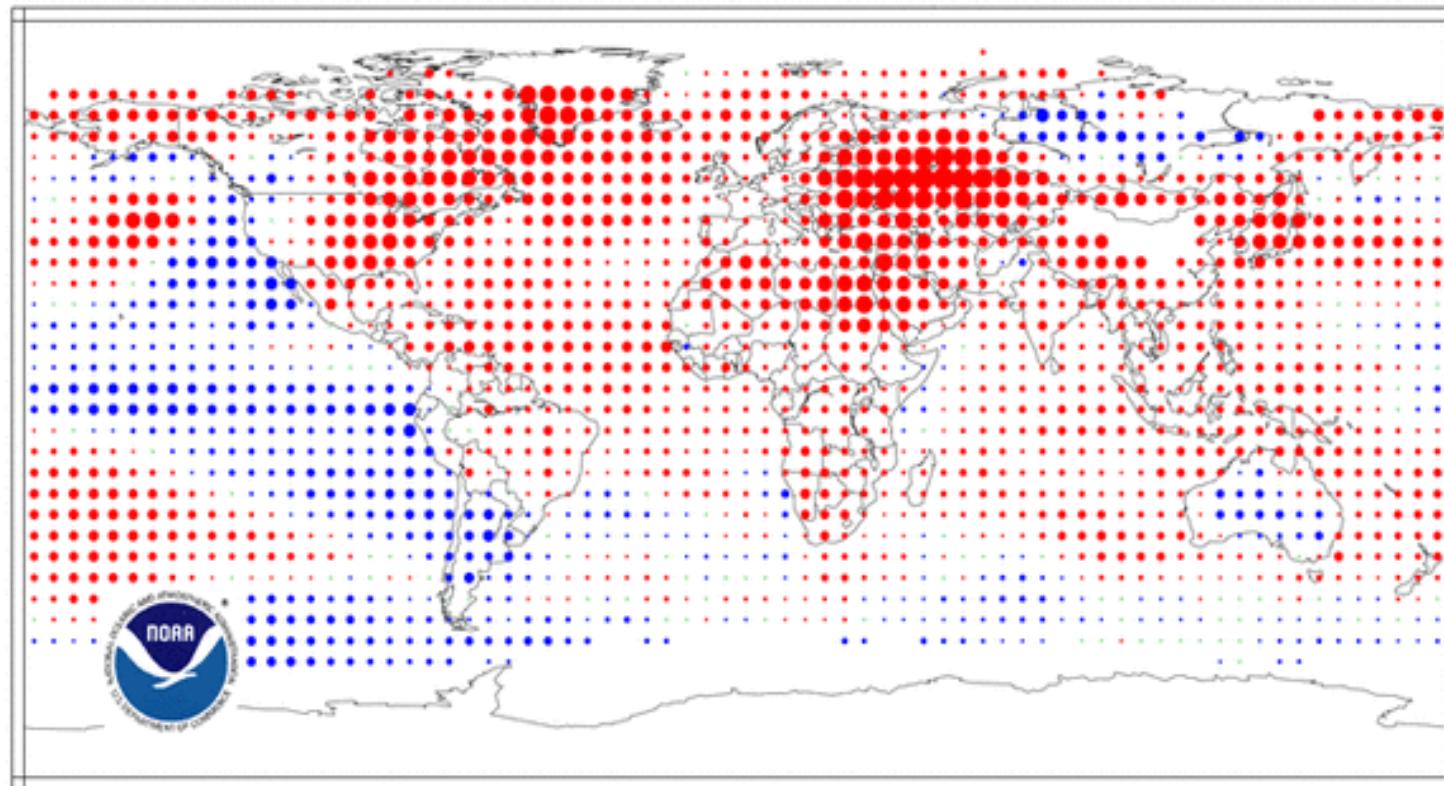
Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.



Temperature Anomalies August 2010

(with respect to a 1971-2000 base period)

National Climatic Data Center/NESDIS/NOAA



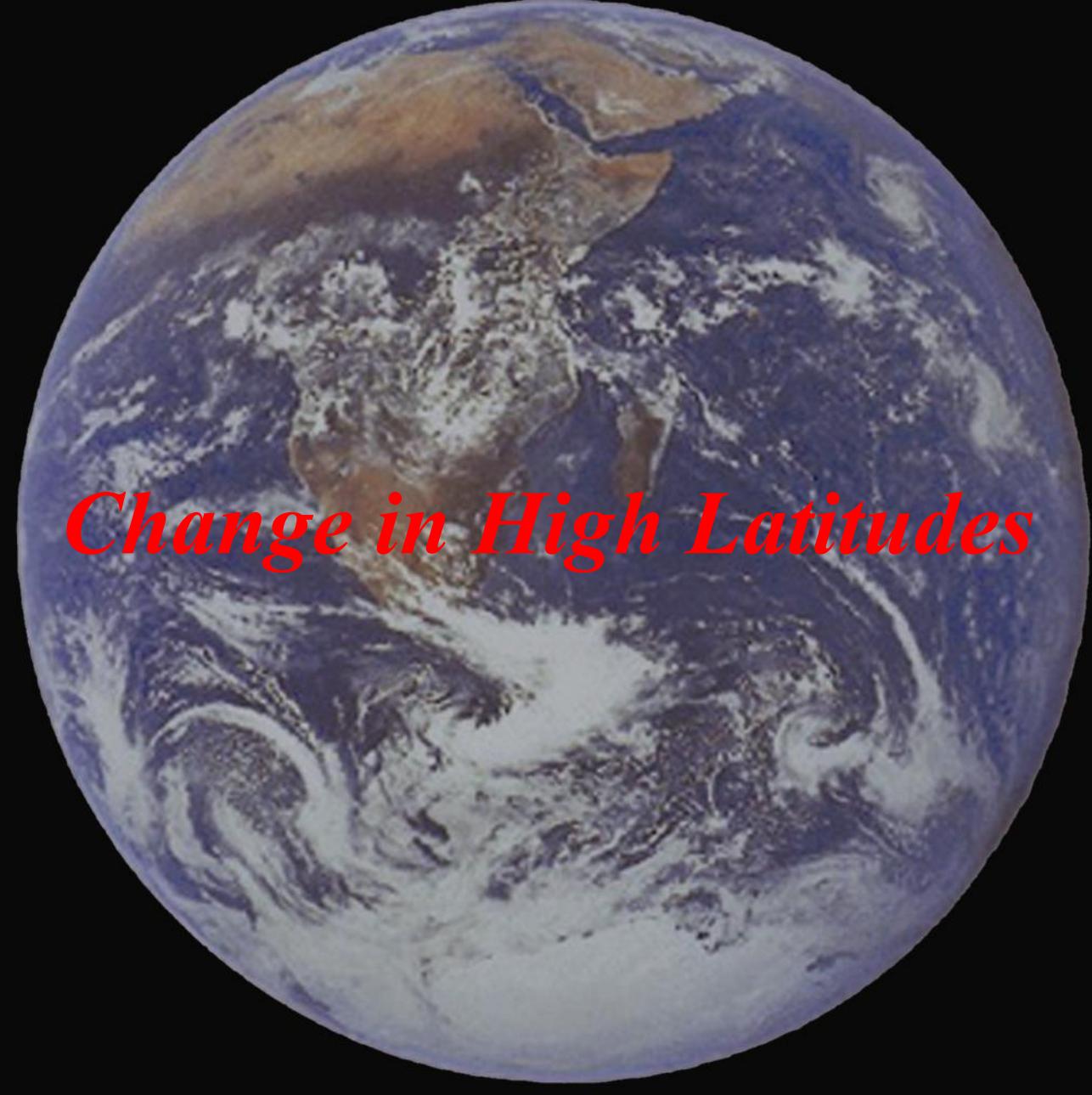
Global Temperature Highlights: 2010

- *The combined global land and ocean average surface temperature for June–August 2010 was the second warmest on record, just behind 1998.*
- *The June–August worldwide land surface temperature was the warmest June–August on record, surpassing the previous June–August record anomaly set in 1998.*
- *The worldwide ocean surface temperature was the fifth warmest June–August on record.*
- *For January–August 2010, the global combined land and ocean surface temperature tied with 1998 as the warmest January–August period on record.*

Global Temperature Highlights: 2010

- *The global average land surface temperature for the period January–September was the second warmest on record, behind 2007.*
- *The global average ocean surface temperature for the period January–September was the second warmest on record, behind 1998.*
- *The global combined land and ocean surface temperature for January–September 2010 was tied with 1998 as the warmest on record.*

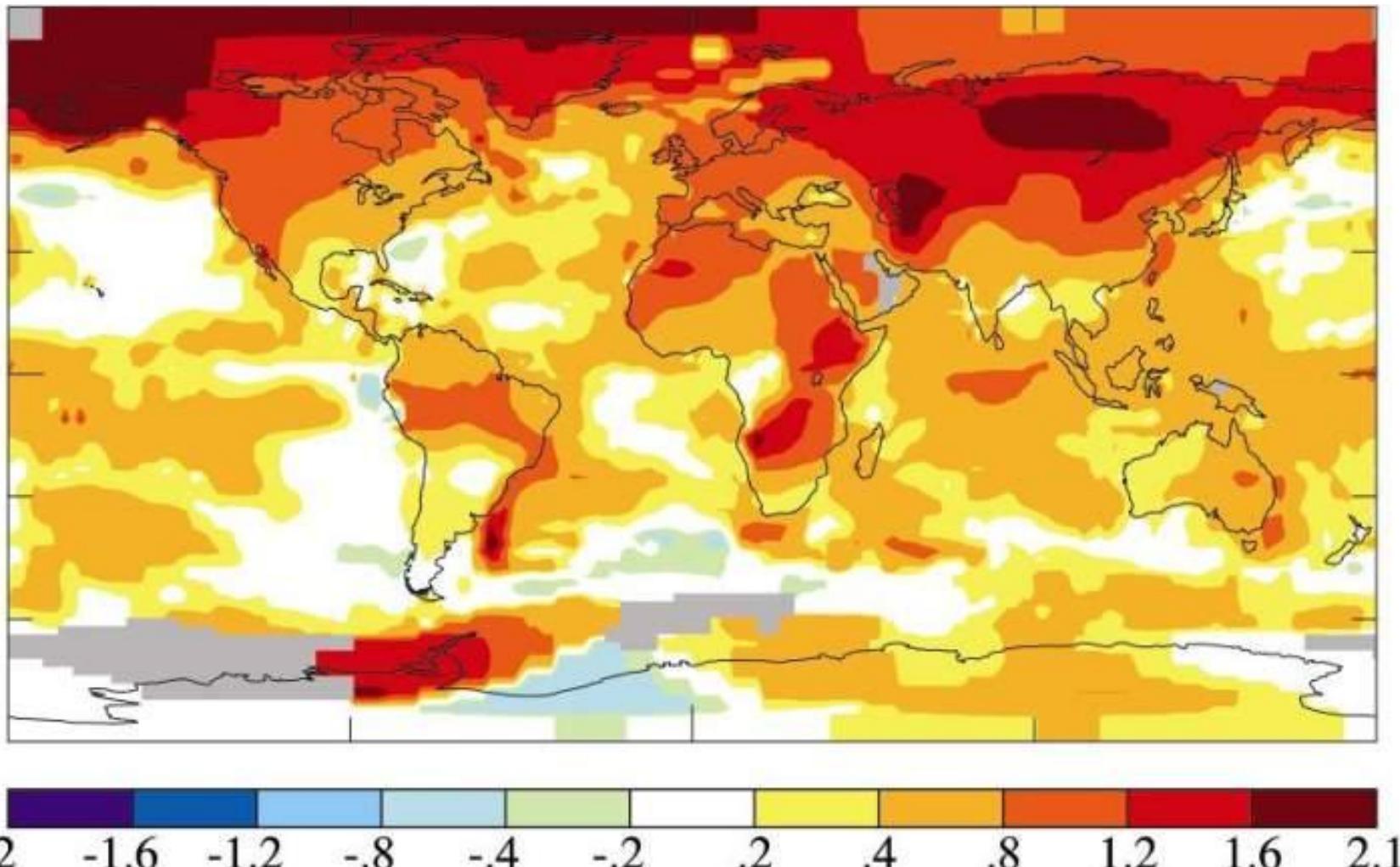
September 2010 was the 307th consecutive month with a global temperature above the 20th century average. The last month with below-average temperature was February 1985.



Change in High Latitudes

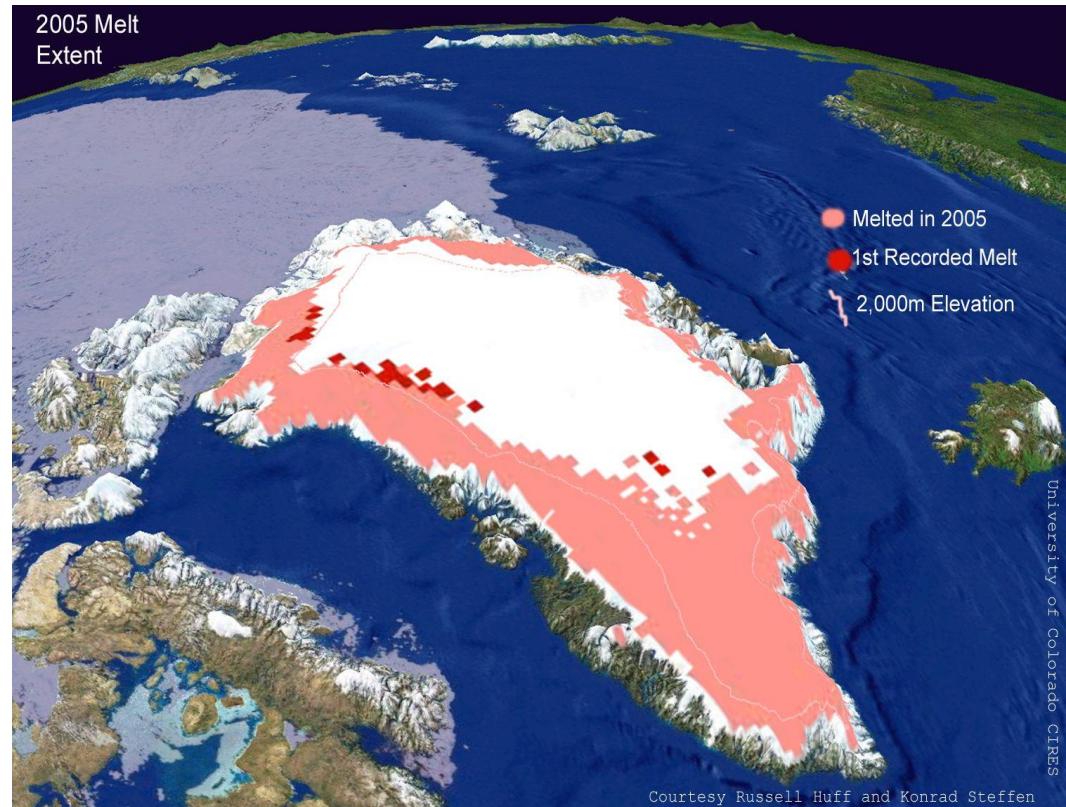
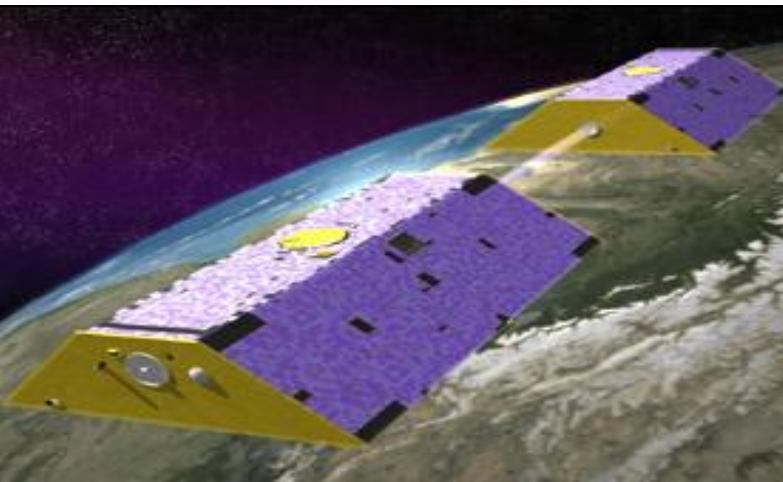
The current heating is not uniform geographically

Surface T in 2001-2005 vs. 1951-1980



Hansen et al., PNAS 2006

Changes in Greenland as seen by GRACE



GRACE Science Team NASA

Greenland Seasonal and Annual Balance

Year	Winter Balance (Gt)	Summer Balance (Gt)	Balance (Gt)
2004	224 ± 19	-384 ± 19	-160 ± 27
2005	332 ± 24	-482 ± 26	-150 ± 35
2006	266 ± 15	-390 ± 15	-124 ± 21
2007	196 ± 13	-507 ± 15	-311 ± 20
2008	201 ± 29		
Average	244 ± 56	-441 ± 63	-186 ± 85

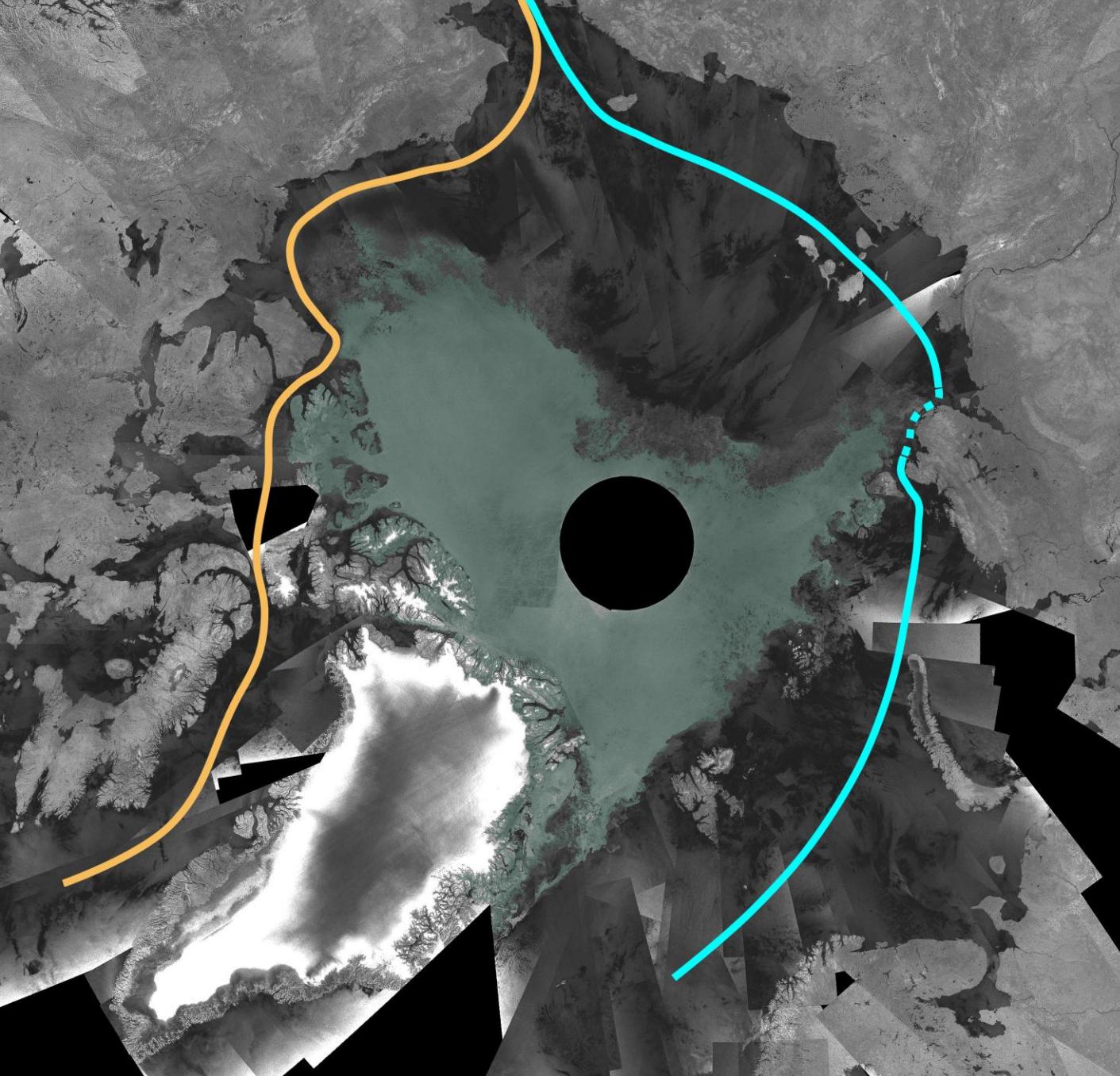
Balance years begin in the fall of the previous calendar year.

2007 net balance at -311 ± 20 Gt

Is 67% larger than 4-yr. average.

S. B. Luthcke, et al., 2008



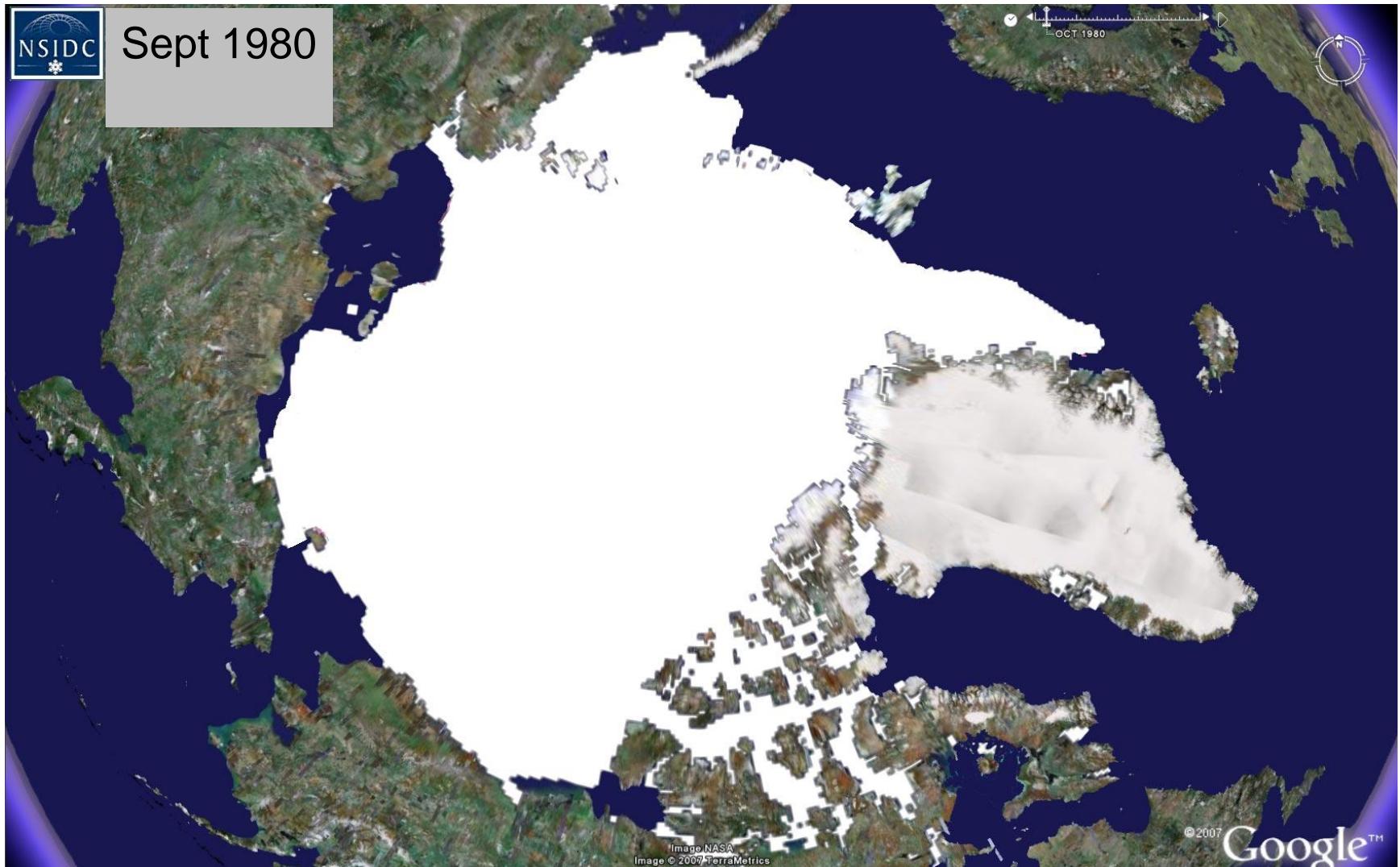


Envisat: A “New”
Northwest Passage
September 2007

Changes in sea ice extent

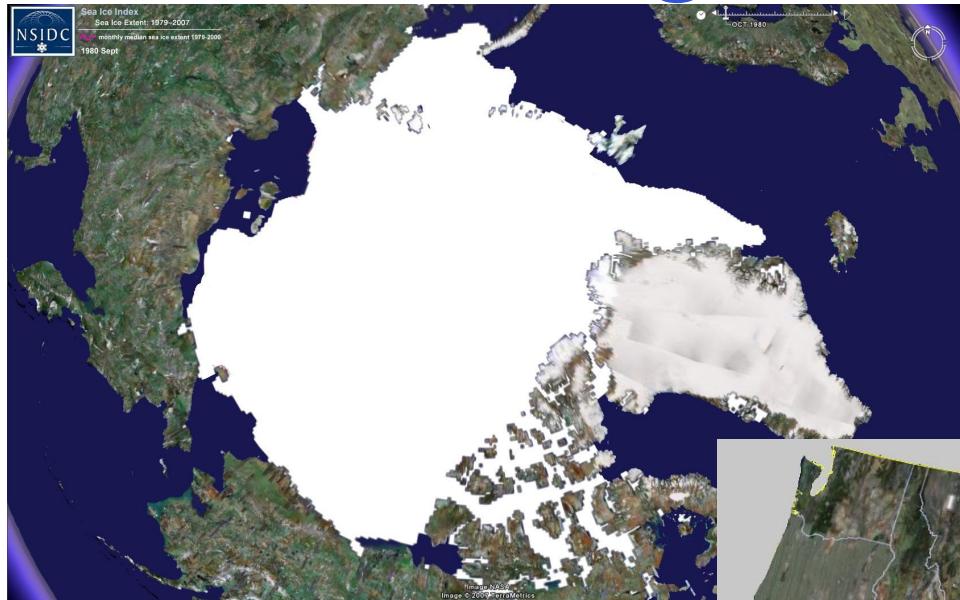


Sept 1980



National Snow and Ice Data Center NOAA

Changes in sea ice extent

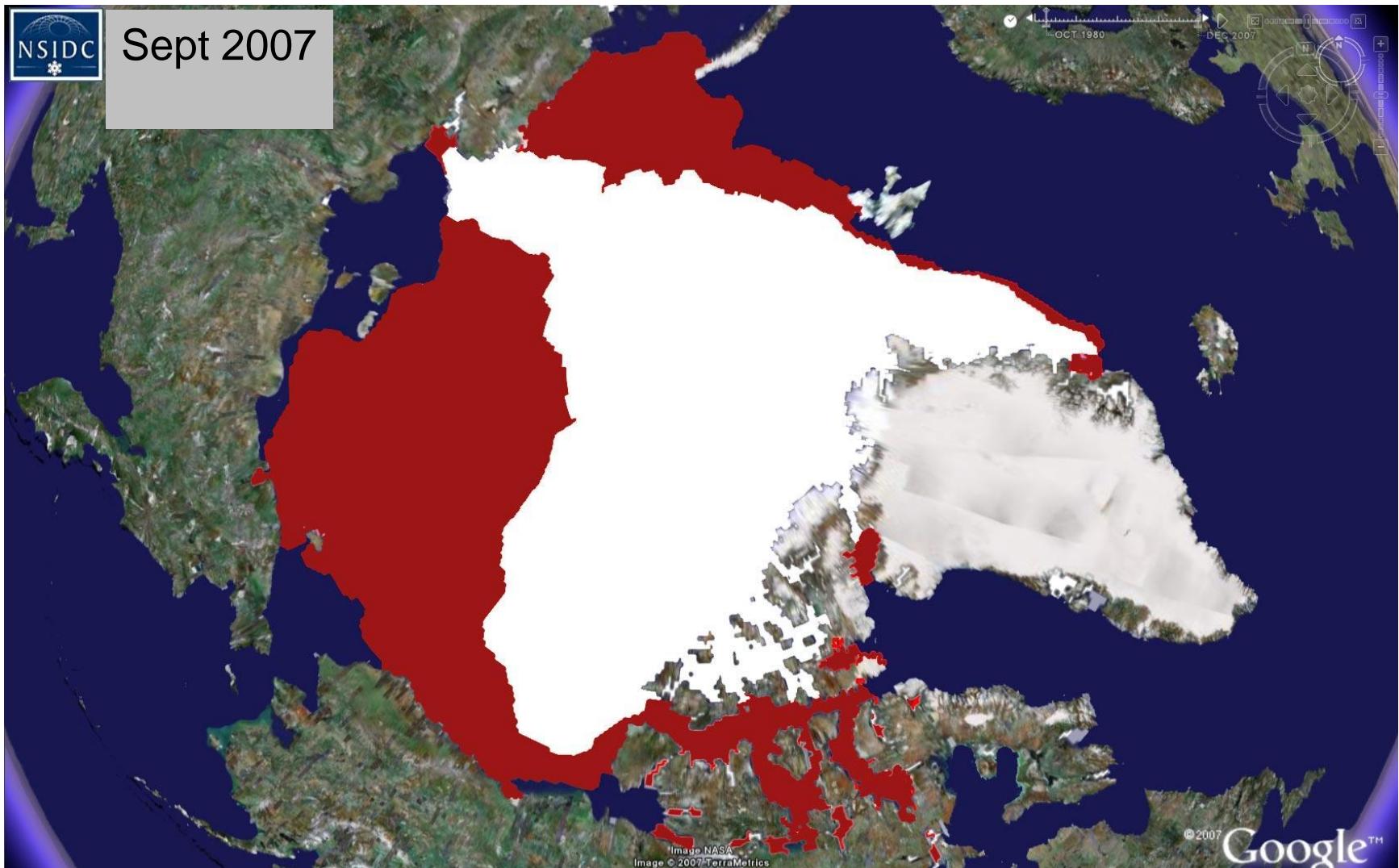


September 1980



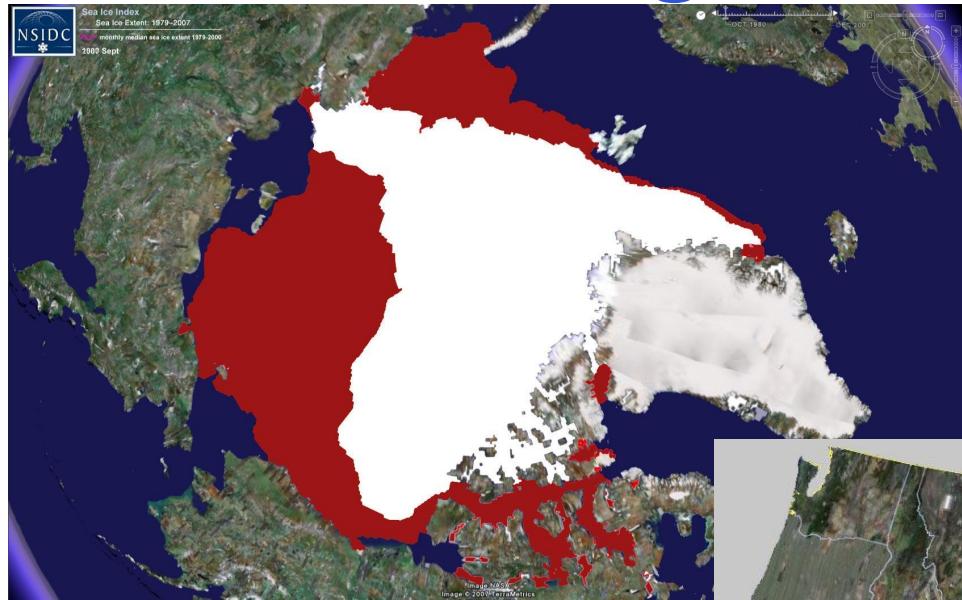
National Snow and Ice Data Center NOAA

Changes in sea ice extent

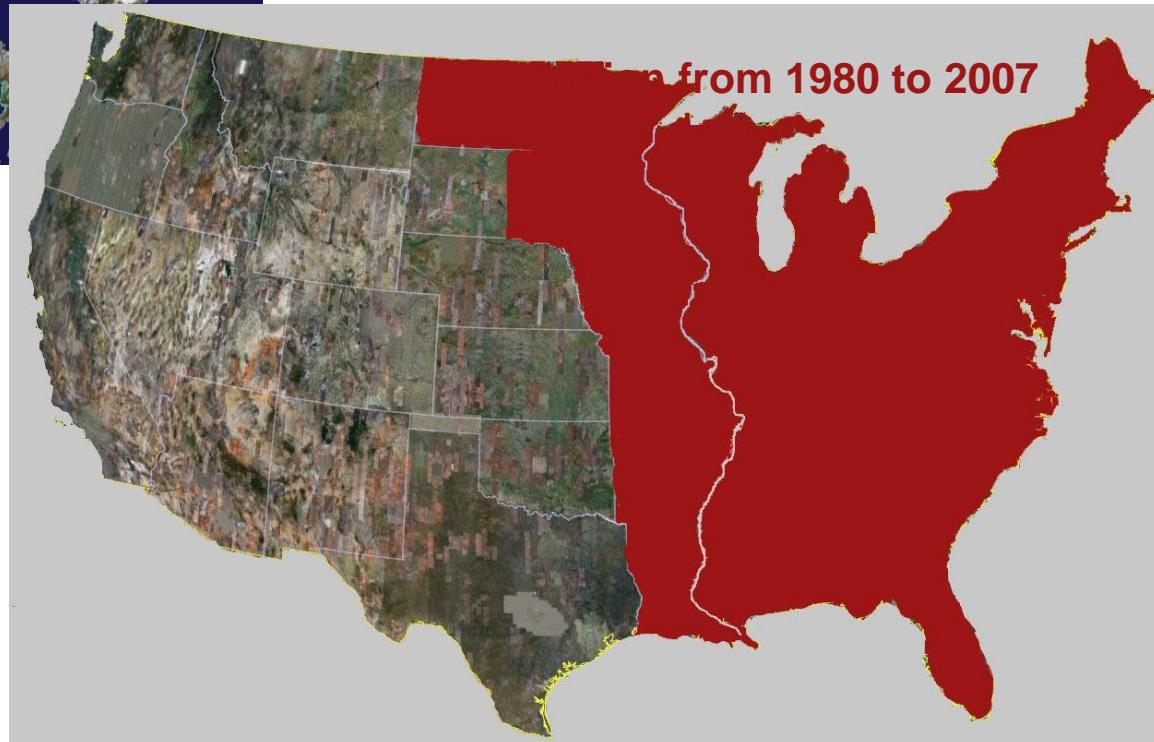


National Snow and Ice Data Center NOAA

Changes in sea ice extent

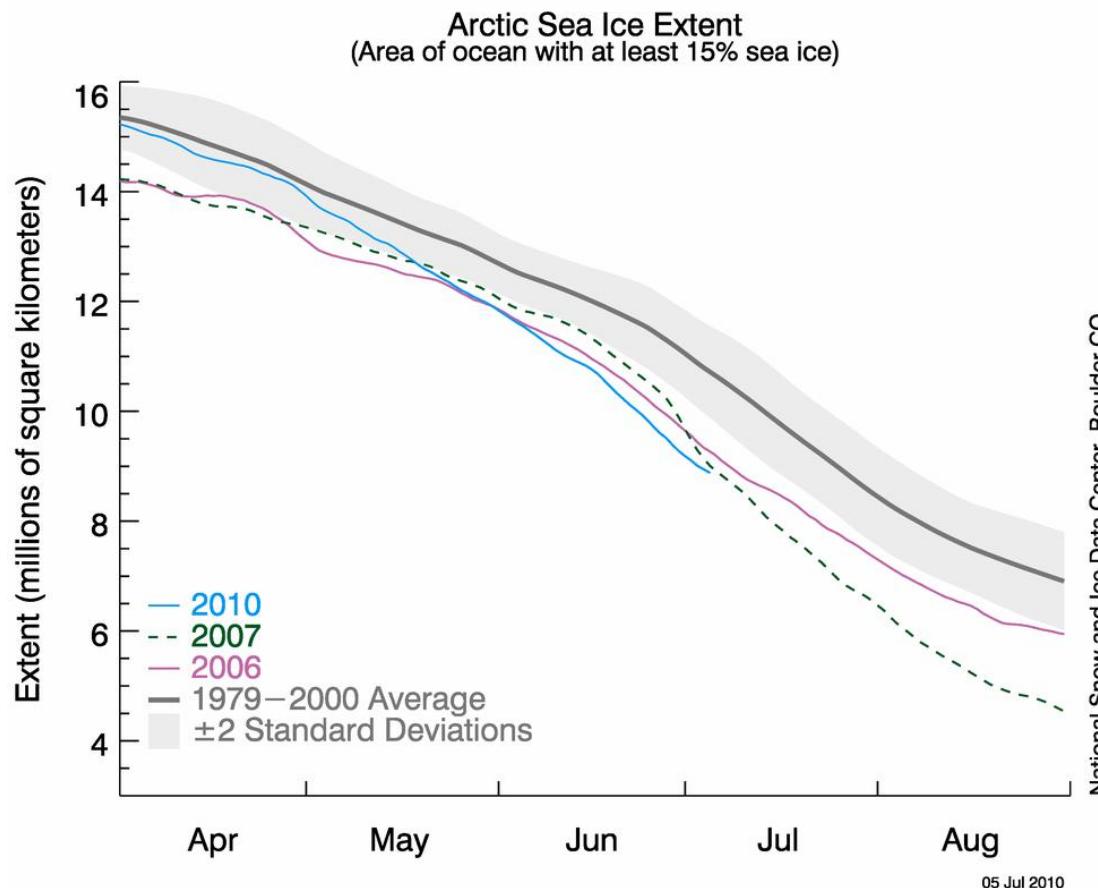


***And Change is
Accelerating***



National Snow and Ice Data Center NOAA

Arctic Sea Ice Extent



National Snow and Ice Data Center NOAA



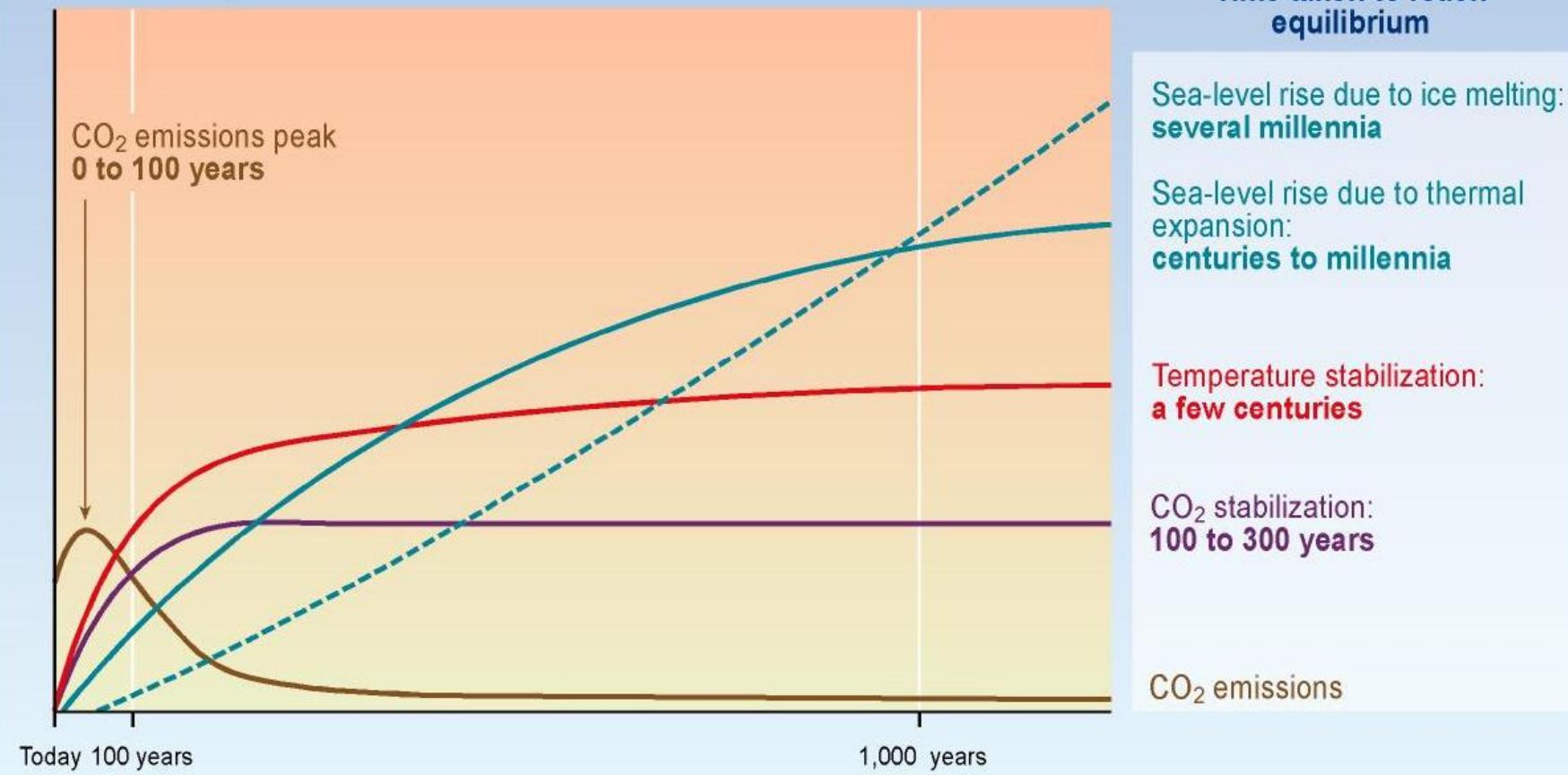


Global Climate Change: A Faustian Bargain—

“Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized.”

CO₂ concentration, temperature, and sea level continue to rise long after emissions are reduced

Magnitude of response



What We THINK We know

- The Planet is warming in response to the increase in the atmospheric concentration of CO₂ (and other greenhouse gases);
- The increase in global temperature will alter rainfall patterns;
- The climate of the Planet will continue to change even after the atmospheric concentration of CO₂ is stabilized, and
- Climate change will change the atmospheric concentration of CO₂—sinks could weaken.

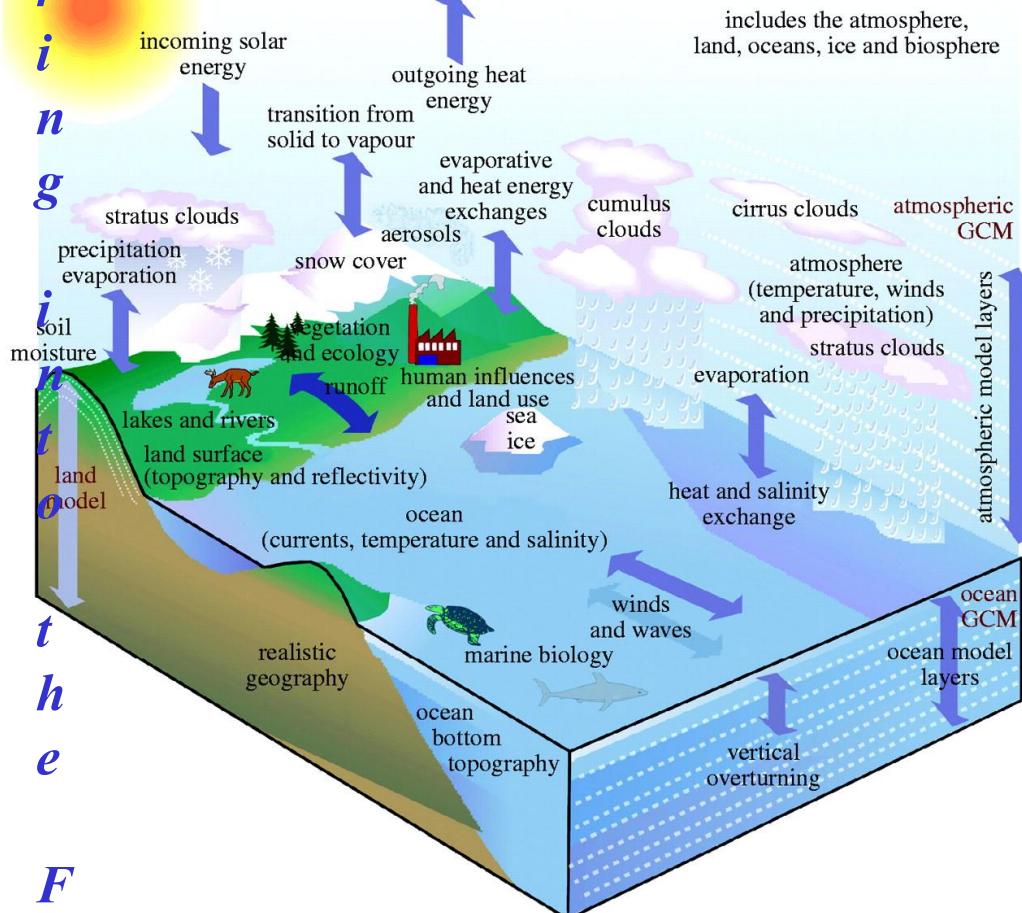




*Climate Futures: Through a
Glass Darkly*

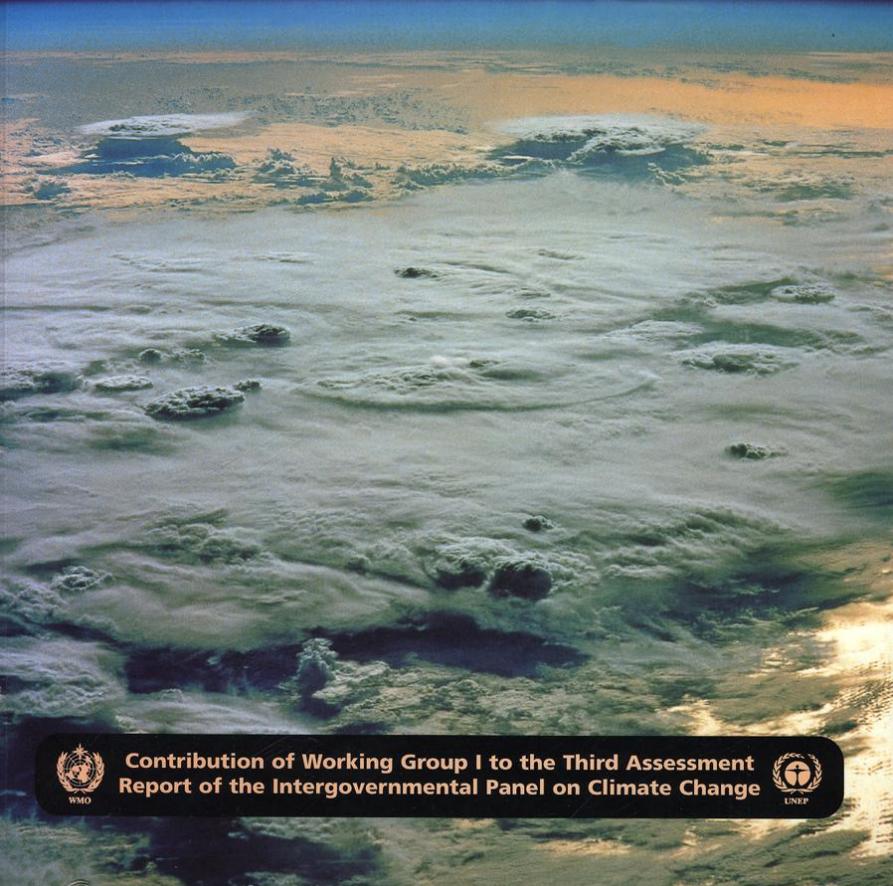
P e r i n i t o t h e

NCAR Community Climate Model



CLIMATE CHANGE 2001

The Scientific Basis

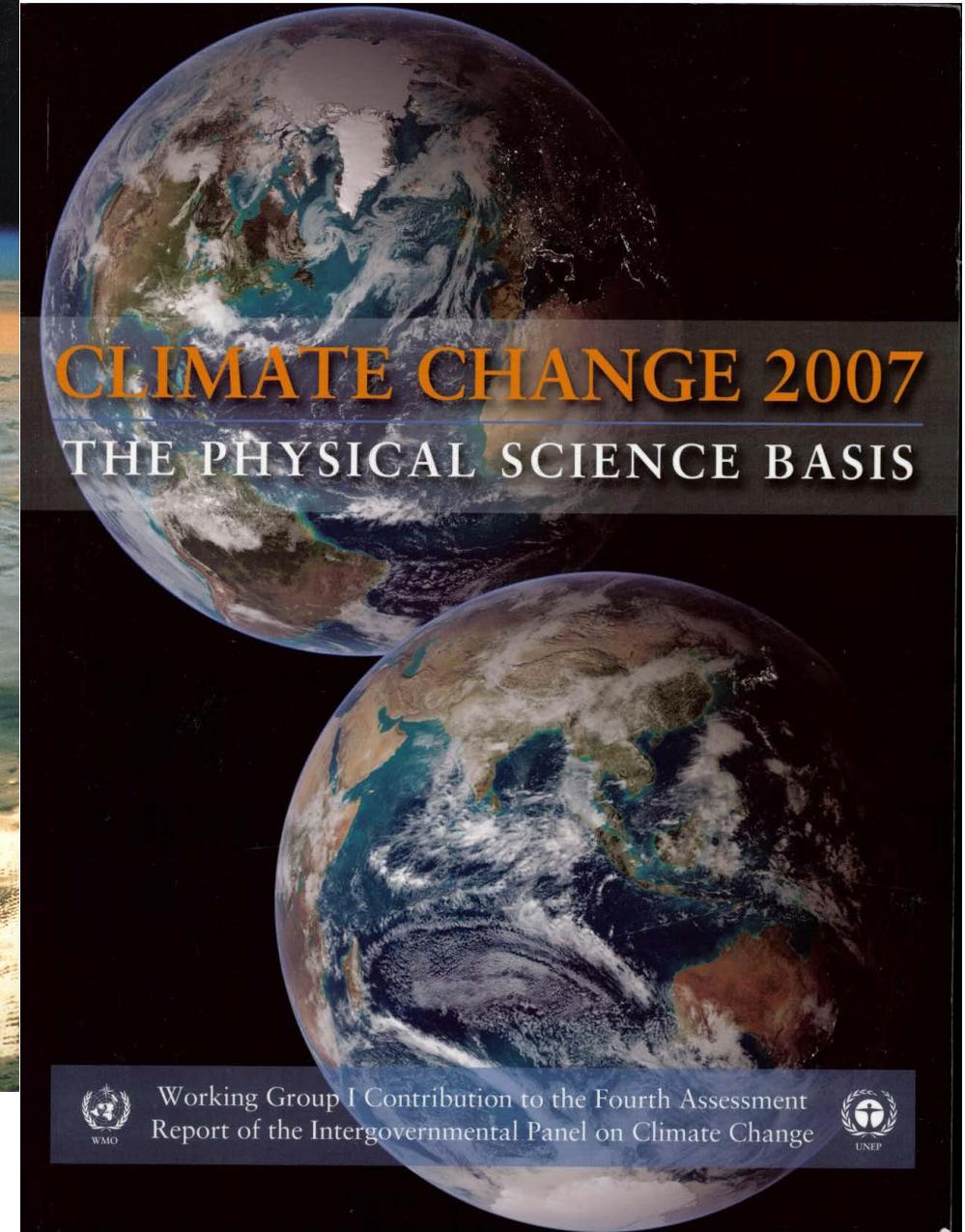


Contribution of Working Group I to the Third Assessment
Report of the Intergovernmental Panel on Climate Change



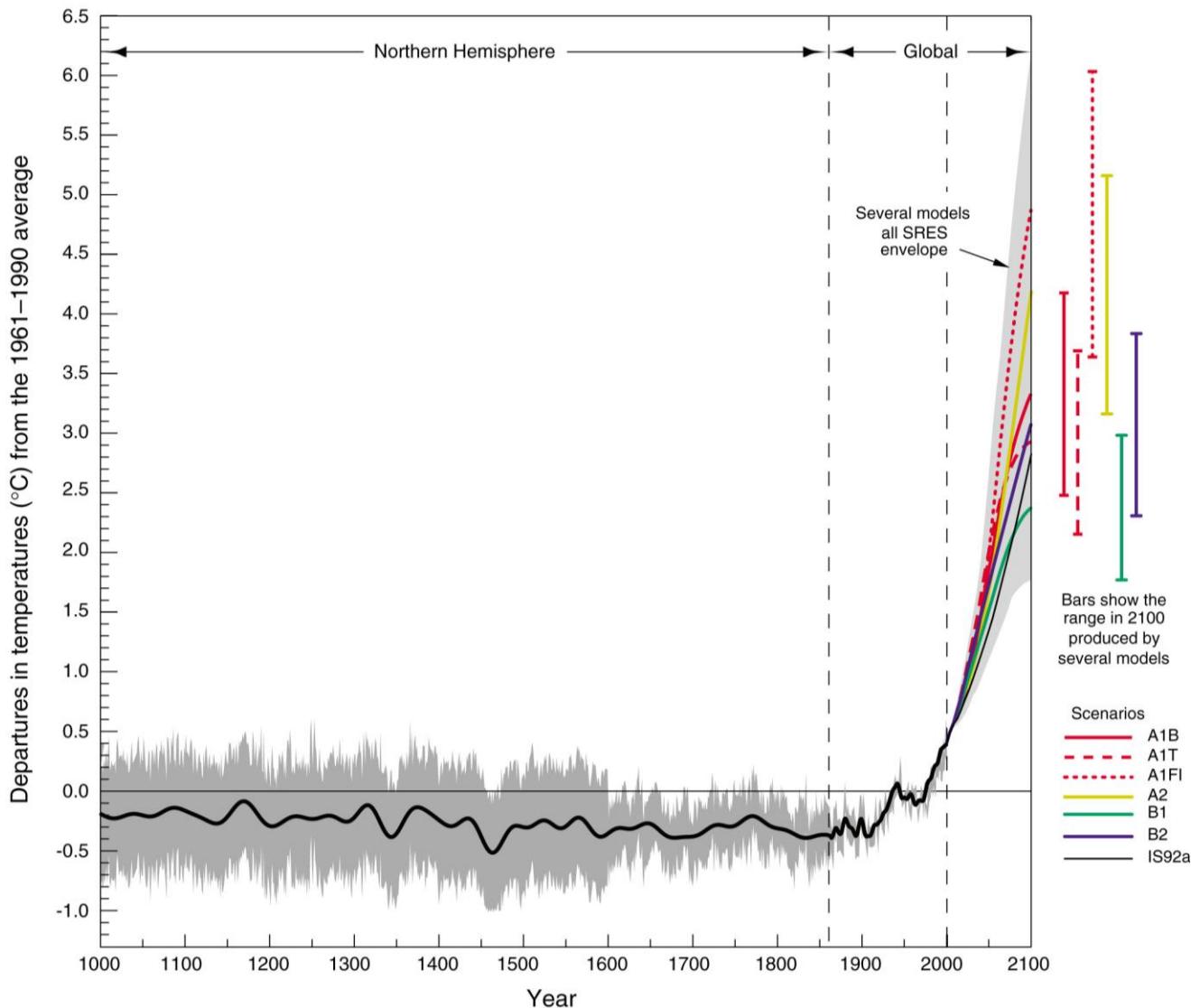
CLIMATE CHANGE 2007

THE PHYSICAL SCIENCE BASIS



Working Group I Contribution to the Fourth Assessment
Report of the Intergovernmental Panel on Climate Change





Global temperature will rise from 1.4-5.8°C over this century unless greenhouse gas emissions are greatly reduced.

Fourth Assessment Report: Climate-Carbon System

Assessed upper ranges for temperature projections are larger than in the TAR mainly because the broader range of models now available suggests stronger climate-carbon cycle feedbacks.

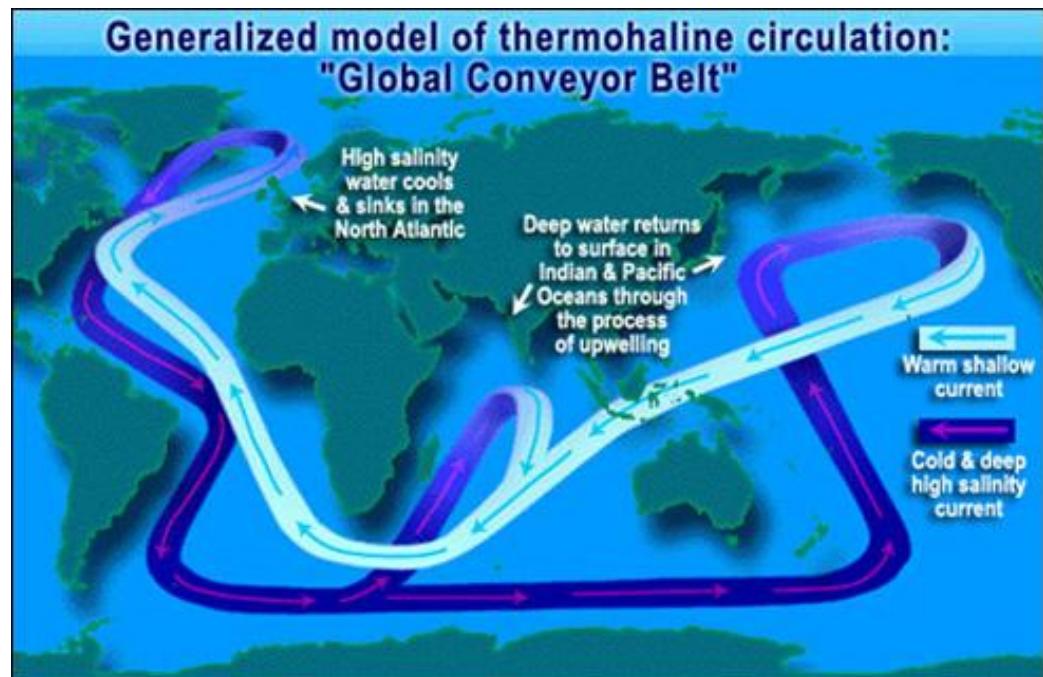
Climate carbon cycle coupling is expected to add carbon dioxide to the atmosphere as the climate system warms, but the magnitude of this feedback is uncertain. This increases the uncertainty in the trajectory of carbon dioxide emissions required to achieve a particular stabilization level of atmospheric carbon dioxide concentration.

Abrupt Climate Change?

Greenland Ice
Sheet Melting?



Changes in the
Gulf Stream?



Model-Data Comparison: A Performance Evaluation

- *Objective measures of climate model performance have used, primarily climatology of atmospheric fields, to assess simulations of the 20th century climate.*
- *Some models appear to perform substantially better than others. However, the relative ranking of models varies considerably from one variable to the next.*
- *A remarkable exception to this finding is that the so-called “mean model” consistently outperforms all other models in nearly every respect.*

The understanding of the Climate System is inadequate to adequately foresee our future.

We are not in a good situation

Improving our Collective “Crystal Ball”

- Progress in improving and evaluating our abilities to project climate-carbon patterns will only be made if we more aggressively explore and test Earth System Models—*Time is of the Essence.*
- The scientific community has agreed upon 44 Essential Climate Variables, which can (should) form litmus tests for Earth System Models.
- The Space-Faring nations need to ensure that the necessary observations are made consistently and that reliable Climate Data Records are produced and widely shared.

What We Do Not SEEM to Know

- How to “swap out” the current energy system of the planet for one that is nearly carbon neutral without wrecking economic havoc:
 - The world consumes 1.2 cubic miles of oil every year, which is 31.5×10^9 barrels per year--there are 31.5×10^6 seconds in a year.
 - Global annual production of the three staple grains – wheat, rice and maize - is about 2×10^9 tonnes. World consumption of gasoline 317×10^9 gallons per year. To offset *just gasoline* we need roughly annually 8×10^9 tonnes biomass (not including energy cost of production)



The Industrial Revolution

#2



Two Central Questions on the CO₂ Forcing

1. Currently, 45% of all CO₂ emissions accumulate in the atmosphere:
How might this change (because of climate or ...)?

Ocean removes 25%



Land removes 30%



2. If current sinks continue “relatively” unchanged, then stabilization of atmospheric CO₂ requires a reduction of anthropogenic emissions by roughly 80+%: How might that be achieved?



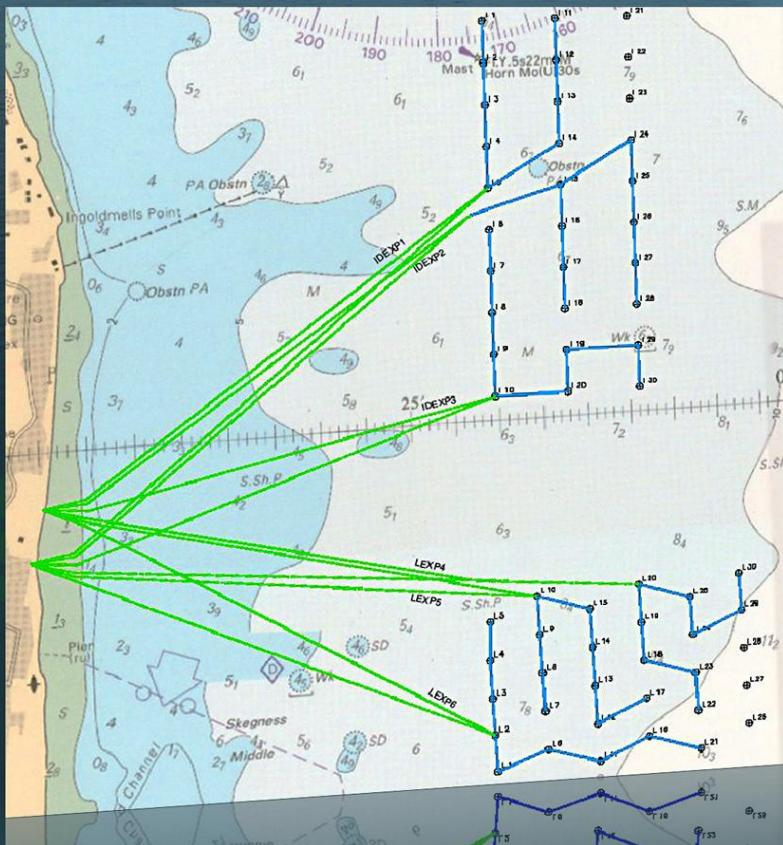
World's Largest Off-Shore Wind Farm

Lynn and Inner Dowsing Wind Farm

54 Turbines

194 MW Peak Output

\$500 million Project Cost



Assume $190 \cdot 10^6$ W is average; Current capacity of wind globally is $160 \cdot 10^9$ W; in other words we have roughly **850 Lynn and Inner Dowsing Wind Farms (eq)**--which is 2% of the world total electricity supply. So, we need roughly **42,500 Lynn and Inner Dowsing Wind Farms** to meet world electricity needs (but best double that since peak output is not output)

And remember current wind is about 2% of current electricity production—but consumption is expected to rise by 2% per year. Need to add current capacity (+) each year to stay “even”—no increase in the size of the pool to be “swapped out”

World's Largest Nuclear Plant

Kashiwazaki-Kariwa (K-K) Nuclear Power Plant

8,212 MW Peak Output

Enough to power 16 million households



Kashiwazaki, Japan



And 8,2121 MW is roughly
42 Lynn and Inner Dowsing
Wind Farms –If we were to
make up the 2% growth in
electricity with Nuclear
Facilities, we would need 20
K-K (eq) per year.

*Concerns about
climate have forced
us to turn off the **light**
at the end of the
tunnel.*



What We REALLY DO NOT Know

How to Communicate with
our fellow citizens so that
they can understand the
reality and nature of
The Climate Challenge.



