Joint Meeting

Environment & Natural Resources Council

Committee on Agribusiness
Committee on Conservation & State Lands
Committee on Energy
Committee on Environmental Protection

Tuesday, November 6, 2007
10:15 AM - 5:00 PM
212 Knott Building

Marco Rubio
Speaker

Stan Mayfield
Chair

The Florida House of Representatives

Environment & Natural Resources Council

Marco Rubio
Speaker

Stan Mayfield
Chair

AGENDA

November 6, 2007
10:15 A.M. – 5:00 P.M.
212 Knott Building

JOINT MEETING

The Environment & Natural Resources Council will meet jointly with the Committees on Agribusiness, Conservation & State Lands, Energy, and Environmental Protection to participate in a **Symposium on the Science and Economics of Climate Change**.

10:15 - 10:30: Welcome and Introductions

The Honorable Stan Mayfield, Chair, Environment & Natural Resources Council

10:30 - 12:30: Panel on the Science of Climate Change

Moderator: **John Reilly, Ph.D.,** Associate Director for Research, Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology

Martin Manning, Ph.D., Director, Intergovernmental Panel on Climate Change, Working Group I Support Unit, University Corporation for Atmospheric Research: Evidence for Warming

Judy Curry, Ph.D., Professor, School of Earth and Atmospheric Sciences, Georgia Institute of Technology: Evidence that Tropical Storms are Affected by Warming

Brian Soden, Ph.D., Associate Professor of Meteorology and Physical Oceanography, University of Miami: What Can We Say About Regional Climate Change?

12:30 - 2:00: Lunch Break

2:00 - 2:30: Overview of Mitigation, Climate Policy, and Climate Risks

John Reilly, Ph.D., Massachusetts Institute of Technology

2:30 - 3:30: Panel on Impacts and Adaptation

Moderator: **John Reilly, Ph.D.**, Massachusetts Institute of Technology

Harold Wanless, Ph.D., Chairman, Department of Geological Sciences, University of Miami: Sea Level Rise and Coastal Impacts

Wendy Graham, Ph.D., Director, Carl S. Swisher Chair in Water Resources, UF Water Institute, University of Florida: Impacts on Water Resources

Jim Jones, Ph.D., Distinguished Professor, Agricultural & Biological Engineering Department, University of Florida: Impacts of Climate Change on Agriculture

3:30 - 4:30: Panel on Mitigation Policies and Costs

Moderator: **John Reilly, Ph.D.,** Massachusetts Institute of Technology

W. David Montgomery, Ph.D., Vice President, CRA International: Economic Cost of Mitigation at the State Level

Gilbert E. Metcalf, Ph.D., Professor of Economics, Tufts University: Cap and Trade, Carbon Taxes, Distributional Effects

4:30 – 5:00: Closing Comments

Martin Manning

Dr. Martin Manning

Dr. Martin Manning is Director of the Working Group I Support Unit for the Intergovernmental Panel on Climate Change (IPCC) and one of the co-ordinators of the recent IPCC assessment of the science of climate change. Working Group I covers the physical science of climate change including what we know about changes in the Earth's climate system and the extent to which we can explain such changes and attribute them to human activities. Dr. Manning was responsible for managing much of the Working Group I assessment project as well as being one of more than 150 authors of the final report.

Prior to taking up his current role, Dr. Manning was a research programme manager in New Zealand, where he lead research on greenhouse gases, atmospheric and oceanic chemistry, and the global carbon cycle at the National Institute of Water & Atmospheric Research. He is the author of over 40 science papers plus numerous book contributions and reports.

The Evidence for Warming and its Causes

Florida Legislature Symposium on the
Science and Economics of Climate Change
6 November 2007

Martin Manning
Director, IPCC Working Group I Support Unit

1. What is the IPCC?
2. An overview of observed climate change
3. What drives climate change
4. Identifying the causes of current changes
5. Some projections for the future

Intergovernmental Panel on Climate Change

IPCC formed in 1988 to provide policy relevant assessments of the science

Governments provide the mandate and control IPCC activities

Assessment is based on what is in the peer reviewed science literature

All text in IPCC reports is controlled by the scientific authors

Structure of the IPCC

Three Working Groups –
involving different areas of scientific & technical expertise

WG I ……. Is it happening?
Physical climate change
Climatology, geophysics, geochemistry, Earth systems science

WG II ……. Does it matter?
Impacts, adaptation and vulnerability
Biology, ecology, health science, social science

WG III ……. Can we do anything about it?
Mitigation options
Energy systems, economics, technology, political science

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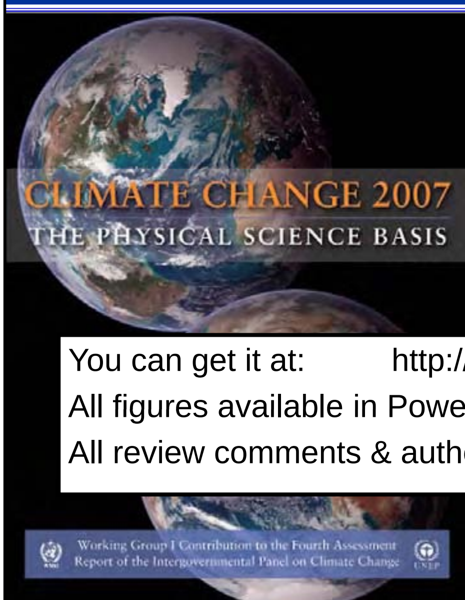
The Working Group I Report



- Started 2003
- Completed February 2007
- 152 Authors
- ~450 other contributors
- ~600 expert reviewers
- 30,000+ review comments

Contents

You can get it at: http://ipcc-wg1.ucar.edu/
All figures available in PowerPoint format.
All review comments & author responses publicly available

- ~5000 literature references
- ~1000 pages

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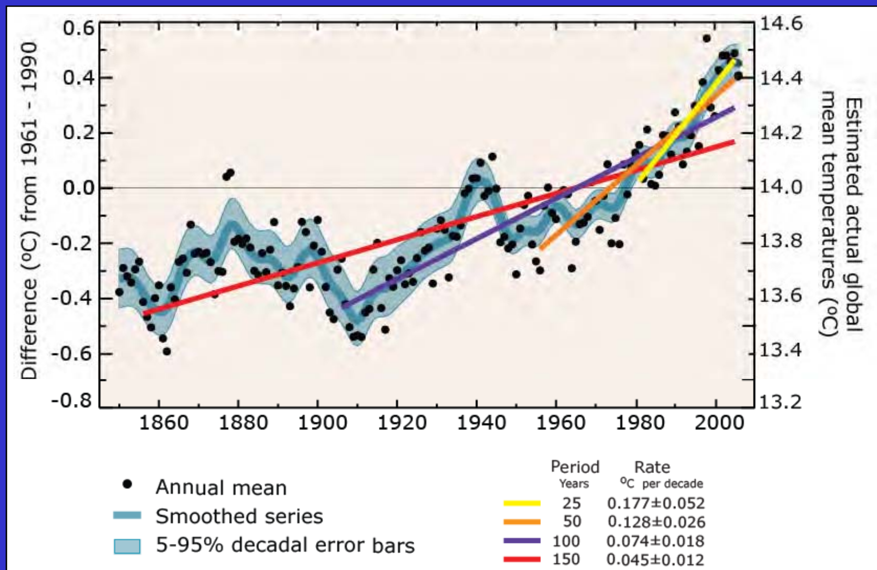
Global average temperature



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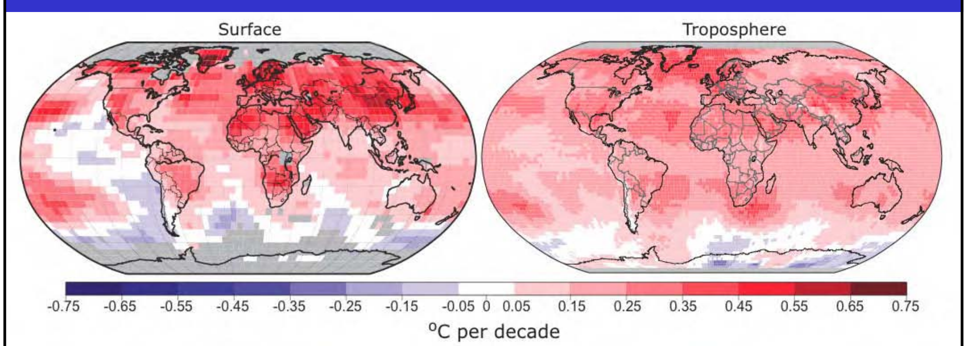
Warming is truly global

Warming trends since 1979 (when satellite measurements started) show:

- Warming is widespread and greater at high northern latitudes;
- Land warming significantly faster than ocean over last 20 years;
- Mid-troposphere warming consistent with that at surface.



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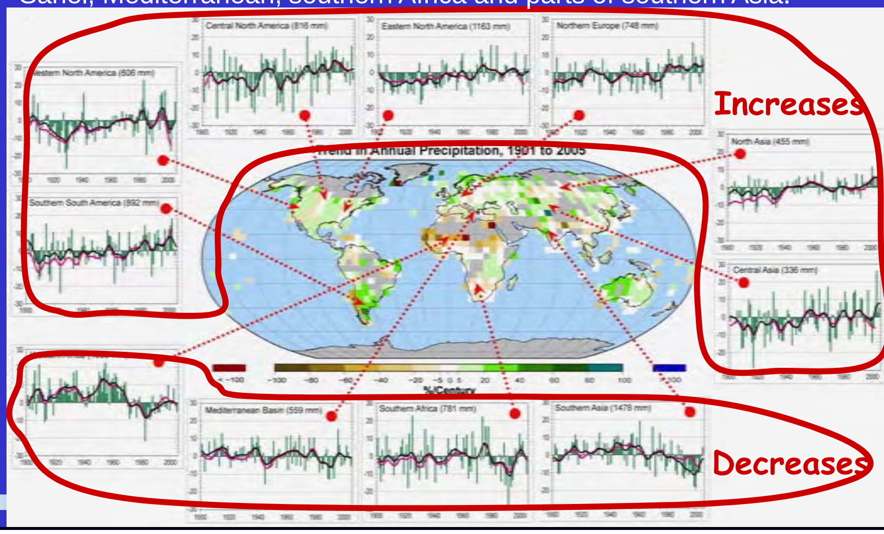
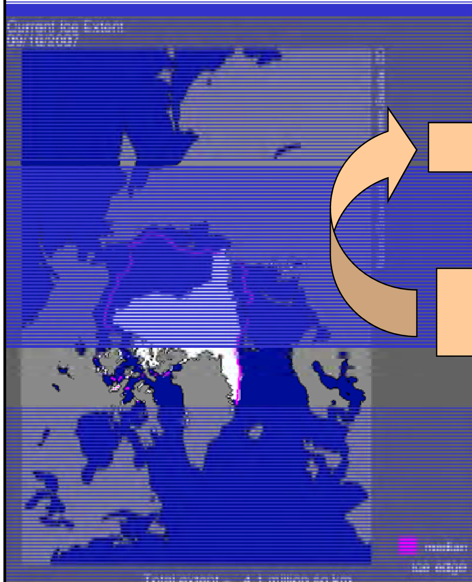
Precipitation (rain & snow) is variable – but there is evidence for systematic change

Precipitation has increased in eastern parts of North and South America, northern Europe and northern and central Asia – and decreased in the Sahel, Mediterranean, southern Africa and parts of southern Asia.

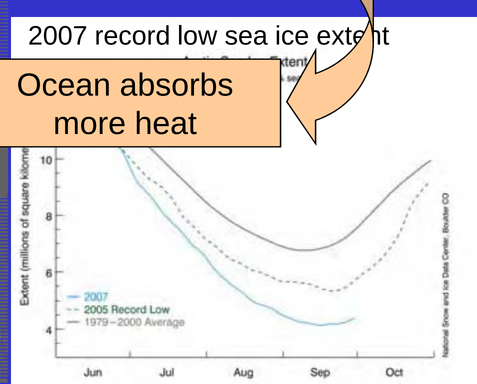


Changes in Arctic Sea Ice Cover



Average Arctic sea ice extent decreased by 2.7% per decade since 1978. Larger decreases in summer

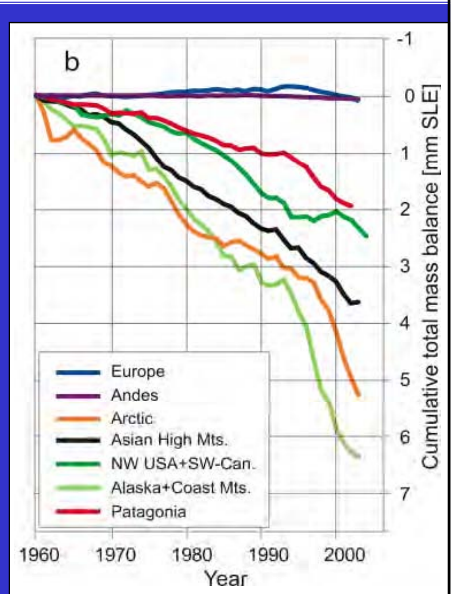
2007 record low sea ice extent



Glacier mass balance

Cumulative loss of glacier mass in many regions

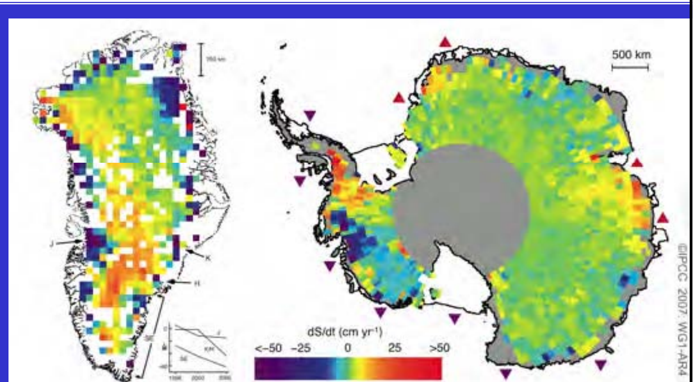
During the 20th century, glaciers and ice caps have experienced widespread mass losses and have contributed to sea level rise.



Changes in ice sheets

Surface elevation changes shown as red hues where rising and blue where falling.

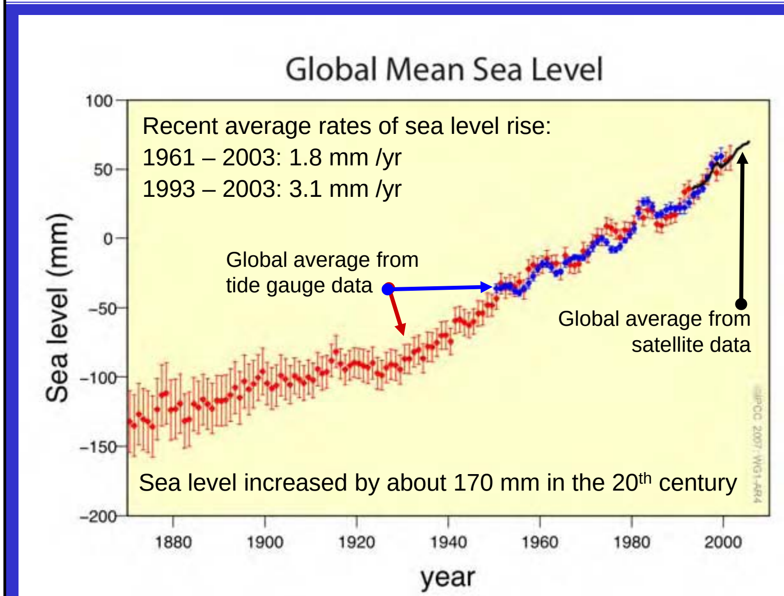
Evidence for rapid changes in ice flow in some regions.



Very likely that Greenland Ice Sheet shrunk from 1993 to 2003. Thickening in central regions more than offset by increased melting in coastal regions.

Antarctic ice sheet also estimated to have lost mass, but uncertainties are larger.

Tide gauge and satellite data on sea level



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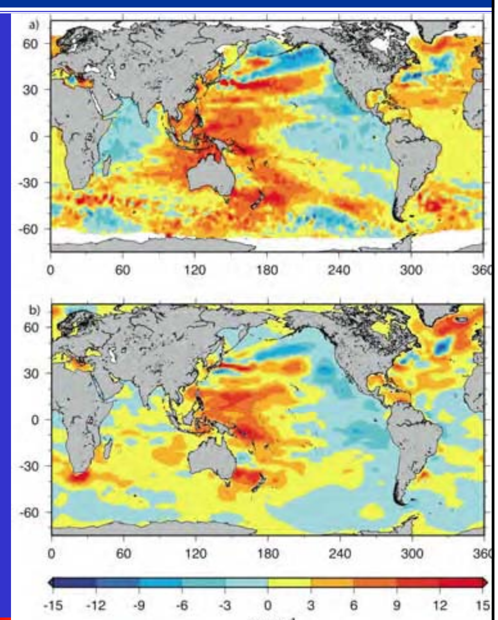
Sea level rise and ocean warming

Satellite measurements show patterns of decadal sea level rise (1993 – 2003)

Sea level rise estimated from expansion due to observed ocean warming to depth of 700 m over same period



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Consistent pattern of warming

- Surface temperatures increasing
- Tropospheric temperatures increasing
- Atmospheric water vapour content increasing
- Ocean heat content increasing …
- … now directly linked to sea level rise
- Greenland and Antarctic Ice Sheets losing mass
- Glaciers and snow cover declining
- Arctic sea ice extent decreasing
- Area of seasonally frozen ground decreasing
- Mid-latitude wind patterns/ storm tracks shifting poleward
- More intense and longer droughts
- More frequent heavy precipitation events over land
- Extreme temperatures increasing
- Tropical cyclone intensity increasing (in North Atlantic)

Unequivocal

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Drivers of Climate Change

Weather can't be predicted more than a week or so in advance – BUT – weather averages (climate) are constrained by basic physics and are more predictable

Natural cycles and internal variability in the climate system occur within limits

Much of past temperature change is explained by external forcing of the climate system

Climate models explain warm periods and ice ages in the past – although our understanding of past rapid changes remains limited.

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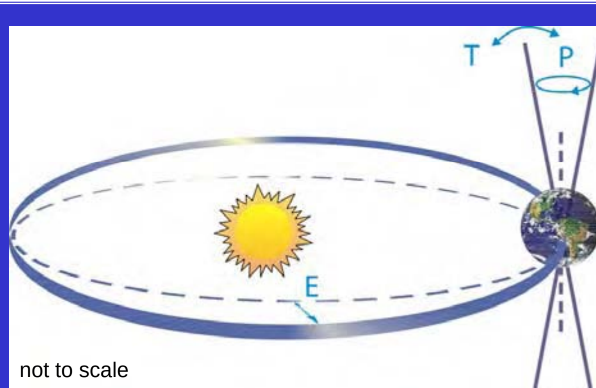
Over the last million years …

… the main climate change driver has been changes in the Earth's orbit around the Sun



T: Tilt – angle of polar axis to the plane of orbit. Cycle time 41,000 years

P: Precession – the orientation of polar axis cycles every 21,000 years

E: Eccentricity – difference from a circular orbit. A mix of various cycle times but roughly repeating every 100,000 years

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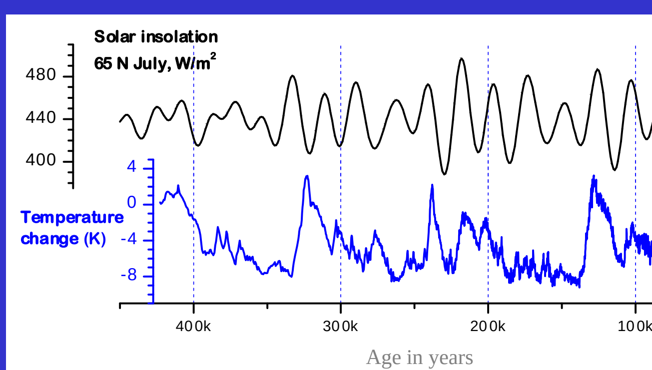
Triggering of Ice Ages



Source: Petit et al, Nature, 1999.
Berger &Loutre, QSR, 1991

Many studies suggest that the amount of summer sunshine on northern continents is crucial: if it drops below a critical value, snow from the past winter does not melt away in summer and an ice sheet starts to grow as more and more snow accumulates.

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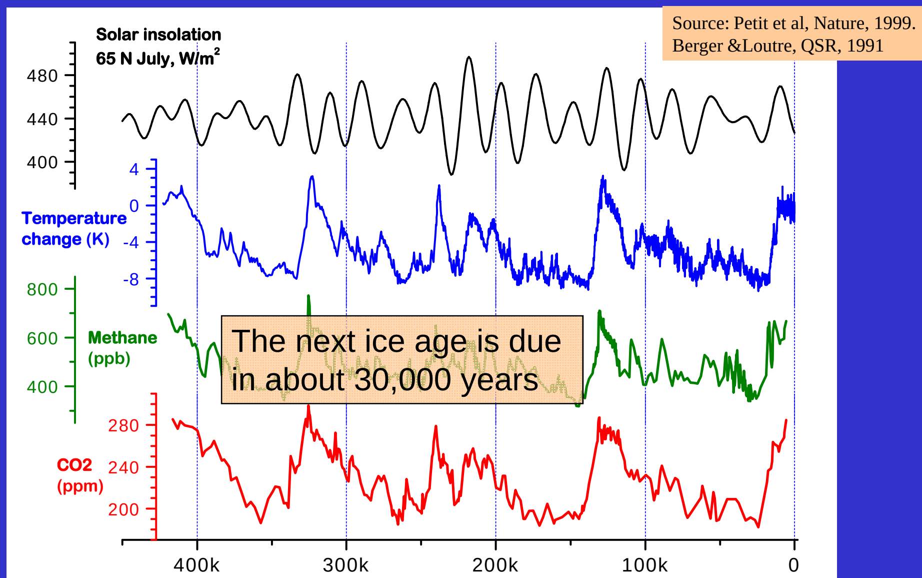
Greenhouse Gases Amplify Climate Changes



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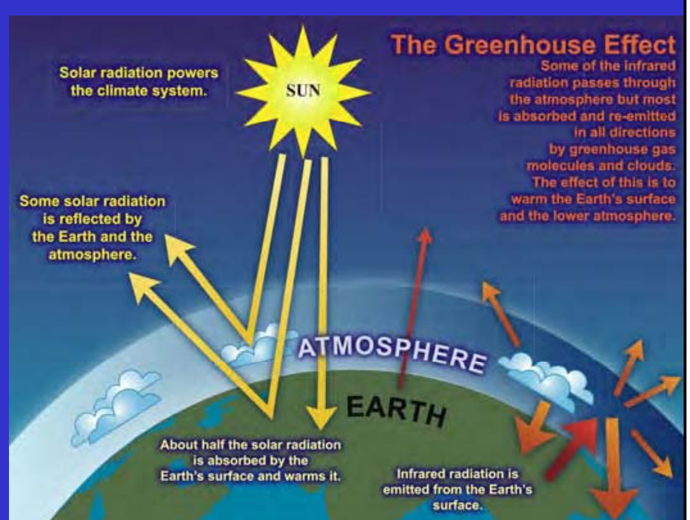
The greenhouse effect

The natural greenhouse effect increases surface temperatures by about 30ºC.

Increasing greenhouse gas concentrations tends to increase surface temperatures.



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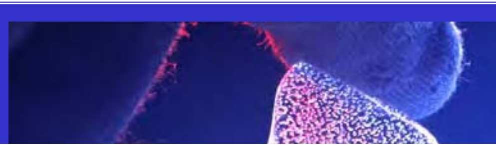
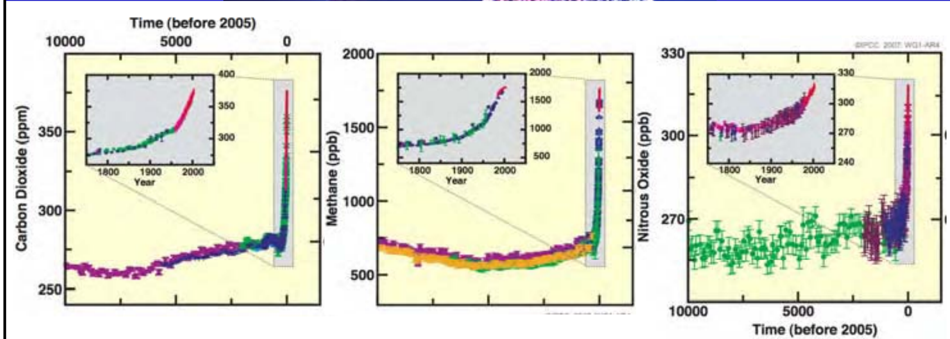
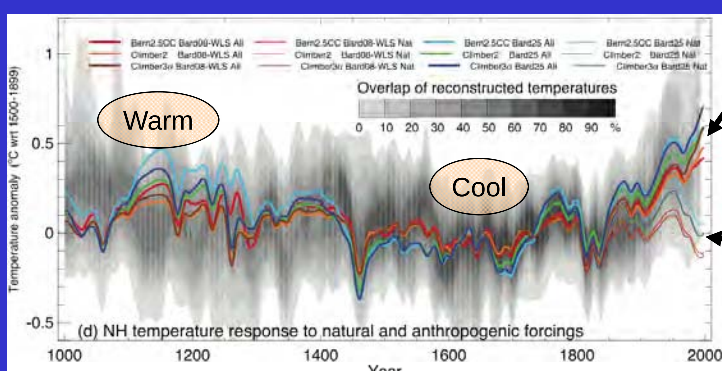
Industrial revolution and the atmosphere





The current concentrations of greenhouse gases and their rates of change are unprecedented.

Climate models track much of past temperature change



Thick lines include increasing greenhouse gases

Thin lines do not

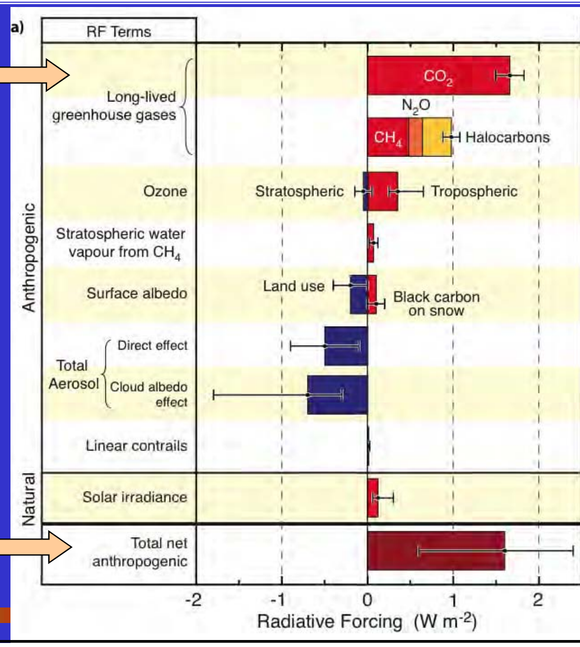
While there is uncertainty in reconstructed temperatures for the past, models using best estimates of solar change and volcanic eruptions reproduce warm and cool periods for which there is broad evidence.

Comparing different drivers of change now

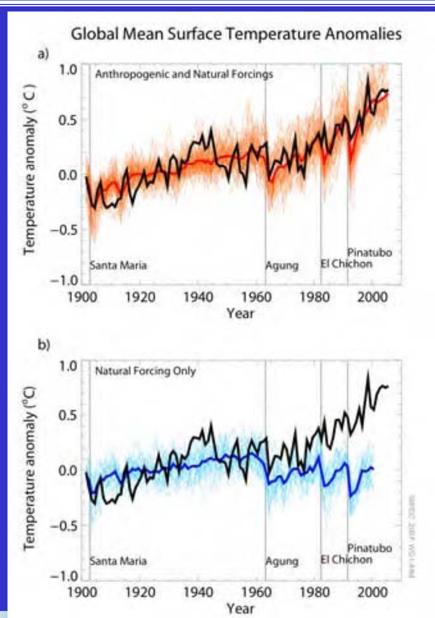
Increased by 20% over 1995 - 2005

Radiative forcing: measures the change in the Earth's energy balance due to different causes of climate change.

Equivalent to about 50 times world primary energy production.



Evidence of a human factor (1)



Climate models explain observed increase in global mean temperatures when greenhouse gases and aerosols included.

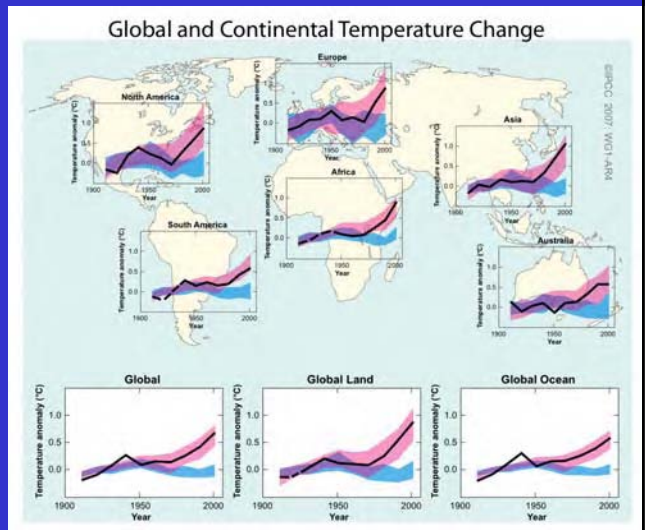
No model can explain observed global mean temperatures without including increased greenhouse gases.

Note – the transient coolings due to named volcanic eruptions

Anthropogenic climate change signals

Attribution –
is based on a large number of climate models and simulations with and without greenhouse gases and aerosols.

Observed patterns can only be explained **with** greenhouse gases and aerosols.



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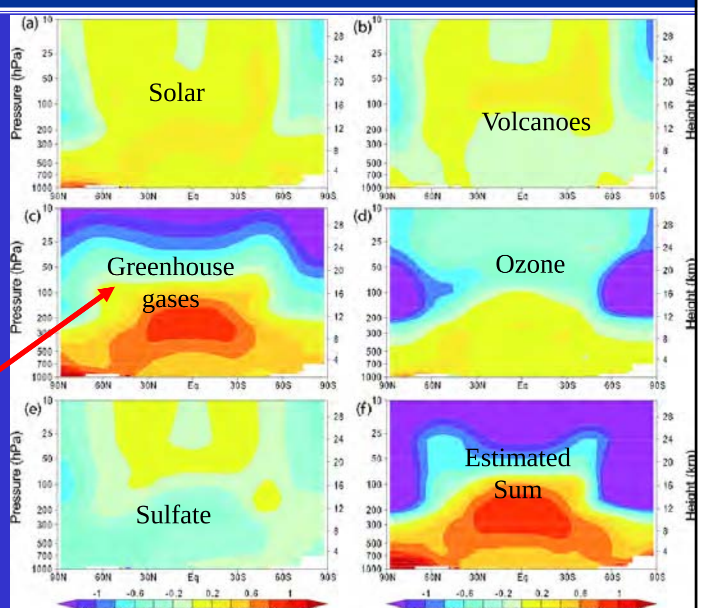
Evidence of a human factor (2)

Different forcing agents have different “fingerprints” of warming in the atmosphere

We can not explain the observed distribution of warming without this component.



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Attribution – the bottom line (2007)

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

**Very likely* means an assessed likelihood of being correct greater than 90%

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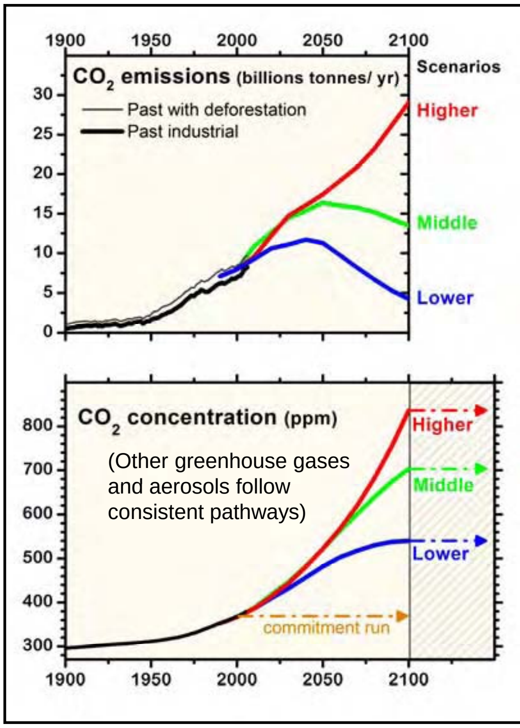

Future climate depends on future GHG emissions

The most detailed climate model projections assume no new climate policy

Consider lower, middle, and higher emission scenarios.

"Physics tests" compare effects of constant atmosphere from year 2000 vs 2100

Results come from
- 14 modelling groups
- 23 models

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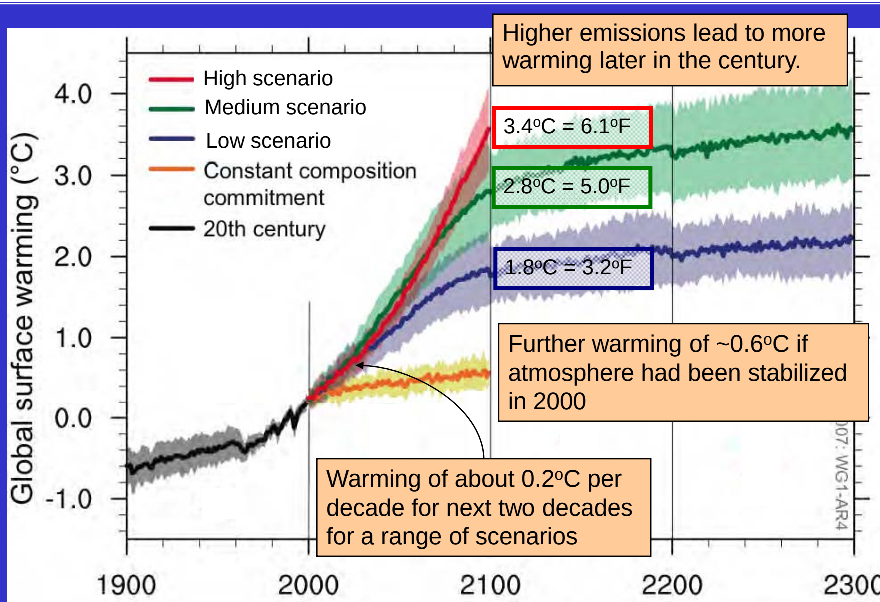
Projected global average warming



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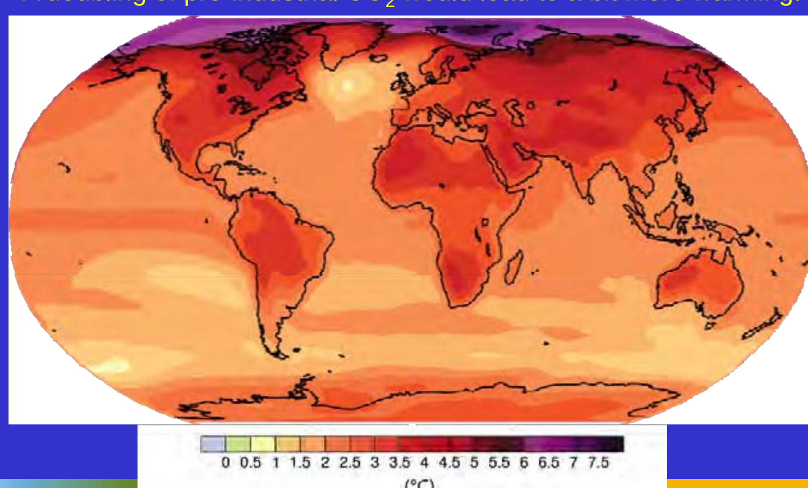
No one lives at the global average

Medium scenario over 2090-2099: Global mean warming 2.8ºC;
Much of land area warms by ~3.5ºC
Arctic warms by ~6ºC.
A doubling of pre-industrial CO_2 would lead to a bit more warming.



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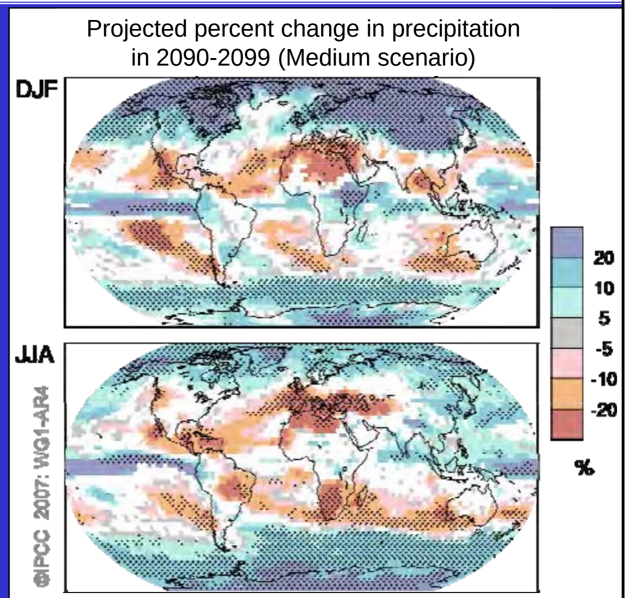
Projected precipitation change

Underlying physics of precipitation change is better understood.

Pattern is: increases in tropics and high latitudes; decreases in sub-tropics.

Consistent with observed trends.

Multi-model mean change shown where >66% of models agree in sign; >90% of models agree in stippled areas.



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Europe – July 2003

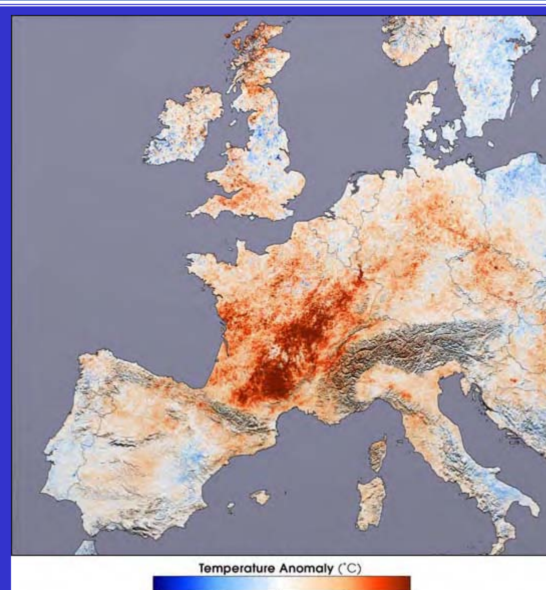
Wide area average temperature anomaly ~3^{o}C

Soil moisture feedback, i.e. less moisture means more warming

Tens of thousands of premature deaths

Loss of about 500 Mt carbon from soils

Unprecedented drop in crop yields



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Extremes will increase

- Projected increases in heavy precipitation and drought are linked to physical processes – principally increased absolute humidity and patterns of convergence and divergence in atmospheric transport.
- Precipitation intensity increases - even where total precipitation decreases.
- Risk of 2003 type heat wave in Europe is already doubled due to current level of greenhouse gases (single study).
- Extreme summer temperatures become at least 20 times more frequent by end of 21st century (average for 3 scenarios and for multiple models).

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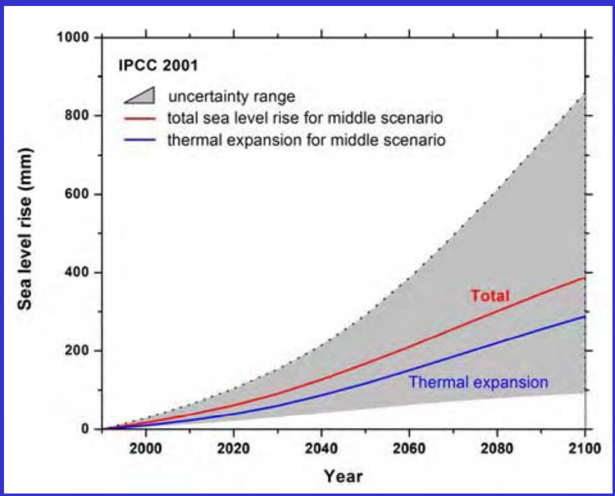
IPCC assessment of sea level rise (2001)



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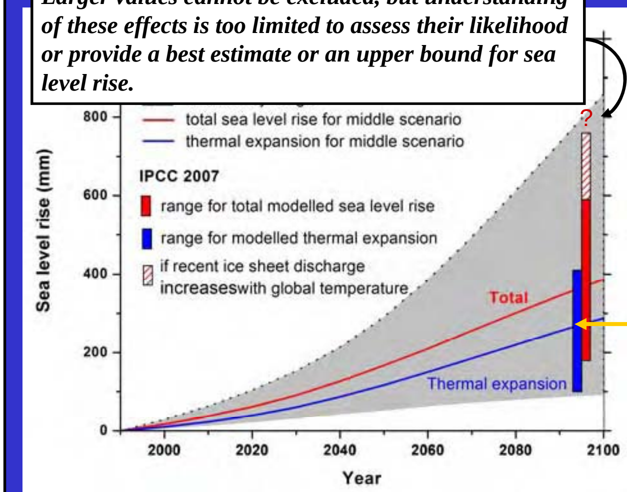
IPCC assessment of sea level rise (2007)

Larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise.



The last time polar regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 m of sea level rise.

For a constant atmosphere after 2100, thermal expansion continues for many centuries.

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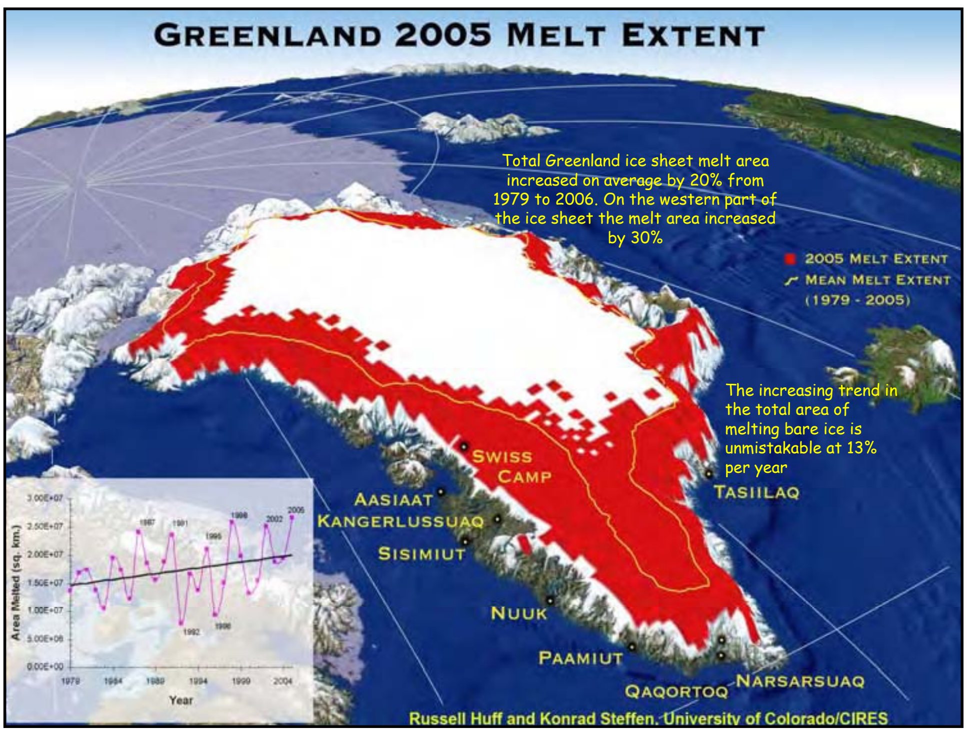

Sea level rise – limits to knowledge

In the last 5 years seeing new ice sheet phenomena that may significantly affect ice discharge into the ocean.

As yet corresponding processes are not in any ice sheet models.

Surface melt on Greenland ice sheet descending into moulin, a vertical shaft carrying the water to base of ice sheet. Photo credit: Roger Braithwaite

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Summary

Evidence for warming of the climate system is now unequivocal.

In the 21st century, Earth's climate will be different from anything experienced during human civilization.

This climate change is different from past (natural) changes because it is happening faster, because it will affect us, and because we are doing it.

Reducing carbon emissions to the atmosphere can limit the magnitude of change.

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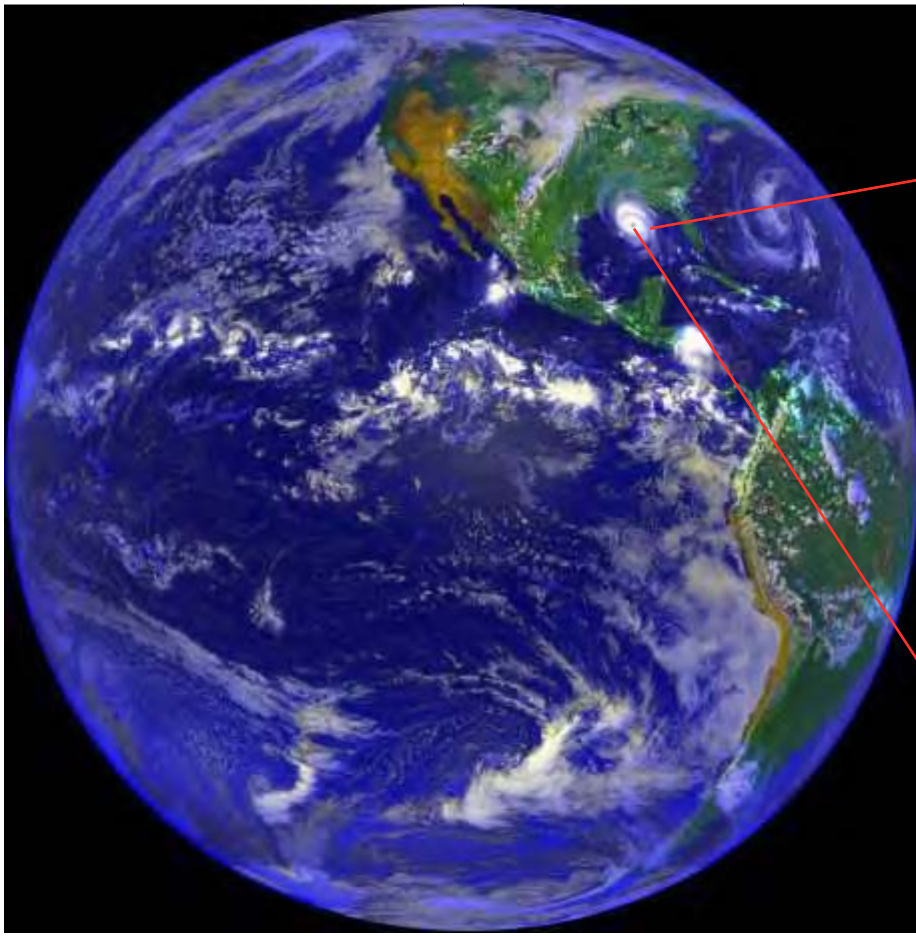
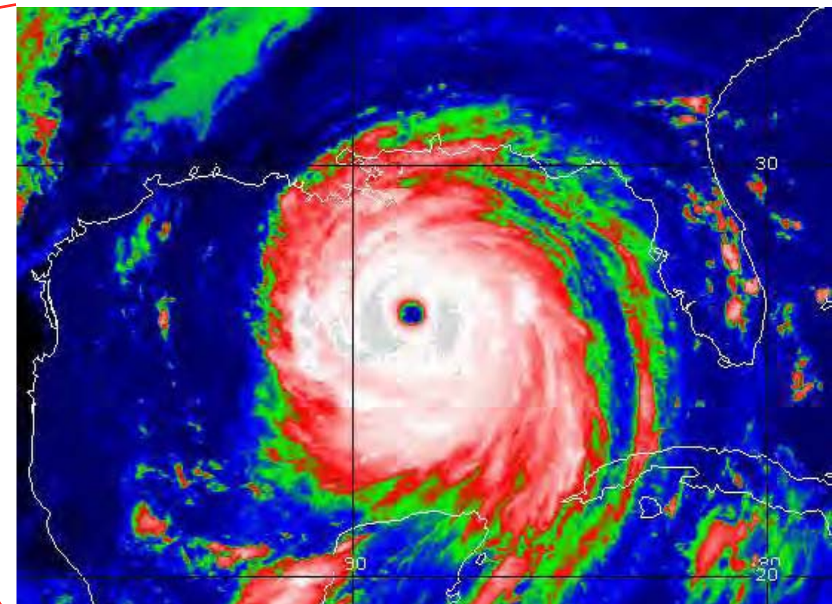
Judy Curry

Dr. Judith Curry

Dr. Judith Curry is Professor and Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. Dr. Curry received a Ph.D. in atmospheric science from the University of Chicago in 1982. Prior to joining the faculty at Georgia Tech, she has held faculty positions at the University of Colorado, Penn State University and Purdue University. Dr. Curry's research interests span a variety of topics in climate; current interests include air/sea interactions, climate feedback processes associated with clouds and sea ice, and applications of satellite data to interpreting recent variations in the climate data record. Most recently she has been investigating the variability of hurricanes on global scales, in the North Atlantic, and landfalling hurricanes striking the U.S. and Latin America. Dr. Curry has recently served on the National Academies Climate Research Committee and the Space Studies Board, and the NOAA Climate Working Group. Dr. Curry is coauthor of the book *Thermodynamics of Atmospheres and Oceans* and is editor for the *Encyclopedia of Atmospheric Sciences*. She has published over 140 refereed journal articles. Dr. Curry is a Fellow of the American Meteorological Society, the American Association for the Advancement of Science, and the American Geophysical Union. In 1992, she received the Henry Houghton Award from the American Meteorological Society.

Global Climate Change and Hurricanes: the Science, the Controversy & the Risk



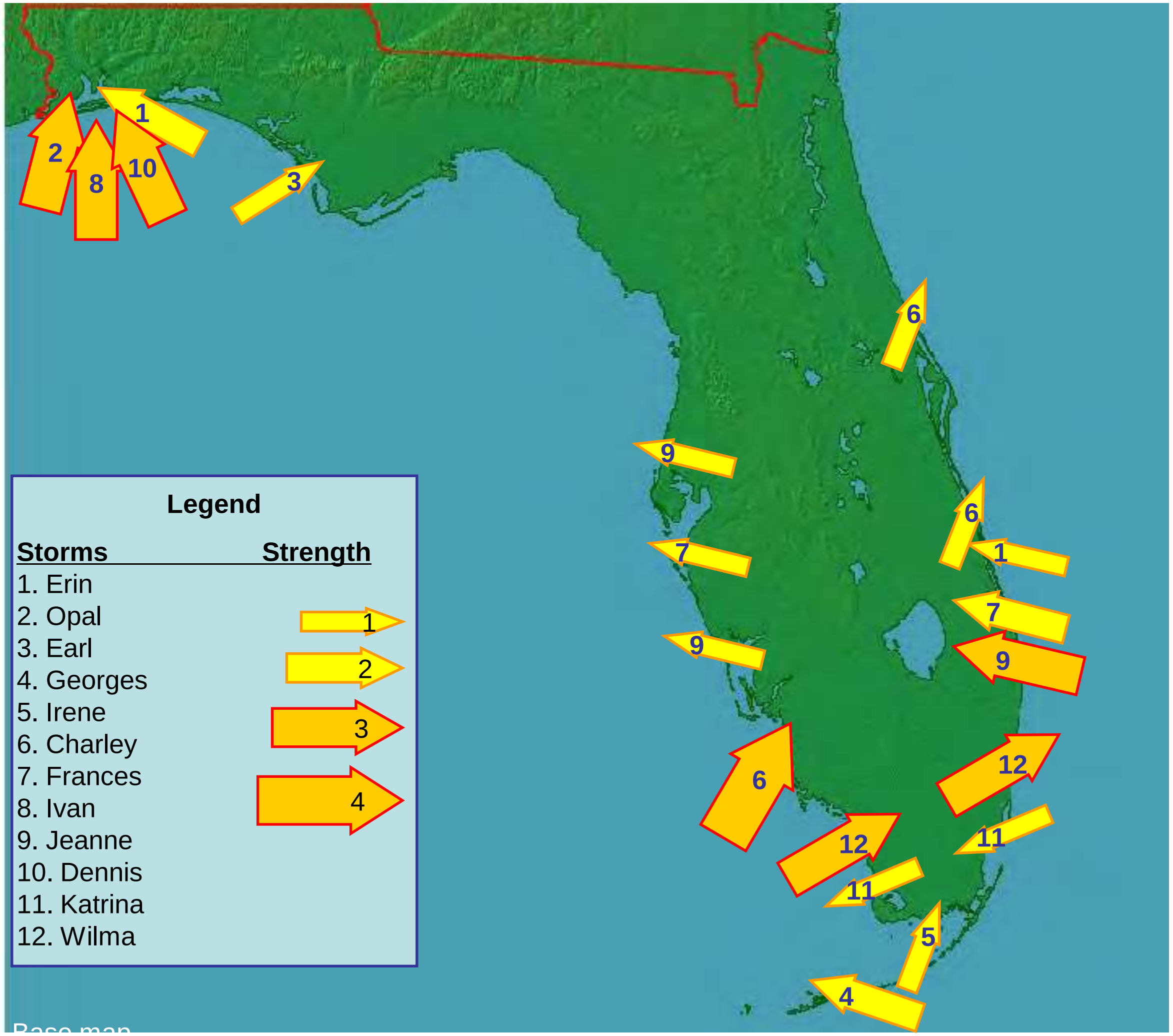


Judith A. Curry

Symposium on Science & Econ of Climate Change
November 6, 2007

Georgia Tech

1995-2005 Florida Landfalling Hurricanes



2004-2005 FL statistics:

- $50B damage
- >100 deaths
- 1 in 5 FL homes damaged in 2004

48% of U.S. landfalling hurricanes have struck FL during this period

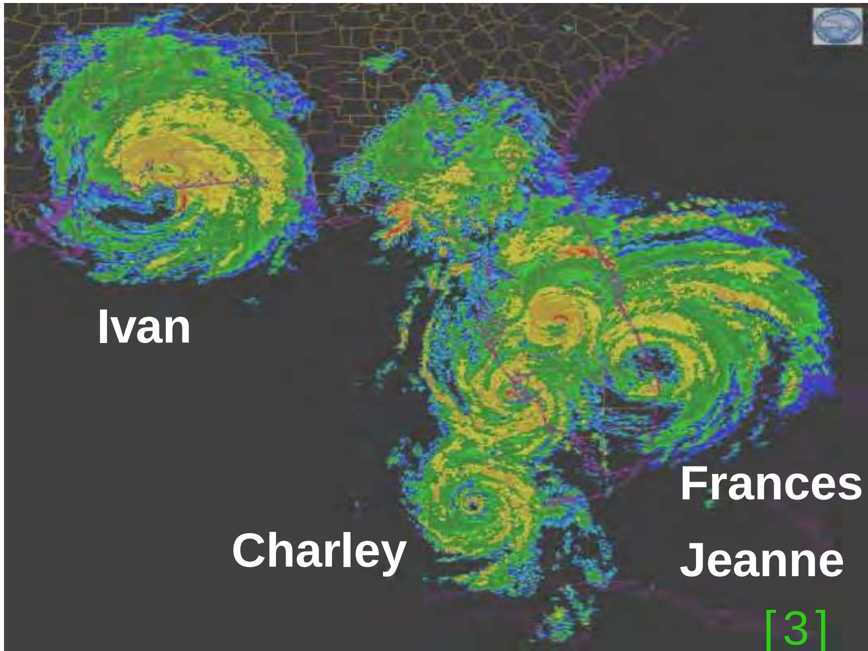
[2]

Are the 2004/2005 hurricane seasons a harbinger of Florida's future?

To assess the Florida's risk from landfalling hurricanes in the coming decades, we must understand:

- Impact of global warming on hurricane activity
- Natural variability in the Atlantic Ocean
- Nature of local risks

Figure by J. Davis



Wall Street Journal February 2, 2006

Cold Front

Debate Shatters Civility of Weather Science

Hurricanes Worsened by Global Warming?

Spats are so tempestuous, sides are barely talking

THE MEDIA

vs

SCIENTIFIC PROCESS

Integration of

- data (uncertain)
- models (imperfect)
- theory (incomplete)

towards refining our understanding and increasing our ability to make predictions

WMO

IPCC AR4: Hurricanes Detection of Change

UNEP

- There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures (SST)
- There are suggestions of increased intense tropical cyclone activity in other regions where concerns over data quality are greater
- Multi-decadal variability and the quality of the tropical cyclone records prior to 1970 complicate the detection of long-term trends in tropical cyclone activity
- No clear trend in the annual numbers of tropical cyclones

[5]

WMO

IPCC AR4: Hurricanes Projections of Future Change

UNEP

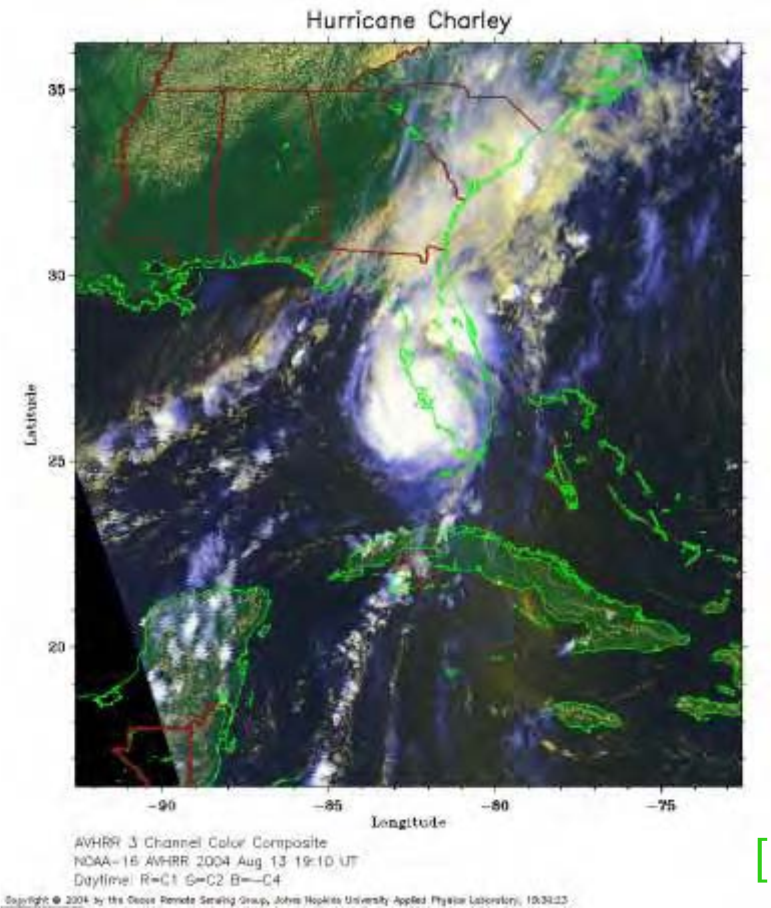
- It is likely [>66%] that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs
- The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period
- There is less confidence in projections of a global decrease in numbers of tropical cyclones.

Future Risk from Landfalling Hurricanes

Risk is the the product of consequences and likelihood: what can happen and the odds of it happening

We can put bounds on the risk given the scientific uncertainty

Prudent risk management should consider the range of possibilities, including the plausible worst case scenario



[7]

What does the future hold for North Atlantic hurricanes?

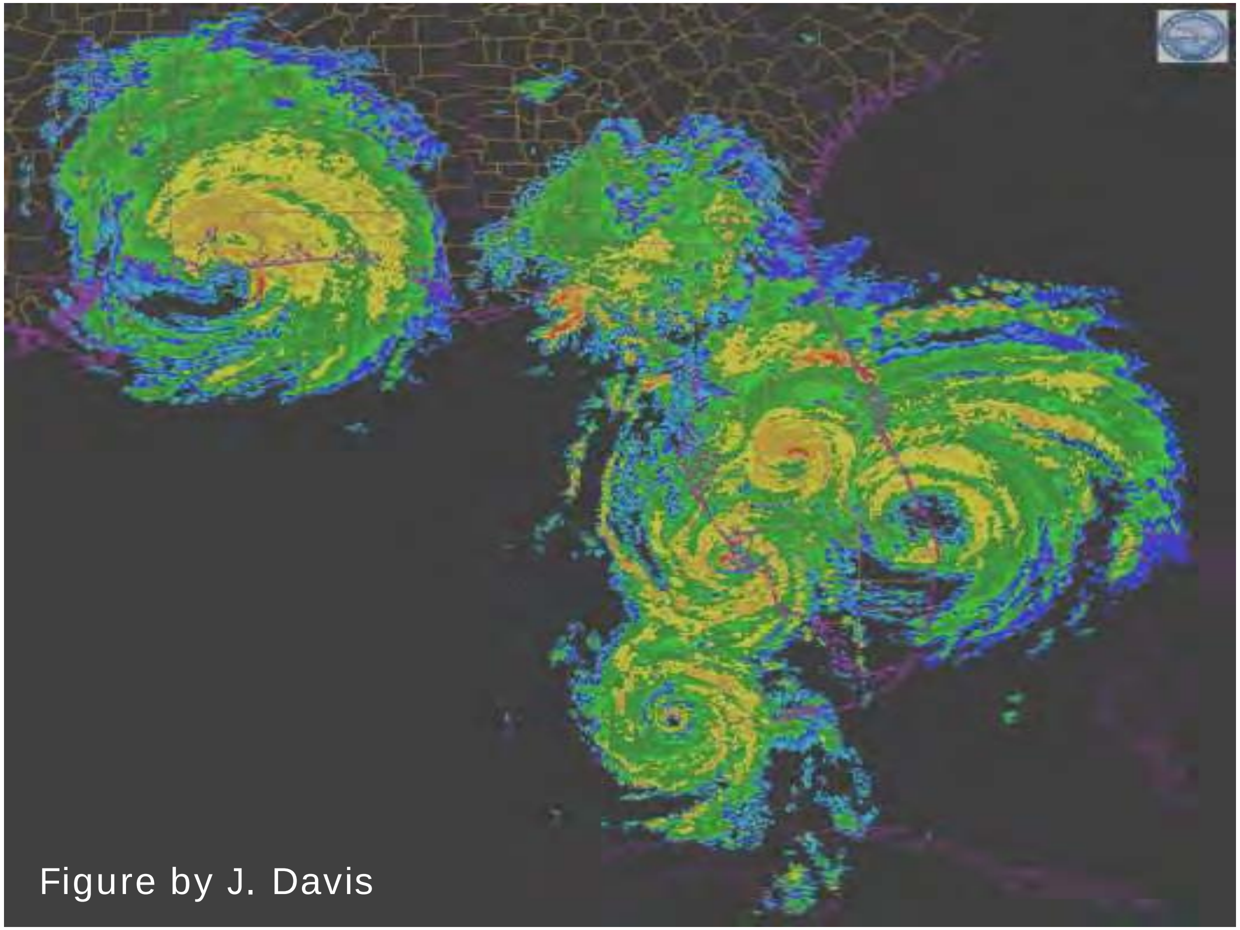


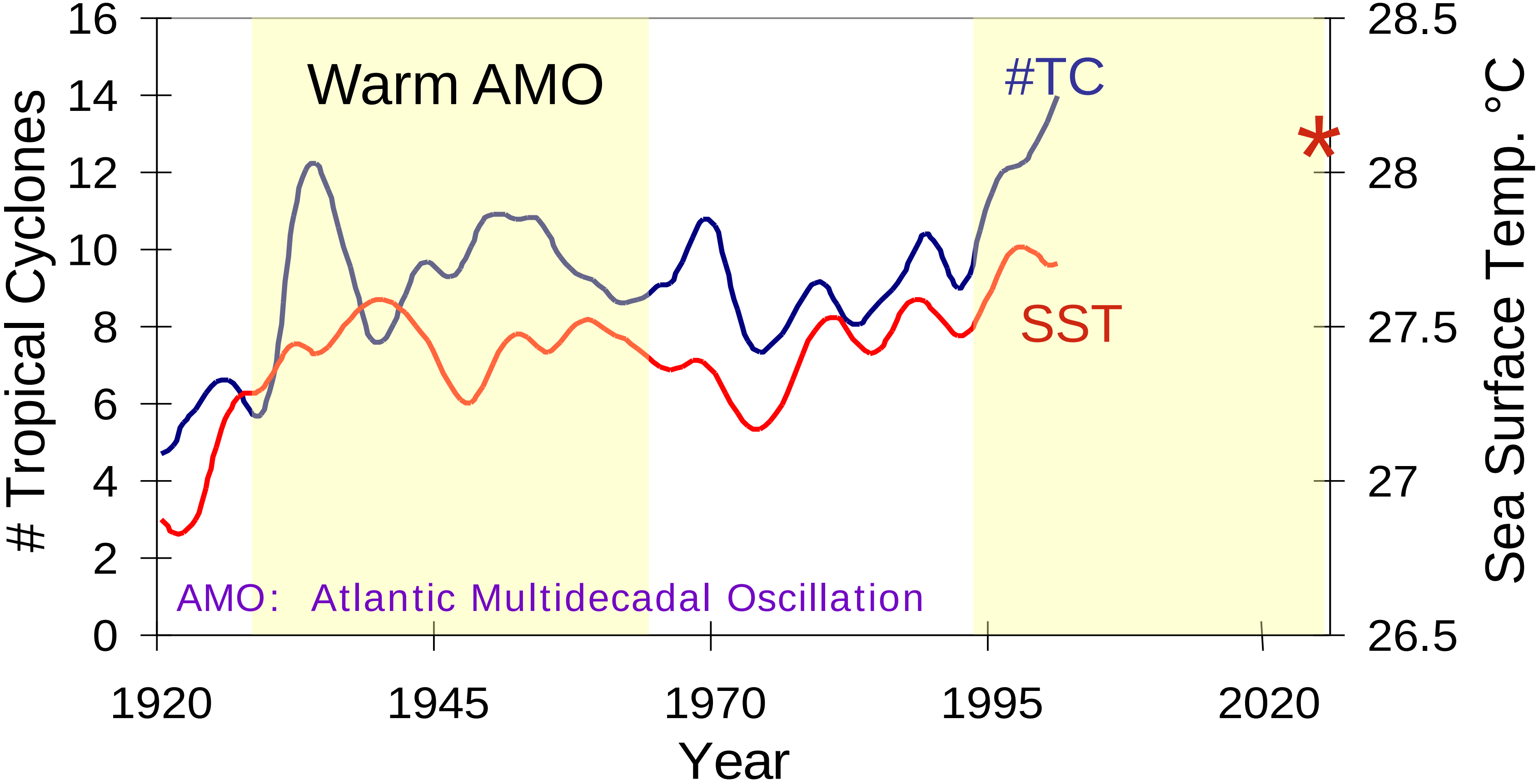
Figure by J. Davis

Combined impacts of greenhouse warming and natural variability

[8]

N. Atlantic Tropical Cyclones & SST

Decadal scale variations: 9 yr Hamming filter



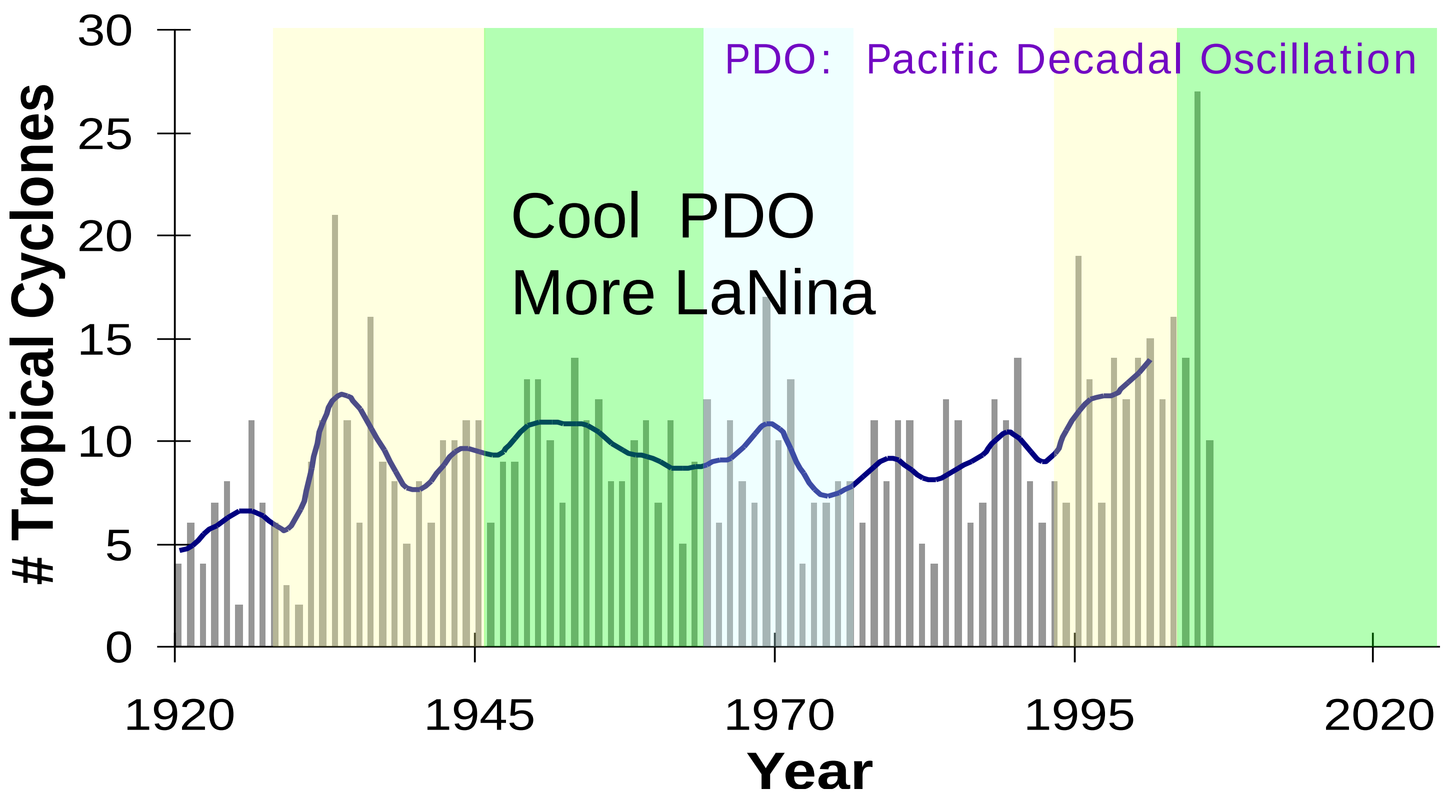
Current warm phase of AMO expected to extend to 2025+

1^{o}F warming by 2025 expected from global warming

[9]

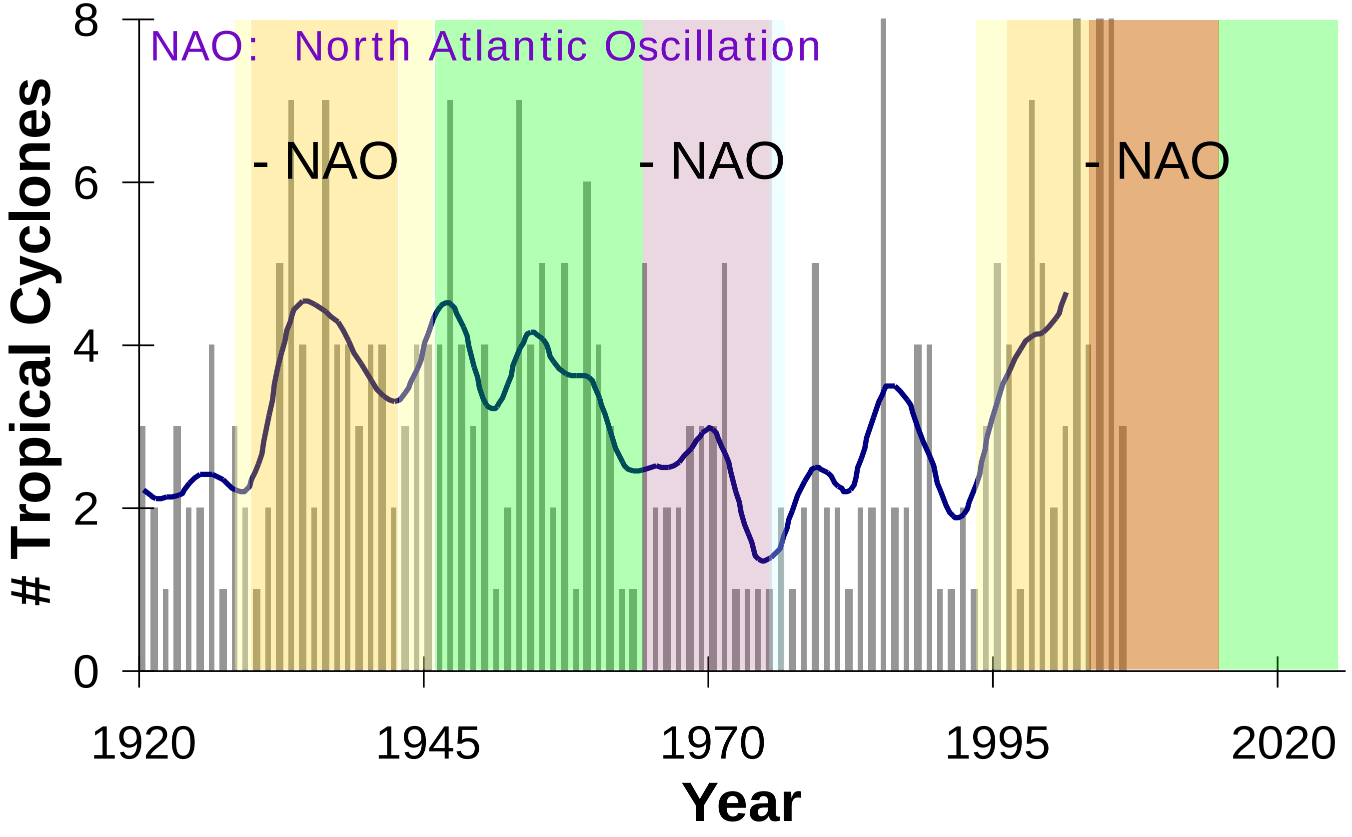
N. Atlantic Tropical Cyclones:

Decadal modes of variability: AMO & PDO



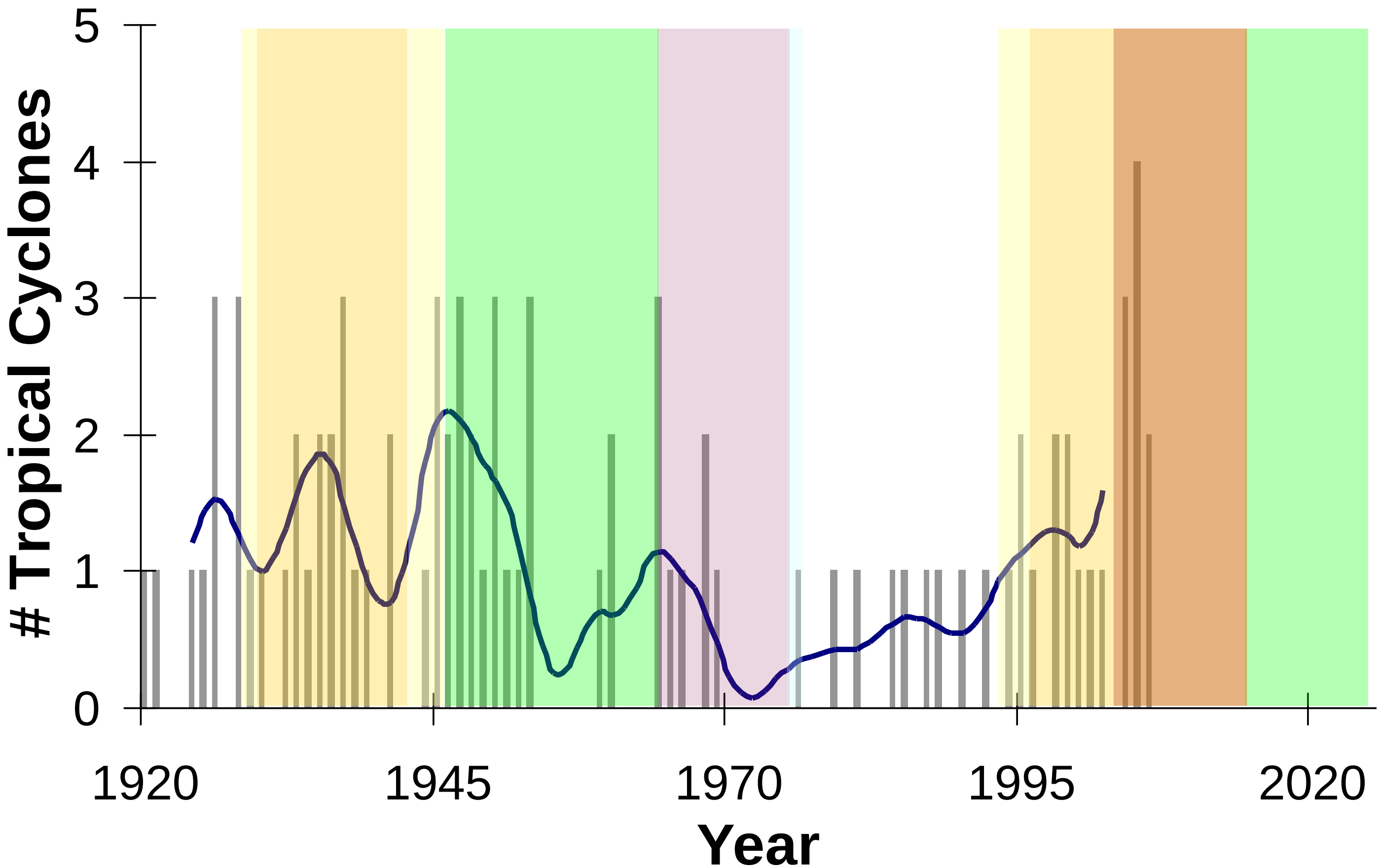
Recently transitioned to cool PDO

U.S. Landfalling Tropical Cyclones



Landfall probability increases with neg. NAO, especially with warm AMO, cool PDO

FL Peninsula Landfalling TCs



Elevated while neg. NAO, warm AMO, cool PDO

Is our understanding sufficient to forecast NATL hurricane activity in 2020-2025?

Warm phase of AMO, cool phase of PDO:

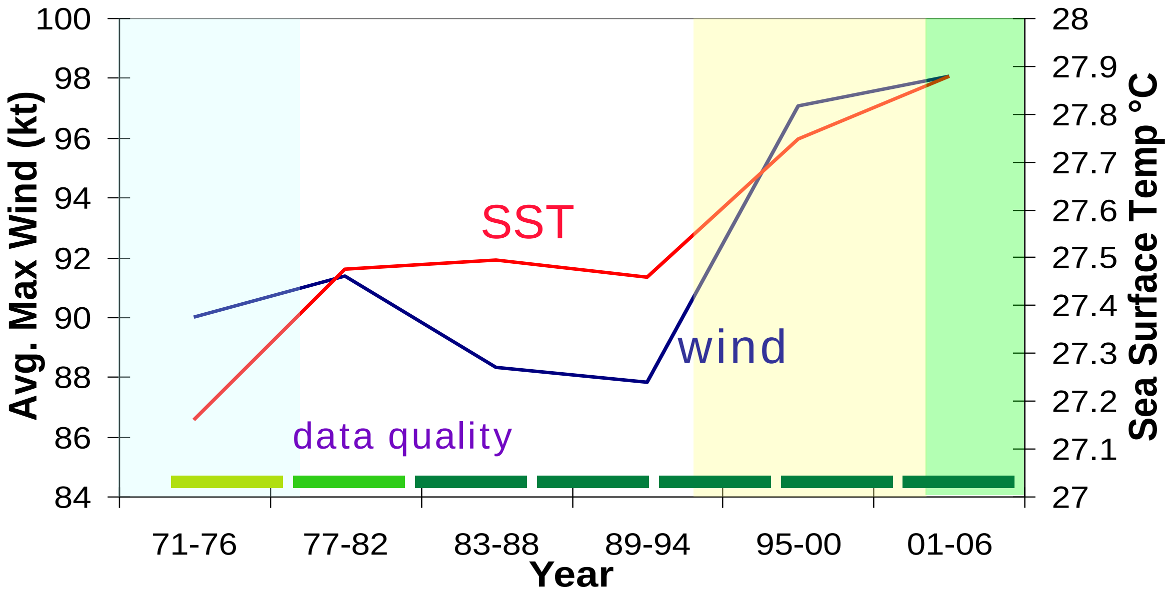
- Elevated hurricane activity
- Predominant landfalls Gulf coast & Florida

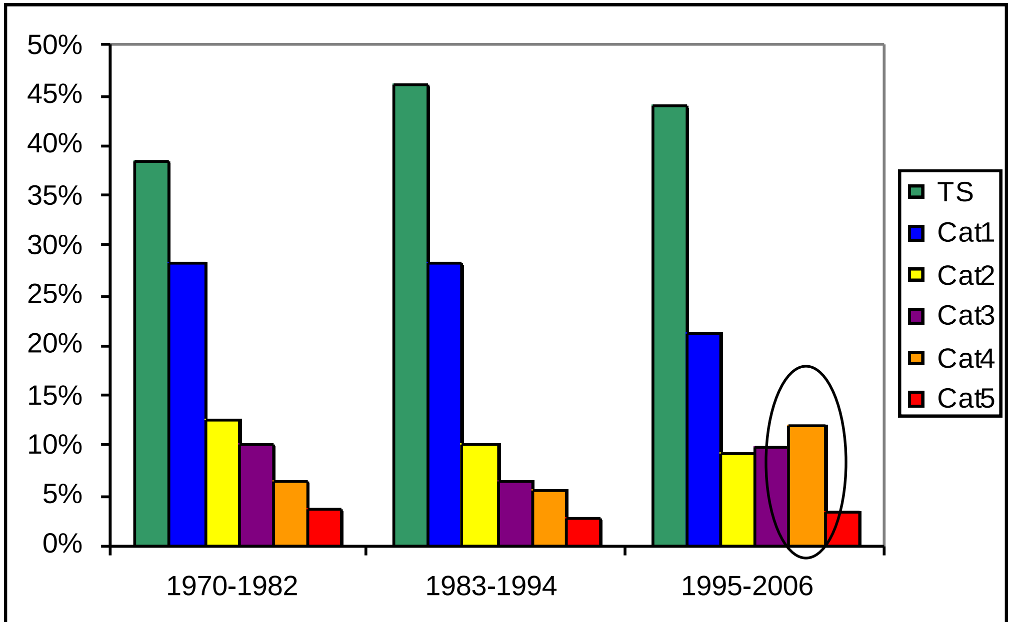
Expected 1^{o}F sea surface temperature increase from global warming

Integrate
- data analysis
- model simulations
- theory

[13]

North Atlantic Hurricane Intensity





Little confidence in data before 1970

1°F SST increase since 1970

7% avg intensity increase since 1970

Shift in intensity distribution towards more cat 4

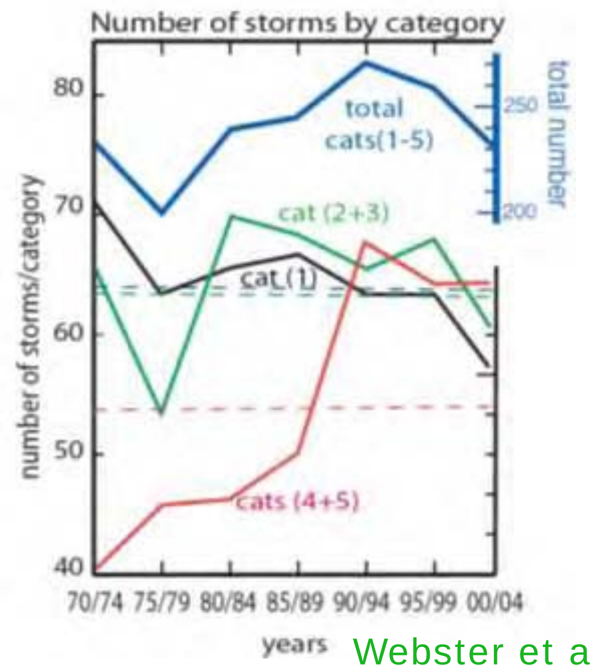
Global warming or natural variability?

[14]

Global Hurricane Intensity Increase

scaled for 1ºF SST increase

Webster et al. obs:	+6.0%
Climate models:	+2.0%
Potential intensity theory:	
Emanuel	+2.7%
Holland	+5.3%



Webster et al. 2005

.

Observations, theory, & models agree intensity should increase; disagree on the magnitude.

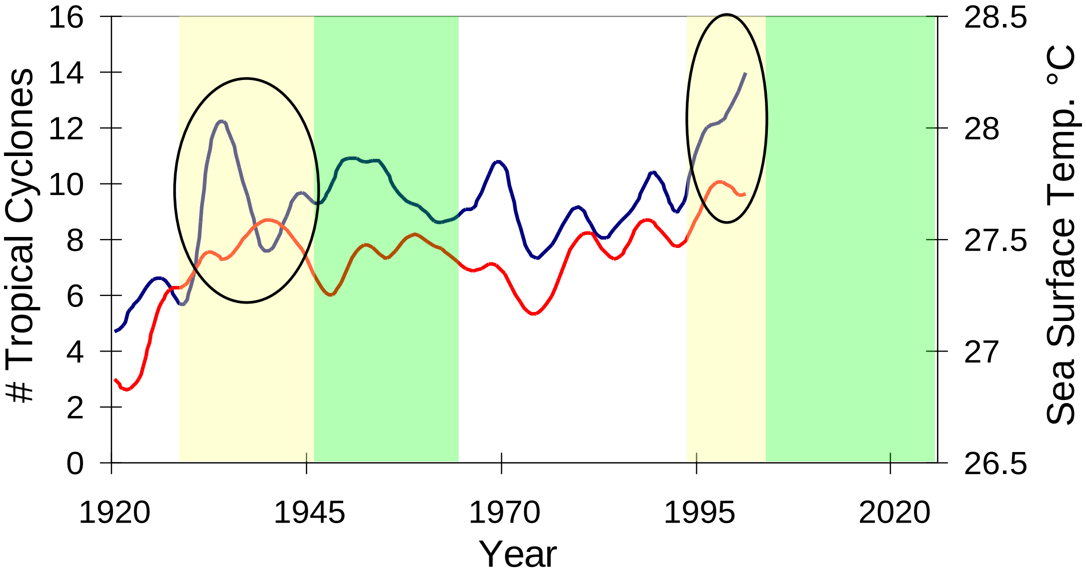
Likely avg intensity increase:
2-5%

Avg damage increase:
15-40%

Intensity distribution shift:
more cat 4-5

Change in # of tropical cyclones

scaled for 1°F SST increase



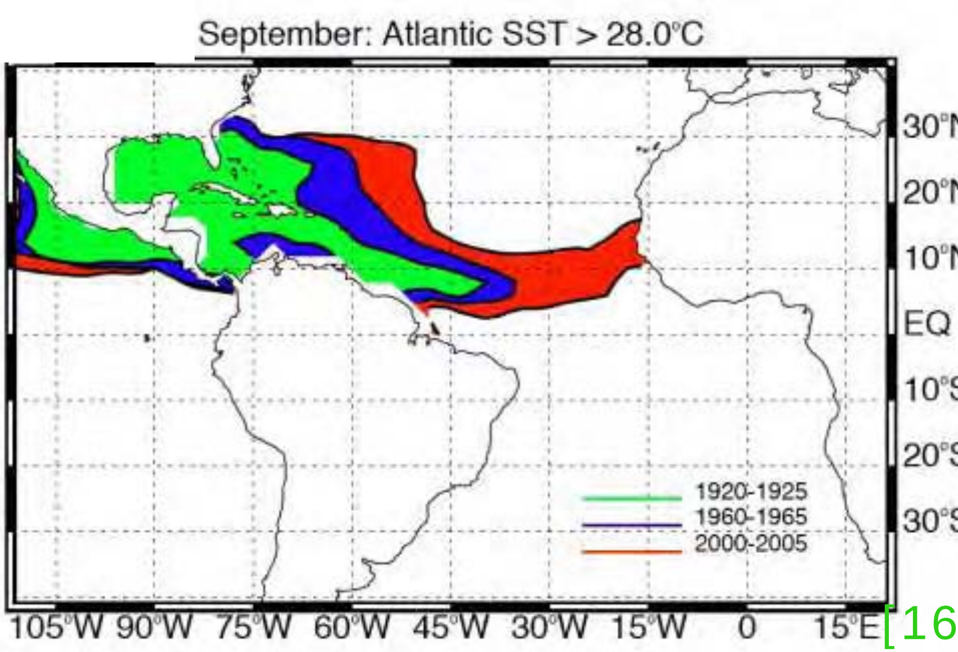
Data indicates +6

Undercounting in early period of 1-2 TCs

Most likely increase: +3 to +4

Expanding NATL warm pool

- Extends genesis region, season length
- Reduces wind shear



[16]

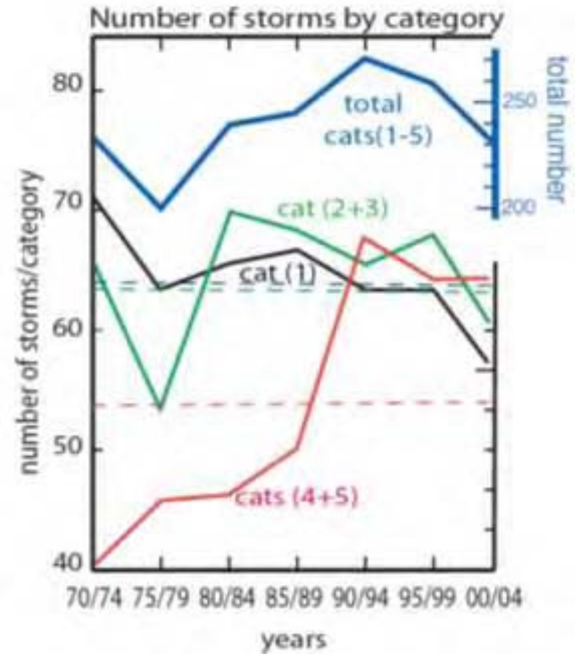
Global Hurricane

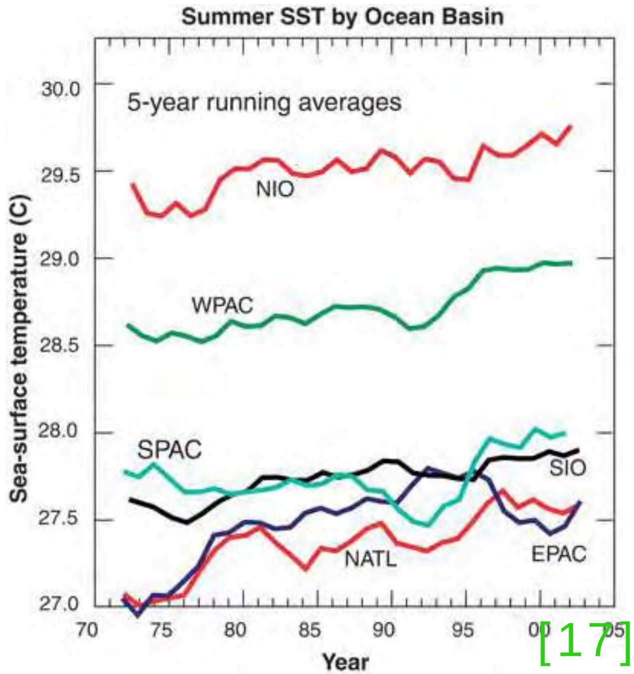
Webster et al. 2005

No observed global increase in #

Climate models suggest
- decrease in global hurricane #
- 0 to small increase in NATL #

Why an increase in NATL #?
- relatively cool SSTs, just above the genesis threshold of 26.5ºC;
- NATL # not yet "saturated"





Projected NATL hurricane activity ca. 2020-2025

Hurricane intensity increase:
  2-5%; 15-40% in damages

increase:
  0-4 tropical cyclones/year

Landfall distribution:
  increased landfalls Gulf coast, FL

Projected N. Atlantic hurricane activity ca. 2100 (relative to 2025) +5^{o}F warming

Hurricane intensity increase: 10%?

Hurricane frequency increase: 0?

Landfall distribution: ?

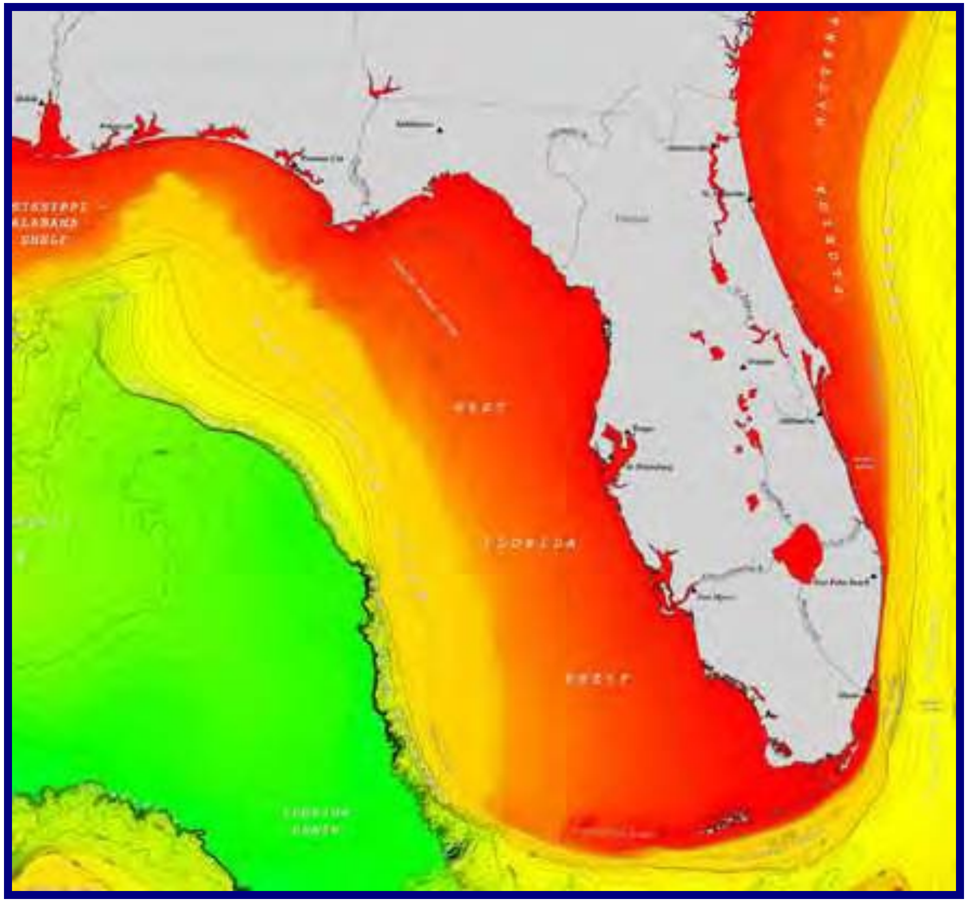
What does the increase in North Atlantic hurricane activity mean for Florida?

http://www.ncdc.noaa.gov/img/climate/research/2004/sep/frances-landfall-pg.gif

Susceptibility to storm surges

increases with increased hurricane intensity

West coast (Tampa), South Florida, and JAX/Daytona areas

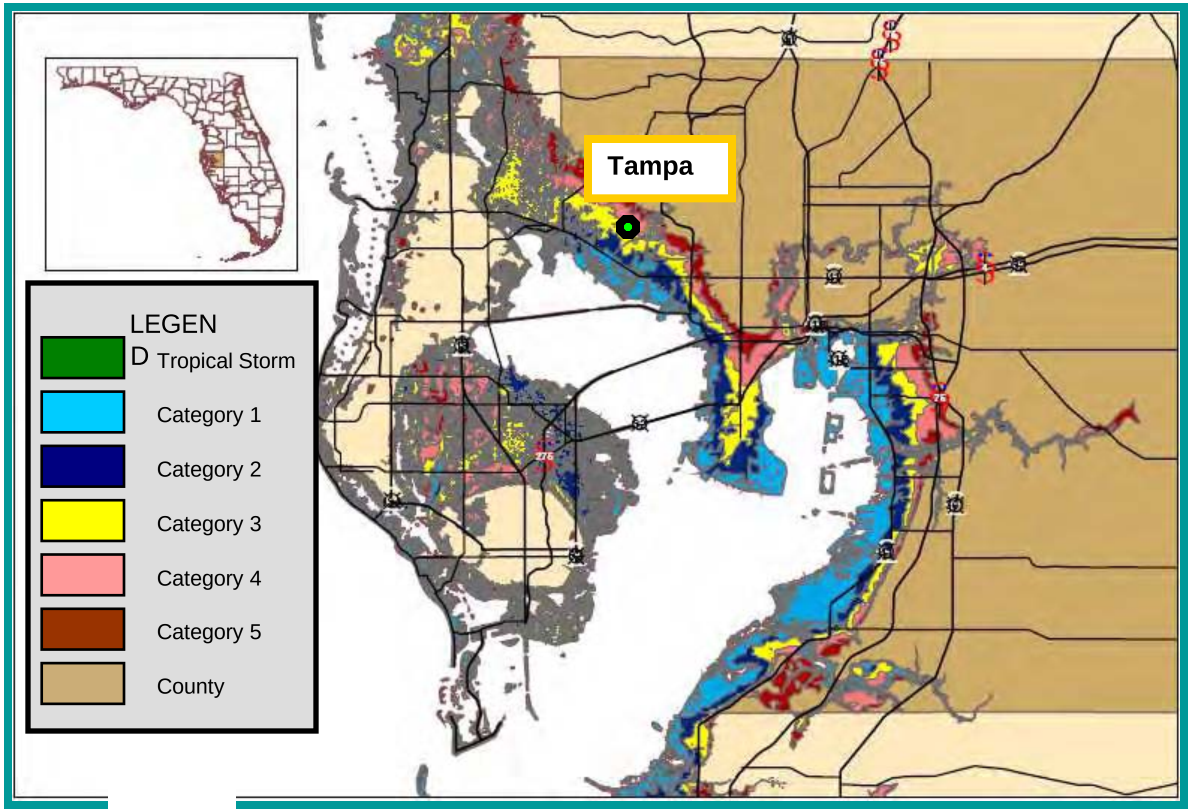


shallow continental shelf

http://www.ngdc.noaa.gov/mgg/fliers/00mgg02.html

low elevation

Tampa Vulnerability



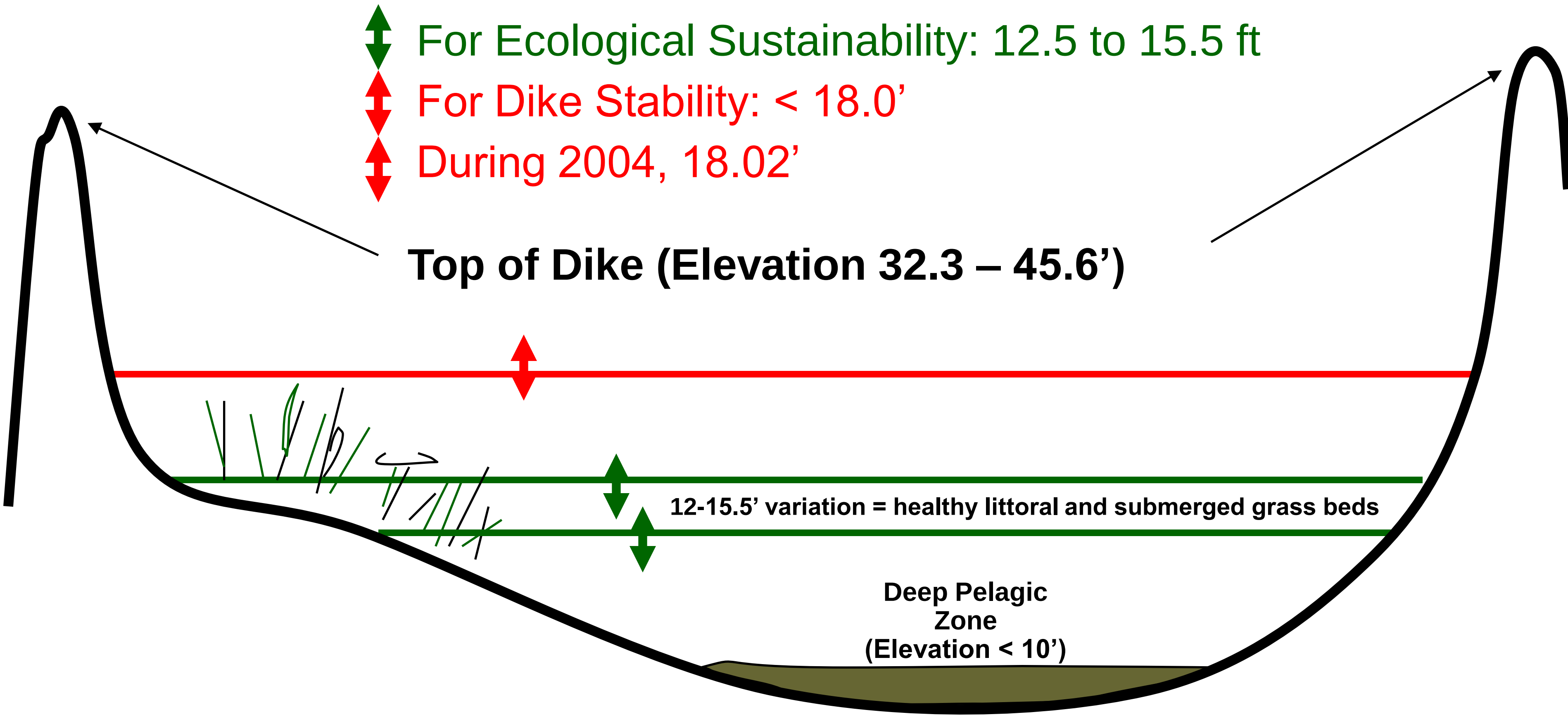
www.floridadisaster.org/PublicMapping/index.htm

Potential 25 ft storm surge in cat 4 storm

No major hurricane since 1921

The Tampa Bay area, because of its large population and geography that can trap the storm surge and push it even higher, is considered the second most dangerous area in the country for storm surge behind New Orleans. [21]

Lake Okeechobee



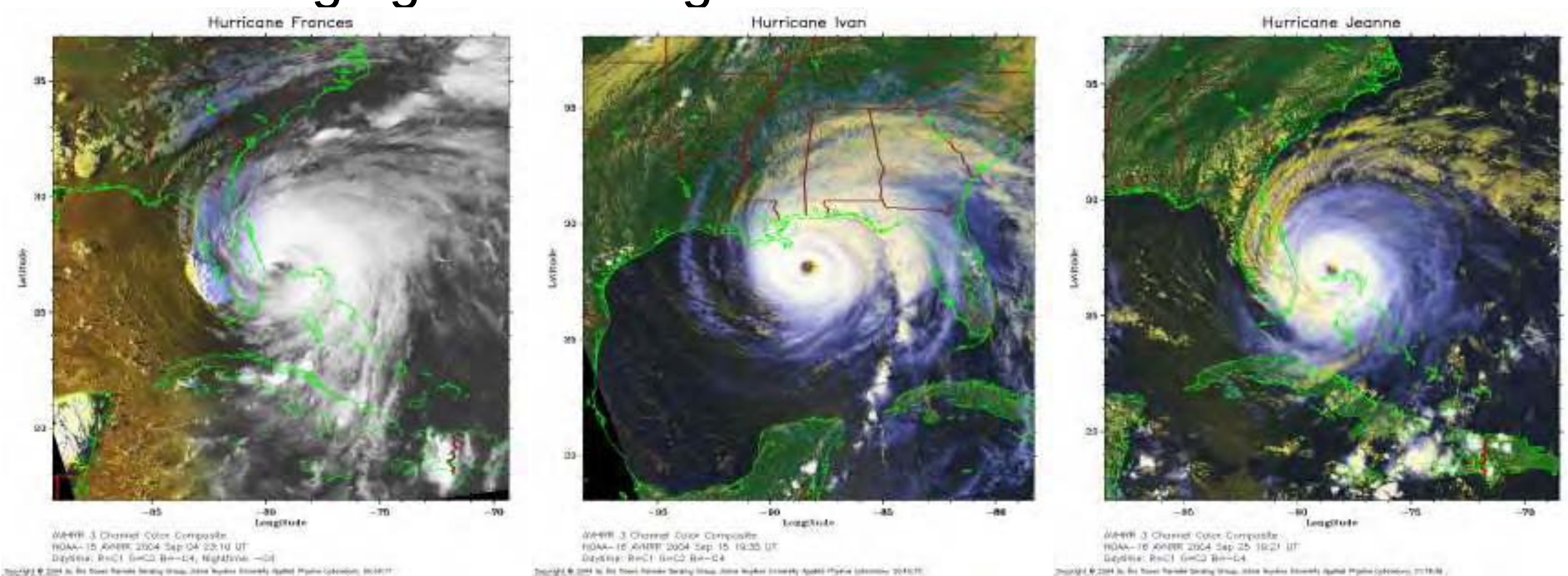
Rainfall from 2004 hurricanes brought 6′ of water into lake

Warm phase of AMO brings more rainfall to south, central FL

Global warming: more intense hurricanes, more rainfall [22]

Summary: Risks to Florida

- ✓Increased number and intensity of FL landfalls
- ✓Tampa is highly vulnerable to a storm surge (25 ft anticipated for a category 4 storm)
- ✓Heavier rainfall and higher winds puts Lake Okeechobee at risk for a lake surge that would breach the dikes
- ✓Rising sea level is increasing the vulnerability of South Florida to a damaging storm surge



[23]

The Challenges

1. As the climate warms, it is likely that global hurricane intensity will increase and that the number of North Atlantic hurricanes will increase, although the magnitude of the increase is uncertain. FL landfalls are expected to remain high

2. The increasing hurricane activity coupled with increasing coastal vulnerabilities indicates an urgent need for adaptation.

3. Reducing carbon dioxide emissions will help avoid the longer term risks associated with sea level rise and storm surge expected from increasingly intense hurricanes.

There is no “silver bullet” solution:
“silver buckshot” approach needed

Brian Soden

Dr. Brian J. Soden

Dr. Brian J. Soden is an Associate Professor of Meteorology and Physical Oceanography at the University of Miami's Rosenstiel School for Marine and Atmospheric Science. Dr. Soden specializes in the use of satellite observations to test and improve computer model simulations of climate change. During the past 15 years he has published over 60 peer-reviewed papers on a variety of topics, but most often related to the response of the atmospheric hydrological cycle to global warming. He received his B.S. degree from the University of Miami, and M.S. and Ph.D. degrees from the University of Chicago. Before returning to the University of Miami, Dr. Soden was a Visiting Scientist at Princeton University, and a Physical Scientist with NOAA's Geophysical Fluid Dynamics Laboratory in Princeton, NJ.

Dr. Soden also served as a Lead Author of the chapter on atmospheric observations for the 2007 IPCC Report. His awards include the American Meteorological Society's Henry G. Houghton Award, the National Space Club’s David S. Johnson Award, and several outstanding research paper awards from NOAA and NASA.

What Can We Say About Regional Climate Change?

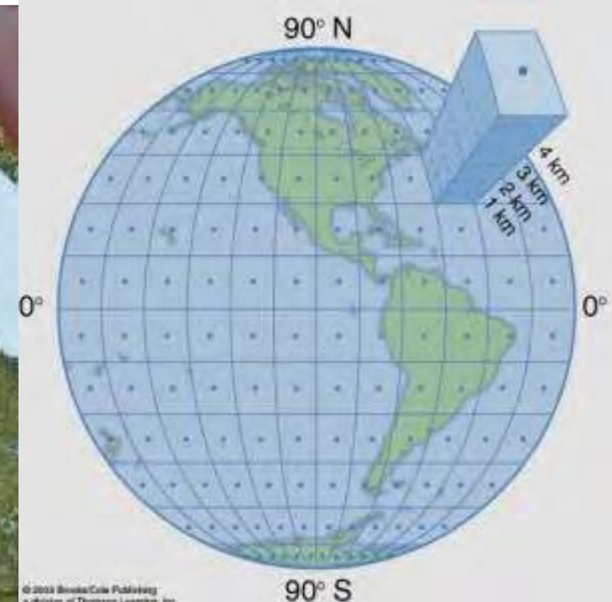
Brian Soden
Rosenstiel School for Marine and Atmospheric Science
University of Miami

Topics:

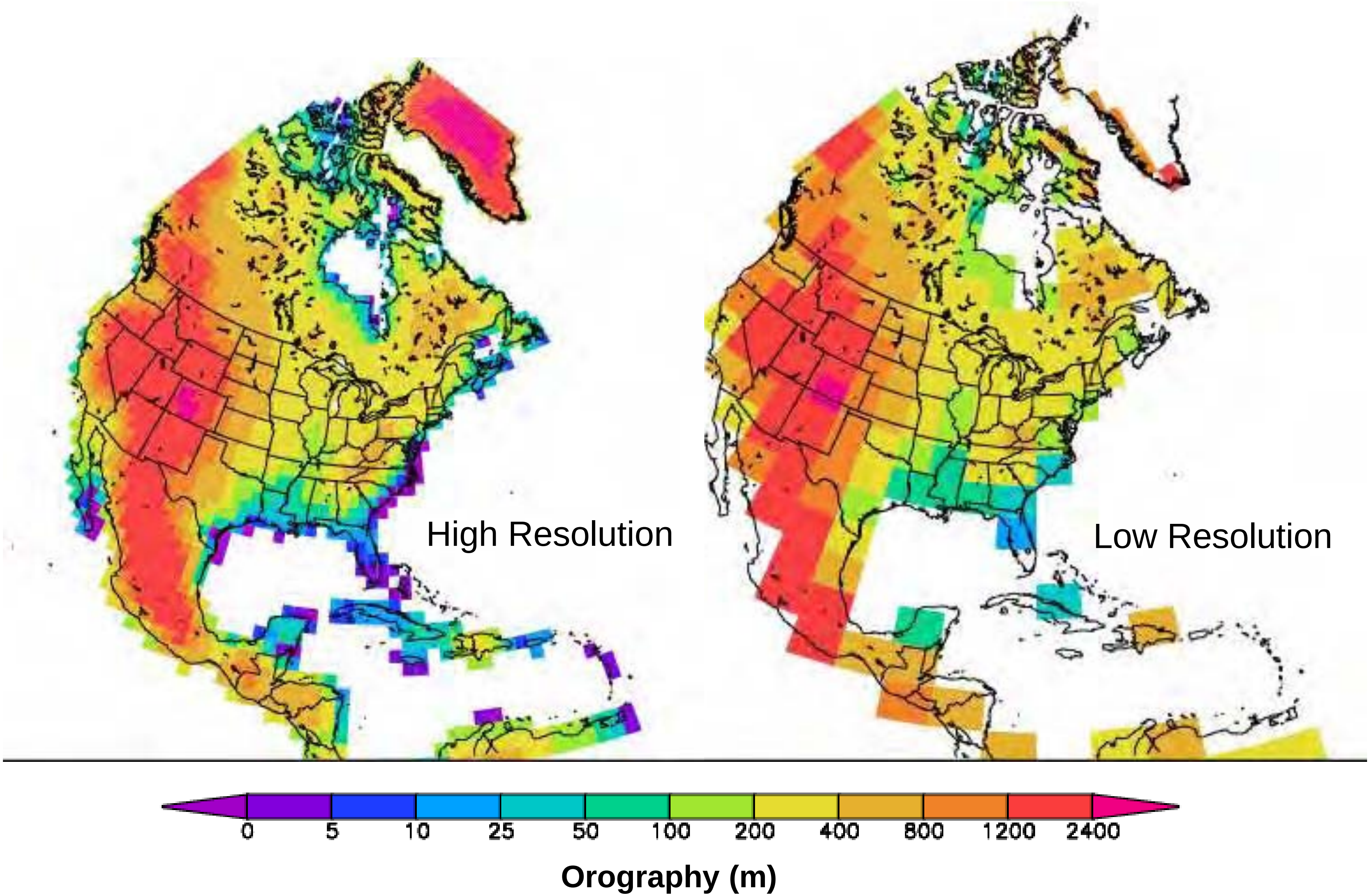
I) Limitations of global climate models for making regional predictions.

II) Consequences of global warming for regional-scale weather extremes.

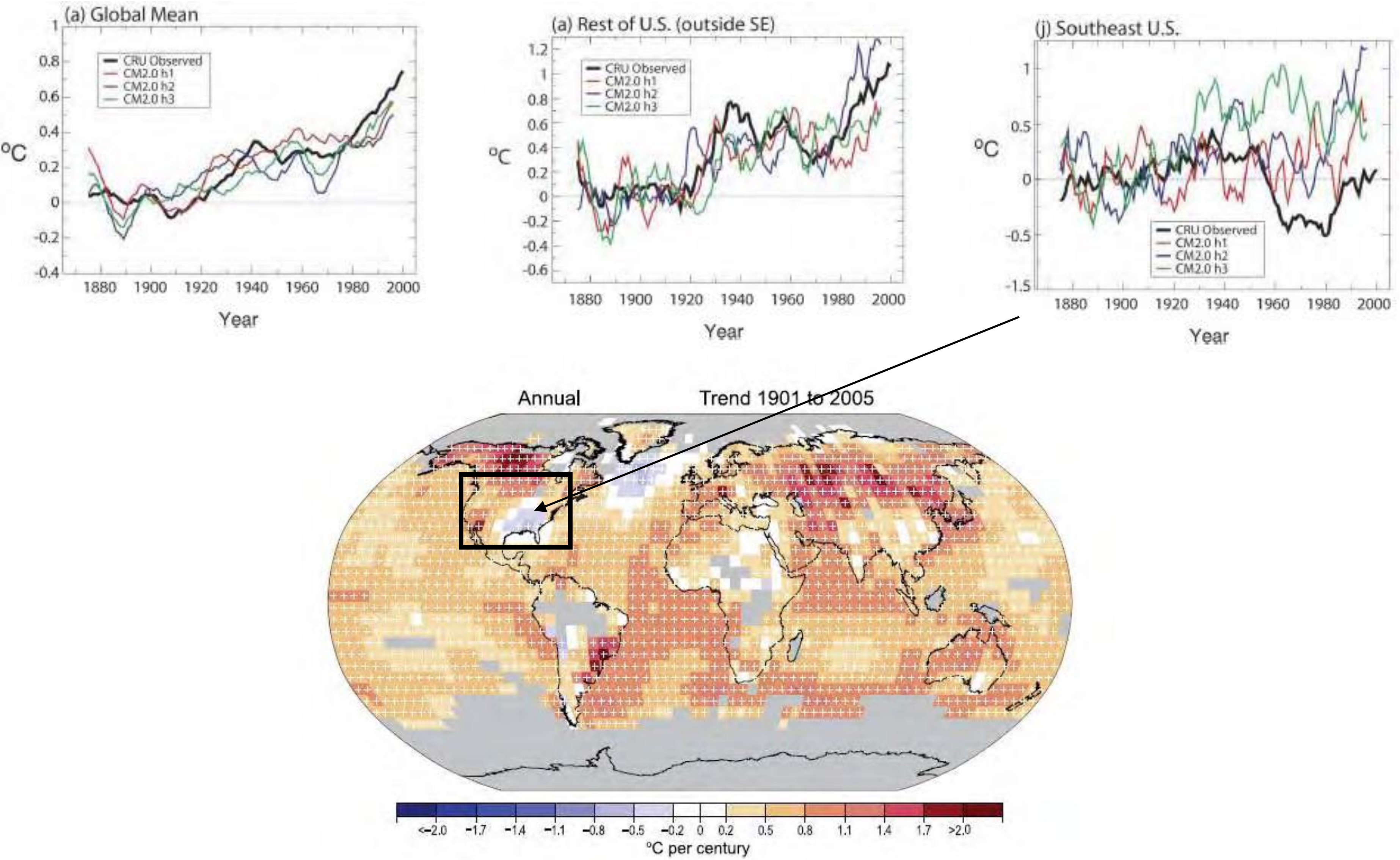

ATLANTIC OCEAN
CARIBBEAN SEA


90° N
0°
0°
4 km
3 km
2 km
1 km
90° S

Climate Model Grid Boxes

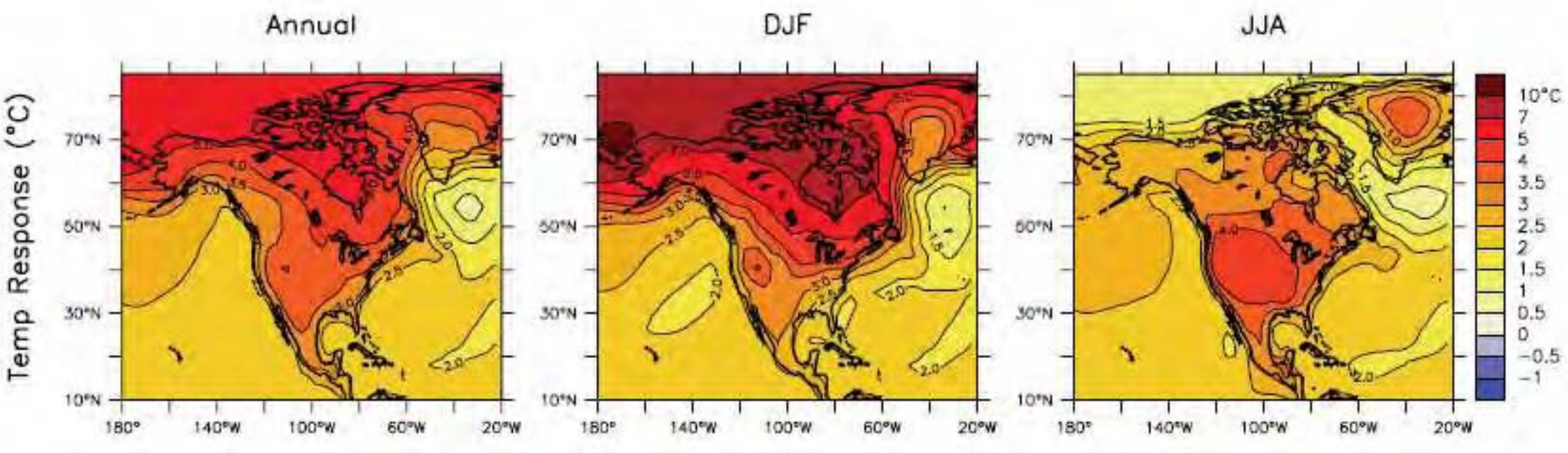


Variability at Global to Regional Scales



Sources: Knutson et al. 2006, Trenberth et al. 2007

Model Projected Changes in Temperature at 2100

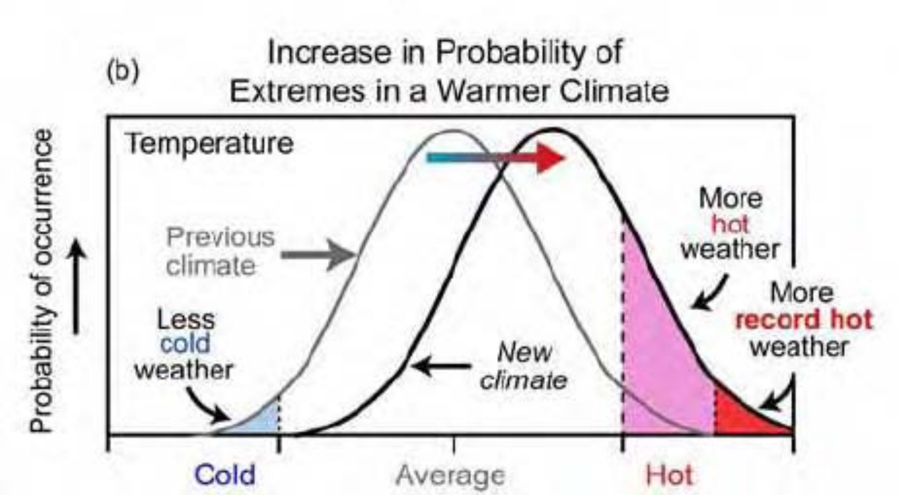


Source: Hewitson et al. 2007

Weather and Climate

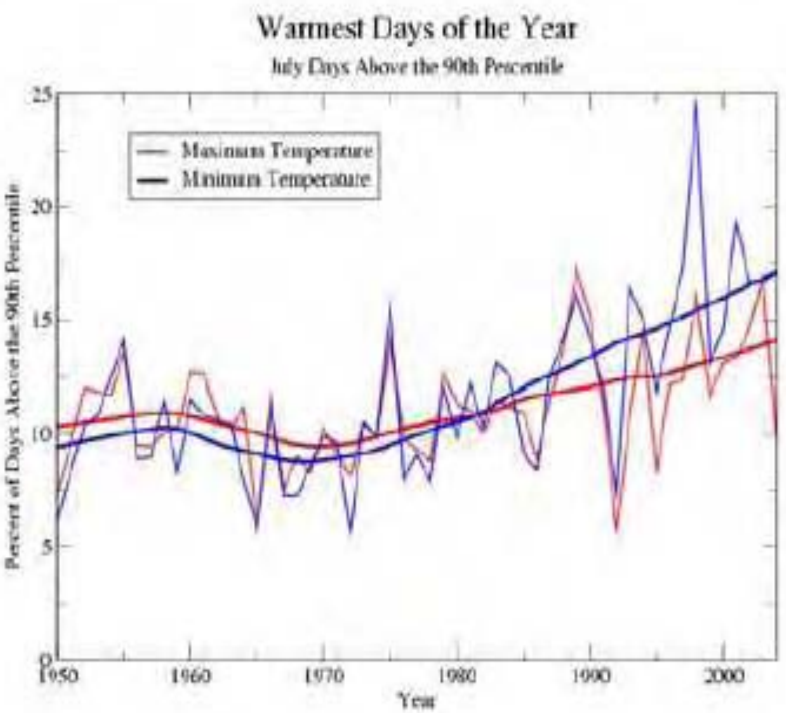
“Climate is what we expect,
weather is what we get.”

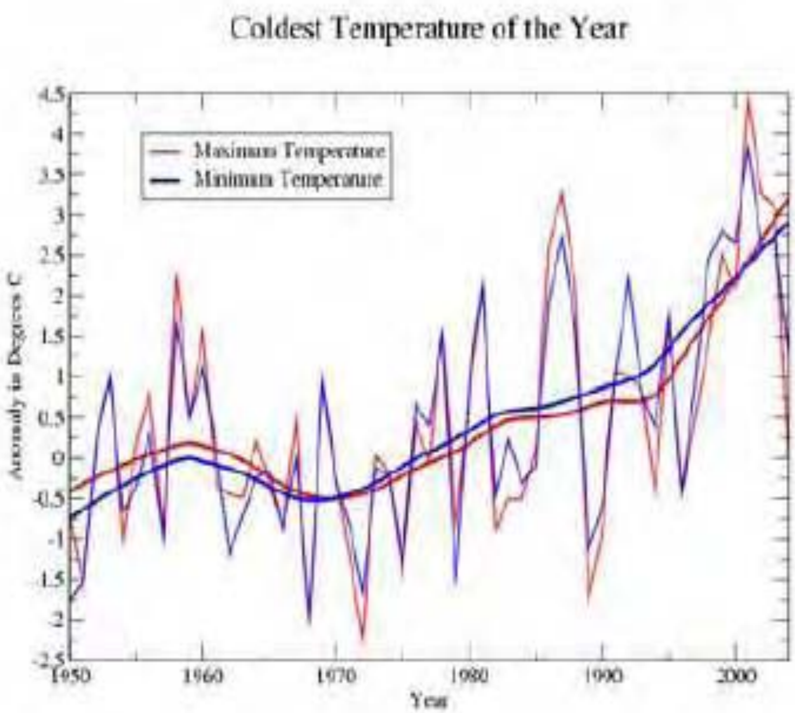
- Mark Twain



- **The larger scale climate response to global warming is manifest on changes in regional-scale “weather extremes”.**

Observed Changes in U.S. Temperature Extremes



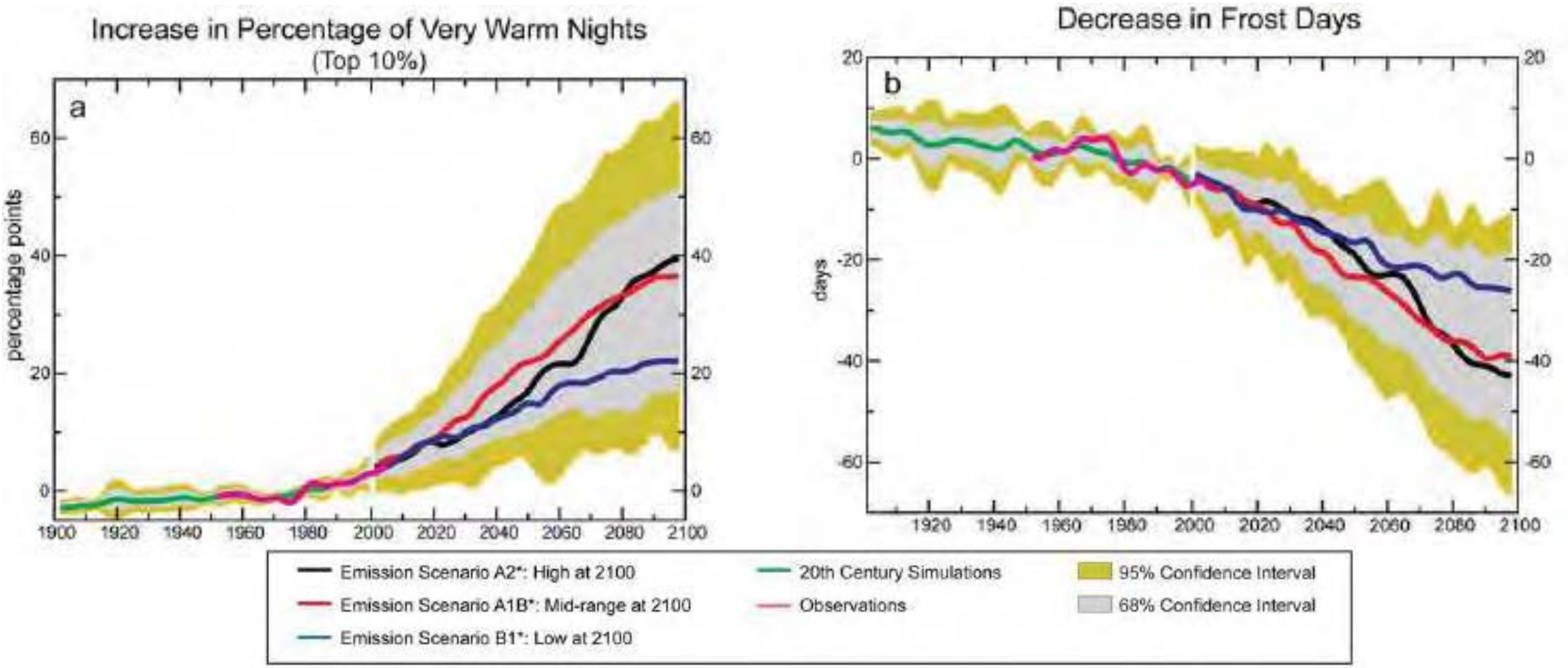


<u>Observed changes over continental US during the last half century:</u>

- **Warm days have become more common. Warmest days have gotten warmer.**
- **Cold days have become less common. Coldest days have gotten warmer.**

Source: Peterson et al. 2007

Projected Changes in U.S. Temperature Extremes



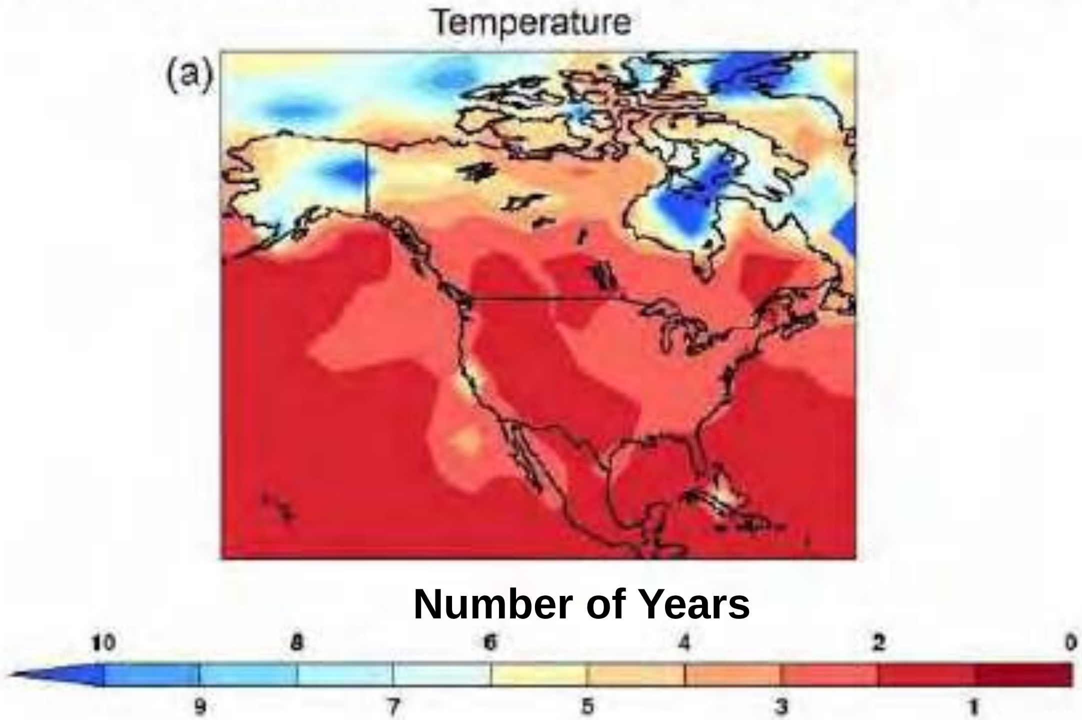
Averages over the continental US from:

- **Observations for 1950-2000 (pink)**
- **Model simulations for 20th Century (green)**
- **Model projections for 21st Century (red, black, blue).**

Observational data : Peterson et al. 2007 Model Simulations: CMIP-3 Data Archive.

Changes in Frequency of Heat Waves

Projected Occurrence of a 1-in-20 Year "Hot Day" by 2100

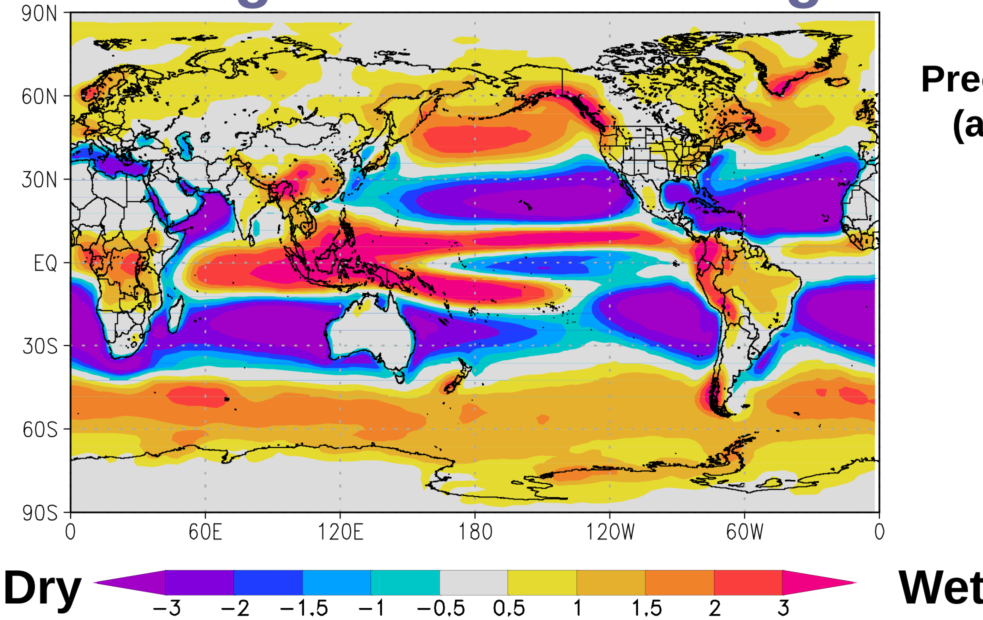


<u>For Tallahassee at 2100 under this scenario:</u>

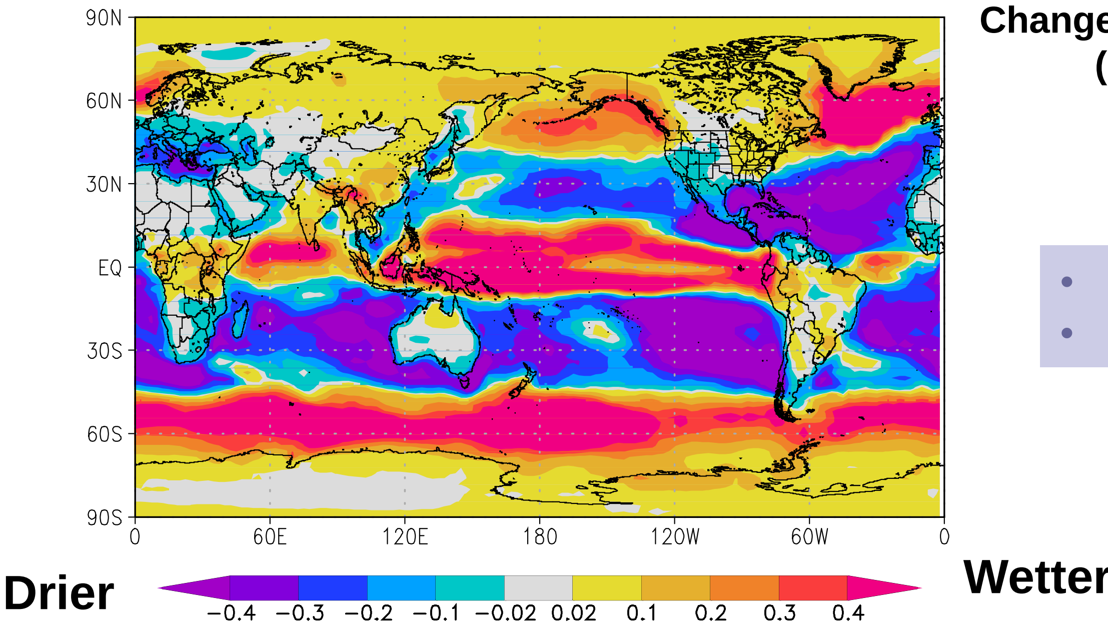
- **High temperature of 103 F would occur every ~2 years.**
- **1-in-20 year temperature would increase from 103 F to 109 F**

Source: Wehner 2005

Changes in Water: Wet get wetter, dry get drier



Precipitation – Evaporation: Today
(average of 22 Climate Models)

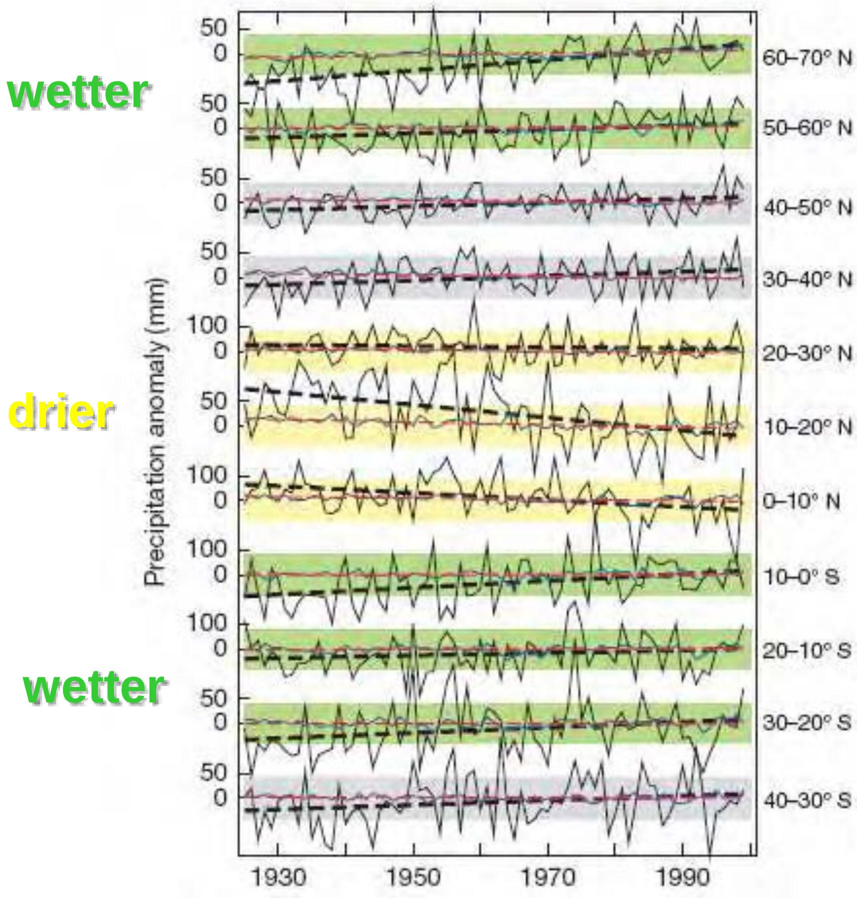


Change in Precipitation – Evaporation: 2100
(average of 22 Climate Models)

- **Wet regions become wetter.**
- **Dry regions become drier.**

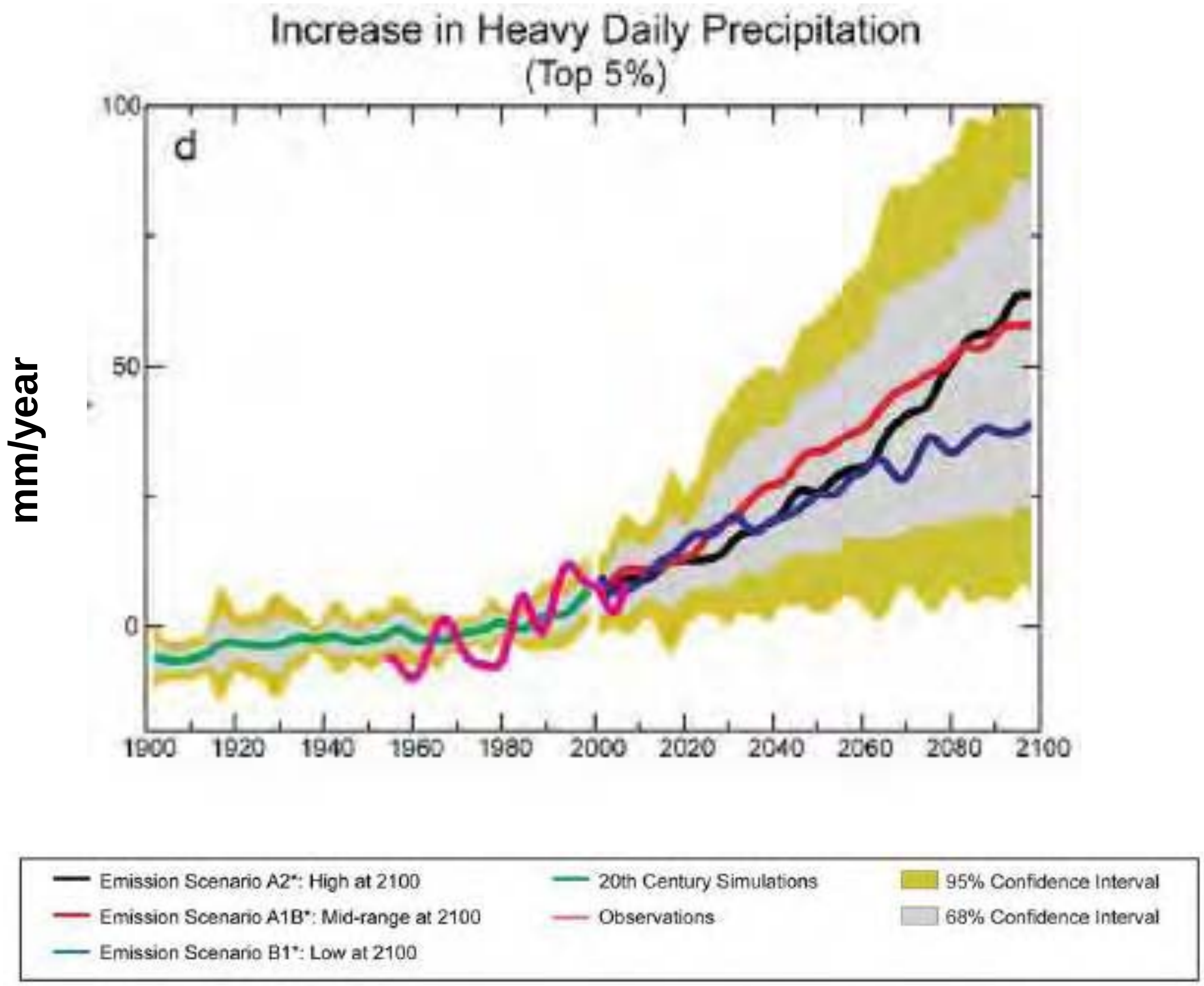
Source: Held and Soden 2006

20th Century Precipitation Changes

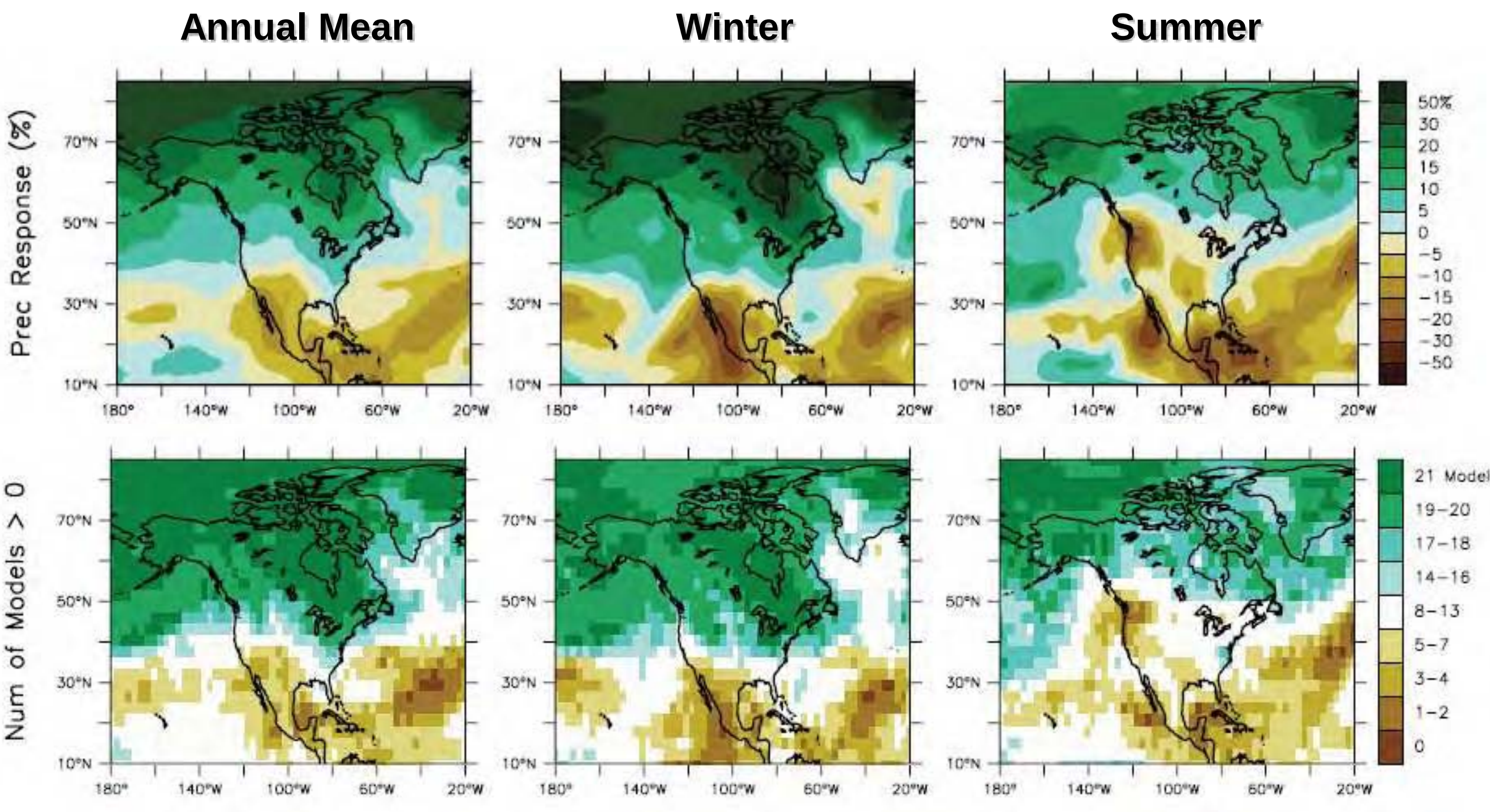


Source: Zhang et al. 2007

Projected Changes in Heavy Precipitation over U.S.

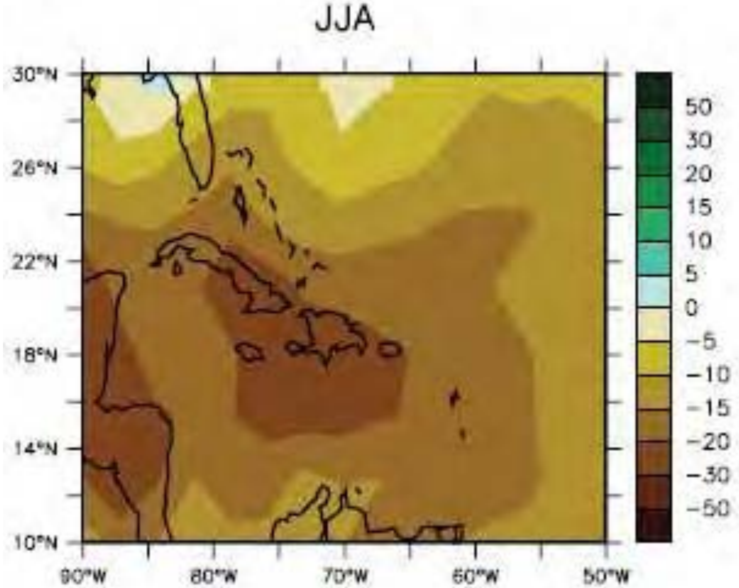


Projected Changes in 21st Century Precipitation

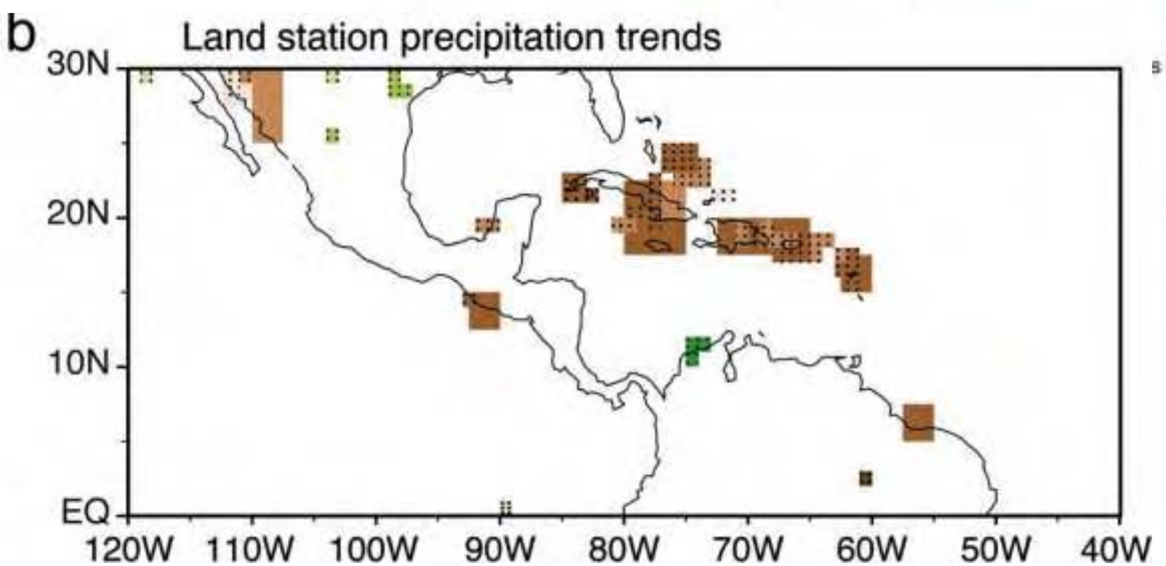


Source: Hewitson et al. 2007

Precipitation Changes over the Caribbean



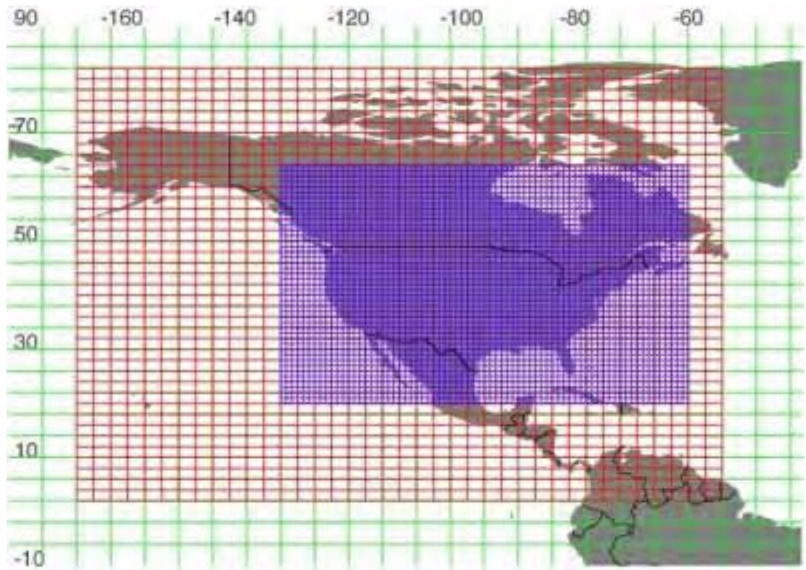
Model Projected Changes for 21st Century



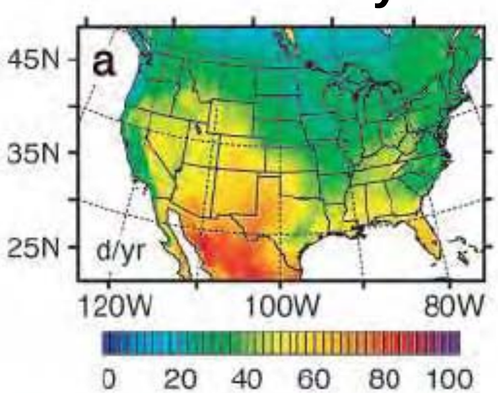
Observed Changes 1950-2002

Source: Neelin et al. 2006

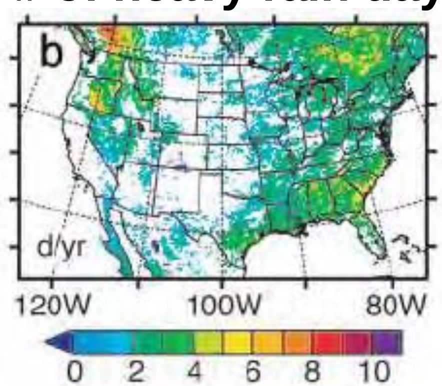
Regional Downscaling Models



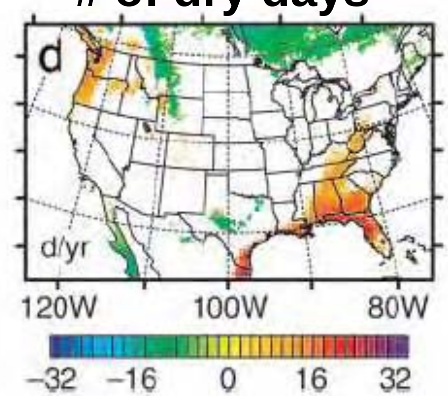
# of hot days



# of heavy rain days



# of dry days



Source: Diffenbaugh et al. 2005

Summary

Statements about the expected climate change for specific regions are limited by coarse resolution of models and the larger noise of natural climate variability at smaller scales.

But there are robust changes in regional-scale “weather extremes” which are a consequence of the larger-scale climatic changes from global warming.

Changes in temperature extremes follow the average temperature:

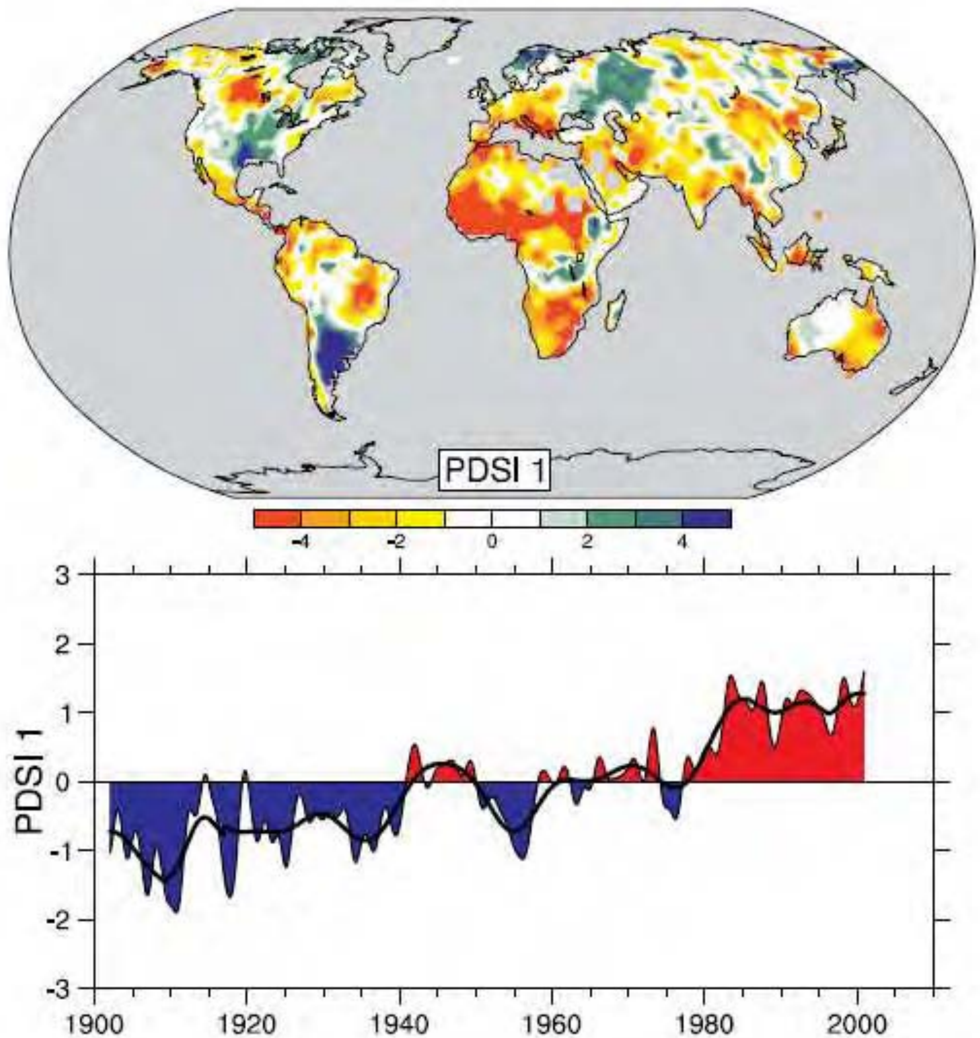
- Increase in extreme high temperatures (heat waves).
- Decrease in extreme low temperatures (frost events).

Changes in moisture enhance both wet and dry extremes:

- Increase in frequency/intensity of heavy rainfall events.
- Increase in length/severity of droughts.

These changes can have significant impact on human health, agriculture, water availability, and ecosystems.

20th Century Drought Changes



Source: Trenberth et al. 2007

John Reilly

John Reilly

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Dr. Reilly is the Associate Director for Research in the Joint Program on the Science and Policy of Global Change and a Senior Lecturer in the Sloan School at MIT, with a Ph.D. (1983) and M.S. (1980) in economics from the University of Pennsylvania, and a BS (1978) from the University of Wisconsin. His research career has focused on the integrated assessment of climate change, including modeling of energy use, biofuels, and greenhouse gas emissions and climate's effects on agriculture including consideration of land use change. His work is published in over 150 articles, reports, and volume chapters. He has served in a variety of capacities on the Intergovernmental Panel on Climate Change, was the Co-Chair of the US National Agricultural Assessment on Climate Variability and Change, and served on early committees in the Federal government that shaped the direction of the US Global Change Research Program, and on a wide range of advisory committees. Prior to joining MIT in 1998, he spent 15 years with the US Department of Agriculture's Economic Research Service, with prior service for the Pacific Northwest National Laboratory and the Institute for Energy Analysis, Oak Ridge Associated Universities.

From Evidence for an Anthropogenic Contribution to Climate Change to Projections of Future Change, Potential Impacts, Adaptation and Mitigation

John Reilly

Joint Program on the Science and Policy of Global Change
Massachusetts Institute of Technology

Prepared for the:

Florida Legislature's Symposium on the Science and Economics of Climate Change

November 6 , 2007

Tallahassee, Florida

jreilly@mit.edu

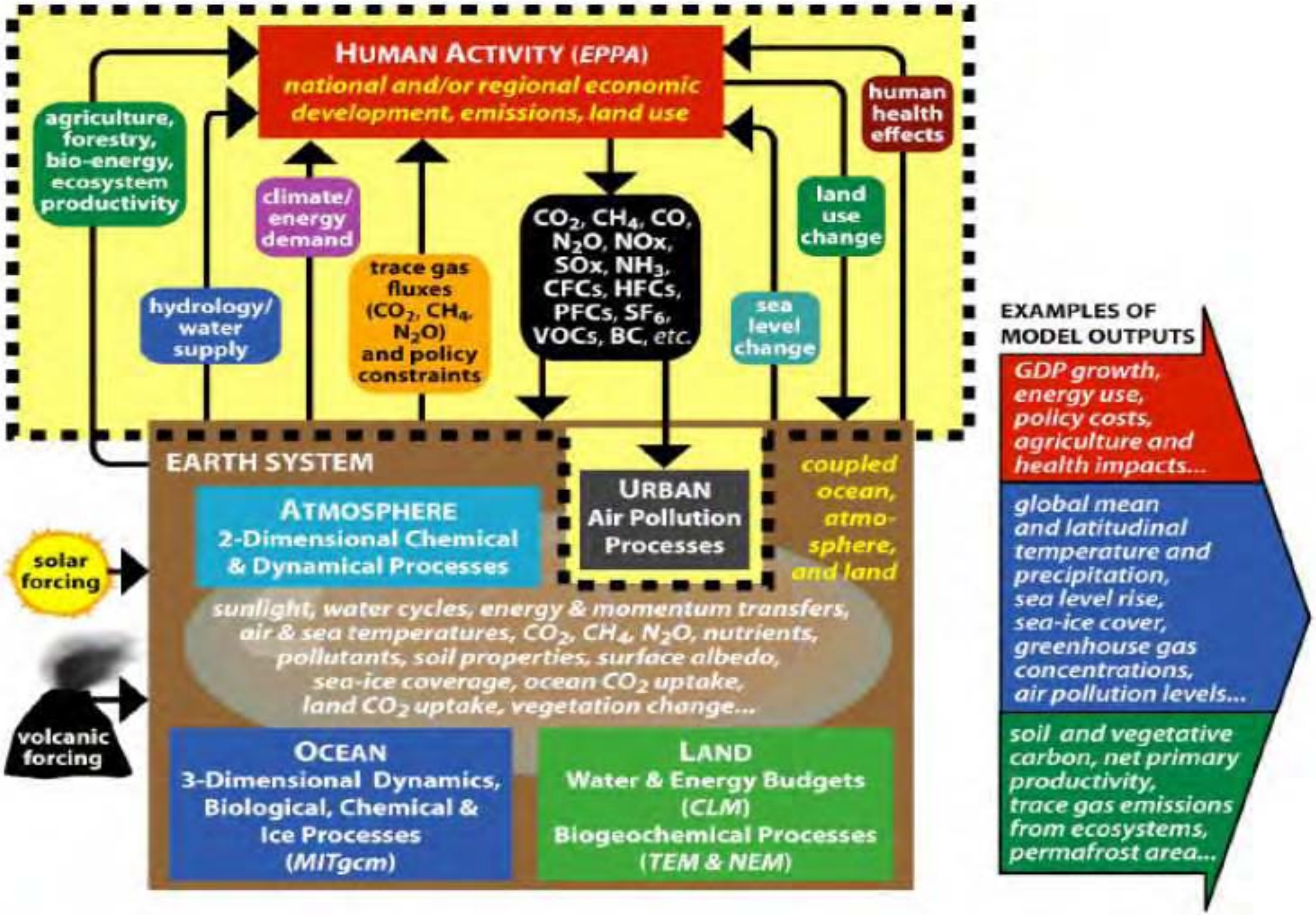
Why use models?

- Models cannot prove (or disprove) climate change.
  - Models represent what we think we know—quantification forces discipline.
  - Structure and parameters from physical laws, experimental and observational data; tested to see whether they can reproduce observed behavior.
  - Observational record is limited; hard to prove models are "right" but they are a best attempt to reconcile many pieces of information with the observed record.
- From "Back of and envelope" calculations to computer models.
  - Swedish physicist Arrhenius first proposed CO_2 as a factor in climate change in 1896 and was not far off current estimate of what a doubling of CO_2 would cause.

Why Projections?

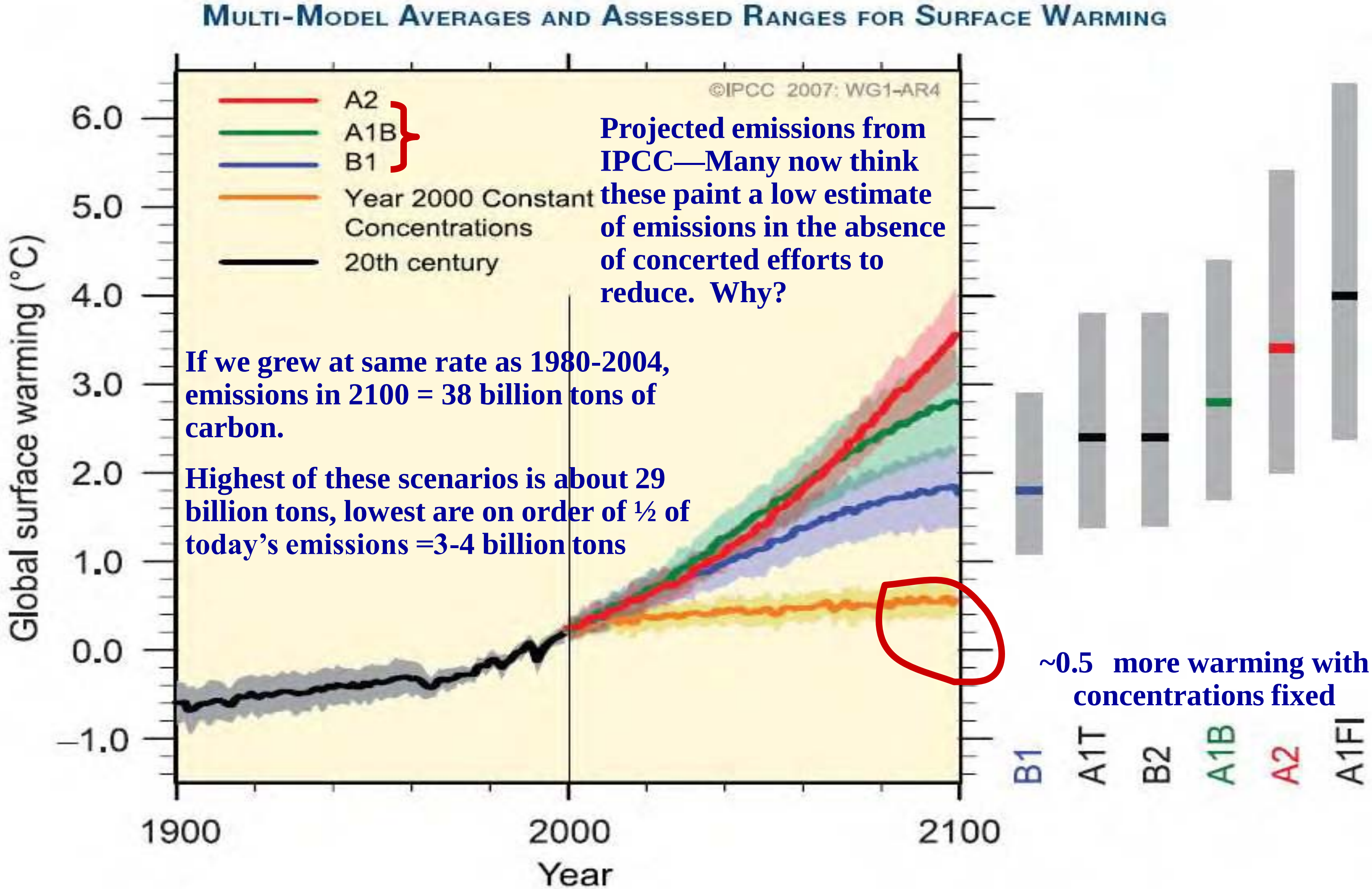
- Anthropogenic greenhouse gases are very long lived in the atmosphere.
- CO_2 in fossil fuels would mostly remain out of active circulation—what's called the carbon cycle.
- Combustion releases CO_2 into the atmosphere; its rapidly partitioned among the atmosphere, the ocean, and terrestrial vegetation/organic matter in soils—about ½ remains in the atmosphere.
- Individual molecules of CO_2 continue to be exchanged between air, ocean, and vegetation/soils but the net addition to the carbon cycle is for practical purposes there forever.
- THIS MEANS: (1) If we get to a climate state we don't like it is essentially impossible to go back.
- EVEN MORE TROUBLING: (2) The ocean is a "heat sink" and if at (1) atmosphere will warm more even if we stop all CO_2 emissions immediately.
- SO: (3)The only way to understand where we are heading in time to do something about it is to make absurdly long term projections…50, 100, more years into the future.

Cartoon of Earth System Model and System Interactions



Source:IPCC, WG-I
Summary for Policymakers

Recent US CCSP 2007 Report projects in absence of policy year 2100 emissions around 25 billion tons.



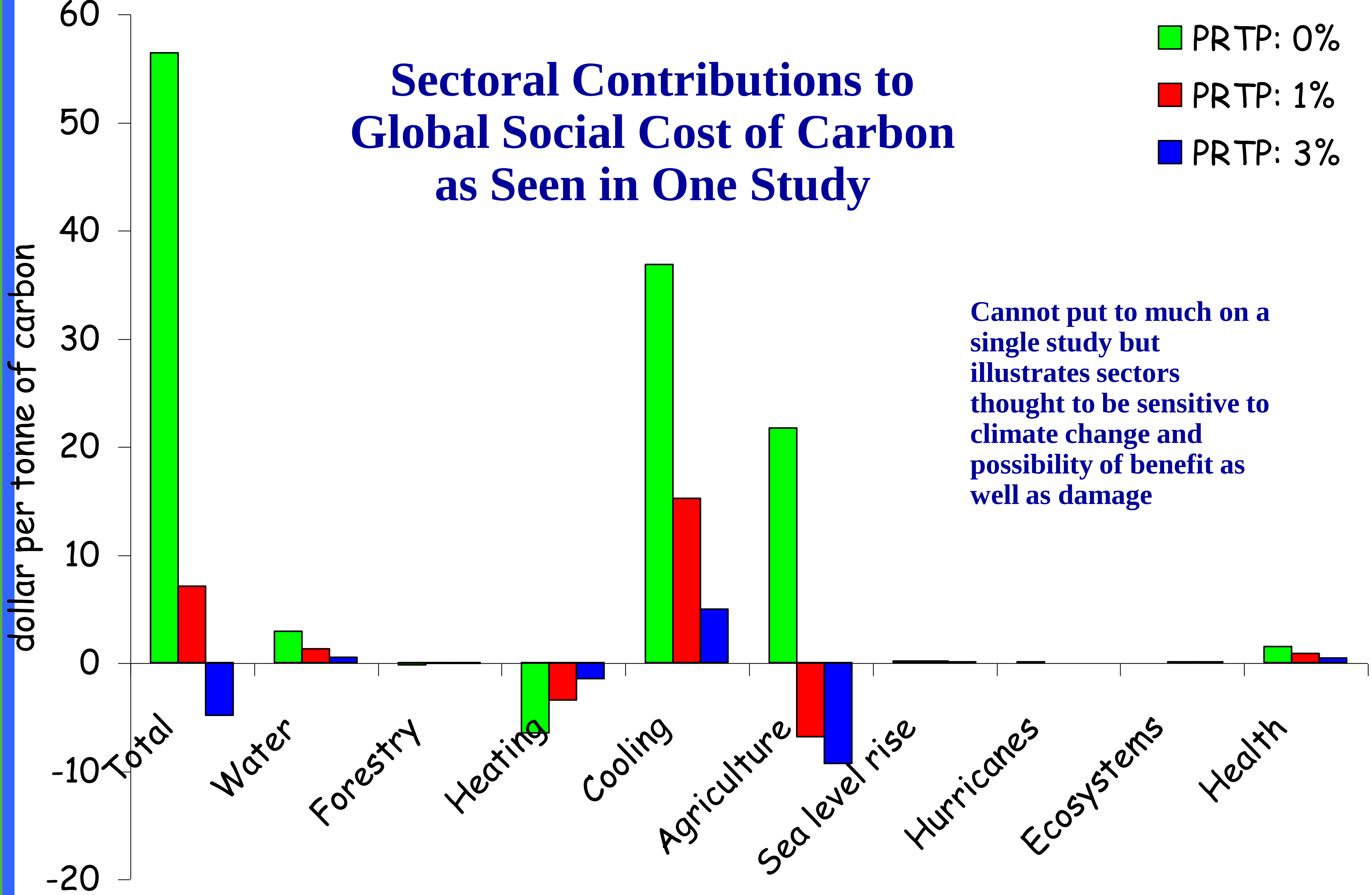
Projected emissions from IPCC—Many now think these paint a low estimate of emissions in the absence of concerted efforts to reduce. Why?

If we grew at same rate as 1980-2004, emissions in 2100 = 38 billion tons of carbon.

Highest of these scenarios is about 29 billion tons, lowest are on order of ½ of today's emissions =3-4 billion tons

~0.5 more warming with concentrations fixed

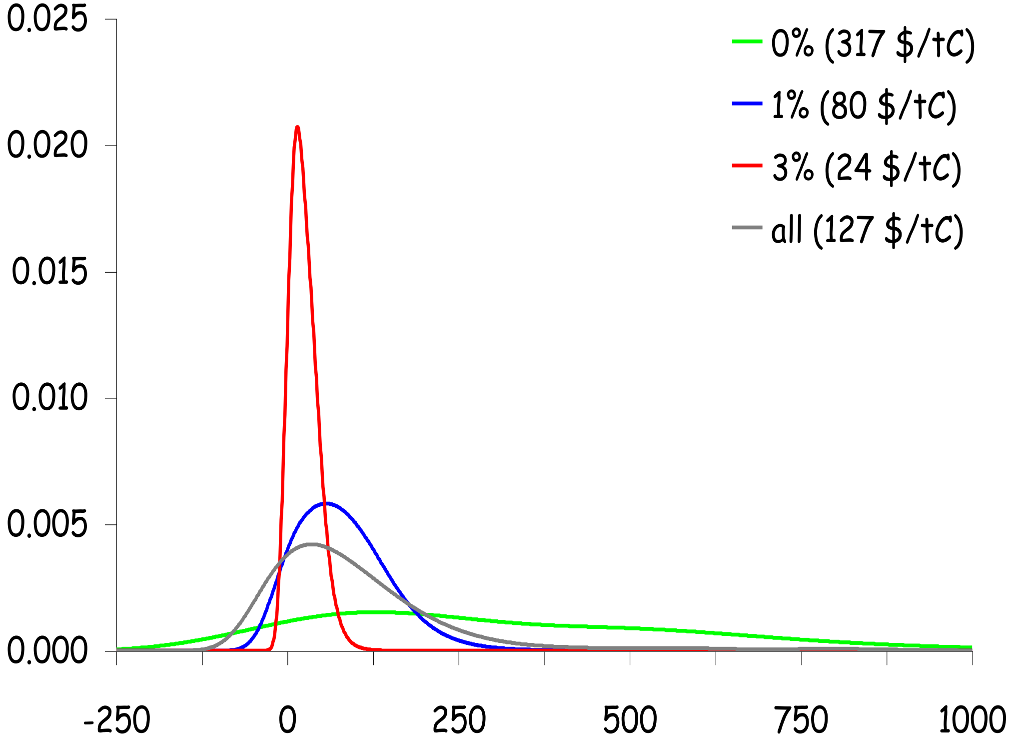
Sectoral Contributions to Global Social Cost of Carbon as Seen in One Study



Cannot put to much on a single study but illustrates sectors thought to be sensitive to climate change and possibility of benefit as well as damage

Source: From Richard Tol FUND3.0

Tol's Meta-Analysis of the Marginal Damage Costs



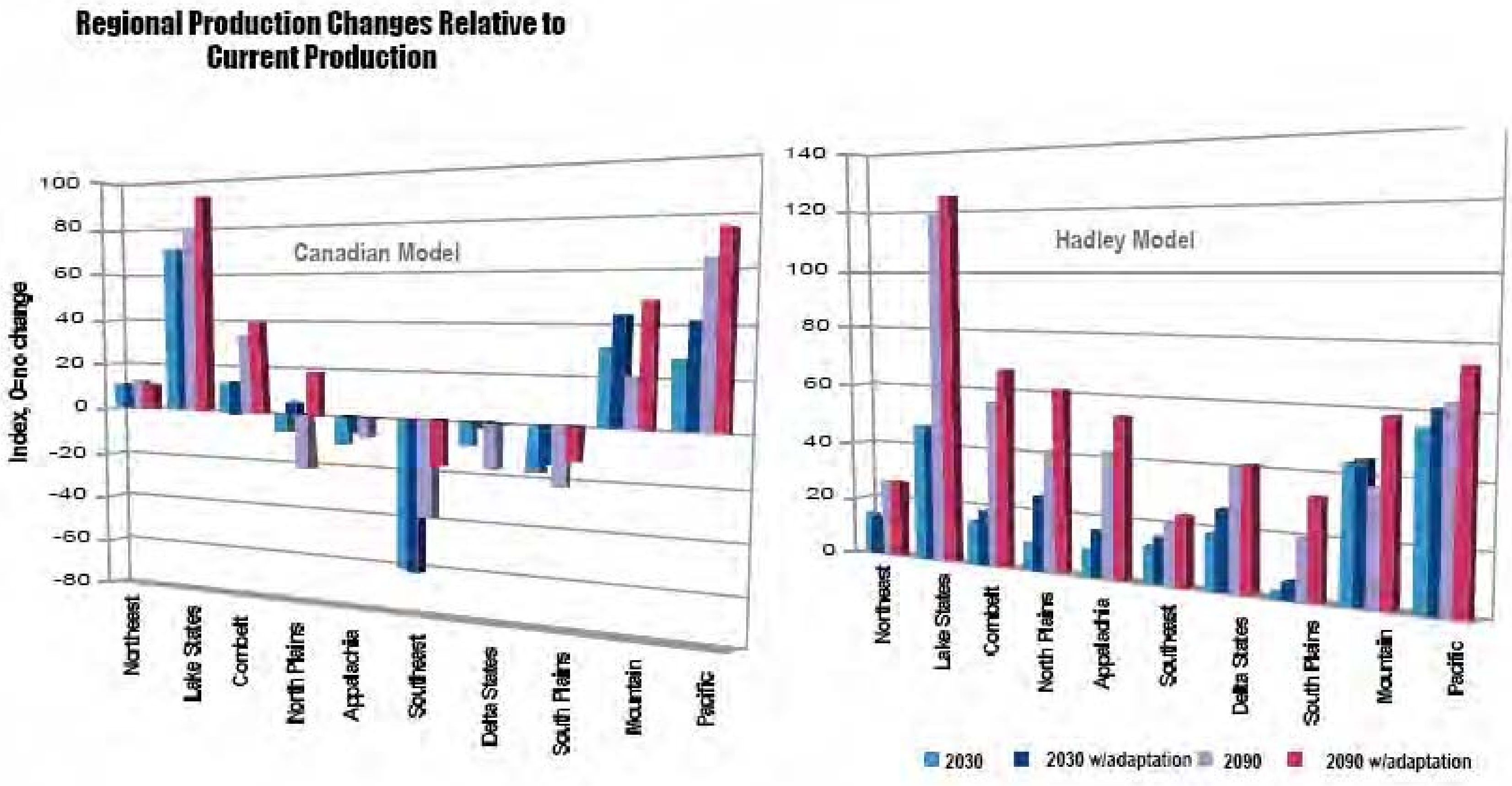
Note: these are per tons C—later we will use figures in tons CO2—must divide these numbers by 3.66 to be comparable: $24/tC=$6.6/tCO2

Discount rate makes a big difference in damage costs →big effects, if estimated, are in the relatively distant future

Caveats: Efforts to estimate global social cost of carbon are heroic: inability of climate model to project regional climate very well (especially precipitation), modes of variability (e.g. ENSO), extreme events (e.g. tropical storms). Literature behind rapidly moving science.

Hesitation with such estimates—are they helpful or misleading?

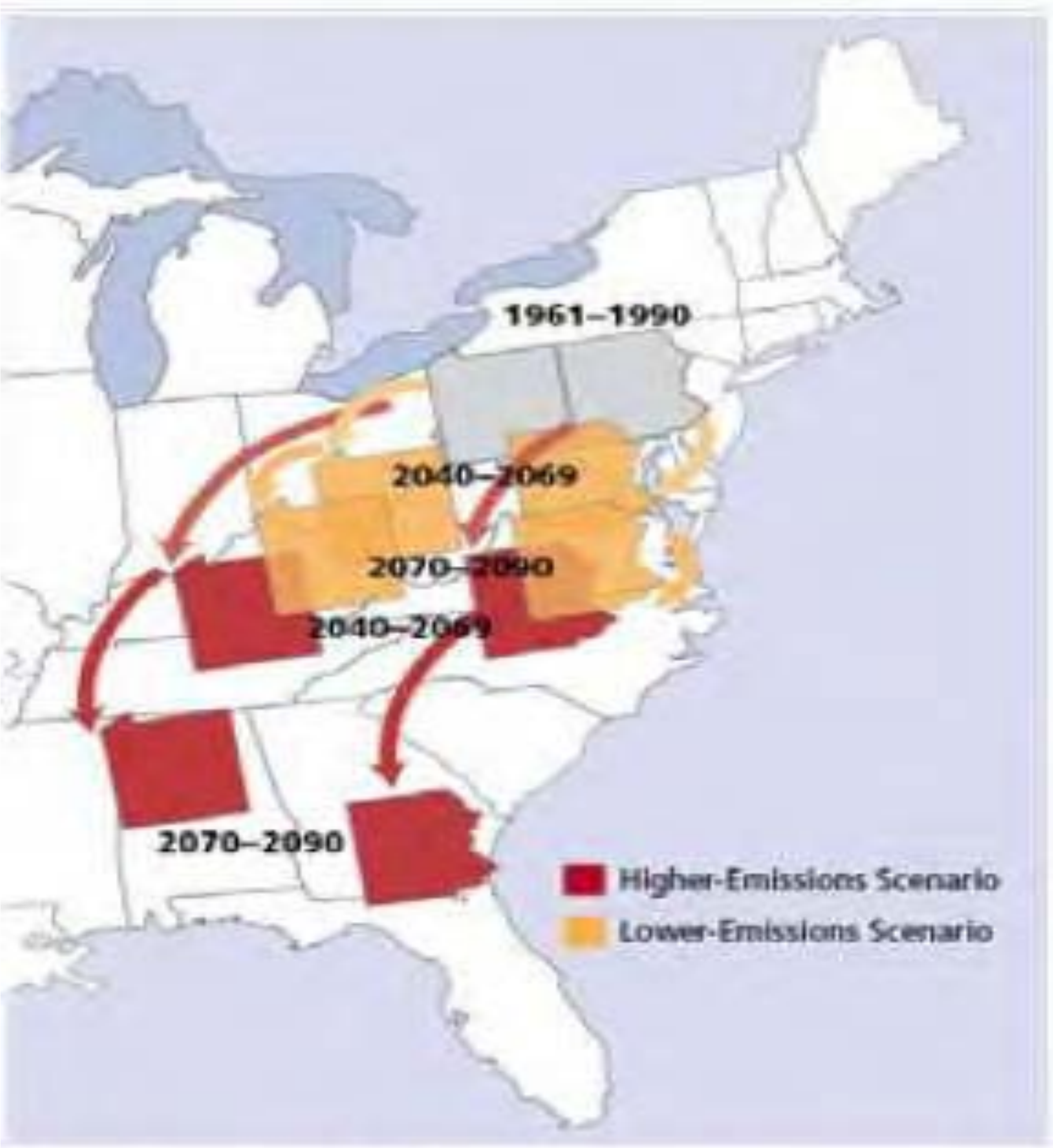
A wide range of potential agricultural effects: Most analyses show southern areas relatively disadvantaged compared with northern areas



Source: US NATIONAL ASSESSMENT OF POTENTIAL CONSEQUENCES OF CLIMATE VARIABILITY AND CHANGE

One way to think about what climate change means—Eastern Pennsylvania Climate will be like Southern Georgia.

Source: A report of the Northeast Climate Impacts Assessment (NECIA), July 2007



Migrating State Climate

Overall summary of this line of research

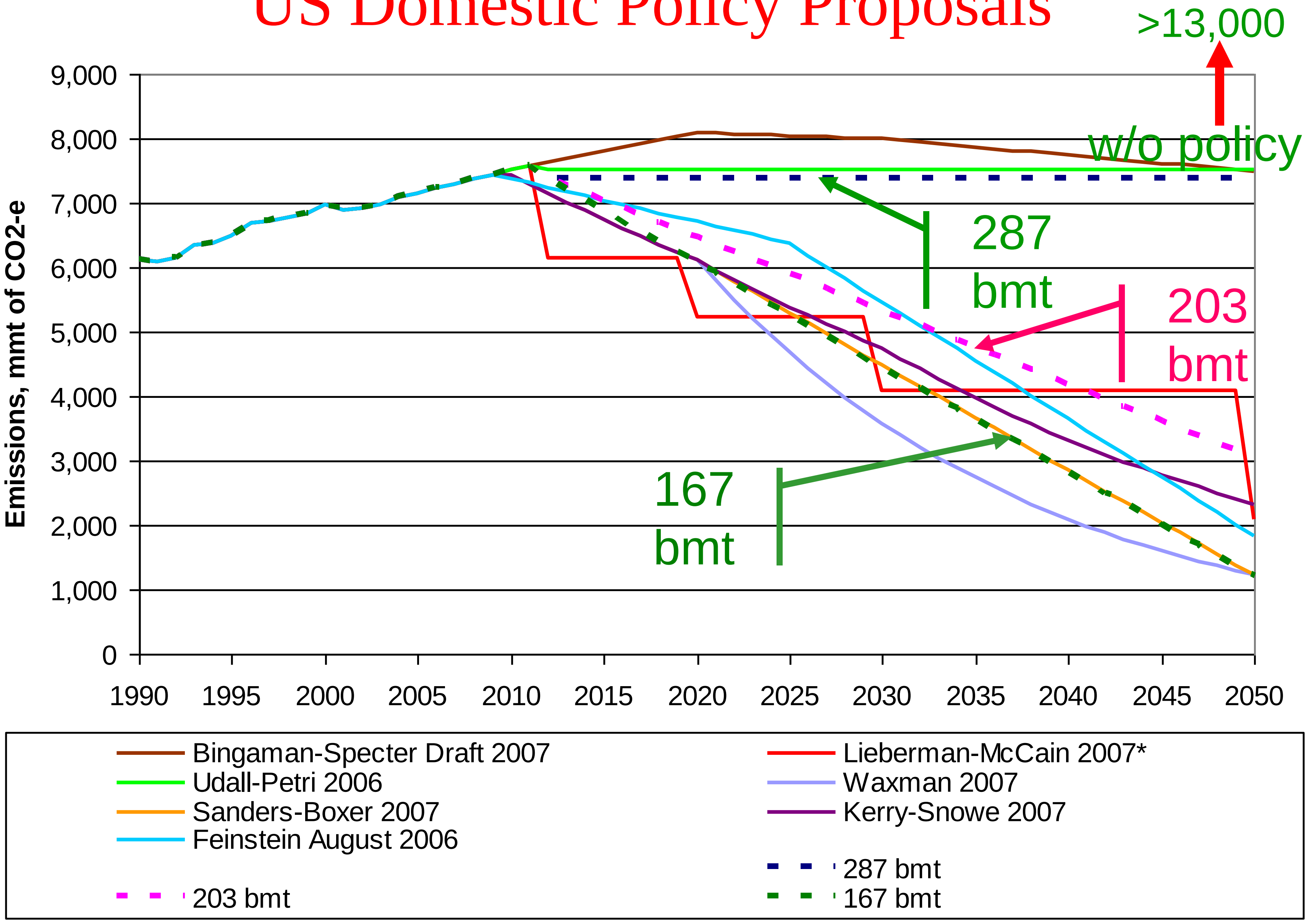
- Evidence is for small macroeconomic impacts (1 to 2% of economic activity) in near, even distant future.
- Why?
  - Climate change is big/fast in terms of earth history, but small/slow relative to spatial, seasonal variability to which human society appears adapted.
  - Sectors directly affected by climate are a small share of the economy.
  - "Big" impacts are non-market—no direct consequence for the macro-economy.
  - Like a change in long term productivity growth, rather than disruptive event.
  - Positive effects at least partially offset negative effects.
- Is this characterization correct? Possibility for big macro-economic consequences?
  - GCMs and impact research protocols tend toward "ensemble" approaches which smooth out climate events.
  - For particularly vulnerable regions effects may be larger.
  - GCMs may be wrong, just a central tendency—small chance of "abrupt" catastrophic change, or important details not represented.
  - Nature of our dependence on climate, ecological services is underestimated.
  - Social response may amplify effects: domino effect spreads to other sectors, regions.

A forthcoming probabilistic assessment of risks of global mean temperature increase to 2100 (from preindustrial) (Rework of Webster et al., 2003)**

	$\Delta T > 2^{o}C$	$\Delta T > 4^{o}C$	$\Delta T > 6^{o}C$
No Policy	ALWAYS	4 in 5	1 in 3
Stabilize at 650	49 in 50	1 in 5	<1 in 100
Stabilize at 550	97 in 100	1 in 20	<1 in 100

****Subtract about 0.8 for temperature rise from present to account for the increase that has already from pre-industrial to today**

US Domestic Policy Proposals



A possible post-2012 global policy

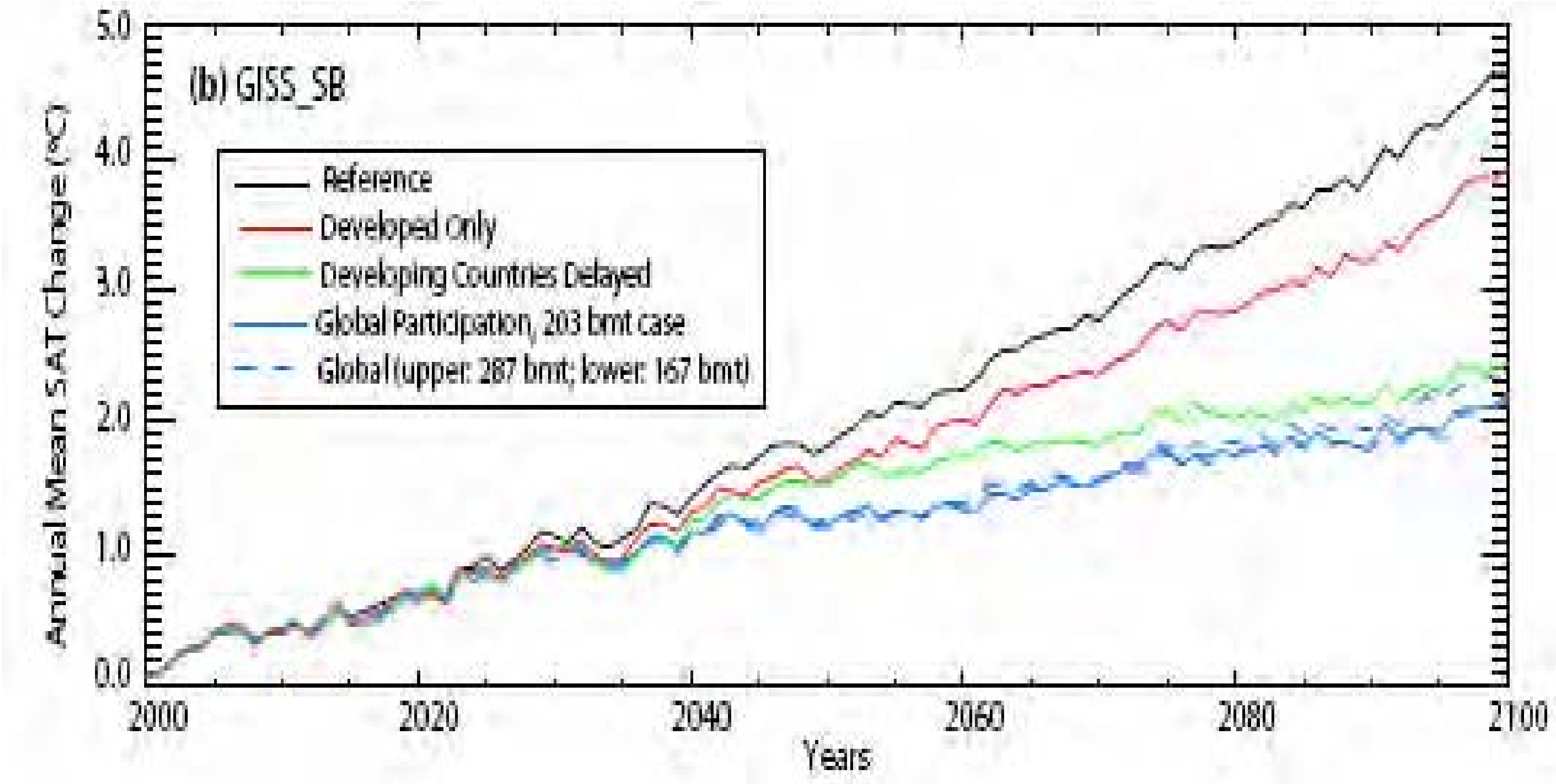
- US proposals captured by 3 synthetic versions (sum of emissions 2012-2050)
  - 167 bmt (≅ 80% reduction below 1990)
  - 203 bmt (≅ 50% reduction below 1990)
  - 287 bmt (stabilization at current emissions)
- Mitigation by others
  - Europe, Canada, Japan, Aus-NZ: post-Kyoto decline to 50% below 1990 by 2050. (G8 call)
  - Others: In 2025 return to 2015 level, then to 2000 level from 2035 onward.
- Hold at these levels through 2100
  - What if “Others” delay until 2050, or do nothing?

Source for these results: Paltsev, et al., 2007

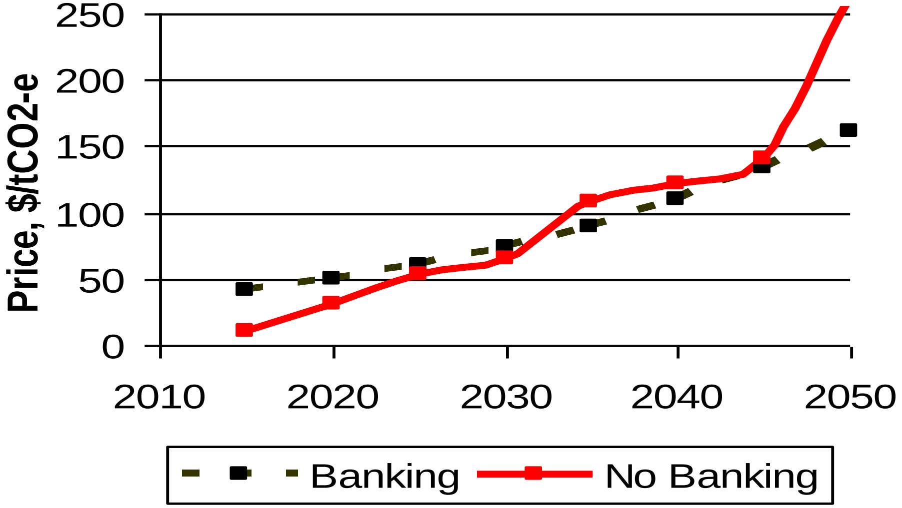
-Global policy limits the temperature rise—to 2.0 to 2.4 C above present with GISS parameterization of IGSM (1.5 to 2.0 for CCSM/GFDL GCMs). Much less risk of very high temperature, but still substantial warming.

-Developed countries alone are not very effective—need worldwide collaboration but if other regions join at mid-century a lot of progress is possible.

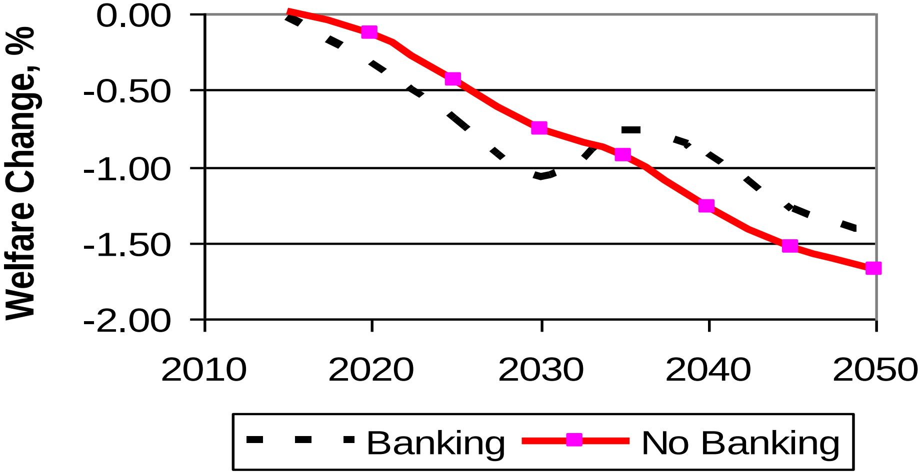
-Going first needs to include a strategy to get others to follow.



Costs of 203 bmt case—50% below present by 2050

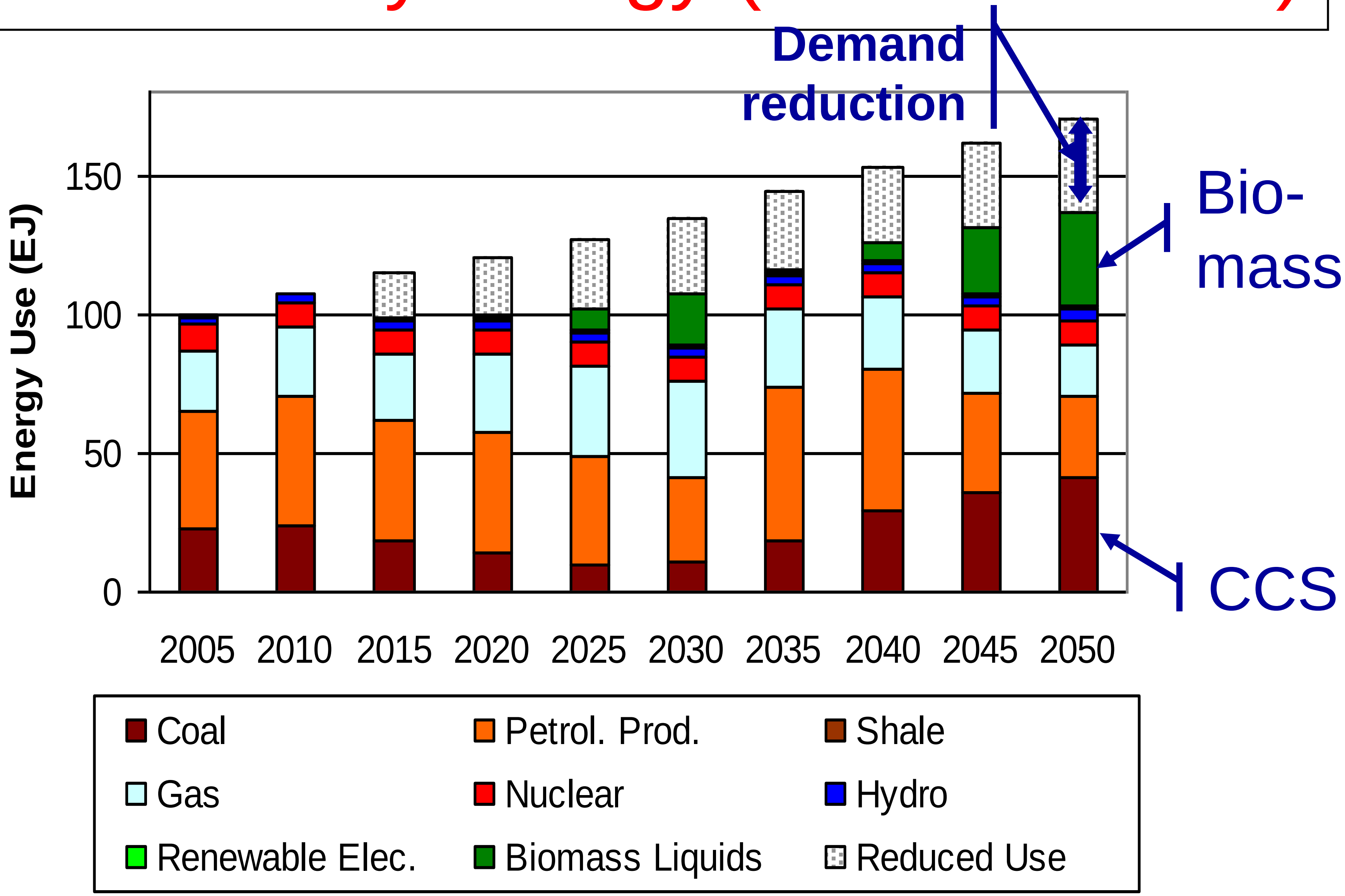


CO_2-e prices: banking smooths out shocks



Welfare Cost: small percentage but about ½ trillion $ in a US economy that has more than tripled

US Primary Energy (203 bmt Case)



Overall Summary

- Emissions growth worldwide has been quite rapid over the past few years and we are likely to see global mean surface temperature increases in the range of 3.5 -5.0 C (~6 - 9 F) by 2100 from present in a business as usual case; we can't rule out considerably greater change.
- Central estimates of damage costs and mitigation costs, in terms of the overall economy are manageable—of the same scale.
- Biggest motivation for mitigation: temperature increases of 3.0 C+ over short time period are unprecedented in recent earth history, and we have a relatively poor understanding of the effects of such change. Central damage estimates may be too optimistic, and fail to accurately factor in the risks of abrupt changes.
- *For Florida:*
  - *What does climate change mean for Florida's climate and where are its vulnerabilities? What can Florida legislature do to make the state's citizens, economy more resilient for inevitable change?*
  - *On mitigation, what should Florida do given global nature of the problem and possible Federal action? Lead or prepare the state for likely Federal efforts that will increase price of fossil fuel-based energy?*

Terms, sources, explanations

There are different conventions for reporting CO_2. One reports weight of the entire molecule, and the other just the carbon (C). To get tons of CO_2 from tons of C, multiply by 3.66. To get dollar cost per ton CO_2 from an estimate in tons C, divide by 3.66.

Other greenhouse gases sometimes converted to CO_2-equivlanets, and reported as tons CO_2-e

Convention is to report temperature change in Celsius---C. Multiply by 9/5 to get change in more familiar Fahrenheit—F.

Some report T change forecasts from pre-industrial, some from present. Subtract about .8 C to get change from present if reported as change from pre-industrial.

Citations:

IPCC [Intergovernmental Panel on Climate Change], 2007. Climate Change 2007: The Physical Science Basis (WG-I) & Impacts, Adaptation, and Vulnerability (WG-II) Cambridge University Press, Cambridge (UK).

US CCSP [Climate Change Science Program], 2007. U.S. Climate Change Science Program Synthesis and Assessment Product 2.1, Part A: Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations (L. Clark, J. Edmonds, H. Jacoby, H. Pitcher, J. Reilly, R.Richels), US Department of Energy, Washington DC

Richard S.J. Tol, 2005 The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties, Energy Policy 33 (2005) 2064–2074, and Snowmass presentation, 2007 via personal communication.

A report of the Northeast Climate Impacts Assessment (NECIA), July 2007; http://www.climatechoices.org/ne/resources_ne/nereport.html

Reilly, J. F. Tubiello, B. McCarl, and J. Melillo, "Agriculture," In: Climate Change Impacts in the United States [J. Melillo, T. Janetos, and T. Karl, co-chairs], Cambridge U. Press, Cambridge, 379-403, 2001.

Paltsev, S., J. Reilly, H. Jacoby, A. Gurgel, G. Metcalf, A. Sokolov & J. Holak, "Assessment of U.S. Cap-and-Trade Proposals," MIT Joint Program for the Science and Policy of Global Change, Report No. 146, April 2007

Webster M.D., C.E. Forest, J.M. Reilly, M.H. Babiker, D. Kicklighter, M. Mayer, R. Prinn, M.C. Sarofim, A. Sokolov, P. Stone, and C. Wang, "Uncertainty Analysis of Climate Change and Policy Response", Climatic Change, 61: 295-320, 2003.

Harold R. Wanless

Harold R. Wanless is professor and chairman of the Department of Geological Sciences at the University of Miami. He and his students have been studying the recent geological history of south Florida and the Bahamas since the early 1970s. Their research has documented the important control of fine-scale sea-level history and hurricanes on the character and evolution of tropical wetland, coastal and, shallow marine environments. They are currently using this knowledge to forecast future changes in Florida coastal environments in the face of global warming.

Dr. Wanless has been involved in helping to design the RECOVER research and monitoring program associated with the Everglades Restoration. He is co-chair of the Science and Technology Committee of the Miami-Dade County Climate Change Task Force.

Florida's Diminishing Coastal Future

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hwanless@miami.edu

Florida Legislature's Symposium on

the Science and Economics of Climate Change

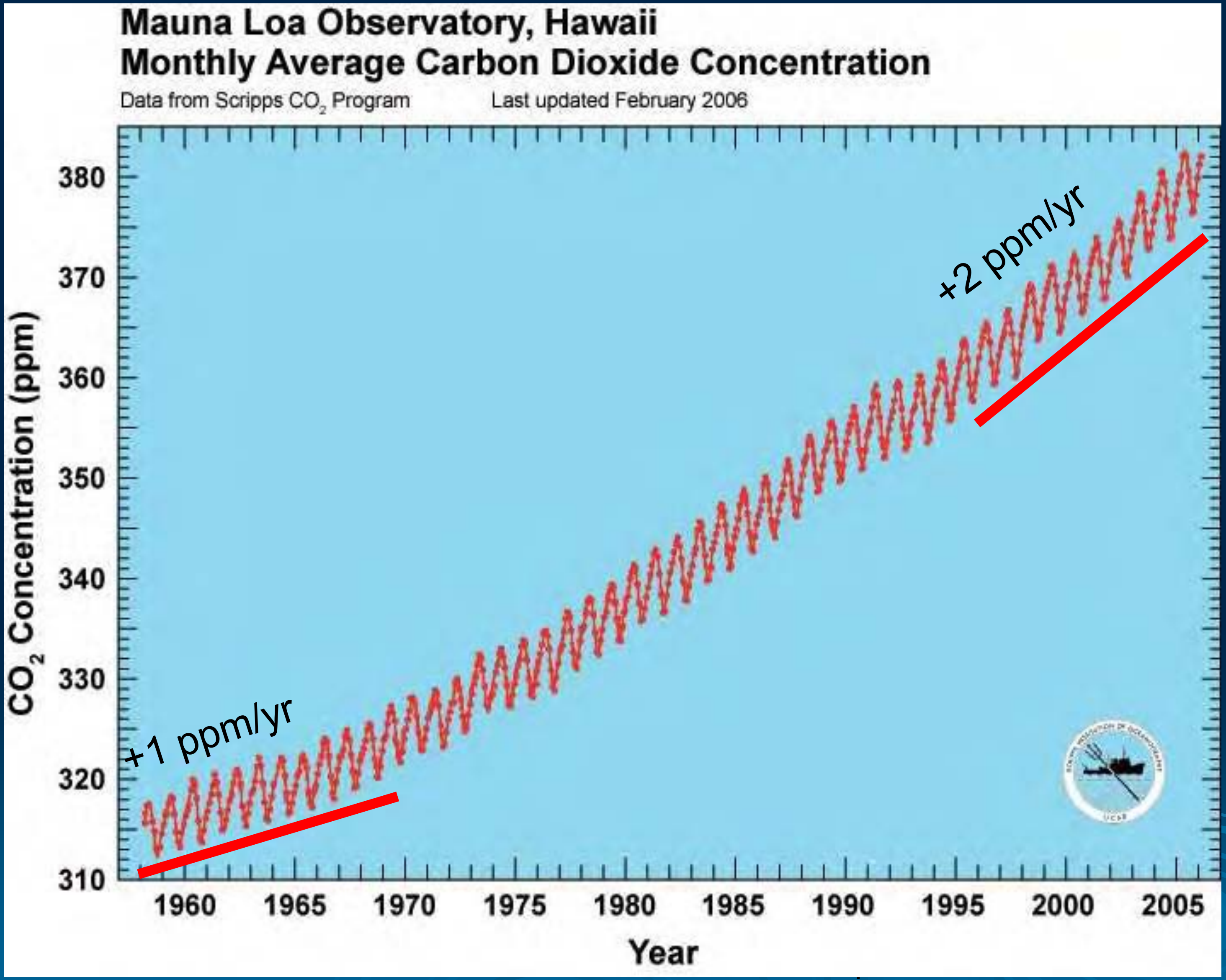
November 6, 2007

HUMAN-INDUCED GLOBAL WARMING IS REAL.

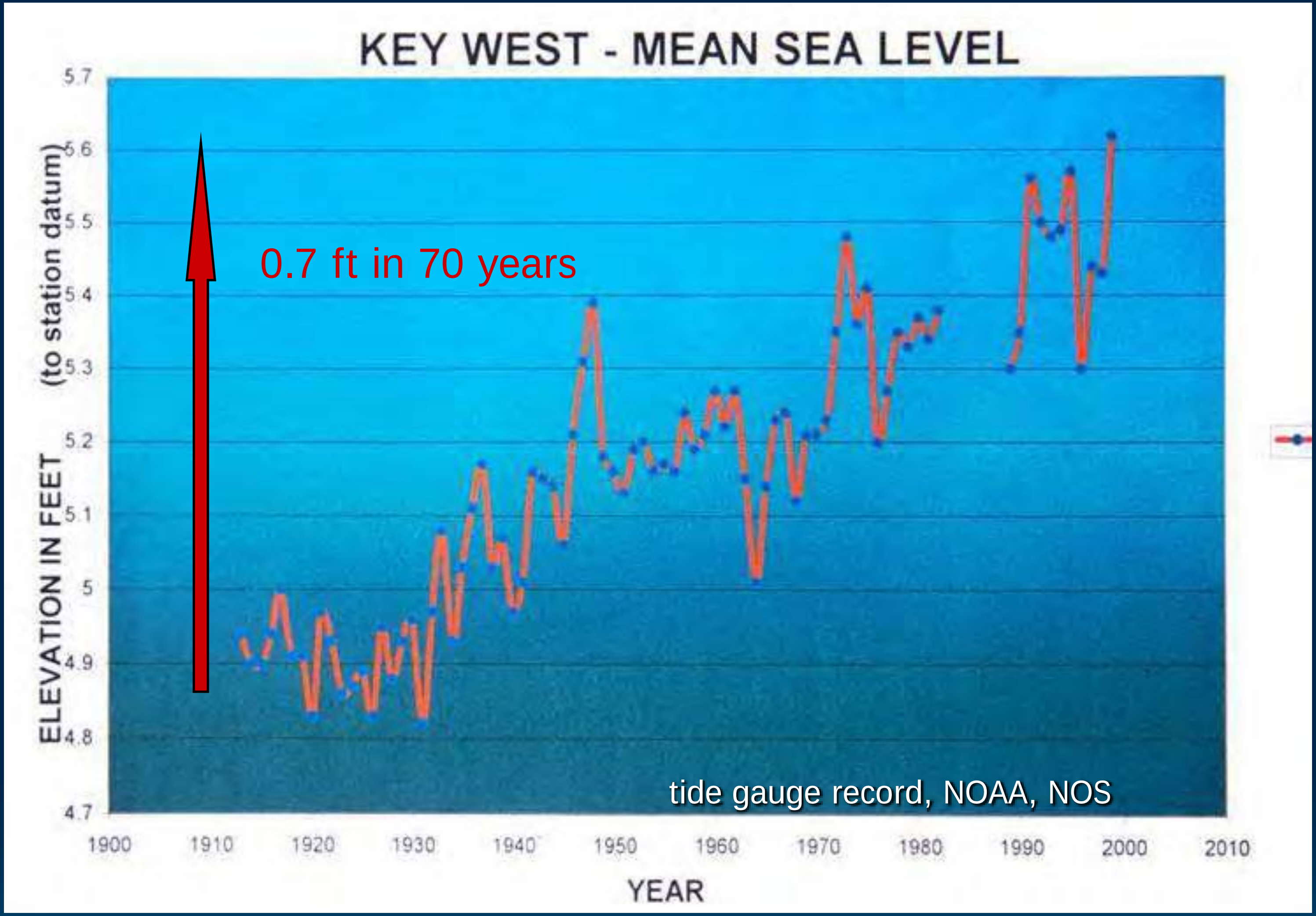
It has already started.

During the coming century, it will change Florida and Earth beyond your wildest imaginations.

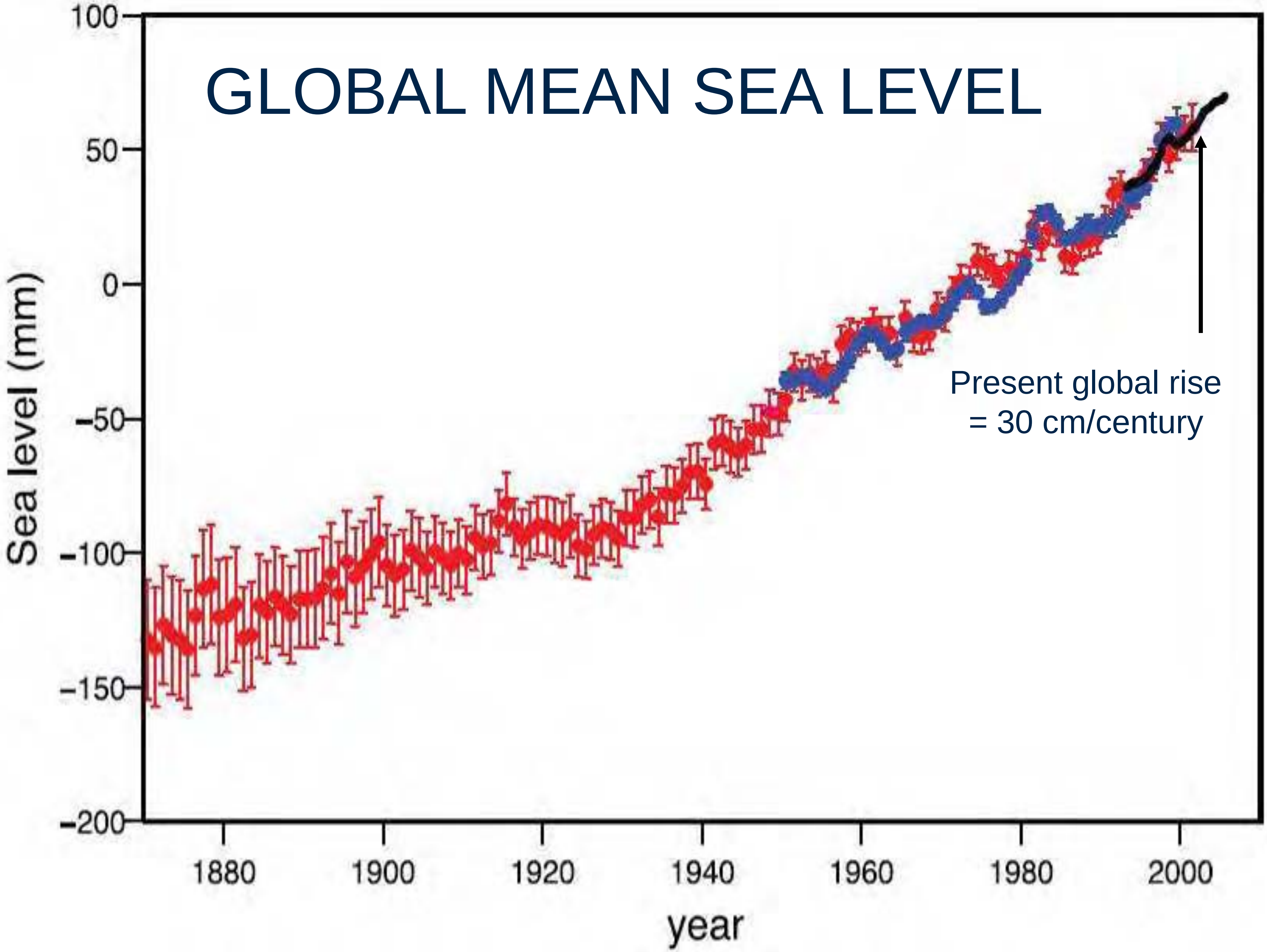
CO2 is increasing at an increasing rate,



and so are methane and the other greenhouse gasses.



Beginning in 1930, the rate of relative sea level rise increased about 8 fold over that of the past 2,000 years. It is presently rising at 30 cm (1′) / 100 years!


GLOBAL MEAN SEA LEVEL
Present global rise
= 30 cm/century
Sea level (mm)
100
50
0
-50
-100
-150
-200
1880
1900
1920
1940
1960
1980
2000
year

Most of this historic rise is the result of warmer, expanded oceans.

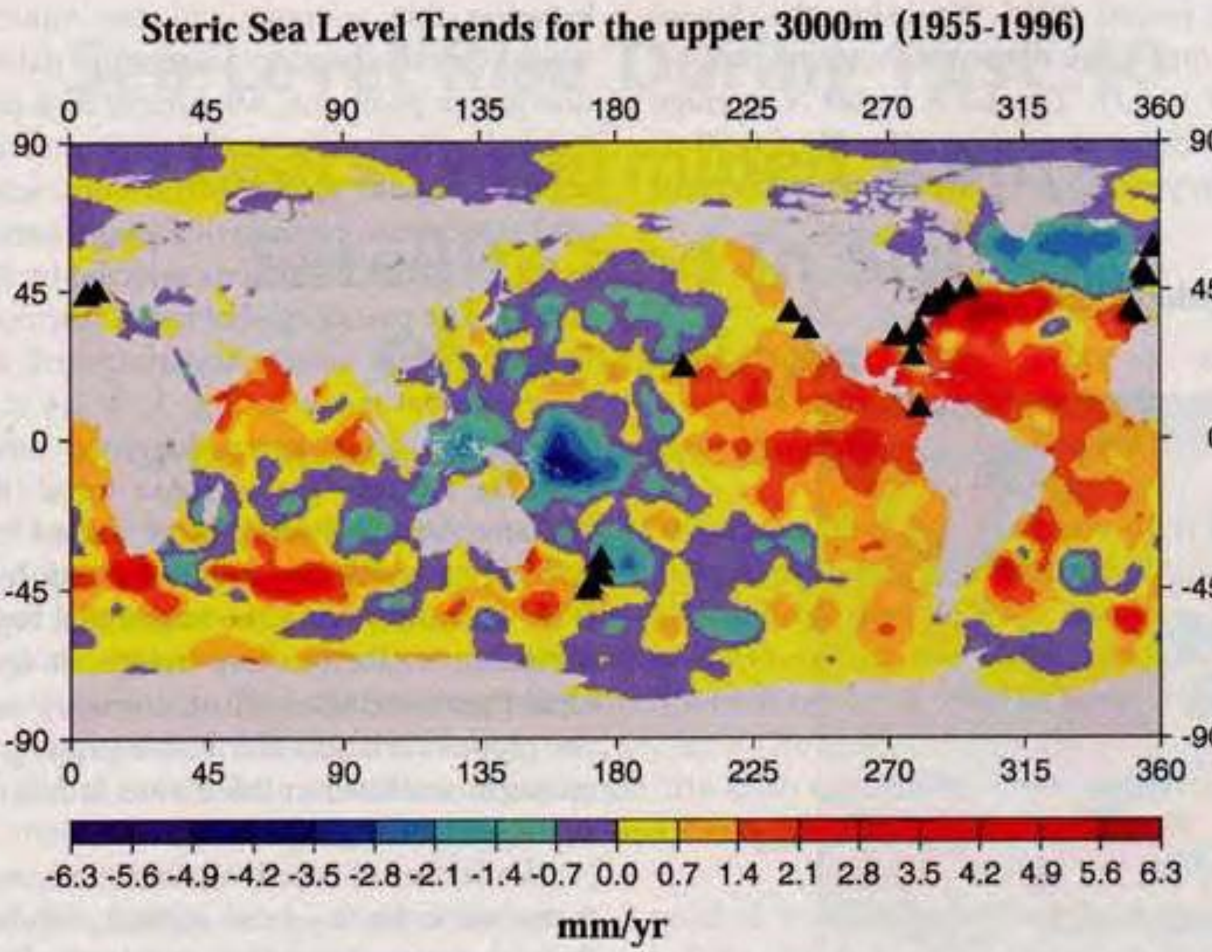


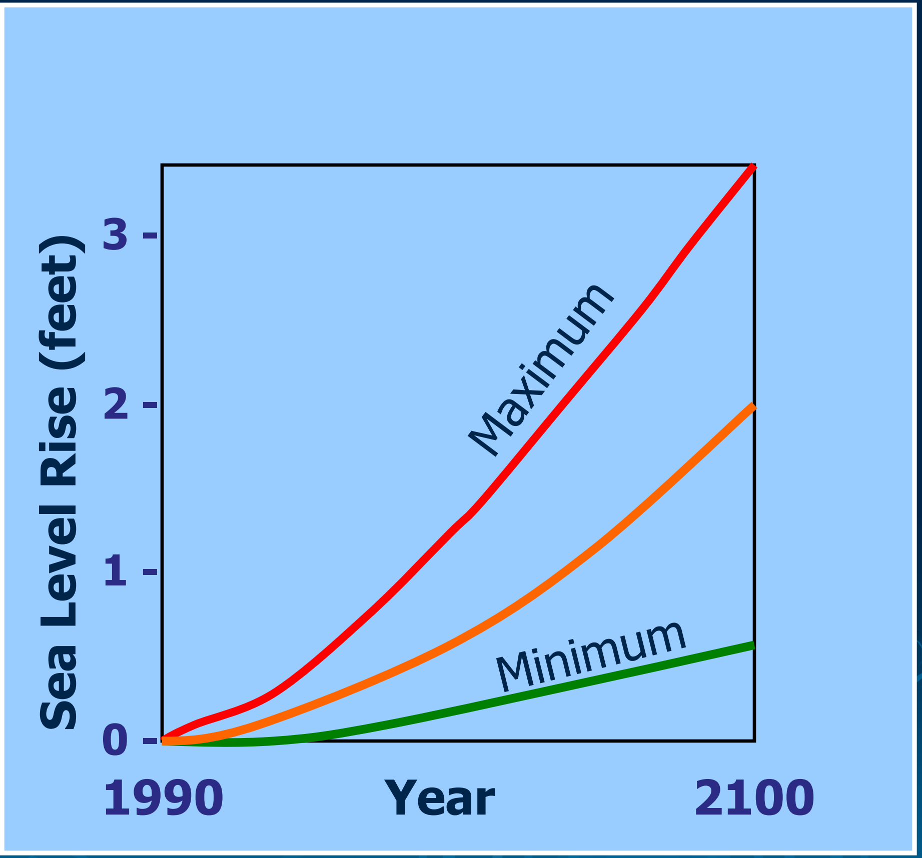
Fig. 4. Map of the geographical distribution of thermosteric sea level trends for 1955–96 computed with temperature data from (3) down to 3000-m depths. Black triangles show the locations of the 25 tide gauges.

Climate and Sea Level Do Not Respond Gradually to stresses

- Like the stress/strain concepts in physics, climate stresses, at some point will result in rapid shifts and changes and new ‘state’.
- IPCC and other climate and sea level forecasts assume gradual responses and changes / not sudden switches to new states.
- This is what has scientists studying climate, the Arctic and sea level close to panicked about the future.

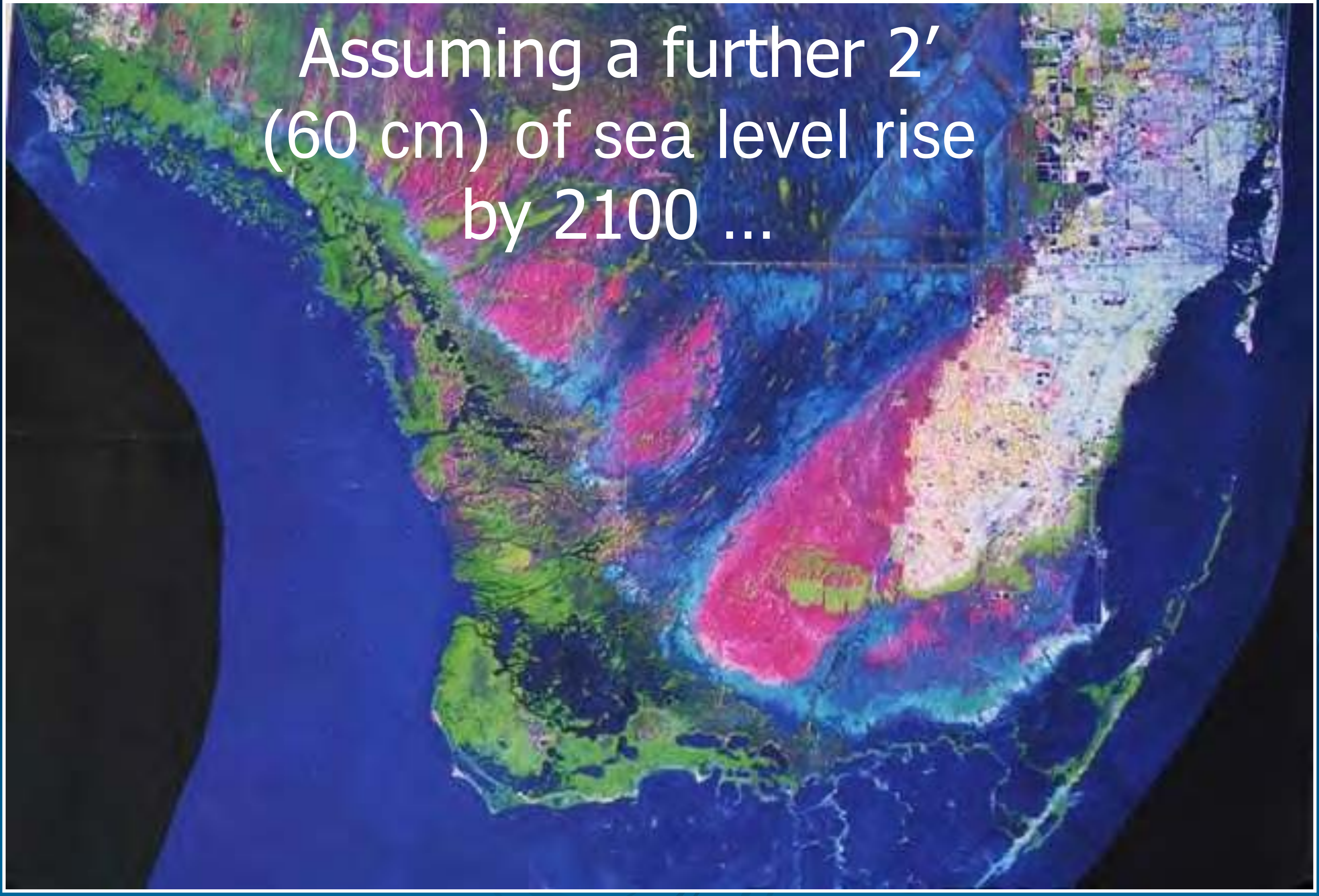
What is forecast for the future?

- Because of global warming, the 2001 UN Intergovernmental Panel on Climate Change forecasted a 2-foot further rise of sea level by 2100.
- These projections assumed a gradual linear response of climate and sea level.



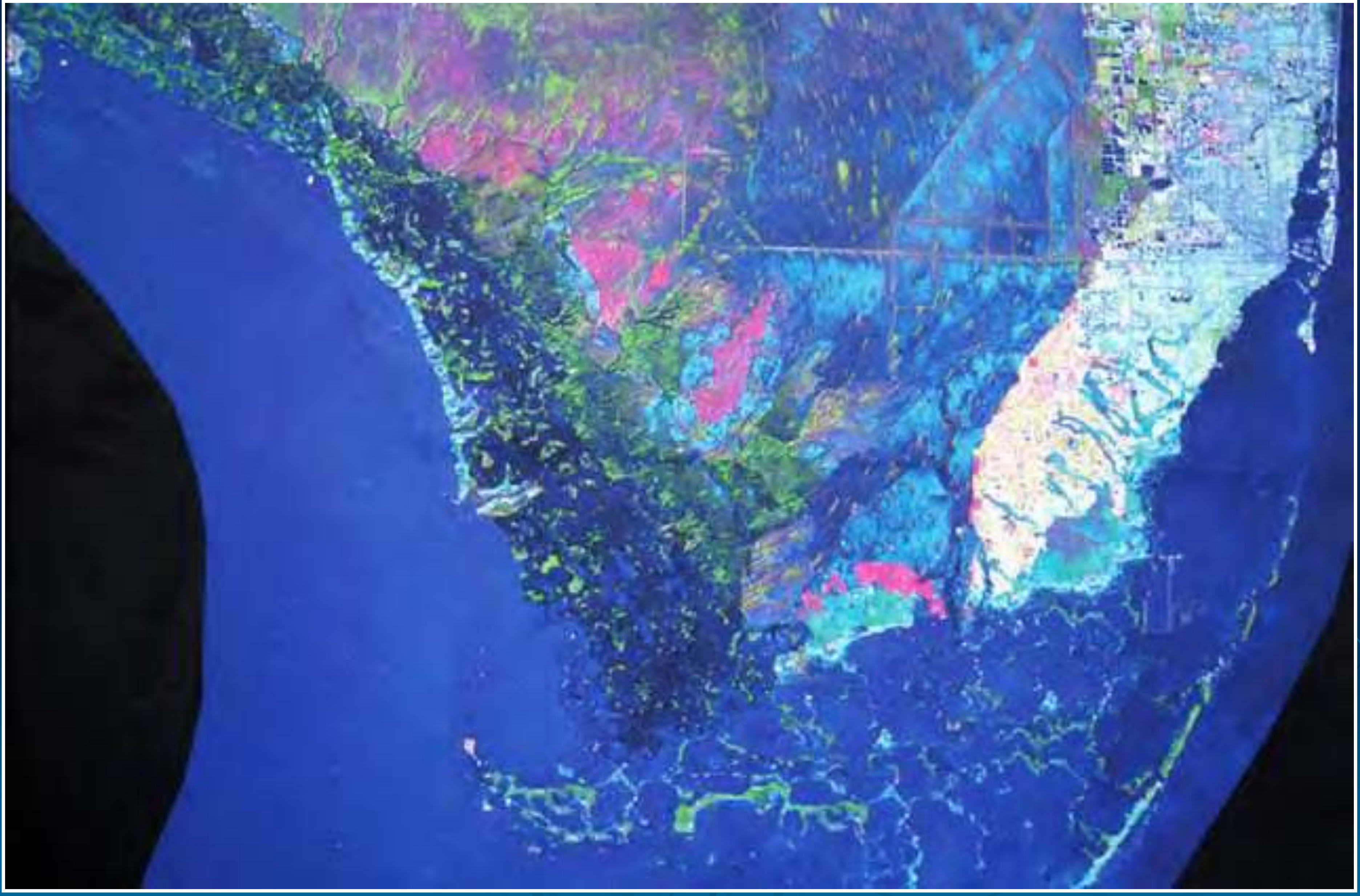
IPCC, 2001

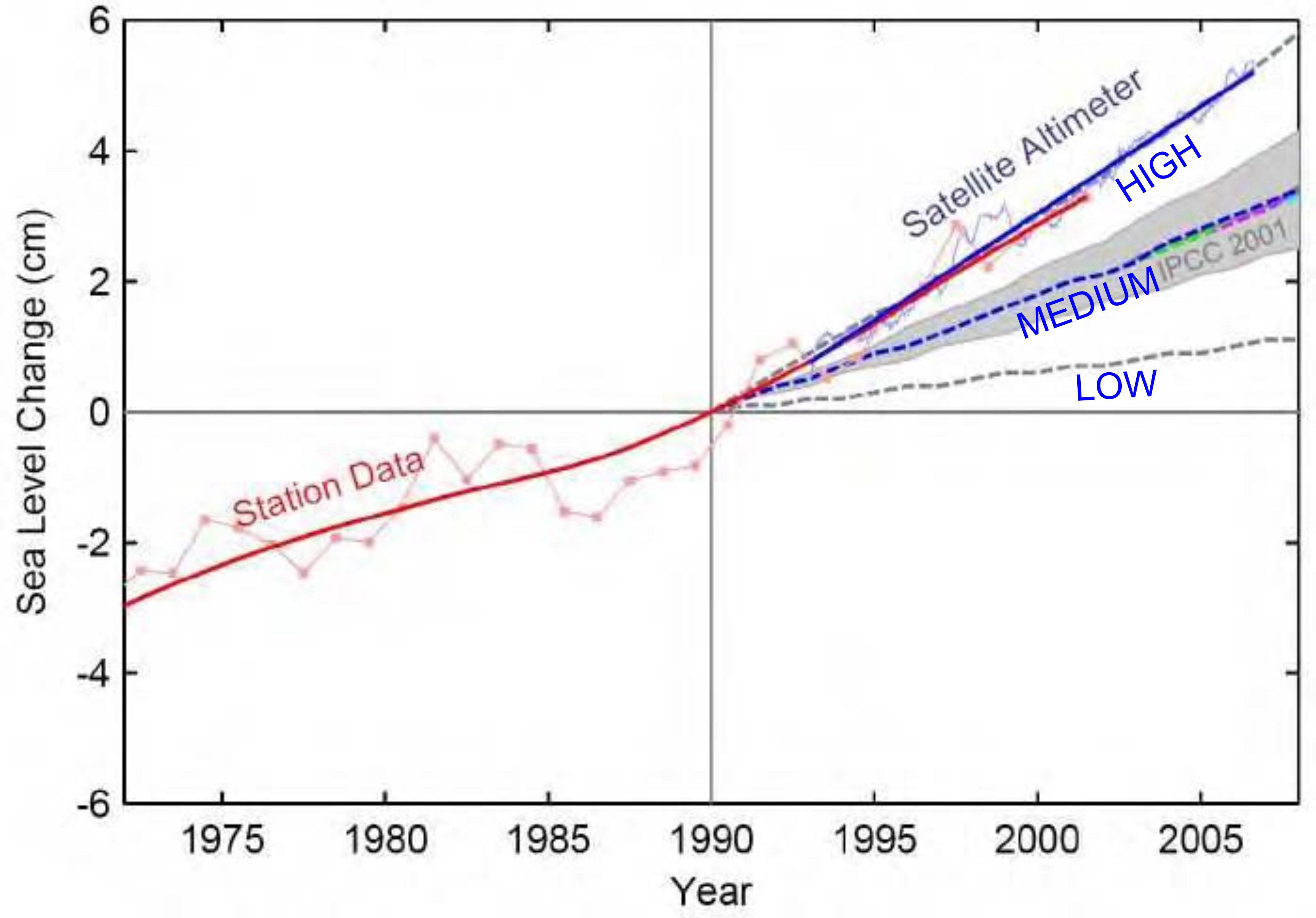
South Florida 1995



+2 foot rise (mhhw = +5.8')

South Florida 2100





Global sea level rise (based on tide gauge and satellite data) has been following the highest end of the 2001 IPCC sea level projection.

Intergovernmental Panel on Climate Change Historical Influences on Global Sea Level Rise

	Global Sea Level Rise (mm yr–1)		
Source	**1961–1992**		**1993–2003**
Thermal Expansion	0.03 ± 0.12	◄	**1.6 ± 0.5**
Glaciers and Ice Caps	0.43 ± 0.18	◄	0.77 ± 0.22
Greenland Ice Sheet	0.003 ± 0.12	◄	0.21 ± 0.07
Antarctic Ice Sheet	0.12 ± 0.41	◄	0.21 ± 0.35
Other	0.83 ± 0.7		0.3 ± 1.0
Observed	**1.8 ± 0.5**		**3.1 ± 0.7**

Calculated from IPCC, 2007

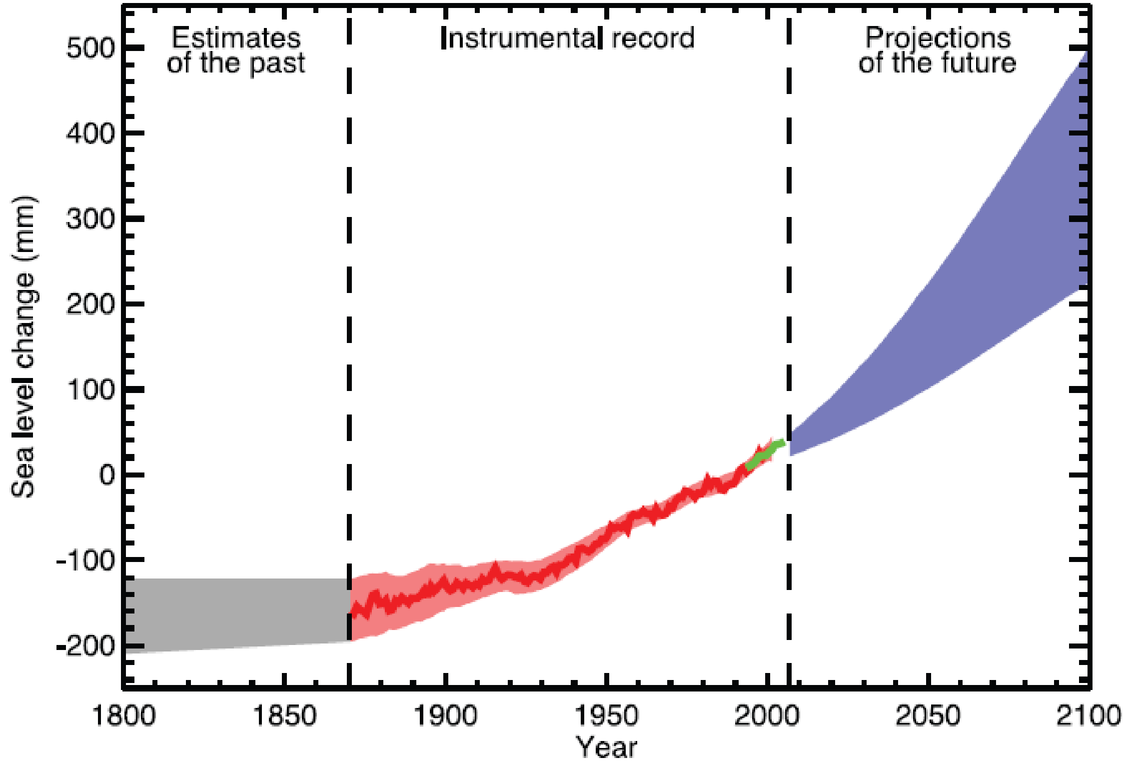
IPCC 2007
Projection For Coming Century

"Thermal expansion is projected to contribute more than half of the average rise, but land ice will lose mass increasingly rapidly as the century progresses.

"An important uncertainty relates to whether discharge of ice from the ice sheets will continue to increase as a consequence of accelerated ice flow, as has been observed in recent years.

"This would add to the amount of sea level rise, but quantitative projections of how much it would add cannot be made with confidence, owing to limited understanding of the relevant processes."

IPCC 2007 Projection



FAQ 5.1, Figure 1. *Time series of global mean sea level (deviation from the 1980-1999 mean) in the past and as projected for the future. For the period before 1870, global measurements of sea level are not available. The grey shading shows the uncertainty in the estimated long-term rate of sea level change (Section 6.4.3). The red line is a reconstruction of global mean sea level from tide gauges (Section 5.5.2.1), and the red shading denotes the range of variations from a smooth curve. The green line shows global mean sea level observed from satellite altimetry. The blue shading represents the range of model projections for the SRES A1B scenario for the 21st century, relative to the 1980 to 1999 mean, and has been calculated independently from the observations. Beyond 2100, the projections are increasingly dependent on the emissions scenario (see Chapter 10 for a discussion of sea level rise projections for other scenarios considered in this report). Over many centuries or millennia, sea level could rise by several metres (Section 10.7.4).*

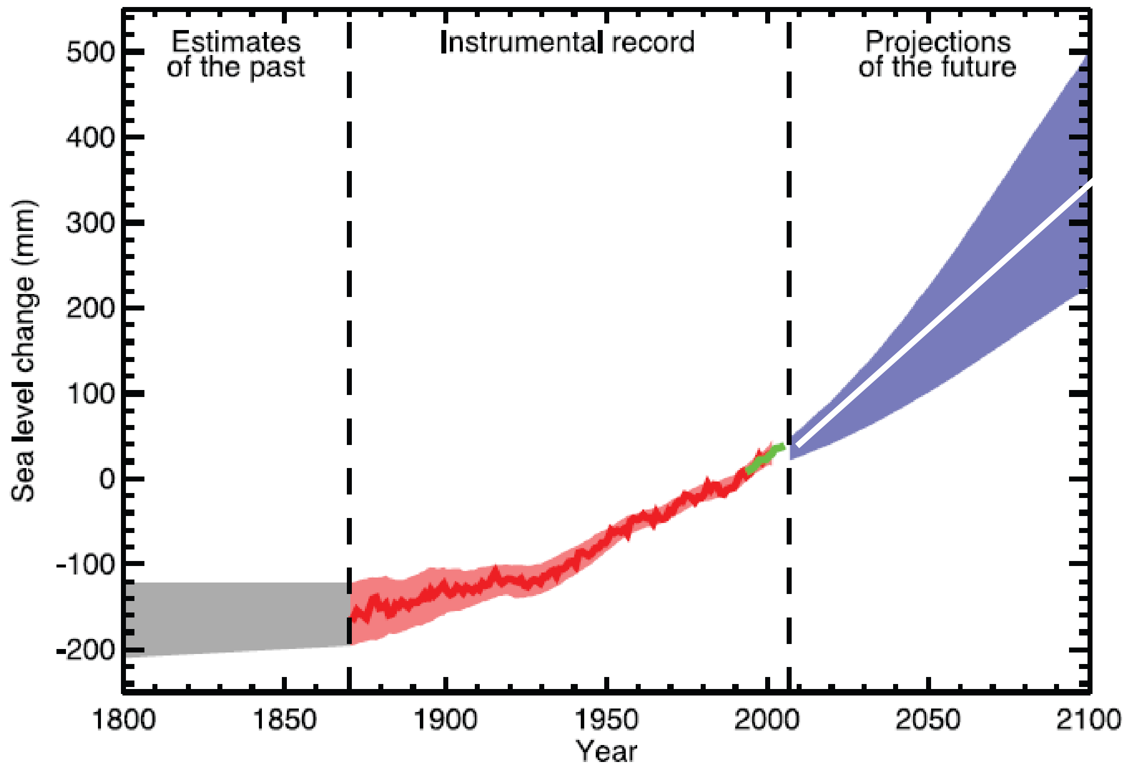
30 cm = 1 foot

This projection has over half the sea level rise as because of warming (expansion) of the ocean water

i.e. only 10-25 cm would be from melting ice input by glacial and ice cap ice.

IPCC, 2007

IPCC 2007 Projection



FAQ 5.1, Figure 1. *Time series of global mean sea level (deviation from the 1980-1999 mean) in the past and as projected for the future. For the period before 1870, global measurements of sea level are not available. The grey shading shows the uncertainty in the estimated long-term rate of sea level change (Section 6.4.3). The red line is a reconstruction of global mean sea level from tide gauges (Section 5.5.2.1), and the red shading denotes the range of variations from a smooth curve. The green line shows global mean sea level observed from satellite altimetry. The blue shading represents the range of model projections for the SRES A1B scenario for the 21st century, relative to the 1980 to 1999 mean, and has been calculated independently from the observations. Beyond 2100, the projections are increasingly dependent on the emissions scenario (see Chapter 10 for a discussion of sea level rise projections for other scenarios considered in this report). Over many centuries or millennia, sea level could rise by several metres (Section 10.7.4).*

30 cm = 1 foot

White line in projection is a continuation of currently observed rate of rise (green line).

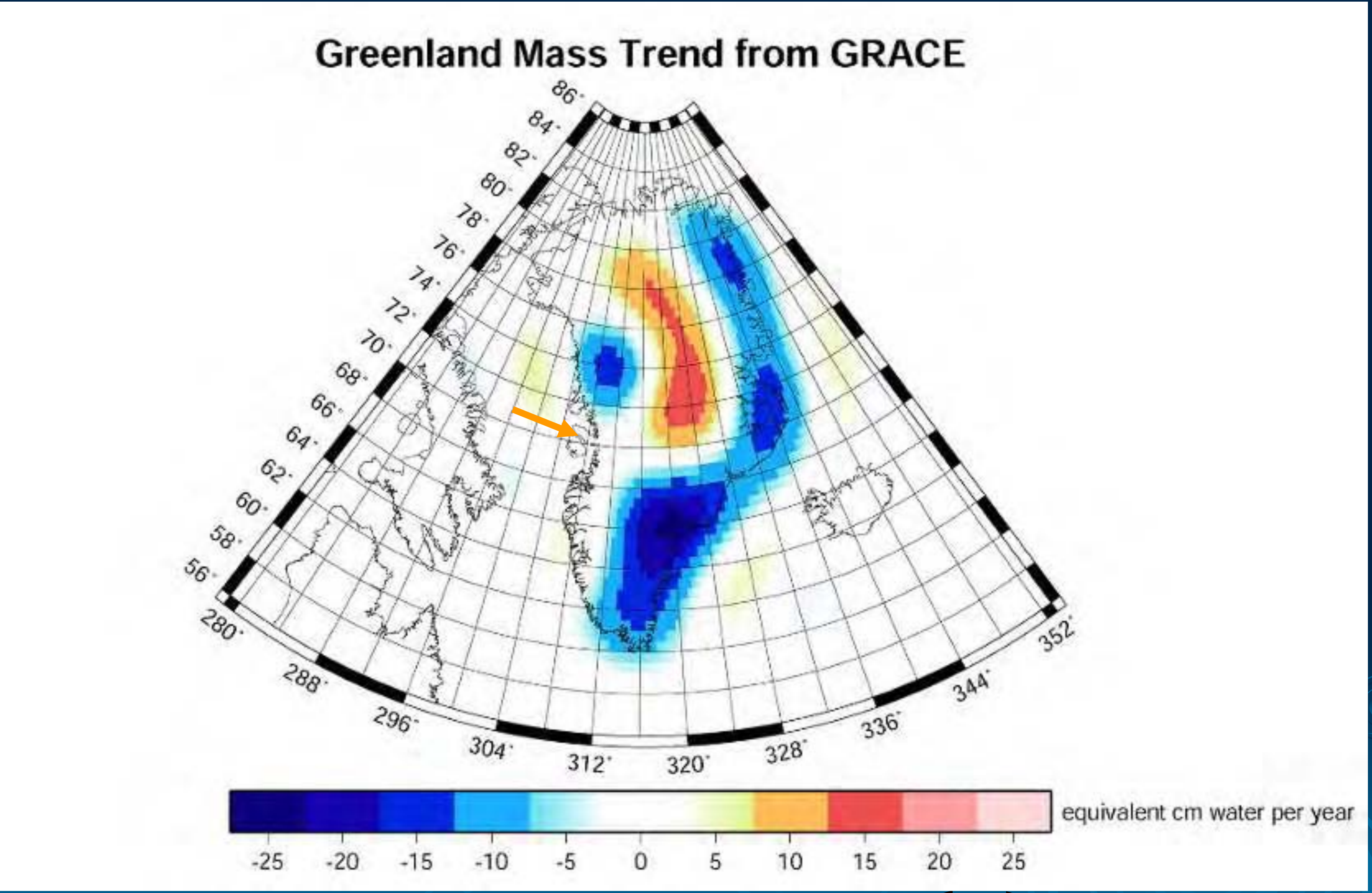
In other words, the 2007 IPCC report projects no increase in rate of global sea level rise through this century!

IPCC, 2007

The Answers to Florida's future lie in the Arctic

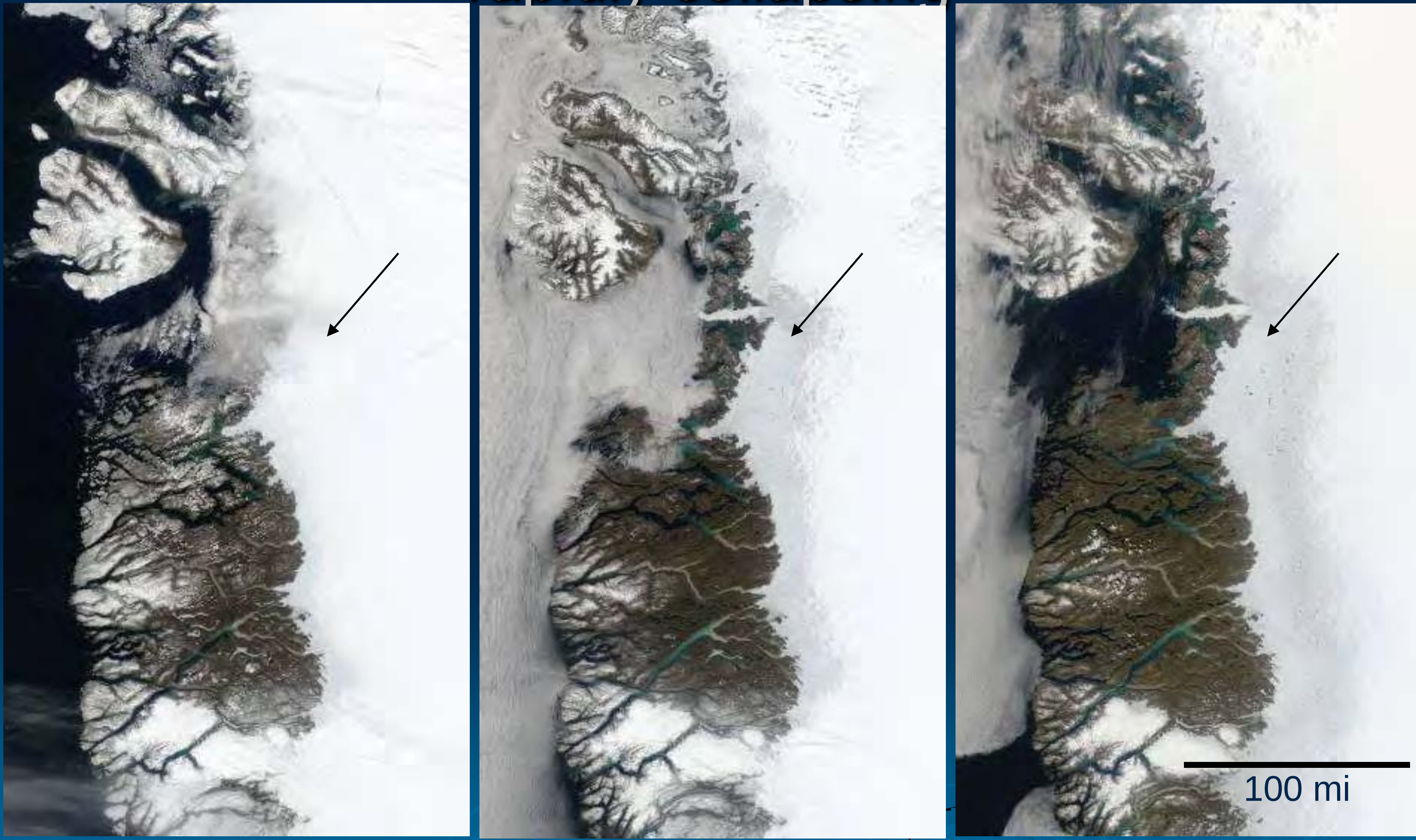
Since 2000,
the Greenland Ice Sheet
and the Arctic Ocean pack ice
have been rapidly falling apart.

Change in mass 2003-2005

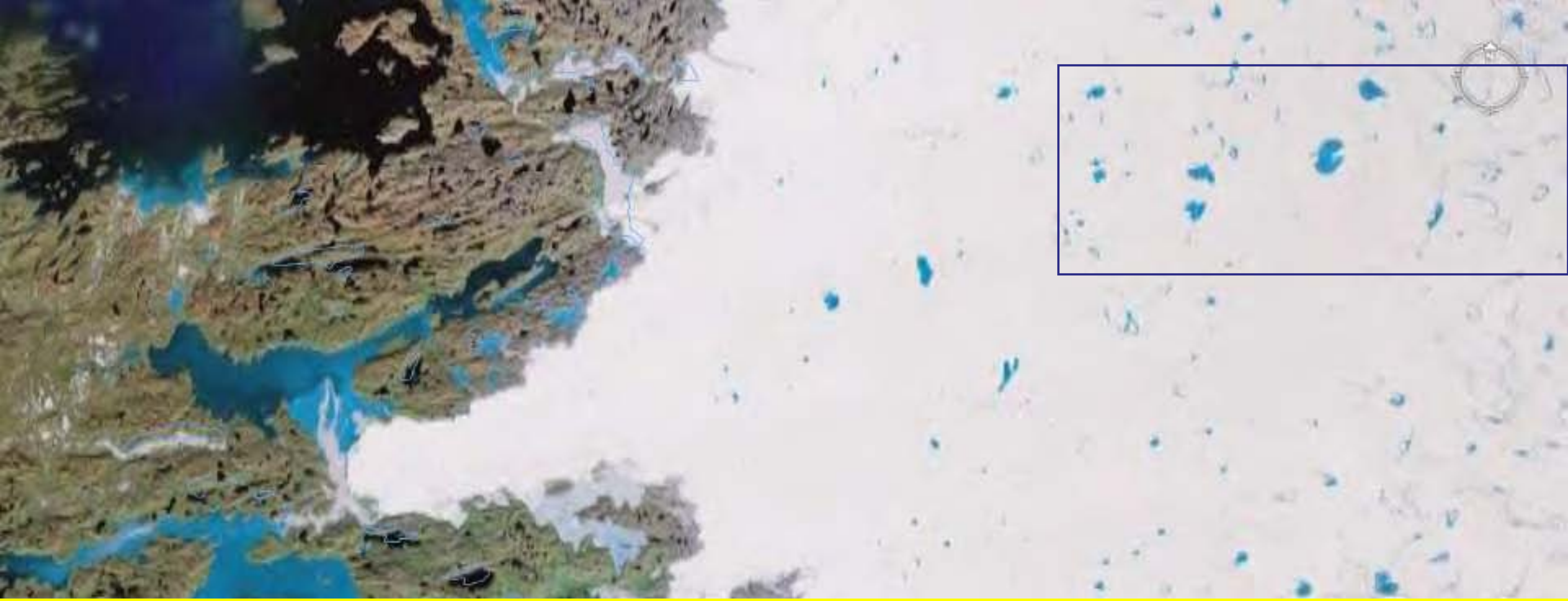


Melt zone is expanding northwards and to higher elevations

The margins of the Greenland ice sheet is rapidly collapsing



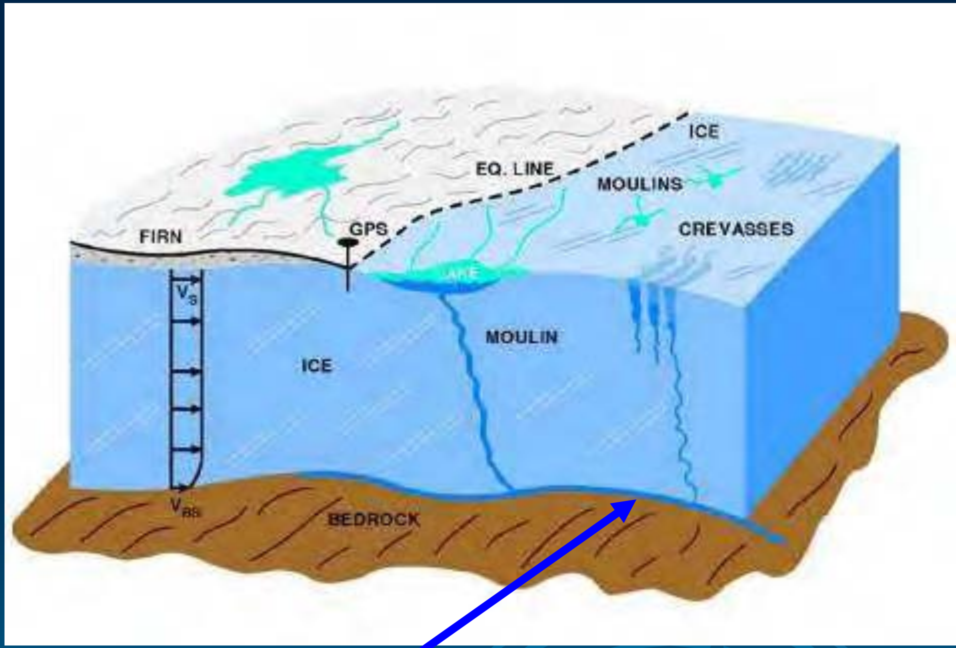
2001 2002 2003



Lakes, rivers and moulins (openings through which water pours down through the ice) in the Greenland Ice Sheet

MOULINS

Like karst in limestones



Water lubricates base of ice sheet

- Thousands of moulins 10-15 meters across have opened up all over.
- melt water is pouring through to the bottom of the glacier, creating a lake 500 meters deep causing the glacier "to float on land."
- These melt-water rivers are lubricating the glacier, like applying oil to a surface and causing it to slide into the sea. It is causing a massive acceleration which could be catastrophic.

(Dr. Robert Corell, Chair Arctic Climate Impact Assessment, Sept 8, 2007)

- The Jacobshavn Isbreen (5 km wide and 1.5 km deep) is now moving at 15km a year into the sea, although in surges it moves even faster. 'One surge moved 5 km in 90 minutes - an extraordinary event. It's exuding like toothpaste.'

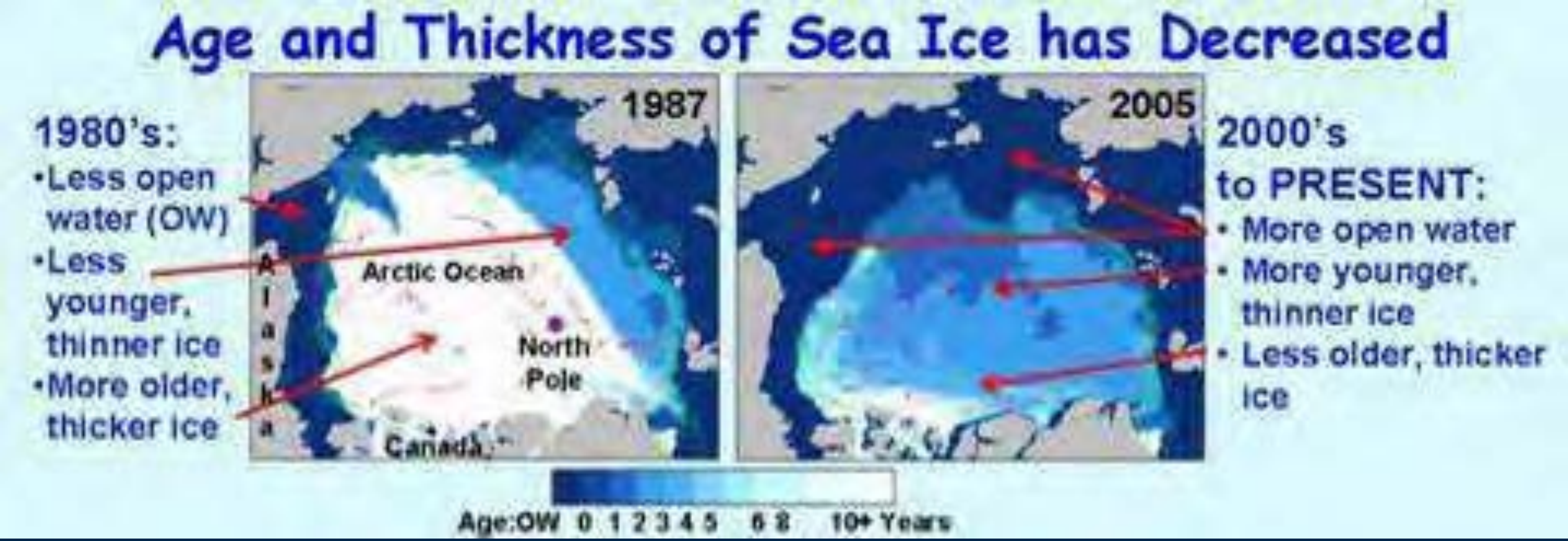
(Dr. Robert Corell, Chair Arctic Climate Impact Assessment, Sept 8, 2007)

Jacobshavn Isbreen I in Ilulissat, Vestgrønland (Greenland); Photograph by Dirk Jenrich

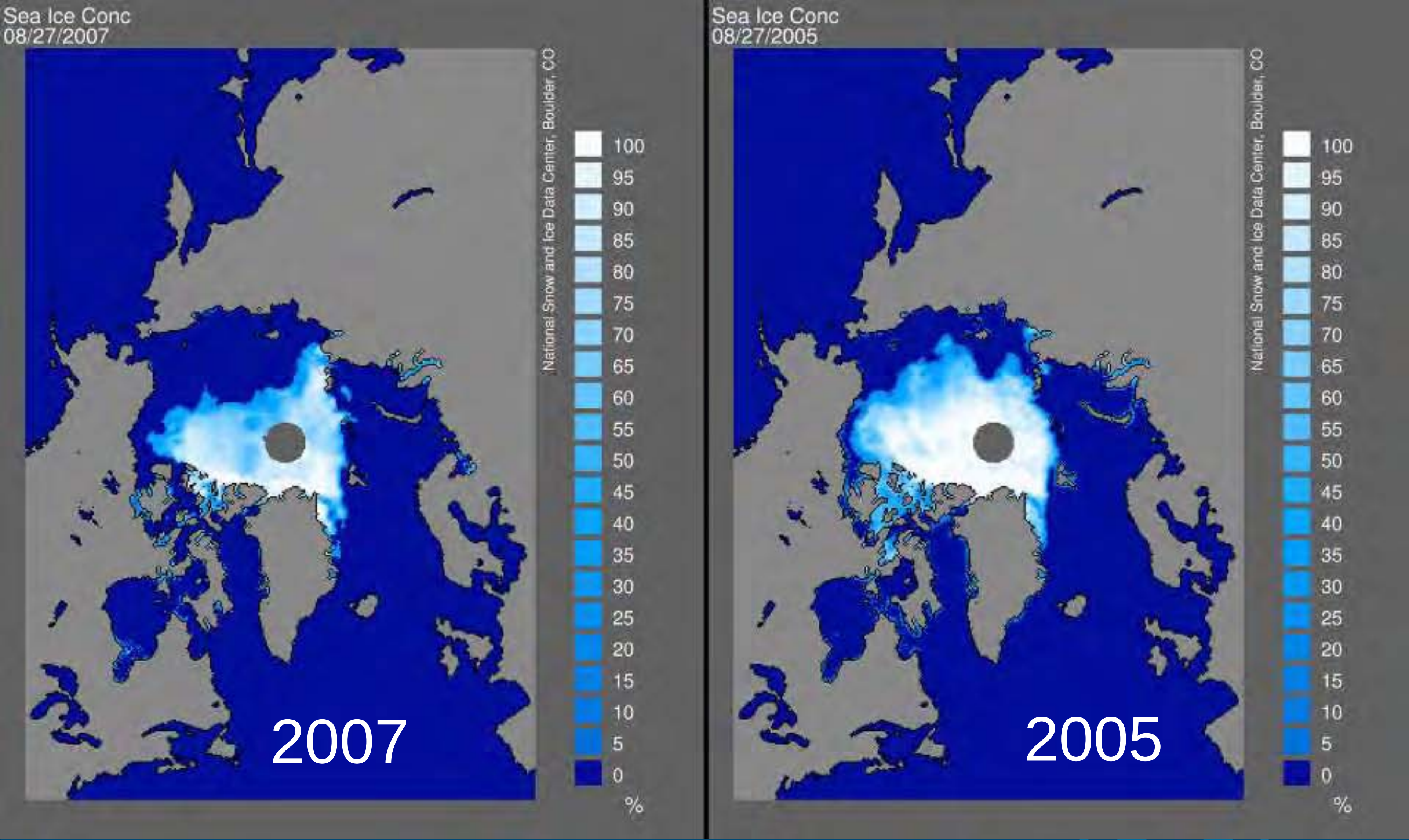
- "Five years ago we made models predicting how much ice would melt and when. "Five years later we are already at the levels predicted for 2040, in a year's time we'll be at 2050."

(Veli Albert Kallio, Finnish polar/ice scientist, September 8, 2007)

Arctic Pack Ice Cover

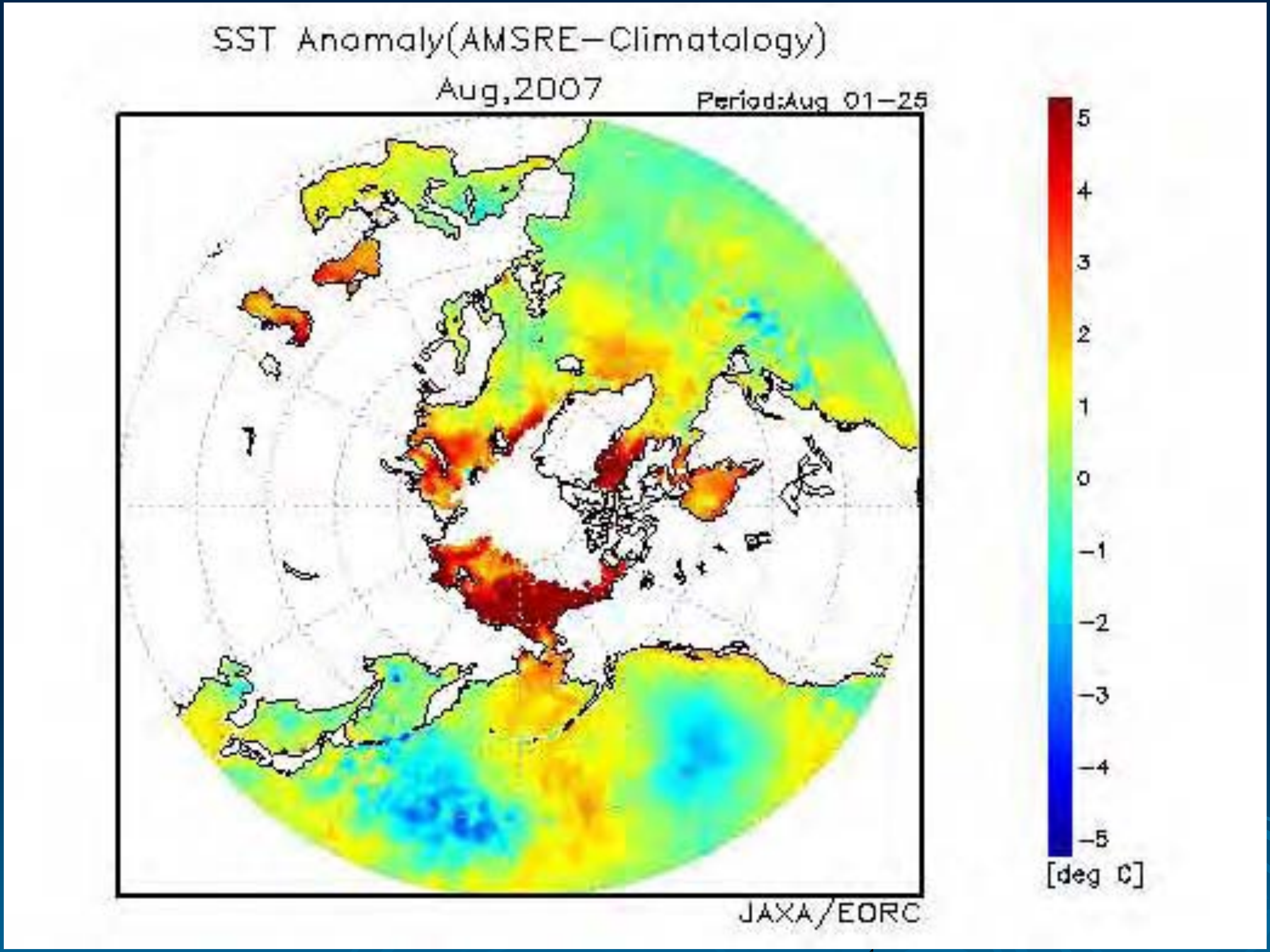


a powerful control on Arctic ocean and land temperatures, permafrost, and methane and carbon dioxide release.



This year the floating Arctic pack ice covered 33% less area than the previous record low in 2005. It is so thin and broken, it could easily just float out into the Atlantic.

Sea Surface Temperature Anomaly



Earth Observation Research Center, Japan Aerospace Exploration Agency

JAXA EORC

North Pole web cam – August 25, 2007

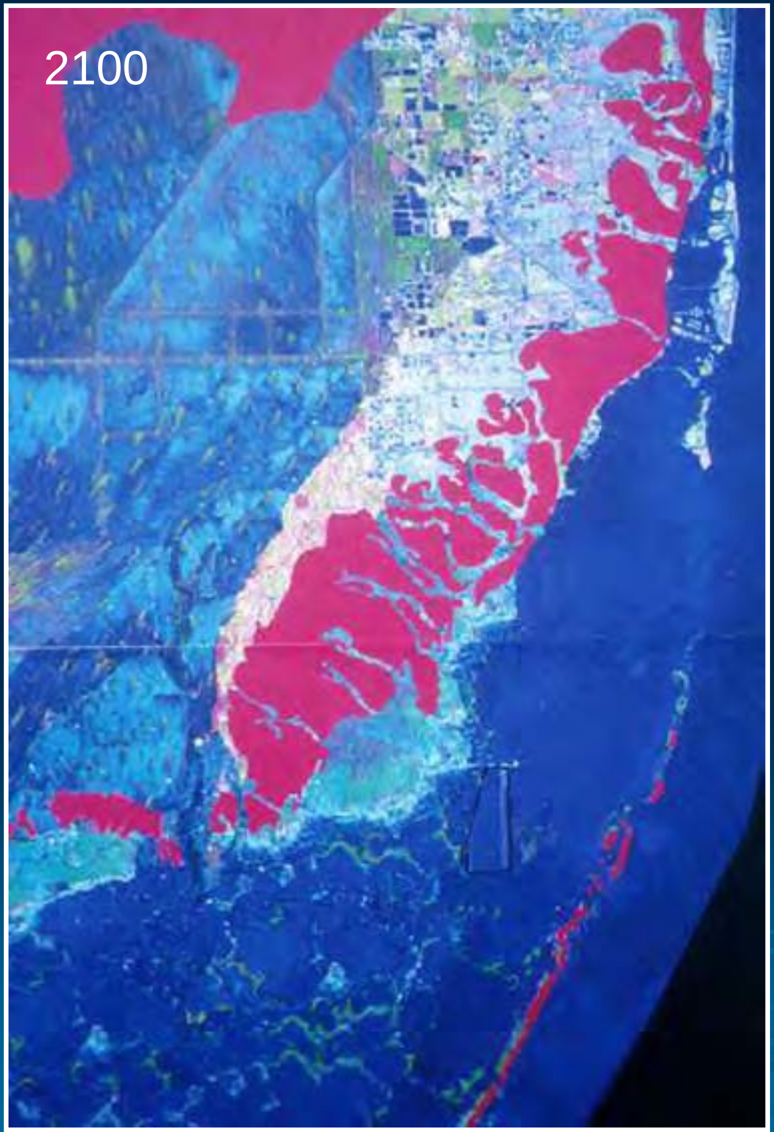
Ice reflects nearly all incoming solar radiation back into the air and space. Open water absorbs over 90% of incoming solar radiation

Scientists on the Miami-Dade Climate Change Task Force:

- “With what is happening in the Arctic and Greenland, [there will be] a likely sea level rise of **at least** 1.5 feet in the coming 50 years and a total of **at least** 3-5 feet by the end of the century, possibly significantly more. Spring high tides would be at +7 to +9 feet.
- “This does not take into account the possibility of a catastrophically rapid melt of land-bound ice from Greenland, and it makes no assumptions about Antarctica.”
- “The projected rises will just be the beginning of further significant releases from Greenland and possibly Antarctica.”

(September 20, 2007)

Red is areas today with limestone more than 5' above 'sea level' (NGVD 1927).

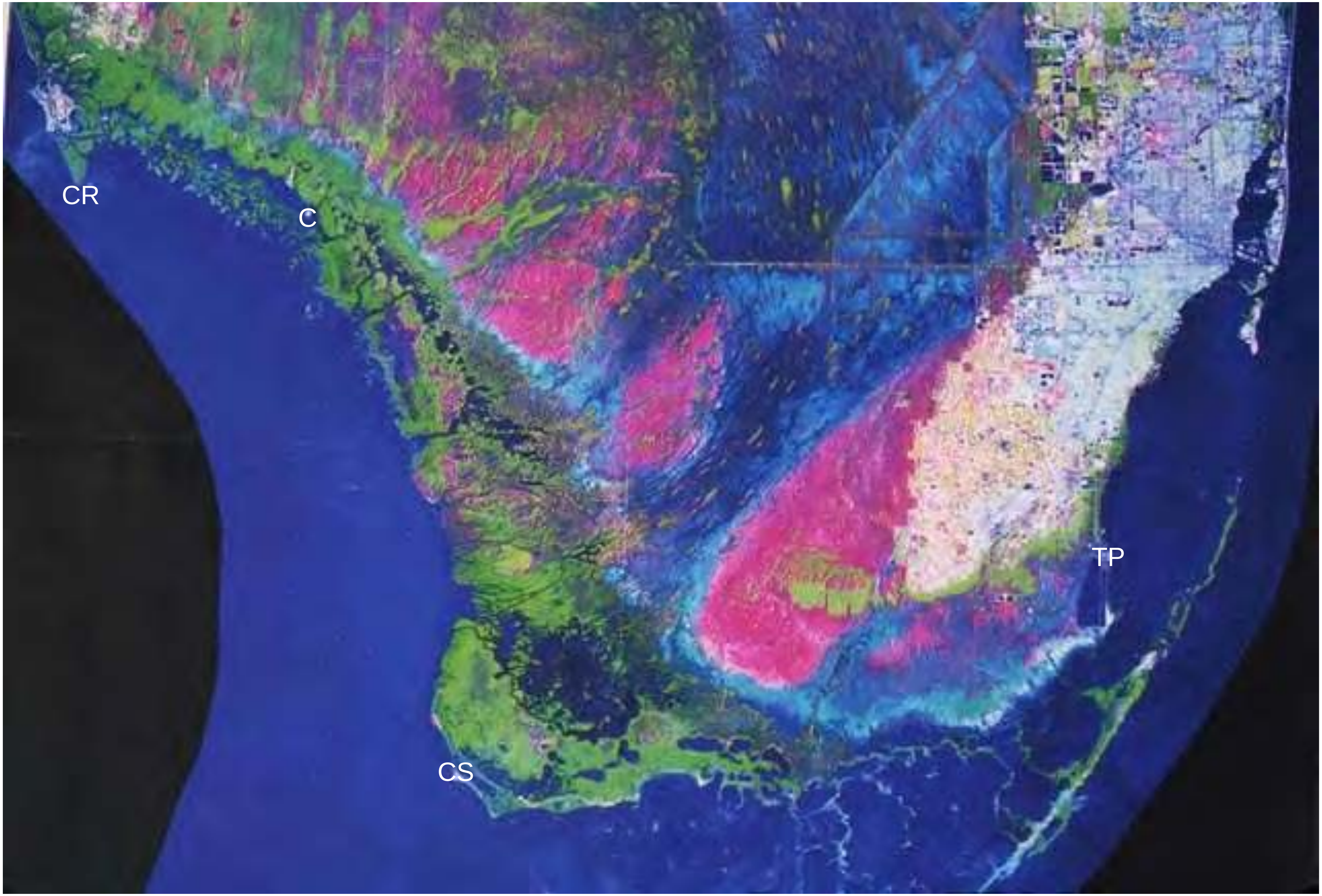


NGVD 1927: 0′ is mean lower low water in 1927.

Today, mean higher high water (MHHW) is about +3.8′.

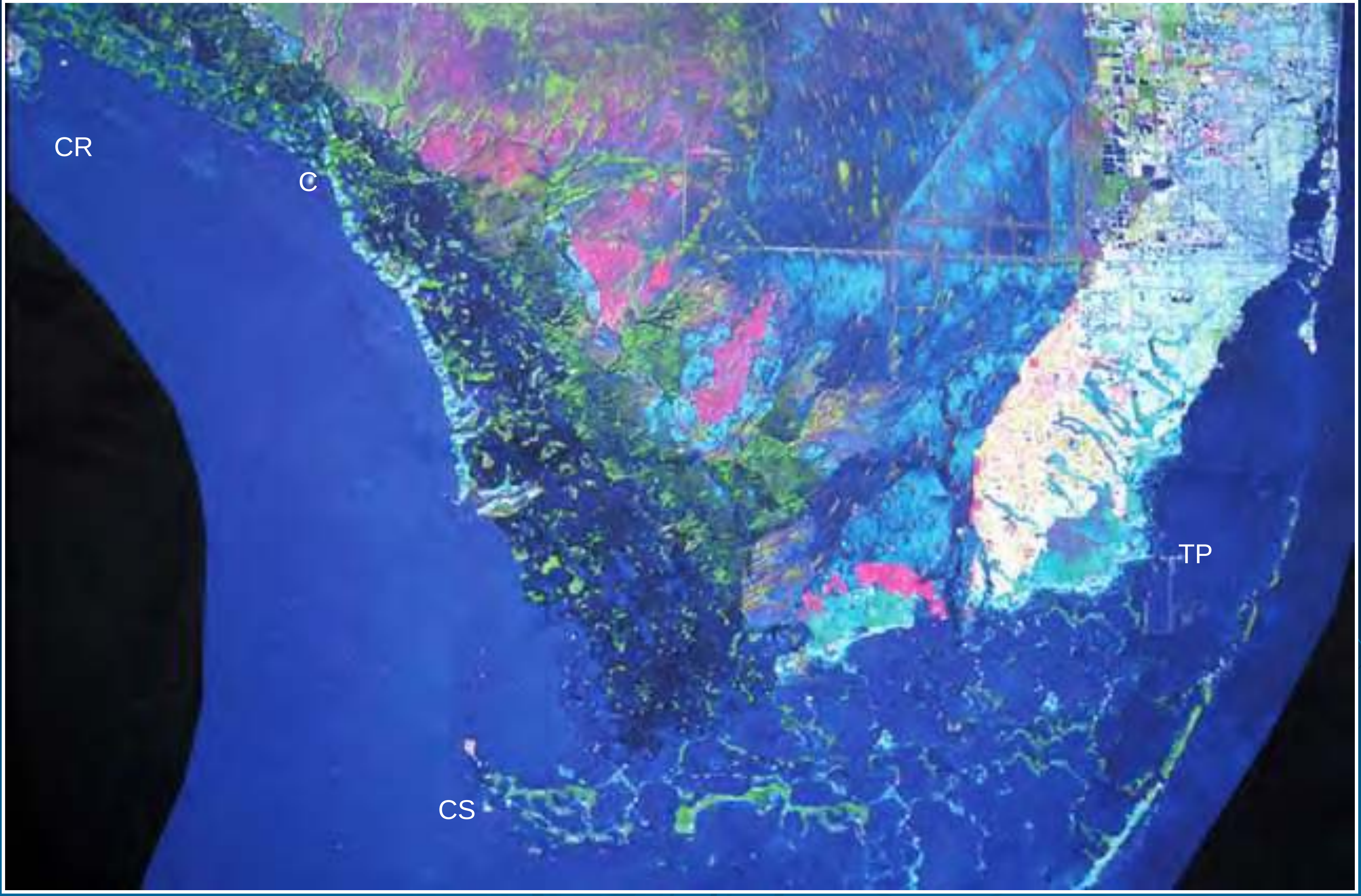
With a 2 ft rise, MHHW will be about +5.8′.

South Florida 1995



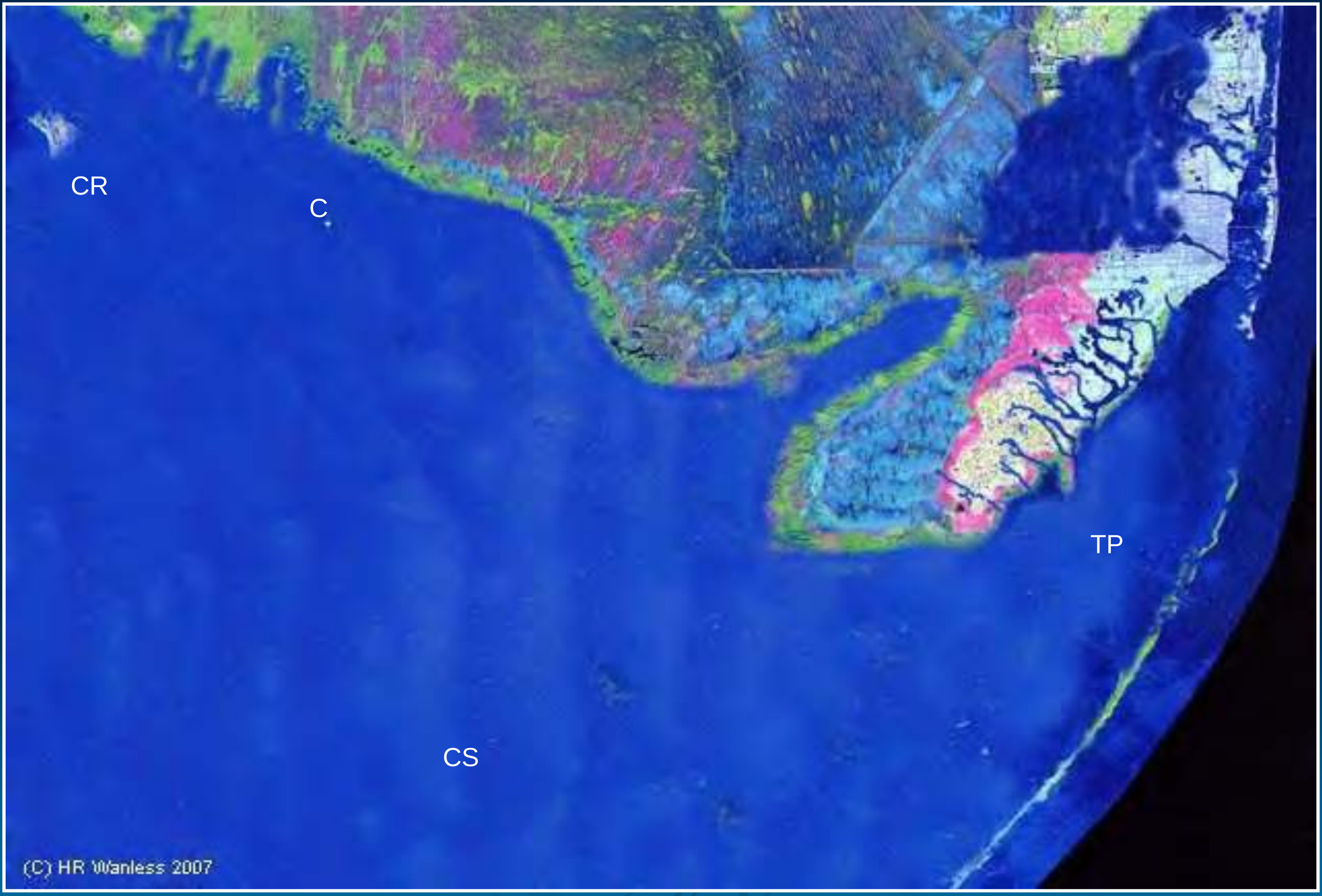
+2 foot rise (mhhw = +5.8’)

South Florida 2100



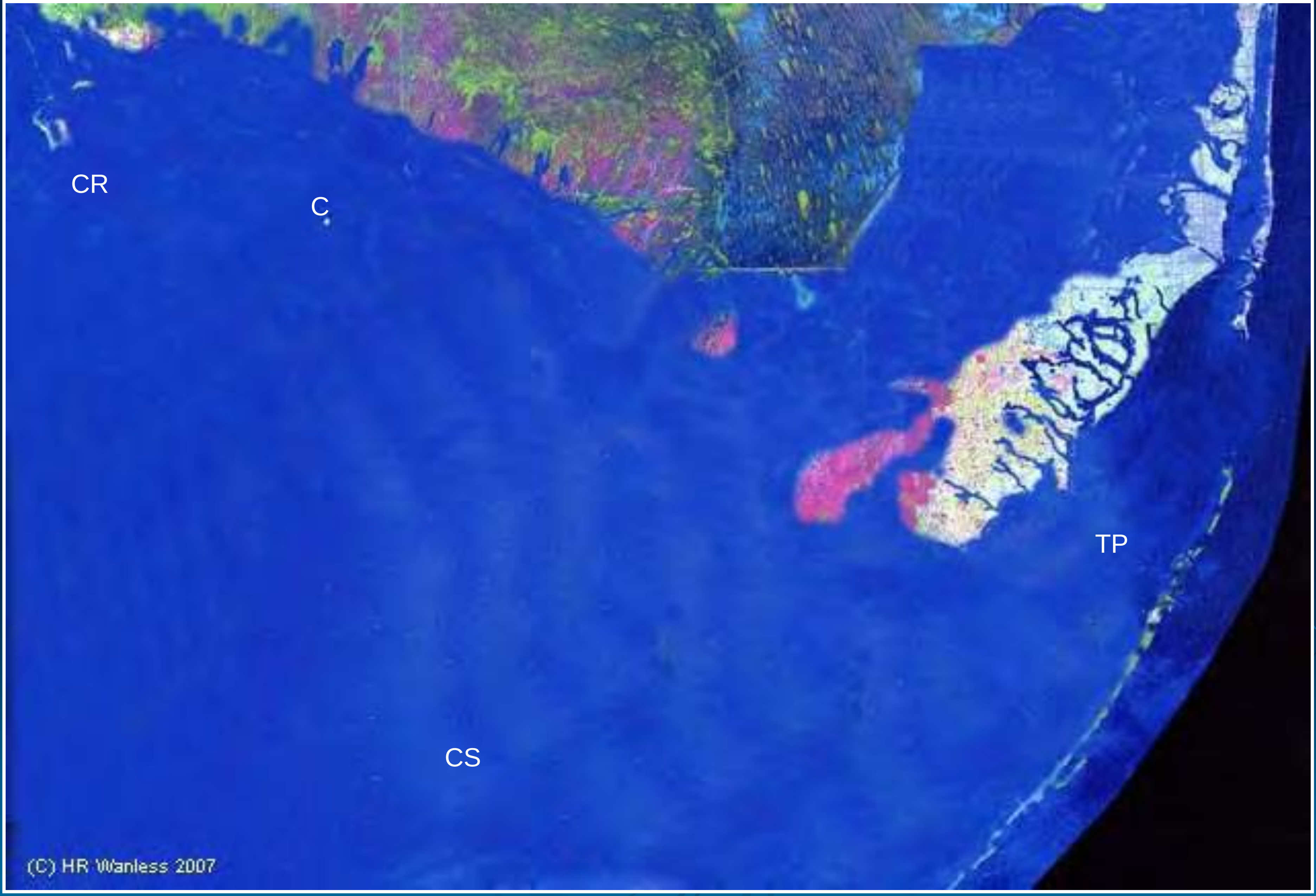
+3 foot rise (mhhw = +6.8')

South Florida 2100



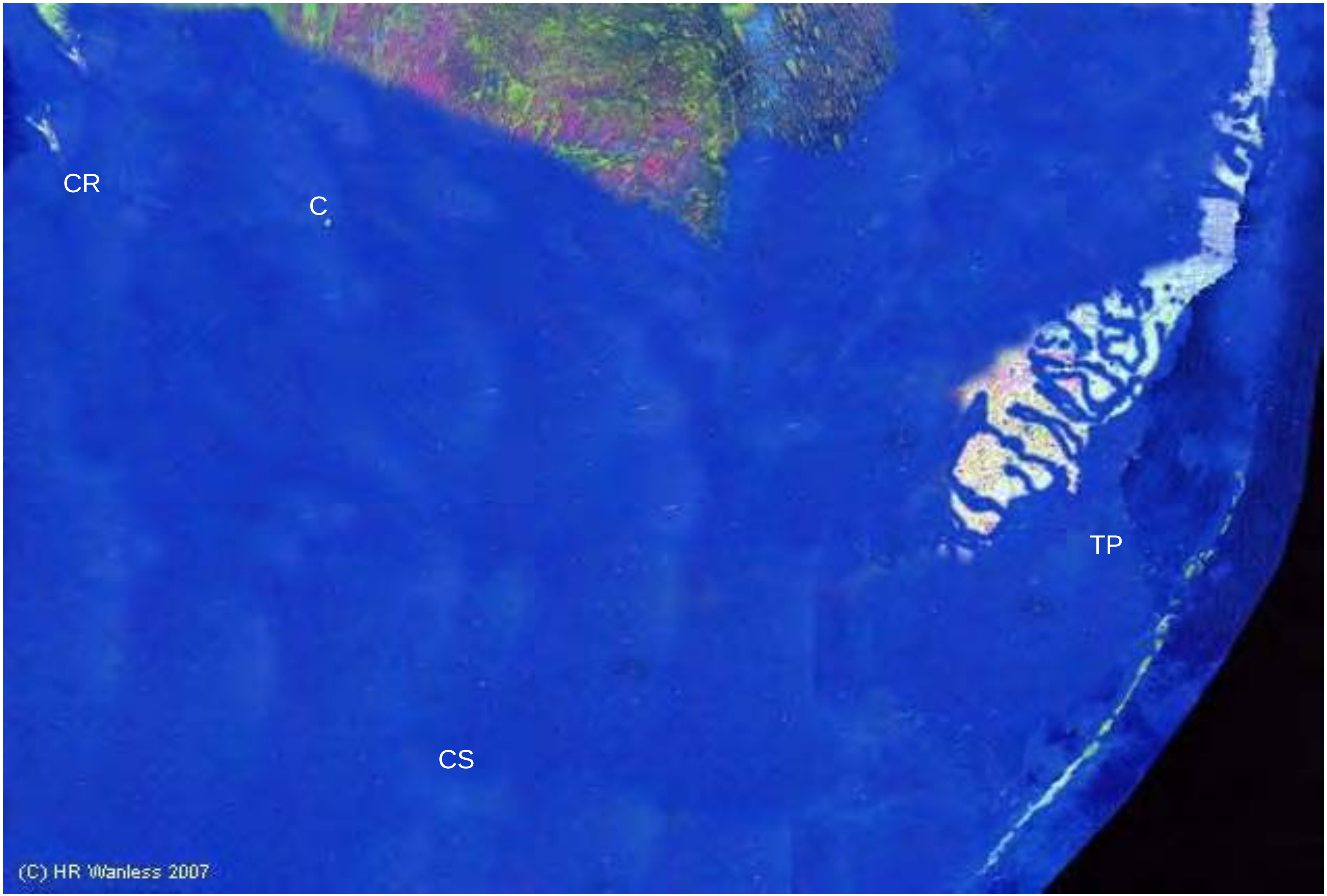
+4 foot rise (mhhw = +7.8')

South Florida 2100



+5 foot rise (mhhw = +8.8')

South Florida 2100



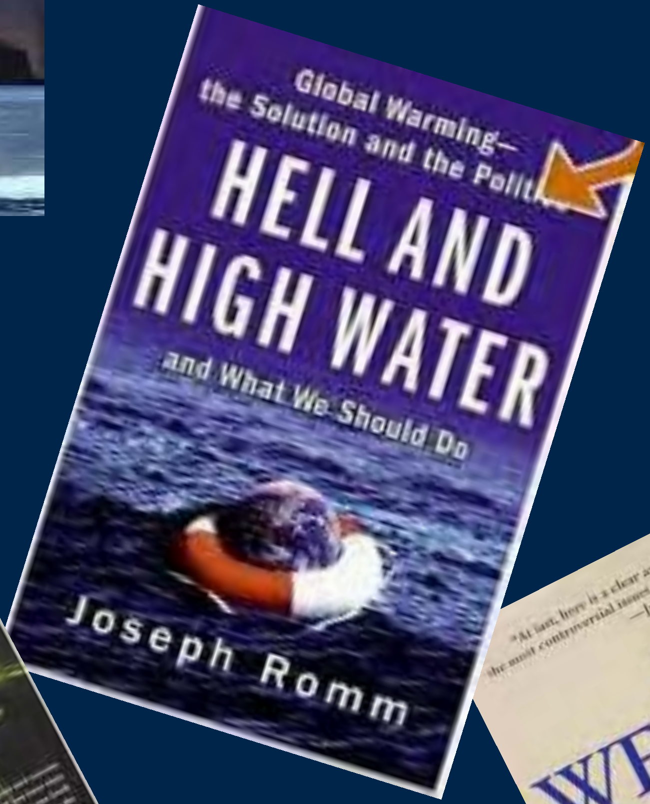
Florida has a close to catastrophic evolution of its coastal environments, infrastructure and resources coming this century.

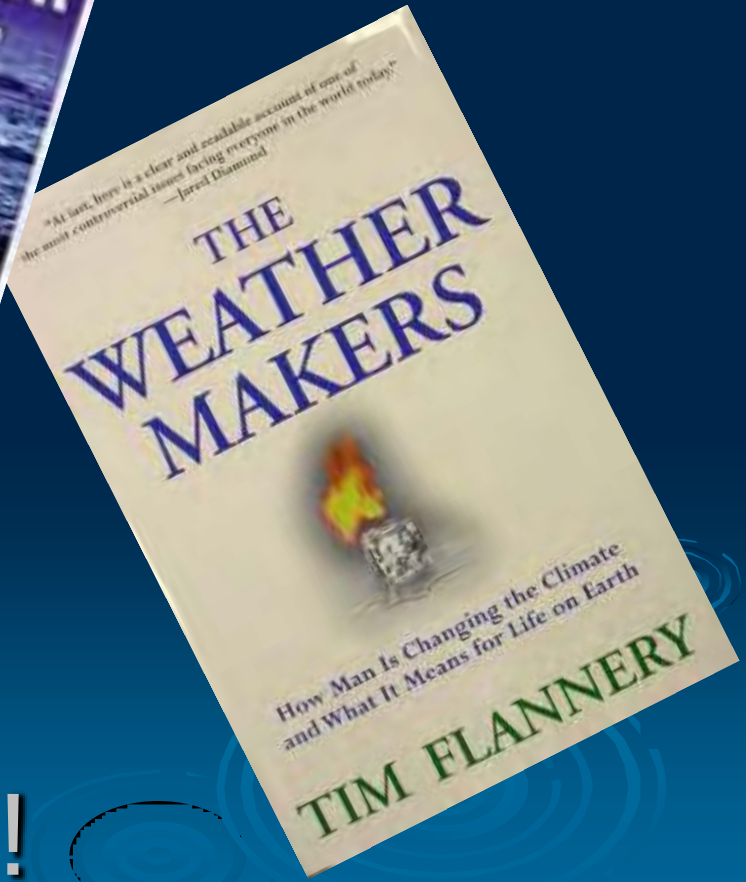
Cape Romano, November 18, 2003

HUMAN-INDUCED GLOBAL WARMING IS VERY REAL.

It is time to become much more responsible in how we manage Florida and pass it on to our children.

realclimate.org





Learn more;
manage wisely!!

hwanless@miami.edu

STATEMENT ON SEA LEVEL IN THE COMING CENTURY

Science and Technology Committee
Miami-Dade County Climate Change Task Force.
September 19, 2007

Significant sea level rise is a very real threat to the near future for Miami-Dade County.

BACKGROUND: Over the past 2,500 years south Florida has experienced an average rate of relative sea level rise[1] of about 1.5 inches per century. Over this time our sandy, mangrove and muddy coastlines were mostly stable or expanding seawards. The broad coastal wetlands and historically stable sandy coastlines of south Florida are a product of this prolonged period of very gradual sea level rise.

Since 1932, south Florida has had about a 9 inch relative rise of sea level. This is a rate of one foot per century and is about 8 times the average rate over the past 2,500 years. Much of this accelerated rise is the result of warming (and expansion) of water in the western North Atlantic Ocean in response to global warming. Our coastal and shallow-marine environments are now evolving in response to the stresses of this rising sea level.

EVALUATION: The 2001 report of the United Nations sponsored Intergovernmental Panel on Climate Change (IPCC) projected an additional sea level rise over the coming century of 1-3 feet (median level rise of 2 feet.). The 2007 IPCC report projected a somewhat lower level, but it did not incorporate the significantly accelerated melting being observed in the Greenland Ice Sheet (apparently because the results had not yet been published in peer-reviewed science journals). As a result, the IPCC report, which should be the guidance for the future, underestimates the amount of sea level rise that is likely to occur in this century.

Since 2000, rapid changes have been occurring to the Greenland Ice Sheet - changes that were projected to begin at the end of this century. Over this past decade, there has also been rapid loss of multiyear pack ice in the Arctic Ocean, a phenomenon not projected to occur until 2070. Simply put, climate and glacial scientists now see that models failed to predict the rapidity and quickness with which these critical changes would occur.

Both the Arctic Ocean and Greenland Ice Sheet have important 'positive feedback' effects that are driving these accelerated changes. Positive feedbacks are secondary effects that further reinforce and accelerate the primary changes. For the Greenland Ice Sheet, (a) summer melt water on the lower elevation margins of the ice sheet is forming surface pools on the ice which absorb incoming solar energy, thus accelerating melting; (b) the melted surface water is flushing down to the bottom through fractures and dissolved moulins (vertical holes) in the ice sheet, forming a lubricated layer over the rock which is dramatically accelerating the rate of the ice sheet breakup and movement towards the sea; and (c) as the ice sheet margins melt and move towards the sea, the elevations on the ice sheet are lowering, placing the surface in yet warmer conditions.

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[1] Relative sea level rise for an area is a combination of the change in ocean level and local changes in response to uplift or subsidence of the land. For example, North Carolina has a greater relative sea level rise than south Florida because the land there is subsiding faster.

Melt effects are expanding northwards on both coasts of Greenland. Even the very northern portions of Greenland have seen increased melting over the past decade.

Field observations from this summer in western Greenland have documented amazing acceleration of marginal glaciers. The Illulissat Icefjord, located 150 miles north of the Arctic Circle, is an outlet for about 7% of the Greenland Sheet. This marginal glacier had been receding in response to increased marginal glacier melt. Beginning in 2002, the ice has surged seaward and is presently moving seaward at over 9 miles per year with additional pulses as high as 3.1 miles in 90 minutes! Melt waters seeping down through the ice sheet have created a 1,600 foot thick layer of water on which the interior ice sheet is now floating, fracturing, and surging to the sea. Acceleration of melting of the Greenland ice sheet is the critical factor to the rise of global sea level in the coming century.

The Arctic Ocean has historically been sufficiently blocked with thick floating pack ice that navigation through the 'Northwest Passage' has remained elusive until recently. The pack ice is floating on the water of the Arctic Ocean and its melting would not in itself change sea level (like a melting ice cube in your glass). However, the white pack ice surface reflects nearly all incoming solar energy back into the air and space. Melting of the pack ice leaves areas of open water which absorb nearly 90 percent of the incoming solar energy. This warms the water, which further accelerates the rate of melting in the Arctic summer and reduces cooling in winter. Historically, the pack ice covering much of the Arctic Ocean through the summer was made of large solid masses of ice that were 4-5 years old, thickening each year. In the past decade, the pack ice has become increasingly younger and thinner. Most of the pack ice this summer is only 1-2 years old. It is thin, highly fragmented and contains many open water areas. As of mid September, this year's summer melt has left 30% less pack ice than the previous record low (in 2005). The large open water areas were 9 degrees Fahrenheit warmer than normal. Melting will continue until at least mid September. The pack ice is now so thin and fragmented that it could potentially float out of the Arctic into the Atlantic.

Climate projections had talked of the possibility of a summer ice-free Arctic Ocean in 40-80 years. Now it looks like that may happen within a decade if recent trends continue. As the pack ice diminishes over the Arctic Ocean, the adjacent land will warm, vast areas of tundra permafrost will melt releasing potentially catastrophic amounts of methane to the atmosphere[2], and melting of the Greenland Ice Sheet will even further accelerate.

In short, the recent changes occurring in the Arctic and Greenland mean that global warming and sea level rise will happen much more rapidly than had been only recently projected. Even recent model projections of future ice melt for Greenland by 2040 have already happened in 2007.

In the Antarctic, there is no inherent reason why the impacts of warming should follow the pattern of the Arctic Ocean. The Arctic is an ocean surrounded by land, whereas the Antarctic is a continent surrounded by ocean. Nevertheless, there has been a gradual loss

[2] Methane is another greenhouse gas. One molecule of methane captures 20 times the heat of a molecule of carbon dioxide. In the atmosphere, methane eventually will oxidize to carbon dioxide and water. This takes about 10 years.

of pack ice through the last half of the twentieth century, but a slight expansion in the past decade (as anticipated by climate models); about a 12% increase in the flow rate of 300 glaciers around the margin of Antarctica between 1993 and 2003; and a significant increase in summer snow melt in both marginal and interior areas of the ice sheet since 2005. Antarctica is a critical unknown to future projections; however, it is showing distinctive early signatures of accelerated ice release.

PROJECTION: A further 2-foot sea level rise by the end of the century, as projected in the 2001 IPCC report, would make life in south Florida very difficult for everyone. Spring high tides would be at about +5.8 feet[3]; storm surges would be higher; barrier islands, fill islands and low-lying mainland areas would be frequently flooded; salt water intrusion would restrict available freshwater resources; drainage would be more sluggish; Turkey Point would be an offshore island; and so on.

Unfortunately, it looks as though sea level in the coming century will rise significantly more than two feet. With what is happening in the Arctic and Greenland, many respected scientists[4] now see a likely sea level rise of **at least** 1.5 feet in the coming 50 years and a total of **at least** 3-5 feet by the end of the century, possibly significantly more. Spring high tides would be at +7 to +9 feet. This does not take into account the possibility of a catastrophically rapid melt of land-bound ice from Greenland, and it makes no assumptions about Antarctica.

The projected rises will just be the beginning of further significant releases from Greenland and possibly Antarctica[5]. Hopefully, the IPCC will quickly revisit the question of sea level rise and provide a more valid and meaningful projection; however, to date, that is not planned until about 2012. When they revisit the current estimates, we expect it will be at least in the 3-5 foot range for this century.

Developed Miami-Dade County as we know it will significantly change with a 3-4 foot sea level rise. Spring high tides would be at about + 7 to 8 feet; freshwater resources would be gone; the Everglades would be inundated on the west side of Miami-Dade

---

[3] Elevations are relative to a zero, which is 'mean lower low water' (spring low tide) when originally established in the late 1920s. This is the datum used for flood elevations in Miami-Dade County. Today, mean higher high water is +3.8 feet, exceptional tides may reach over 4.5 feet, and storm tides and surges are added on to that. For considering future sea level rise, add 3.8 feet to the projected increase for mean higher high water (average spring high tide).

[4] For example: Dr. Robert Corell, a key contributor to the IPCC and chair of the Arctic Climate Impact Assessment, said this September that there is a consensus that new data collected since the IPCC report (i.e., the last two years) shows a 'massive acceleration' in the loss of ice mass in Greenland, and the consequences are outstripping the capacity of scientific models to predict it. Dr. James Hansen, director of NASA's Goddard Institute for Space Studies, suggests that sea level could rise by one to several meters (1 meter = 3.25 feet) by the end of the century.

[5] Total melting of the Greenland ice sheet would add about 23 feet to global sea level. In Antarctica, the collapse of the West Antarctic Ice Sheet would result in another 20 feet. With the warming we have caused and will cause from greenhouse gas buildup, melting of both of these is a distinct possibility in the future. During the previous interglacial period 130,000 to 120,000 years ago, sea level was about 25 feet higher than present.
Were the ice on Antarctica to totally melt, sea level would rise over 200 feet, but that seems unlikely.

County; the barrier islands would be largely inundated; storm surges would be devastating; landfill sites would be exposed to erosion contaminating marine and coastal environments. With a five foot rise (spring tides at nearly +9 feet), Miami-Dade County will be extremely diminished.

REALITY FOR OUR FUTURE: Miami-Dade County, like all other coastal and low-lying counties, is now facing much more challenging decisions than ever imagined. We will work to provide more carefully documented projections, but we hope you see the urgency of reconsidering nearly every aspect of the county's management, zoning, infrastructure, and planning.

One urgent effort is to look at what Miami-Dade County will need to do to remain inhabitable and functional at benchmarks of a further 1, 2, 3, 4 and 5 foot rise in sea level – and at what point portions of the county will need to yield to the rising sea. This will require a detailed documentation of the elevations of infrastructure elements and roadways; susceptibility of coastal, wetland and artificial fill areas to erosion; defining areas of potential pollution and contamination release; determining changing drainage and storm surge risks; assessing structural viability of buildings and levees with changing groundwater levels and saline water intrusion; looking at the future of fresh potable water sources; defining the modifications necessary to maintain connectivity of roadways; and many other aspects.

It should be pointed out that the highly porous limestone and sand substrate of Miami-Dade County (which at present permits excellent drainage) will limit the effectiveness of widespread use of levees and dikes to wall off the encroaching sea.

Respectfully submitted,
Science and Technology Committee[6]

Co-Chairs

Dr. Harold R. Wanless	University of Miami, sedimentology, coastal processes
Dr. Stephen Leatherman	Florida International University, sedimentology and coastal processes

Committee Members

Dr. John R. Bethea	Community Consultant, conflict resolution and public policy
Dr. Adriana Cantillo,	Scientist, chemistry
Ms. Diana Cornley	Miami-Dade County, coastal ecosystem restoration
Dr. Will Drennan	University of Miami, ocean-atmosphere interaction
Dr. David Enfield	Scientist, climate variability
Mr. Peter Harlem	Florida International Univ., sedimentologist, wetlands ecologist
Dr. James S. Klaus	University of Miami, coral reef paleoecologist
Mr. Orestes Lavassas	South Florida Biodiesel, renewable energy
Dr. John F. Meeder	Florida International Univ., sedimentologist, wetlands ecologist
Dr. Georgio Tachiev	Florida international University, hydrology, water resources
Dr. John Van Leer	University of Miami, physical oceanography
Mr. Doug Yoder	Miami- Dade County

[6] All members of the committee have worked together to develop this statement, and all have signed on.

Wendy Graham

Wendy D. Graham

Wendy D. Graham is the Carl S. Swisher Eminent Scholar in Water Resources in the Department of Agricultural and Biological Engineering at the University of Florida and Director of the University of Florida Water Institute. She graduated from the University of Florida with a Bachelor's degree in Environmental Engineering. Her PhD is in Civil Engineering from the Massachusetts Institute of Technology. She conducts research in the areas of coupled hydrologic-water quality- ecosystem modeling; water resources evaluation and remediation; evaluation of impacts of agricultural production on surface and groundwater quality; and development of hydrologic indicators of ecosystem status. She has served as PI or co-PI on over $11 million in grants and contracts, has supervised 30 doctoral and master's thesis committees and has served on an additional 45 graduate student committees.

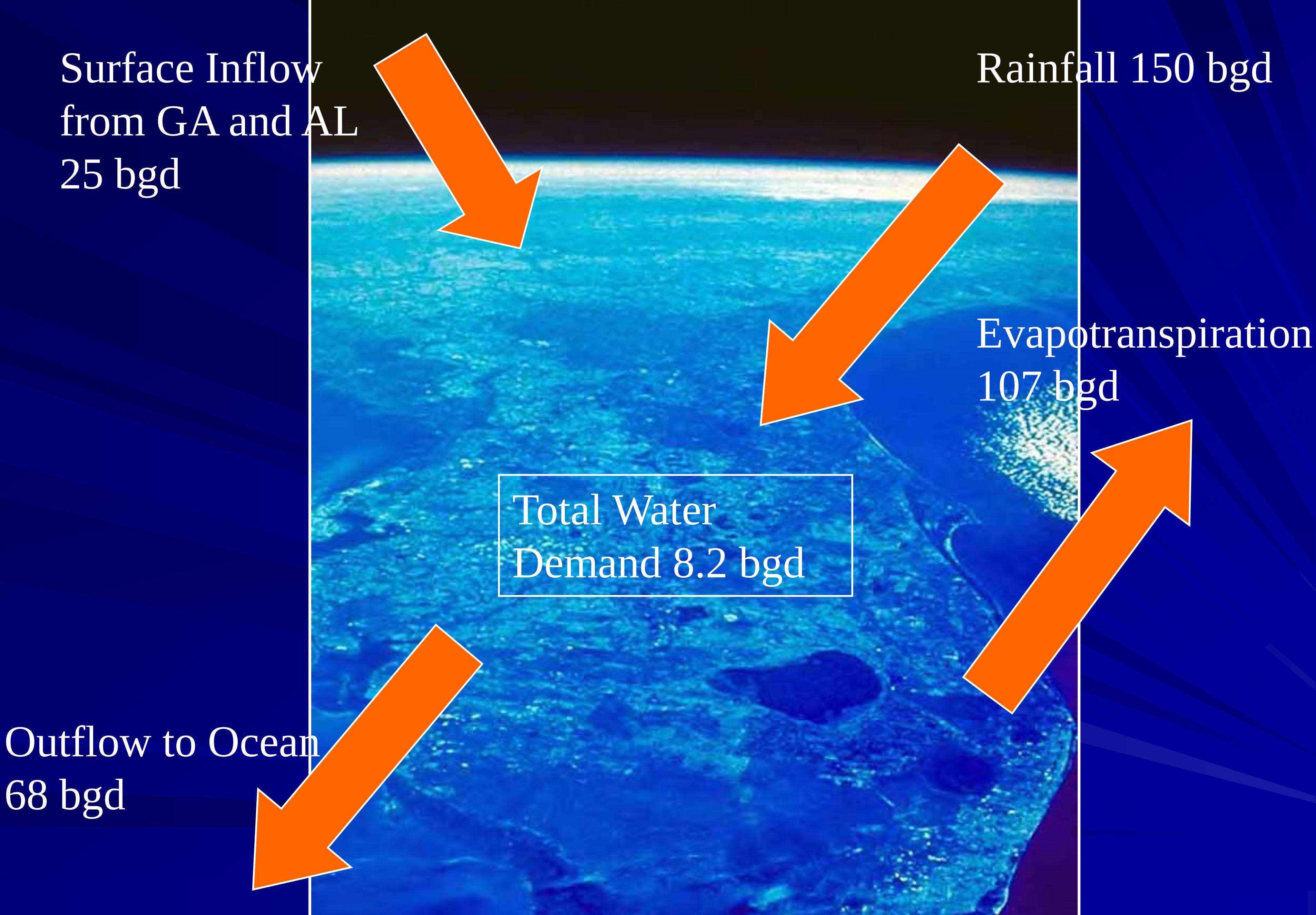
Graham is the recipient of numerous honors, including the Editors' Citation for Excellence in Reviewing for Water Resources Research from the American Geophysical Union; the Emerging Scholar Award from the American Association of University Women; the Young Engineer Award from the Florida Section of the American Association of Agricultural Engineering; the Gamma Sigma Delta Junior Faculty Award of Merit, the Sigma Xi Junior Faculty Research Award, the University of Florida Research Foundation Professorship Award, and the University of Florida Doctoral Advising/Mentoring Award.

Dr. Graham is currently Chair of the Board of Directors for the Consortium of Universities for the Advancement of Hydrologic Science, a member of the ASAE Board of Trustees, and a member of the Florida's Pesticide Review Council. She also served as secretary of the American Geophysical Union's hydrology section; associate editor for Water Resources Research, Advances in Water Resources and the Journal of Contaminant Hydrology; Chair of the Florida section of the American Society of Agricultural Engineers; Chair of the modeling subcommittee of the International Life Sciences Institute working group on the estimation of pesticide concentrations in drinking water; and member of the American Society of Civil Engineers' task committee on stochastic methods in subsurface contaminant hydrology.

Impacts of Climate Variability and Climate Change on Florida's Water Resources

Wendy Graham
Water Institute Director
Swisher Eminent Scholar in Water Resources

Water Institute
UNIVERSITY of FLORIDA



Florida’s Water Budget

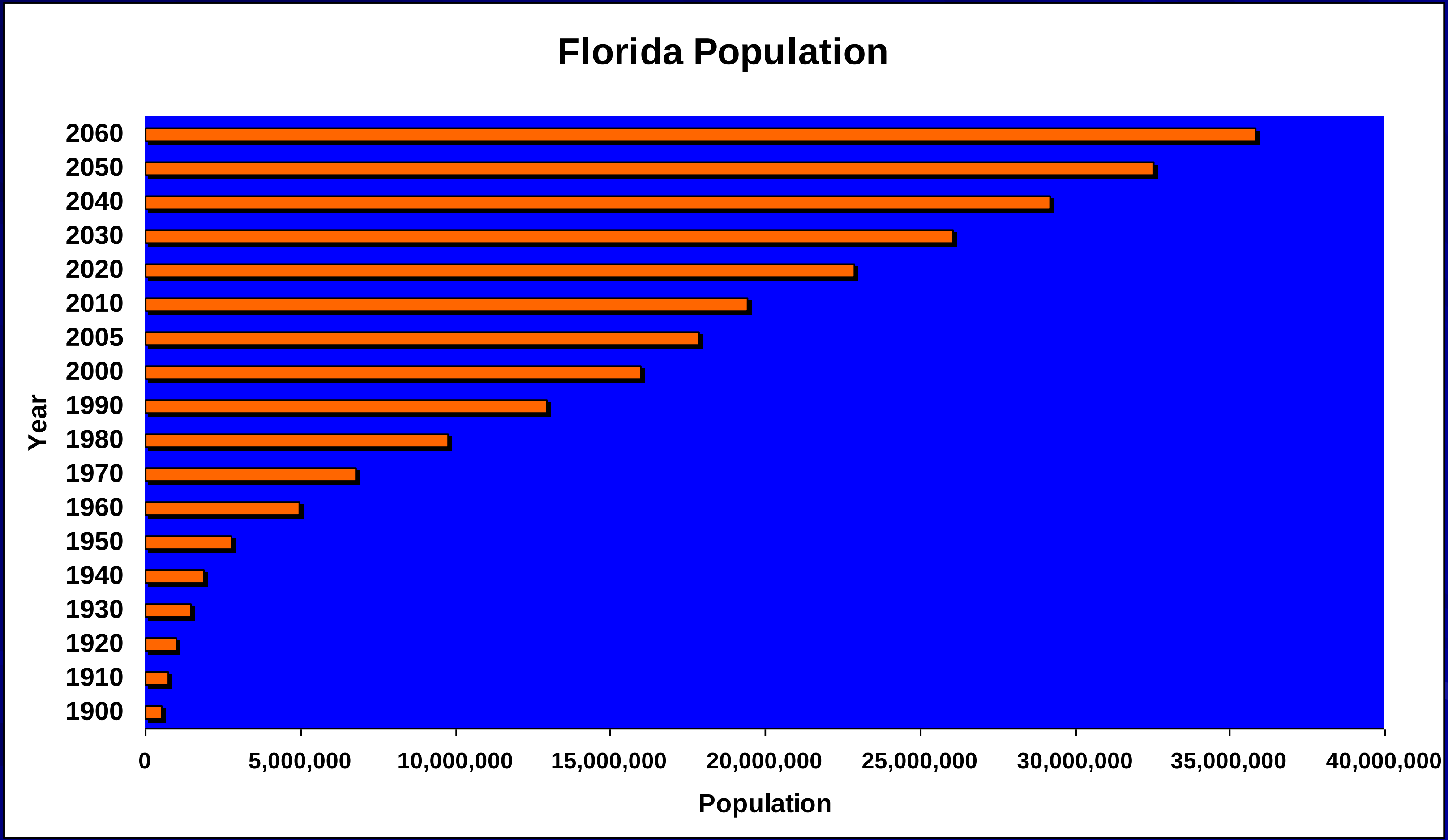
Major Water Challenges

- **Floods & Droughts**
- **Shortage**
- **Pollution**
- **Uncertain future trends**

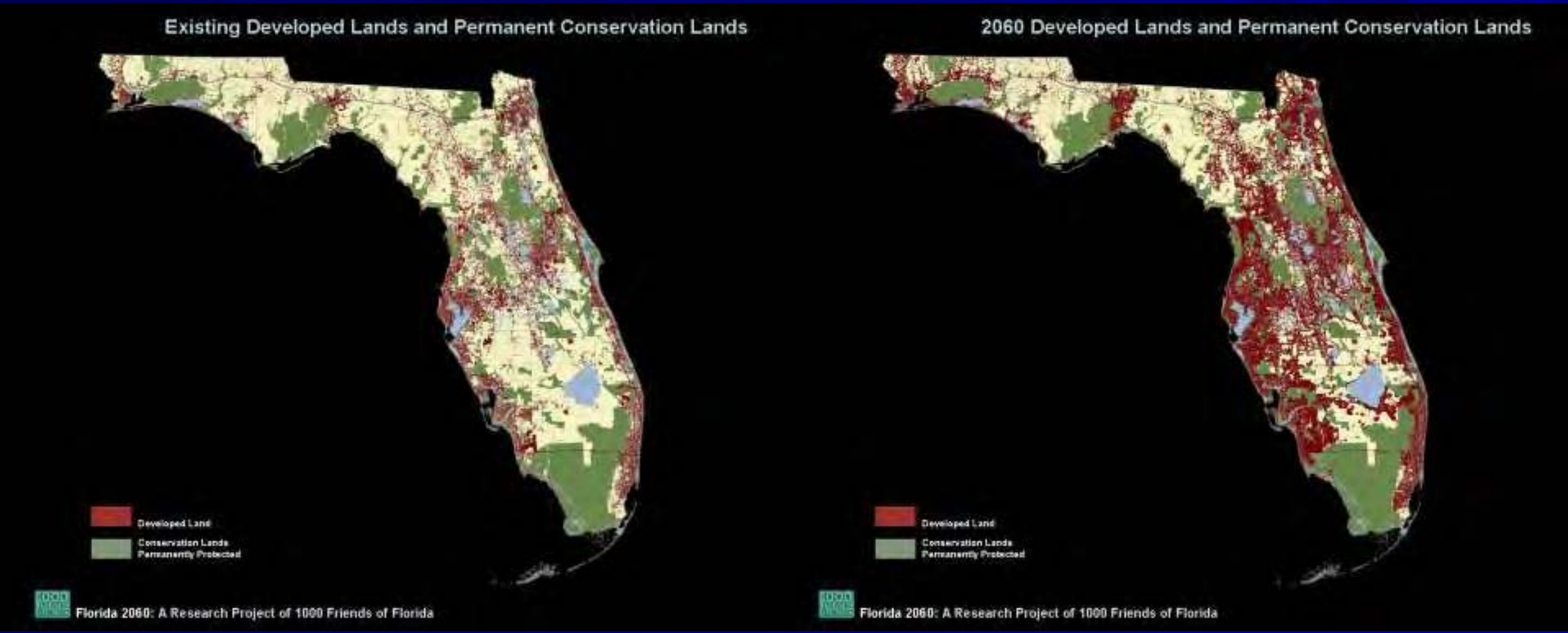

Water, water everywhere……


Yet not a drop to drink……

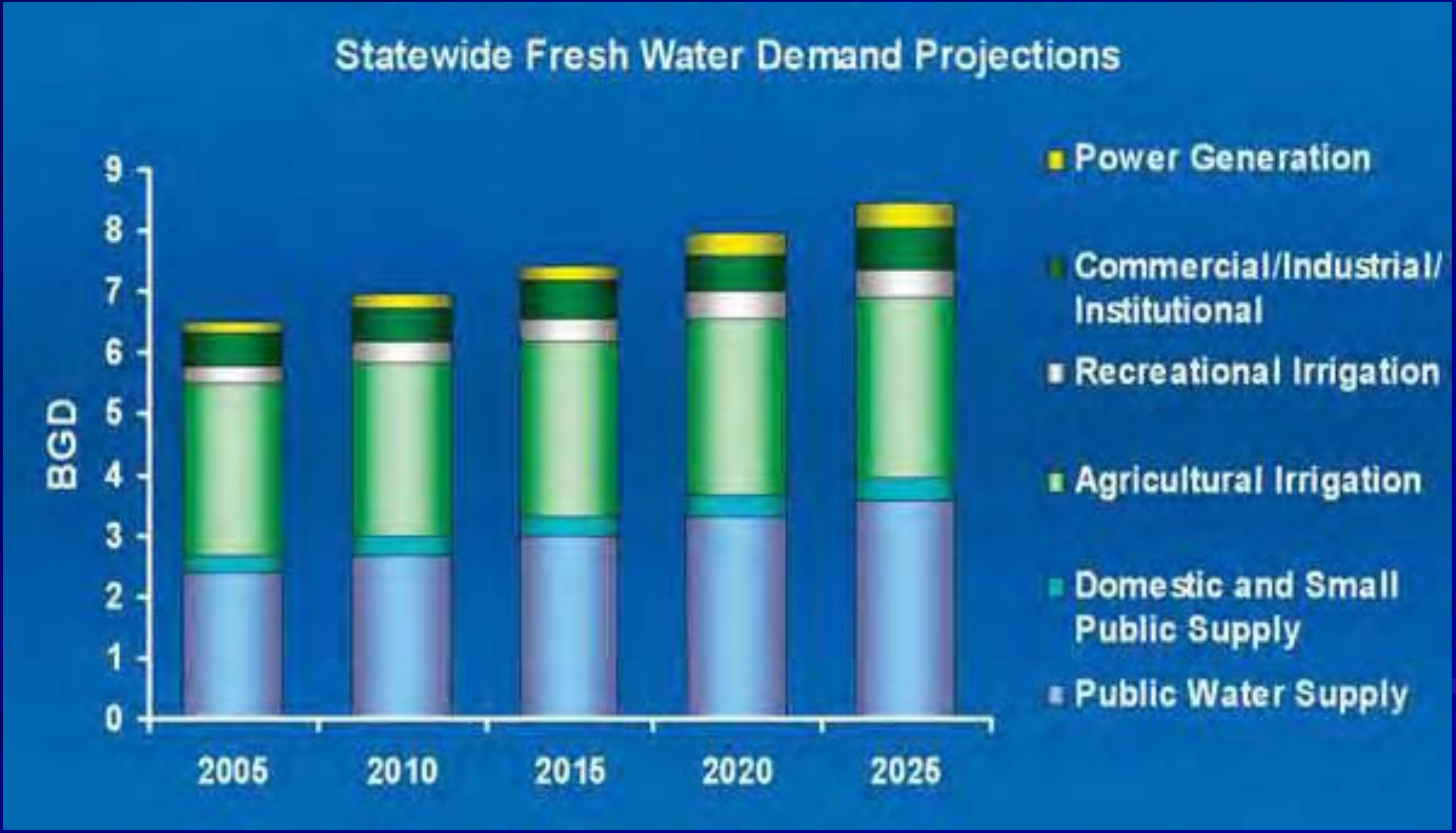
Population Growth



Projected Land Use Change



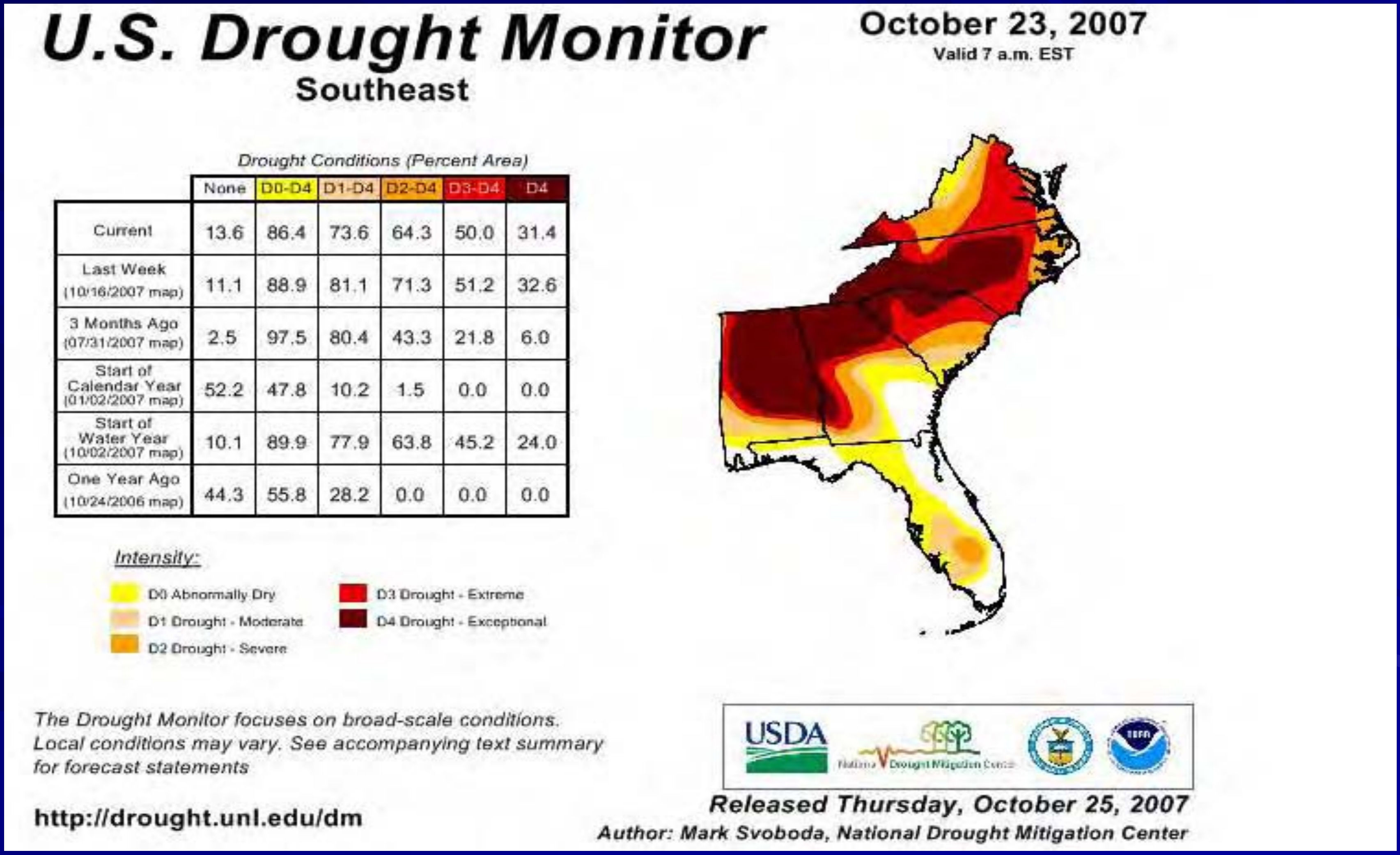
Water Demand Projections



Current Climate Variability Drivers

- Atlantic Multi-decadal Oscillation (AMO)
- El Nino Southern Oscillation (ENSO)
- Drought
- Tropical storm impacts

Example: 2007 SE Drought



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	13.6	86.4	73.6	64.3	50.0	31.4
Last Week (10/16/2007 map)	11.1	88.9	81.1	71.3	51.2	32.6
3 Months Ago (07/31/2007 map)	2.5	97.5	80.4	43.3	21.8	6.0
Start of Calendar Year (01/02/2007 map)	52.2	47.8	10.2	1.5	0.0	0.0
Start of Water Year (10/02/2007 map)	10.1	89.9	77.9	63.8	45.2	24.0
One Year Ago (10/24/2006 map)	44.3	55.8	28.2	0.0	0.0	0.0

Florida strikes deal in water war

Agreement among 3 states lowers levels flowing from Georgia

Tamara Lytle | Washington Correspondent
November 2, 2007

WASHINGTON - Florida Gov. Charlie Crist and governors from Alabama and Georgia worked out a deal with federal officials Thursday to reduce the water flowing south from Atlanta, which is struggling during a historic drought to provide drinking water for its burgeoning population.

It was a temporary truce in the water wars between the three states that have led to lawsuits, legislation and public bickering pitting Atlanta's need for drinking water against the interests of Florida's seafood industry and endangered species and the water needs of Alabama and Florida power companies.

Crist said he was pleased about the deal with Georgia Gov. Sonny Perdue, Alabama Gov. Bob Riley and Bush administration officials. But it raised concerns in Florida among environmentalists and seafood workers, who say they already are hurting by the current water levels, which were cut in May.

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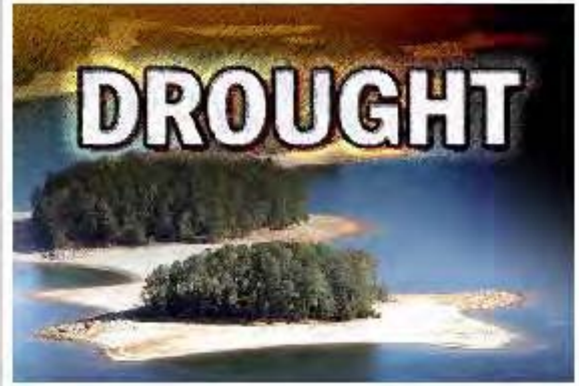

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… Together these factors result in interstate water conflicts….

Drought anxiety rises as water levels fall

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Enlarge

By Michael A. Schwarz, USA TODAY

Because of the drought being experienced in the Southeast, Michael Massicott has stockpiled 36 five-gallon jugs of water in the basement of his Atlanta home.

By Larry Copeland, USA TODAY

ATLANTA — The prolonged drought gripping the Southeast, perhaps most acutely in this booming metropolis, is creating anxiety not seen in previous dry spells.

It's partly those haunting pictures of a slowly dying Lake Lanier, Atlanta's main water source, seen almost daily on the evening news here. It's partly the underlying drumbeat of an escalating water war among Georgia, Alabama and Florida. It's partly the discouraging forecast, which calls for a dry winter, and partly the sneaking suspicion that the Southeast might have grown too much too fast.

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What's this?

PGA lead by 3 shots. SPORTS, 3C

BOX INTO A HOME AWAY FROM HOME

…. intrastate Water Conflict

The Gainesville

SPORTS, 1C

Gators unranked in AP poll • WORLD, 3A **Former Uganda dictator Idi Amin dies**

FINAL EDITION

State water wars pit North vs. South

Impact of shifting water debated

By BOB ARNDORFER
Sun staff writer

This month has made it difficult to believe Central and South Florida will ever need more water.

Thanks to Tropical Storm Erika and a series of other weather systems, those regions have been inundated with rain that has flooded streets, bloated creeks and caused rivers to spill over their banks. Residents of the Tampa Bay area have even donned wading boots to walk in their yards.

Yet the rushing torrents can't disguise the fact that ever-growing Central and South Florida are facing a future shortage of water so critical that they're eyeing the rivers and springs of less-populated North Central Florida to help quench their thirst.

The e-mails of water managers and others concerned about protecting North Florida water resources have been active lately with people relaying copies of a recent St. Petersburg Times story headlined, "North Has It, South Wants It." The story recounts efforts by politically connected business leaders to develop statewide policies to allow for the transfer of water from one region of Florida to another — specifically from north to south.

WATER on Page 5A

"It's absolutely a concern."

WES SKILE…
Member o… Florida Spring… Task Forc…

New report | **School year starts on Monday in county**

…..and intra Water Management District Conflict

9/18/07

PLAN TO PIPE AREA WATER

Possible water sources

Water sources listed during an Alternative Water Supply meeting of local governments, utilities and the St. Johns River Water Management District:

WATER SOURCE	AVAILABLE WATER*
1. Lower Ocklawaha River:	[illegible] million gallons per day
2. St. Johns River at Yankee Lake:	64.4 million gallons per day
3. St. Johns River at Deland:	45.4 million gallons per day
4. Withlacoochee River:	33.9 million gallons per day
5. St. Johns River at S.R. 46:	[illegible] million gallons per day
6. Lake Rousseau:	[illegible] million gallons per day
7. St. Johns River at Lake Monroe:	[illegible] million gallons per day

Rivers to quench a thirsty south?

Conservationists oppose plan to pump from area sources

Water needs

Anticipated Climate Change Drivers

- Higher surface air temperatures
- Longer, more frequent droughts
- Shorter, higher intensity rainy seasons
- Sea-level rise

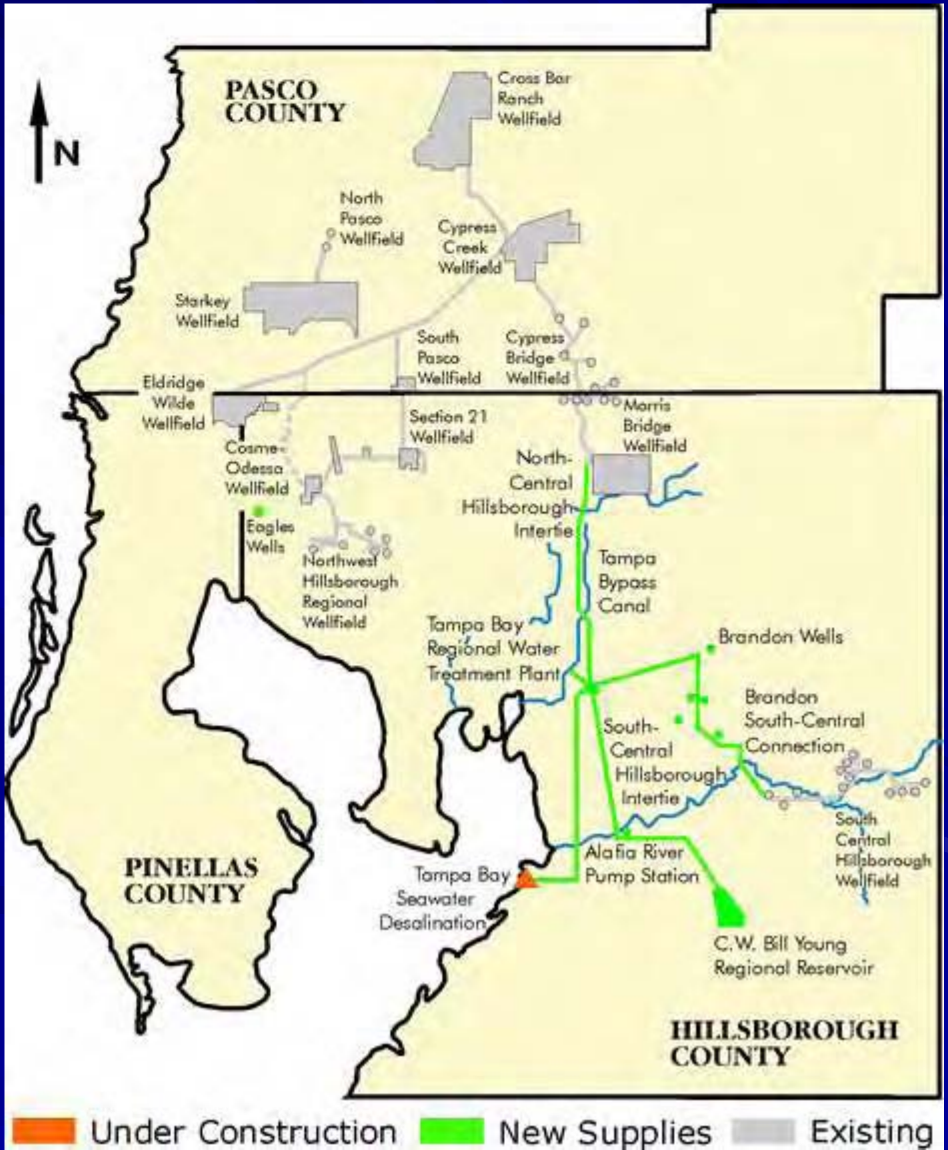
These added pressures will increase water competition among water users requiring interdisciplinary advances in water science, technology and policy

What is needed?

- Large-scale integrated climatic-hydrologic-landuse models that predict
  - hydrologic, ecologic, and socioeconomic impacts of short-term climate variability and water management decisions
  - long-term hydrologic, ecologic and socioeconomic impacts of the effects land and water planning decisions and climate change.

Example: Tampa Bay Water

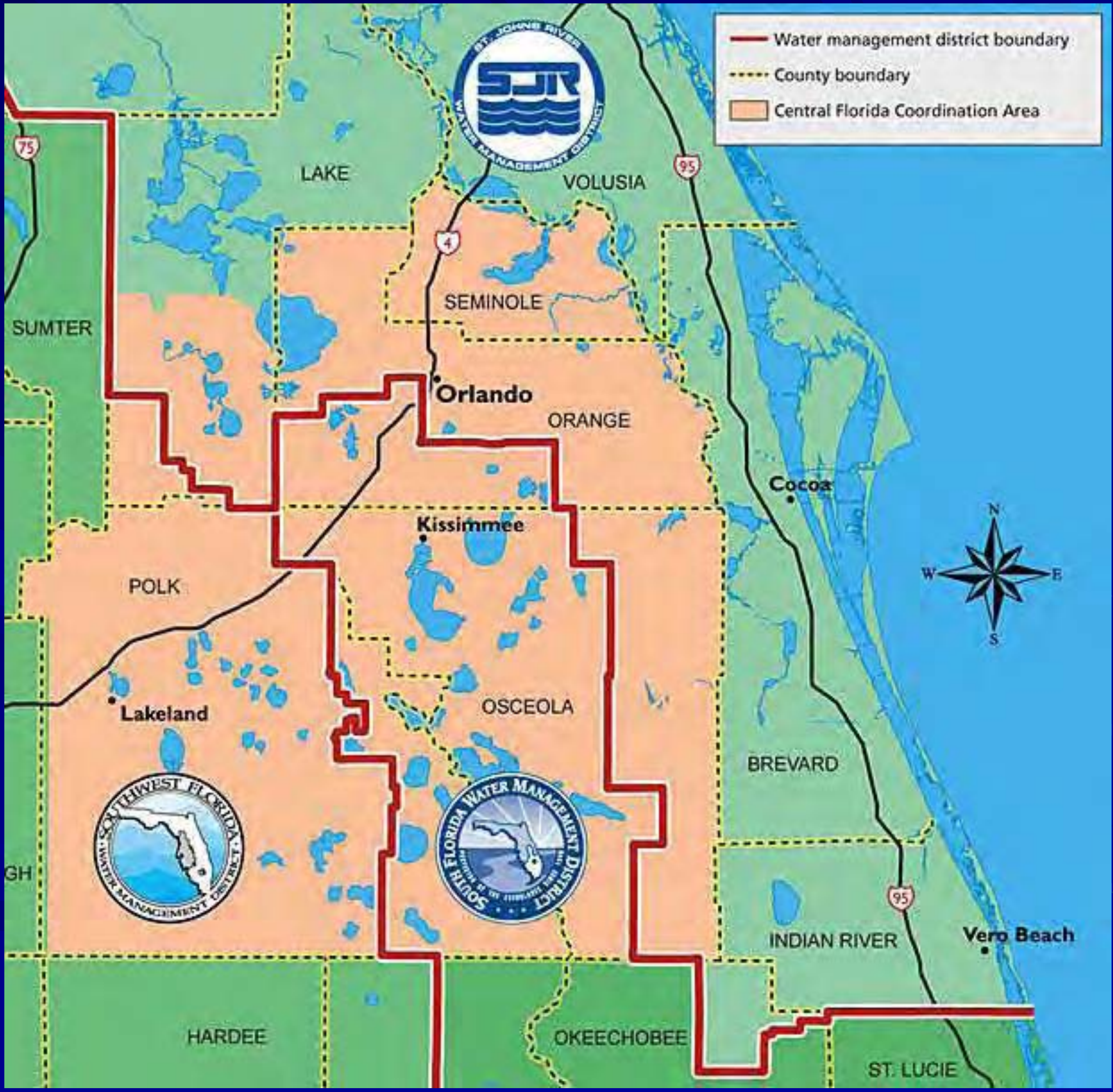
…. In this project we are coupling climate, hydrologic and water demand models to improve water allocation decisions in order to create a more secure, reliable, cost effective and environmentally sound public water supply.



Central Florida Coordination Area

….the availability of sustainable quantities of groundwater in central Florida is insufficient on a regional basis to meet future demands beyond 2013….

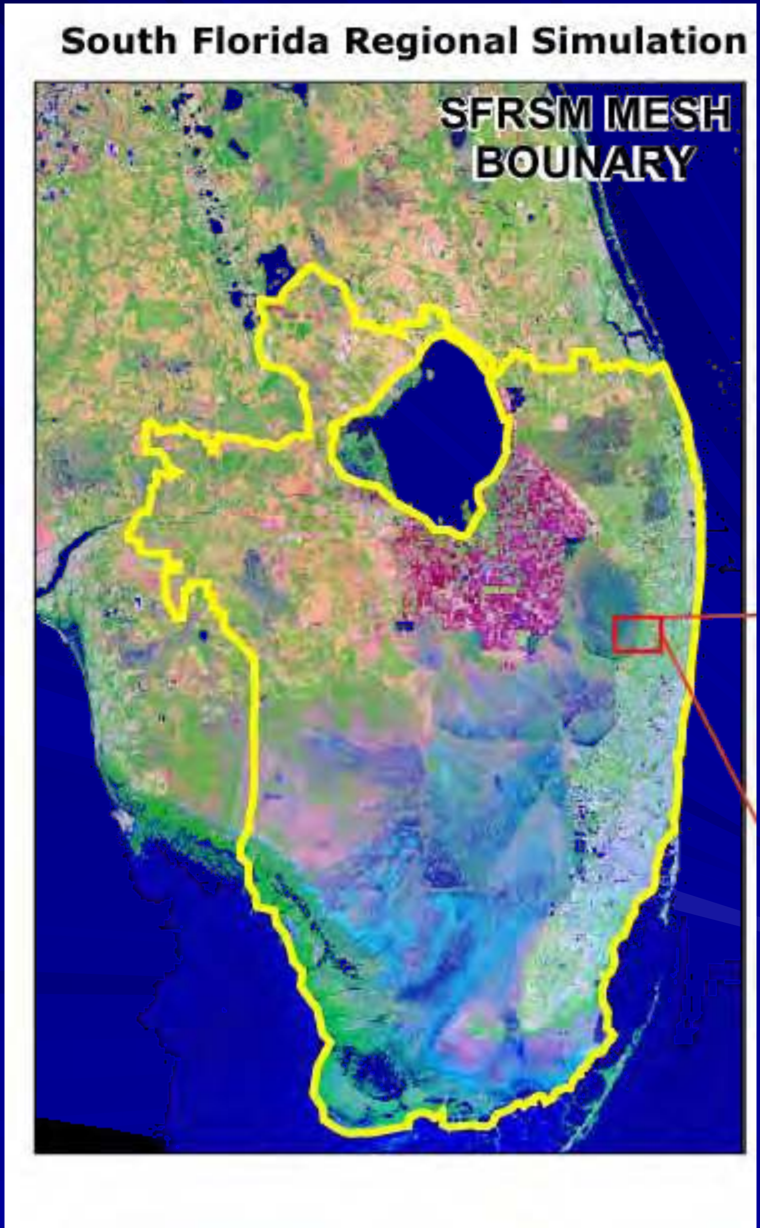
(CFCA Action Plan, Sept 2006)



Comprehensive Everglades Restoration Plan

…Given CERP's geographic scope and multi-decadal planning and implementation horizons, management decisions need to be consistent with and adapt to global climate change and inter-decadal climatic variability….

(Recover, 2006)



Scenario Analyses with these Models will Enable

- Water managers to improve water availability for all users
- Emergency preparedness teams to reduce the impacts of floods and hurricanes
- Agricultural operators and industry to prevent water pollution
- Decision makers and planners to create better behavioral, social and economic policies


Questions ….Comments?

Jim Jones

Dr. James W. Jones

Dr. James W. Jones, Ph.D., is a Distinguished Professor in the Department of Agricultural and Biological Engineering at the University of Florida where he has conducted research and taught graduate classes for the last 31 years. He is an expert in cropping systems modeling and decision support systems. His research has focused on modeling the effects of climate on crops and on applying those models to study effects of climate variability and change on crop yield and for determining management options that minimize risks. He co-leads a 3-state (Florida, Georgia, Alabama) center that conducts research on climate variability, agriculture, and water resources management and provides climate risk management information to farmers, foresters, and water managers through the Cooperative Extension Services. He has led and participated in many interdisciplinary research programs nationally and internationally. He is author of more than 250 scientific journal articles and teaches graduate courses on mathematical modeling and simulation of biophysical systems. He is a Fellow of the American Society of Agricultural & Biological Engineers, Fellow of the American Society of Agronomy, Fellow of the Soil Science Society of America, and serves on several international science advisory committees related to climate and agriculture.

Climate Change and Agriculture

James W. Jones

- General Comments
- Crop Responses to Climate
- Trends in Florida's Crop Yields & Climate
- Florida Initiatives in Agriculture and Climate

UF UNIVERSITY of FLORIDA

Nov 6, 2007

General Comments

- Climate and Agriculture
  - Highly vulnerable
  - Determines type of agriculture
- Climate Change Impacts
  - Production
  - Other

Climate Effects on Production

- Temperature
  - Yield optimum about 22-25 ^{o}C for many crops (or 74-78 ^{o}F)
  - In some seasons, average temperatures are already higher than optimum in Florida
  - Freeze risks, kill crop, trees
  - Higher temperatures increase water use by crops, leading to earlier drought or higher irrigation water demand
  - Temperature change, may increase pest problems, damage

Rainfall

- Drought
  - Common in Florida due to sandy soils, timing of rains, causing yield losses
  - Irrigation is widely used, high yields require adequate water throughout growing seasons
- Excess rainfall
  - May flood crops, decrease yields
  - Drainage is required for some systems
  - Nutrient losses, environmental quality issues
  - More pests and diseases

Other Climate Variables

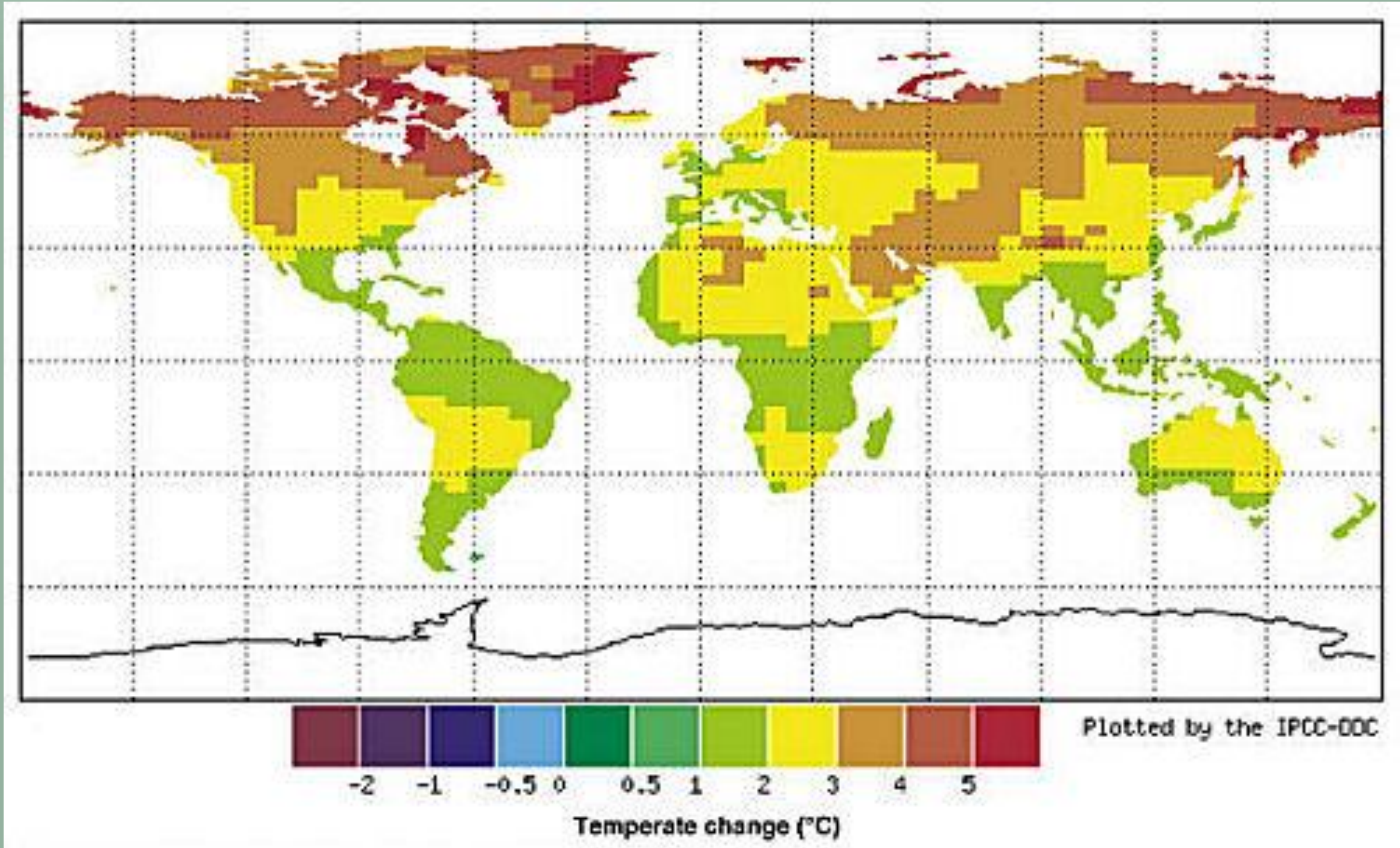
- Wind
- Atmospheric carbon dioxide
  - - - -
- Highly complex responses due to interactions of climate variables that occur in nature
- Crop models developed at UF and elsewhere provide tools to assess impacts of climate conditions and some aspects of how management could be modified to adapt to changed climate.

Some Trends in Florida's Climate & Crop Yields

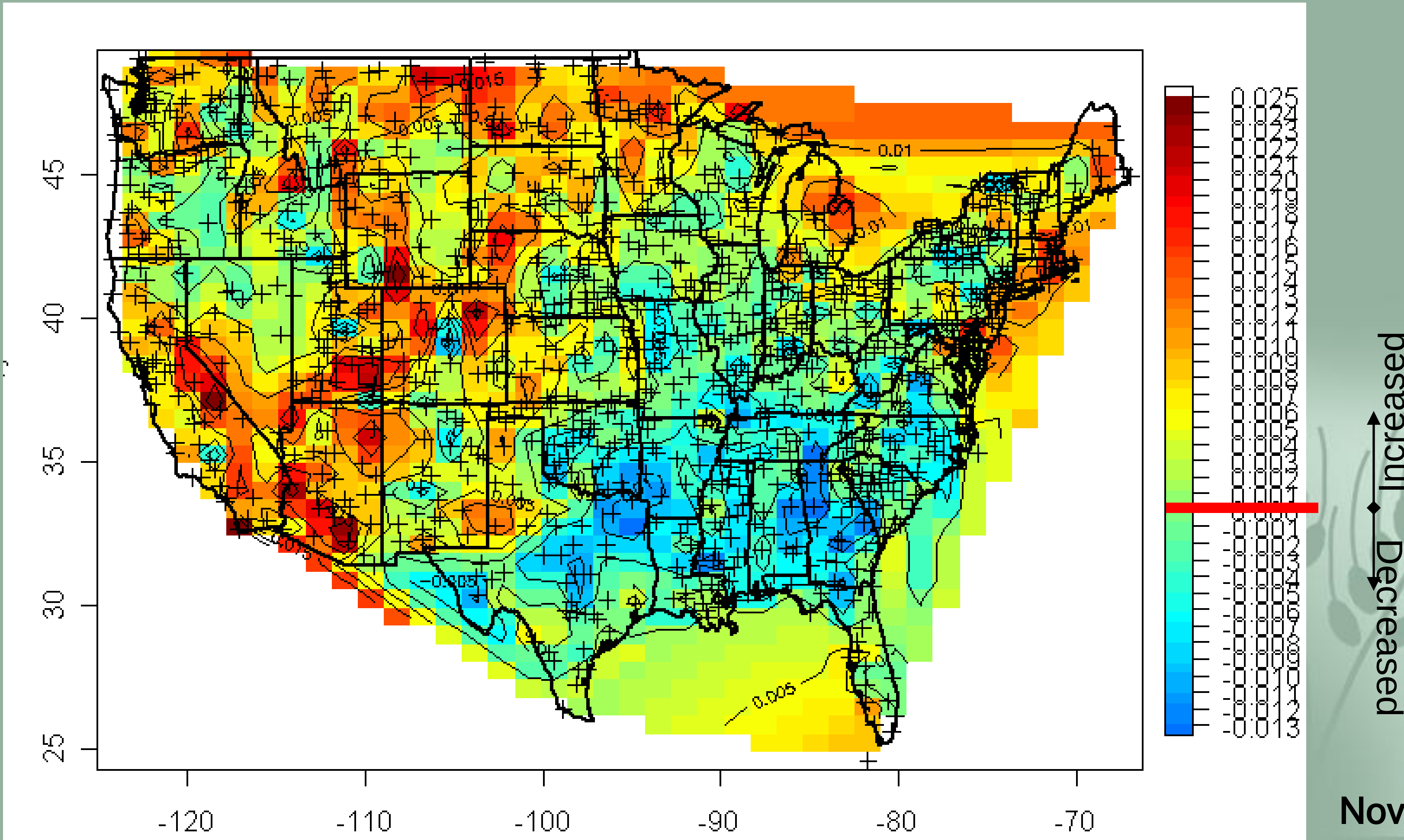
… in the context of global climate changes that are occurring

Nov 6, 2007

IPCC Projected Temperature Changes: Large Regional Differences

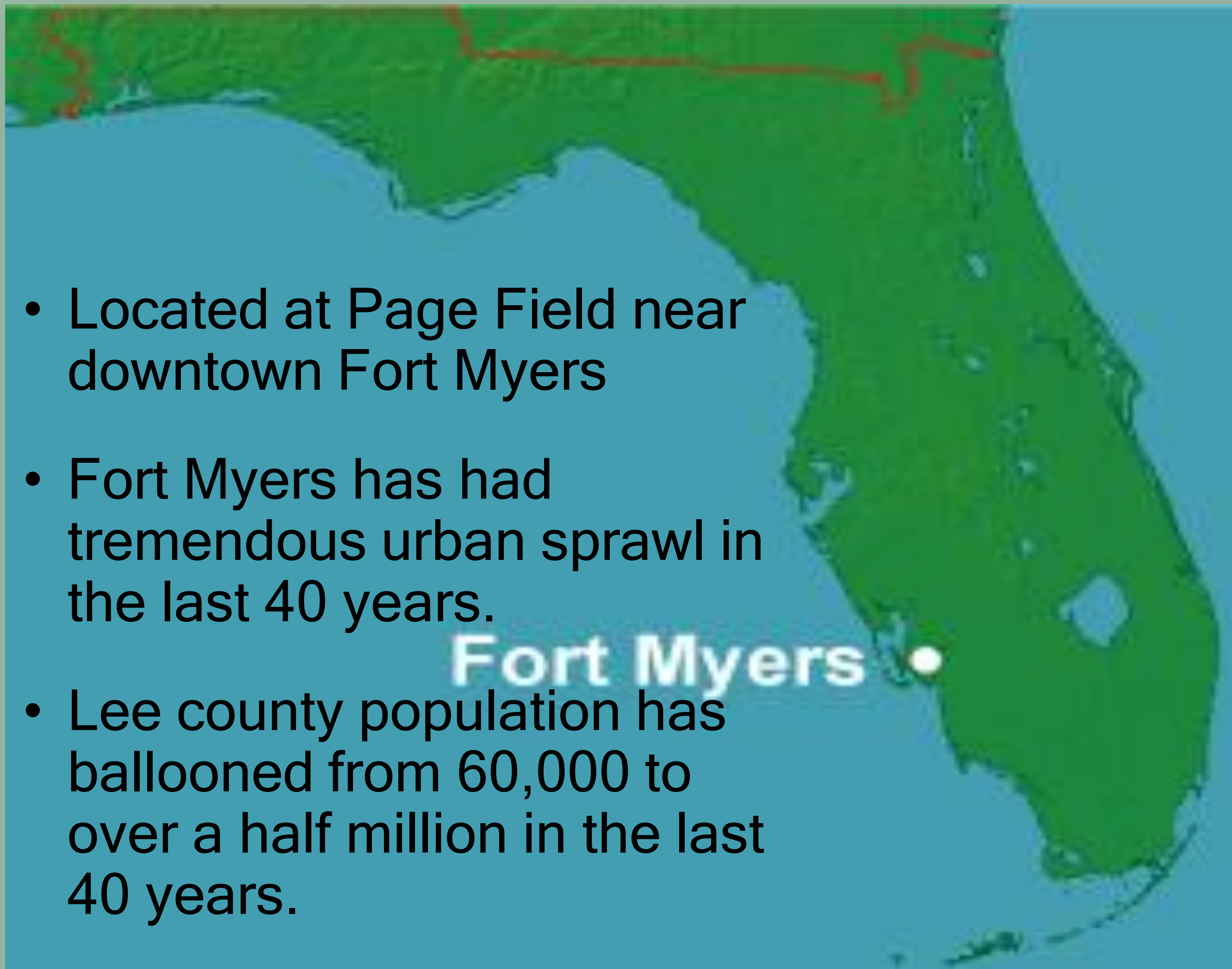


Historical Changes in Annual Temperature Averages Across the USA Over Last 100 Years – Highly Variable



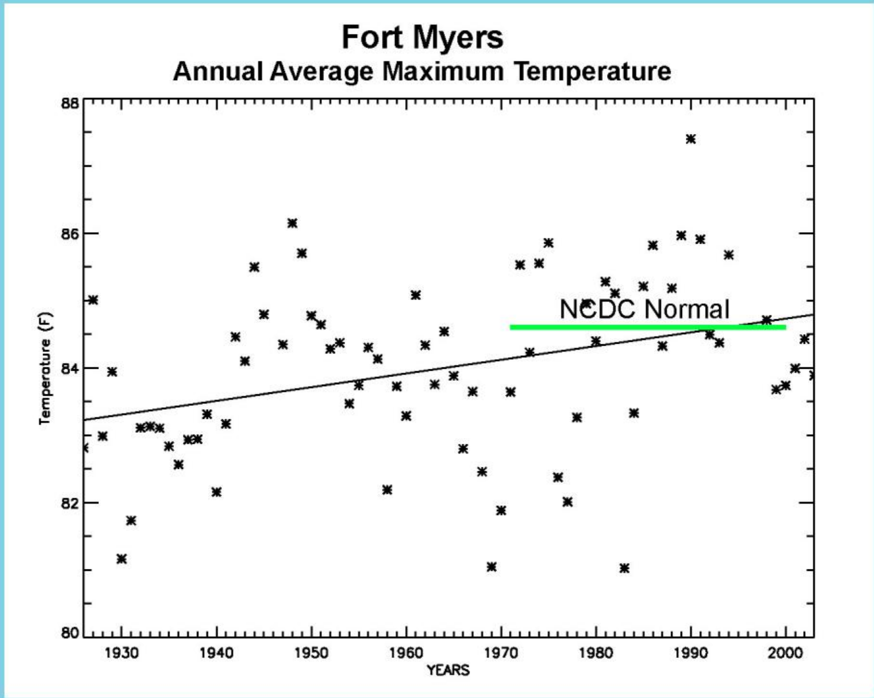
Nov 6, 2007

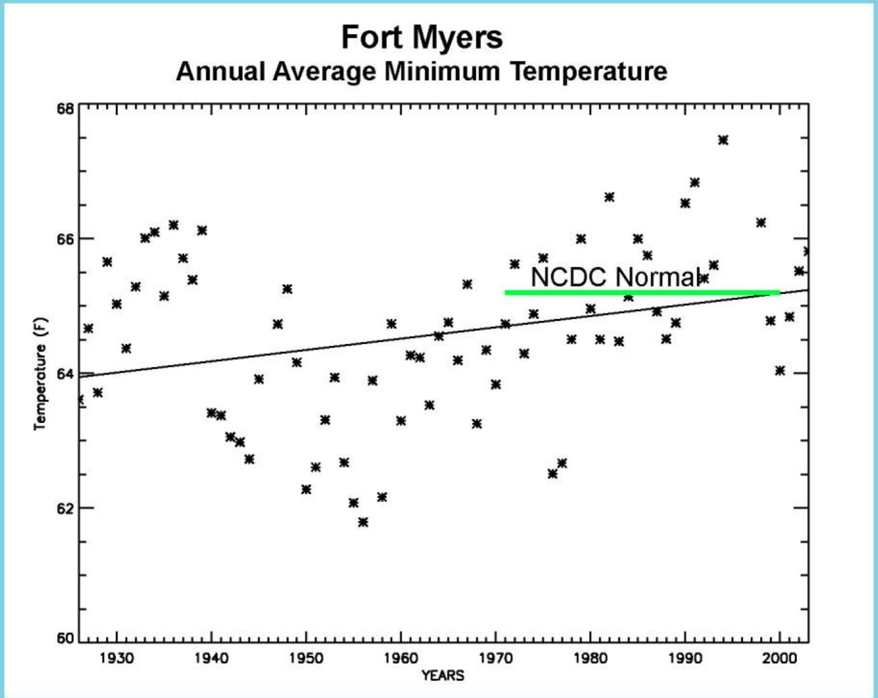
Historical Temperatures of Fort Myers



- Located at Page Field near downtown Fort Myers
- Fort Myers has had tremendous urban sprawl in the last 40 years.
- Lee county population has ballooned from 60,000 to over a half million in the last 40 years.

Annual Average Daily Temperatures
Fort Myers

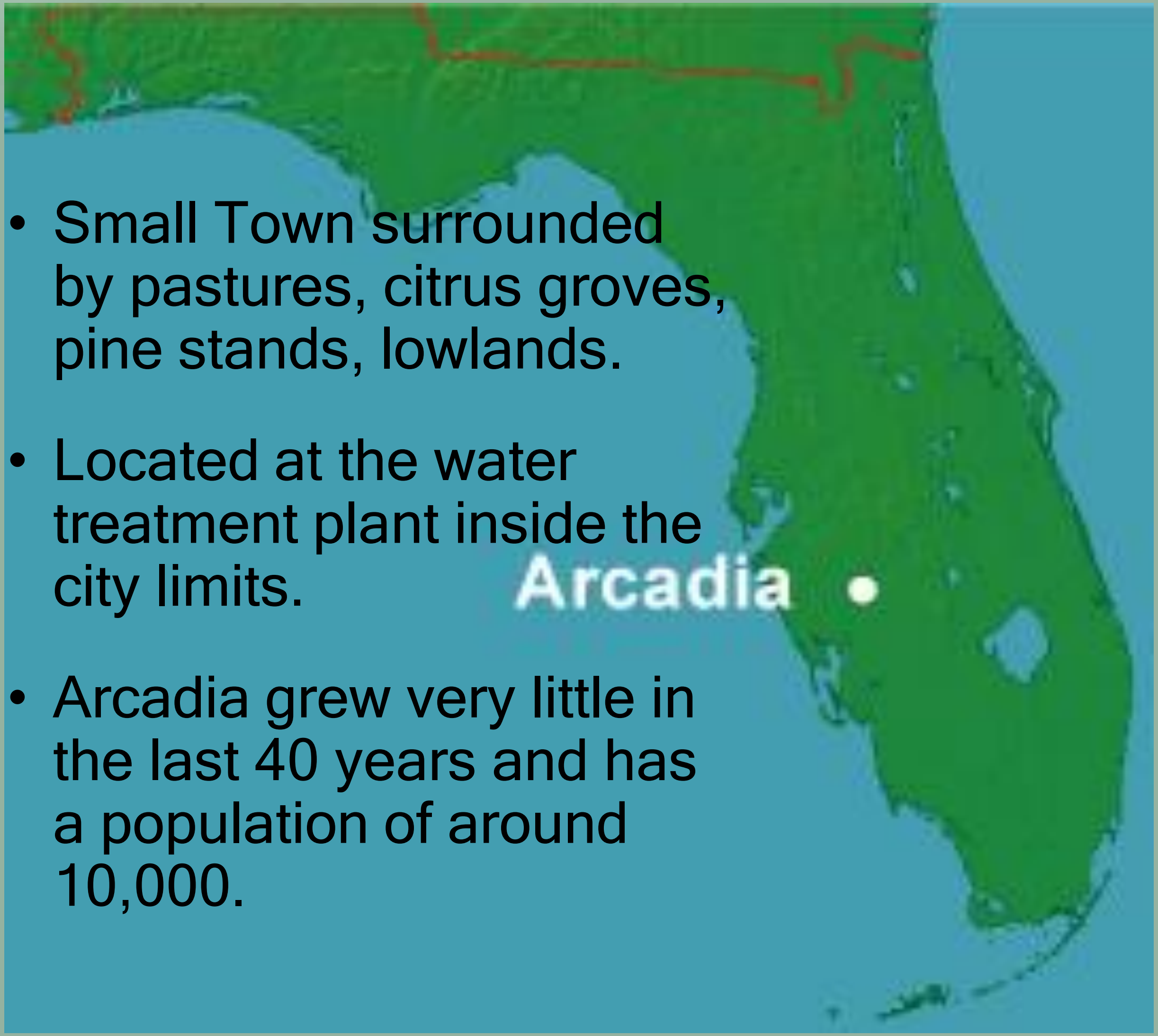




Analysis by D. Zierden, J. O'Brien, FSU

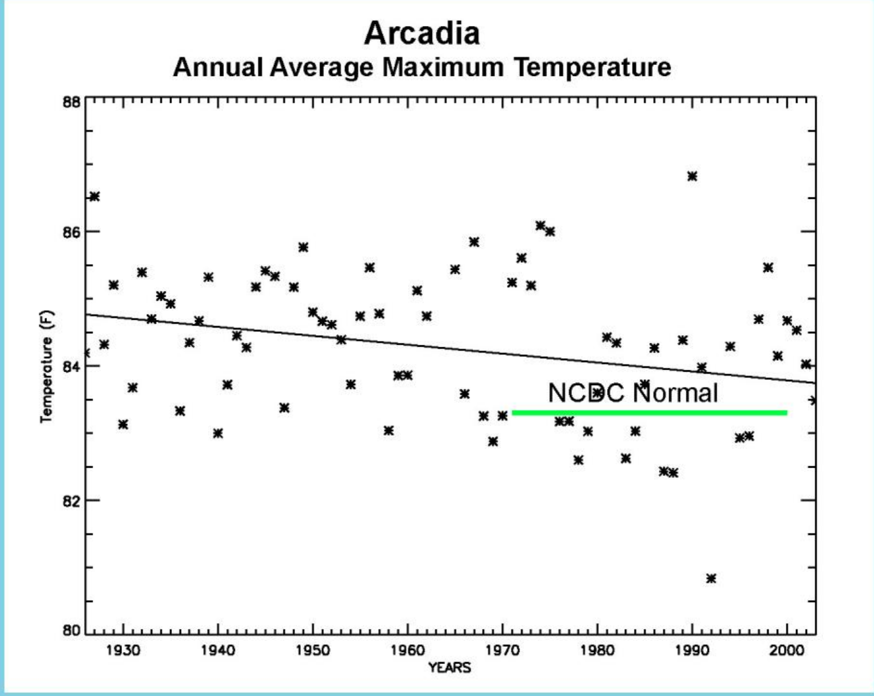
Nov 6, 2007

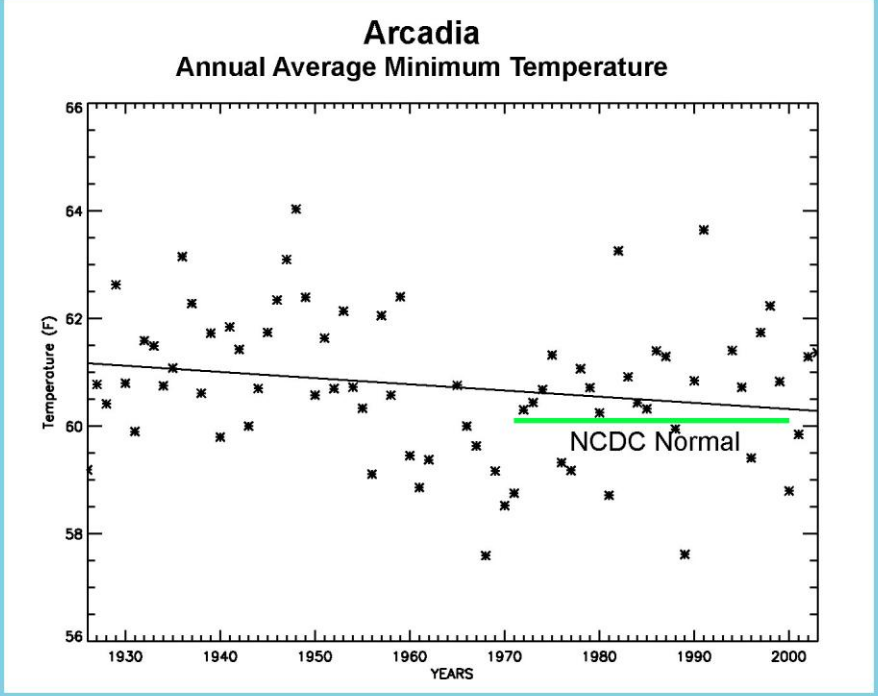
Historical Temperatures of Arcadia



- Small Town surrounded by pastures, citrus groves, pine stands, lowlands.
- Located at the water treatment plant inside the city limits.
- Arcadia grew very little in the last 40 years and has a population of around 10,000.

Annual Average Daily Temperatures
Arcadia





Analysis by D. Zierden, J. O'Brien, FSU

Nov 6, 2007

What These Data Tell Us

- Changes in climate over the last 100 years in Florida have occurred
- Those changes vary over space
- Local temperature changes are affected by changes in land use and development
- Rainfall in Florida also increased some during this 100 year time period
- However, trends vary across the USA and other countries; these are likely to change as climate continues to change globally

Corn Yields Since 1966, Suwannee County

SOUTHEAST CLIMATE CONSORTIUM
AgClimate

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Map for county selection: AL | FL | GA

Customized Info. Enter county and state ▶ SUWANNEE, FL

Current Climate Phase: La Niña

AgClimate Tools

CORN

Yield Residuals

Seasonal Climate

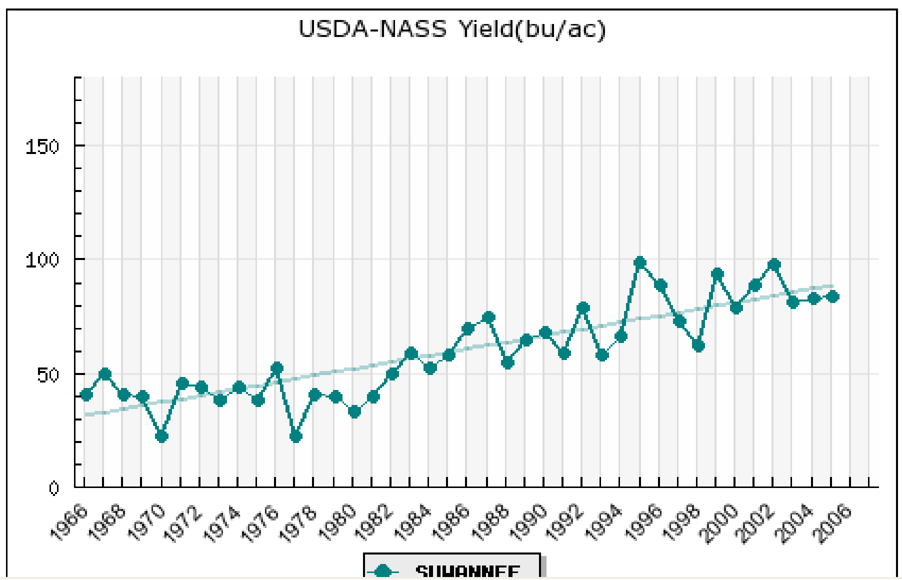
None Rain Temp

State + County

FL

----Select County---
ALACHUA
BAKER
BAY
BRADFORD
CALHOUN
COLUMBIA
DIXIE
DUVAL
ESCAMBIA
FLAGLER

	NEUTRAL	EL NIÑO	LA NIÑA	ALL YEARS
Average	63.8	53.4	55.9	59.2
St.Dev.	19.9	20.8	18.3	20.3
Minimum	33	22	38	22
Maximum	98.9	80.6	93.9	98.9
Median	59	57	46	58



Done

UNIVERSITY OF FLORIDA IFAS

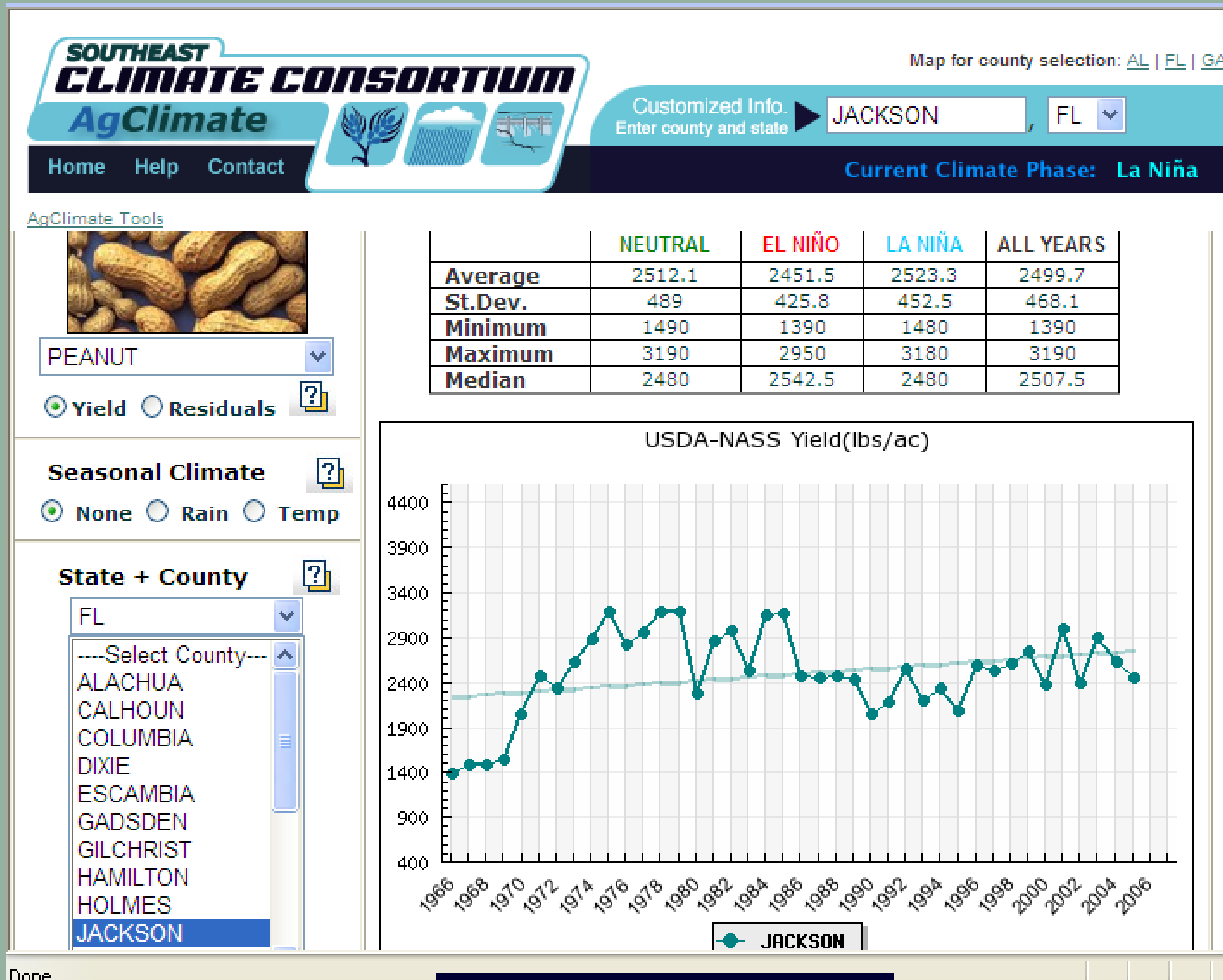
COAPS

University of Miami ROSENSTIEL SCHOOL

http://AgClimate.org

Nov 6, 2007

Peanut Yields Since 1966, Jackson County



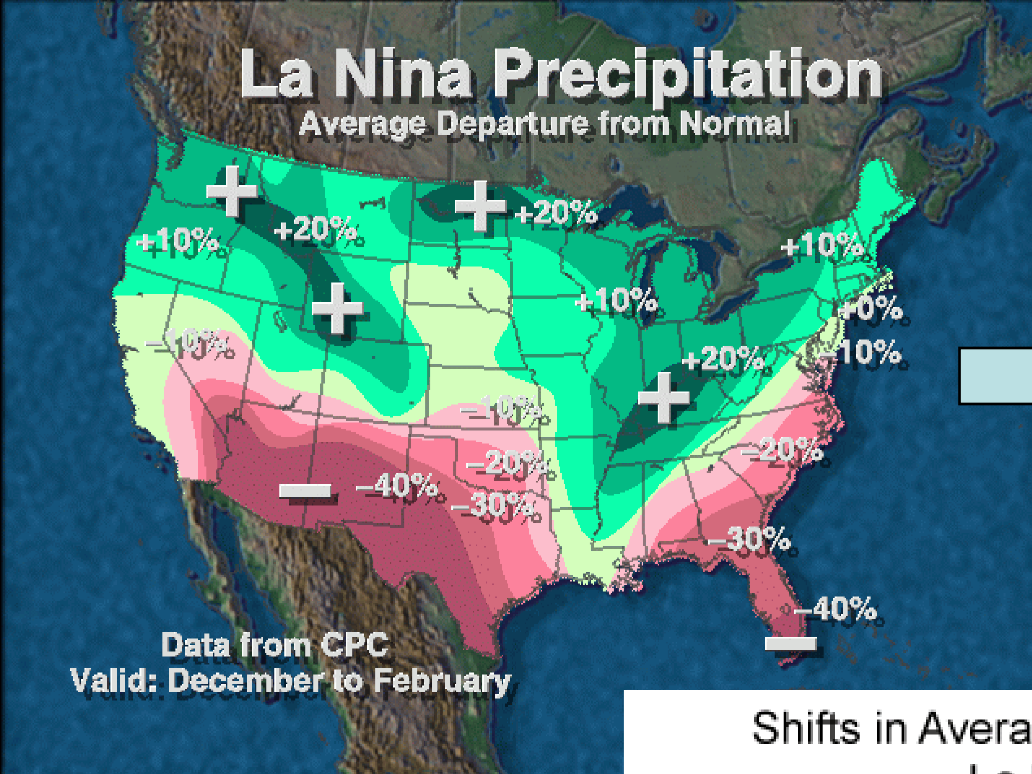
	NEUTRAL	EL NIÑO	LA NIÑA	ALL YEARS
Average	2512.1	2451.5	2523.3	2499.7
St.Dev.	489	425.8	452.5	468.1
Minimum	1490	1390	1480	1390
Maximum	3190	2950	3180	3190
Median	2480	2542.5	2480	2507.5

http://AgClimate.org

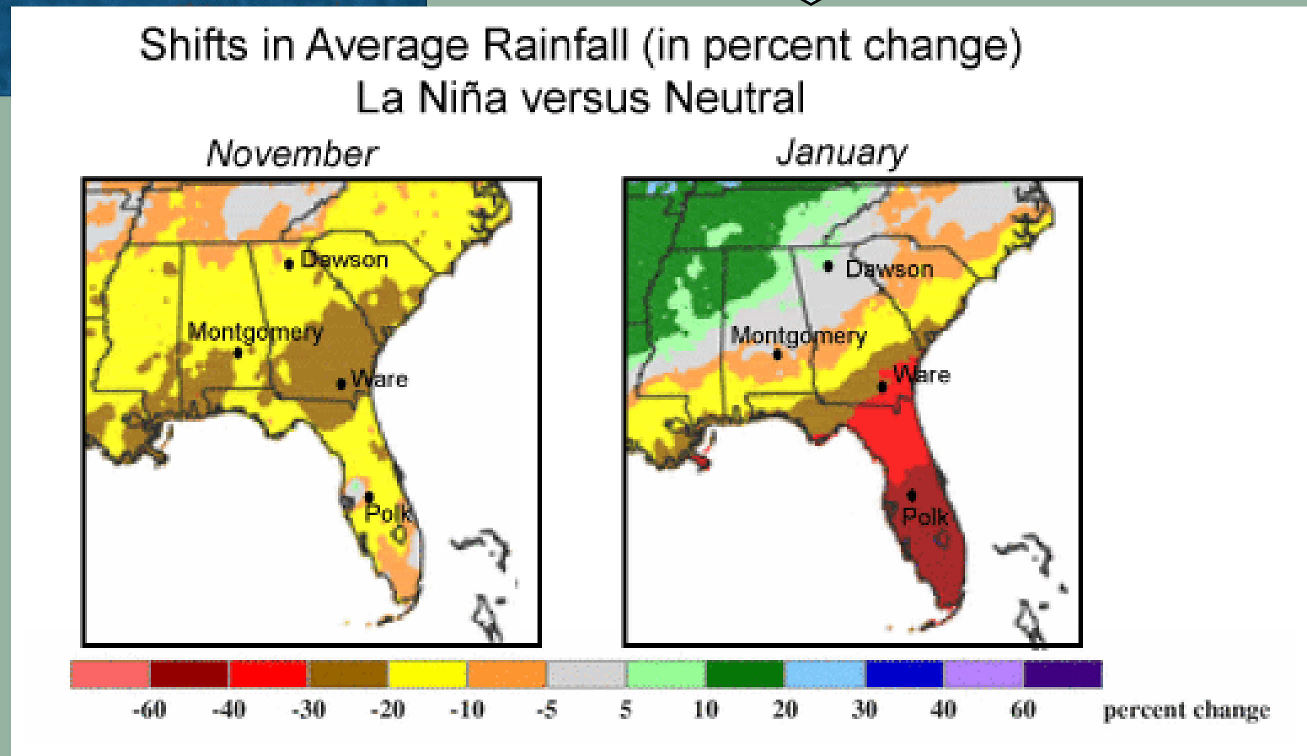
Nov 6, 2007

Florida Initiatives – Agriculture and Water Resources Management

- Climate Risk Management (UF, FSU, UM, UGA, Auburn, UAH)
  - Research
    - Climate forecasts and analysis for Florida, Georgia, Alabama
    - Economic, environmental risks due to climate variability from season at seasonal to annual time scale
  - Extension
    - AgClimate.org risk management system via Florida Cooperative Extension Service
- Climate Change Initiative for Economic and Environmental Benefit in Florida
  - FSU & UF Center of Excellence Proposal



Rainfall Advisory Made in September 2007 for November and January

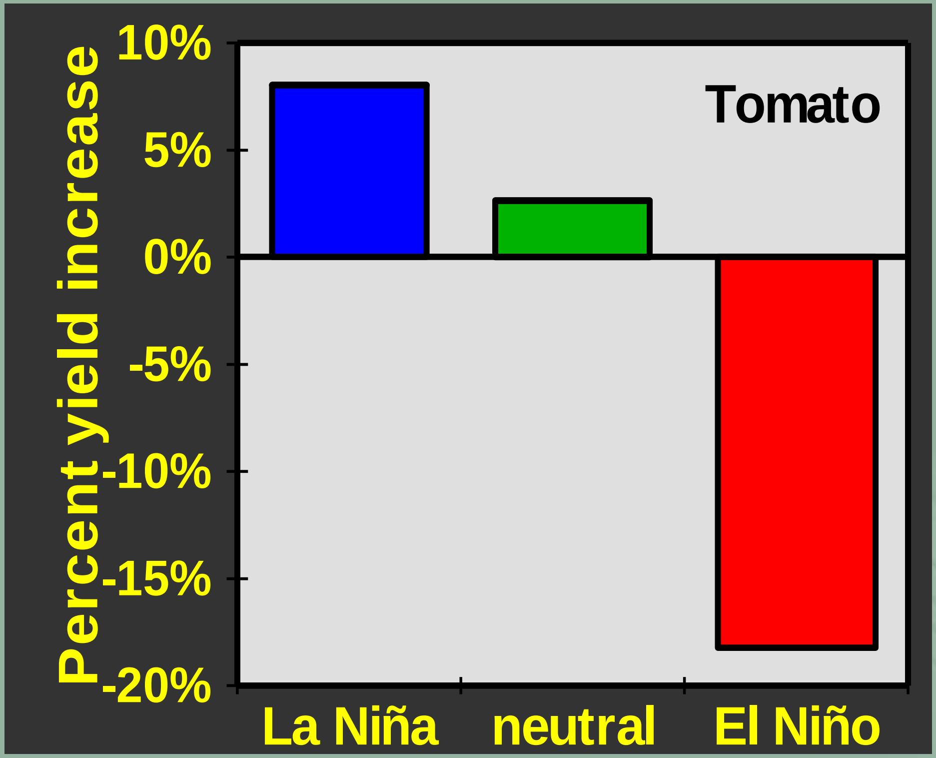


http://AgClimate.org

Crop Production Respond to Climate

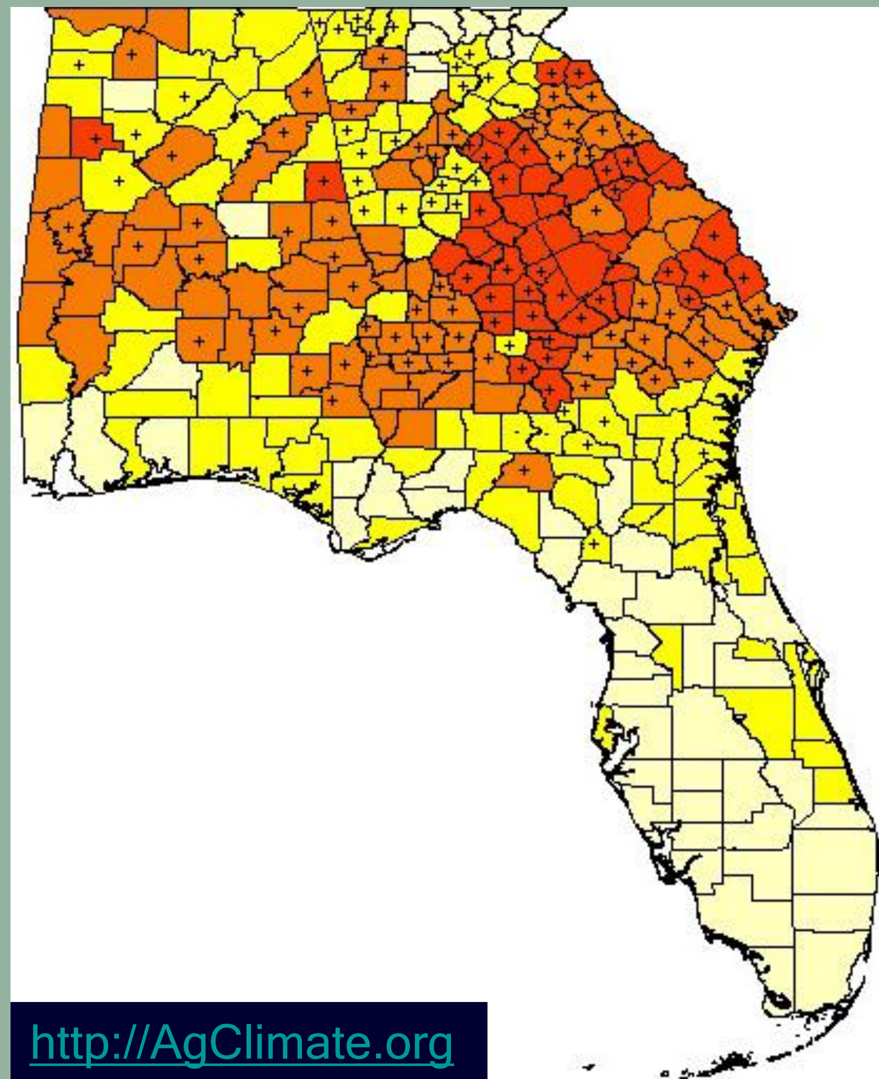
ENSO Phase

Tomato Example

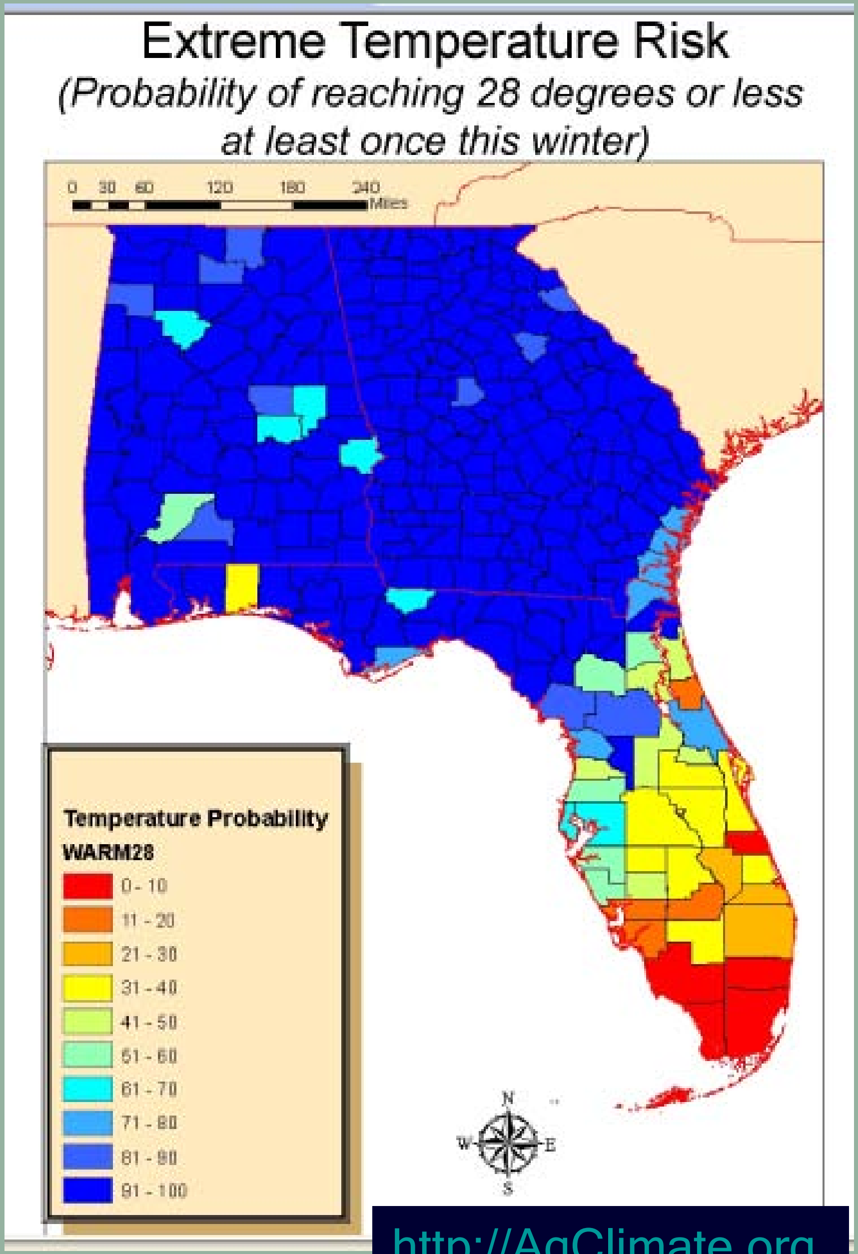


- Yields higher in La Niña winter production season.
- Non-irrigated winter pastures have high risk of drought

July Drought Forecast, made in April 2007 KBDI Severely Dry Conditions (probability of severe drought > 80% for much of GA



Risk of Freezing Temperatures



http://AgClimate.org

Nov 6, 2007

Some Adaptation Worries

- Water availability for irrigation
- Increased variability of extremes (drought, flooding, freezes)
- Hurricane activity
- Energy costs
- Environmental issues
- Smaller farmers have fewer options

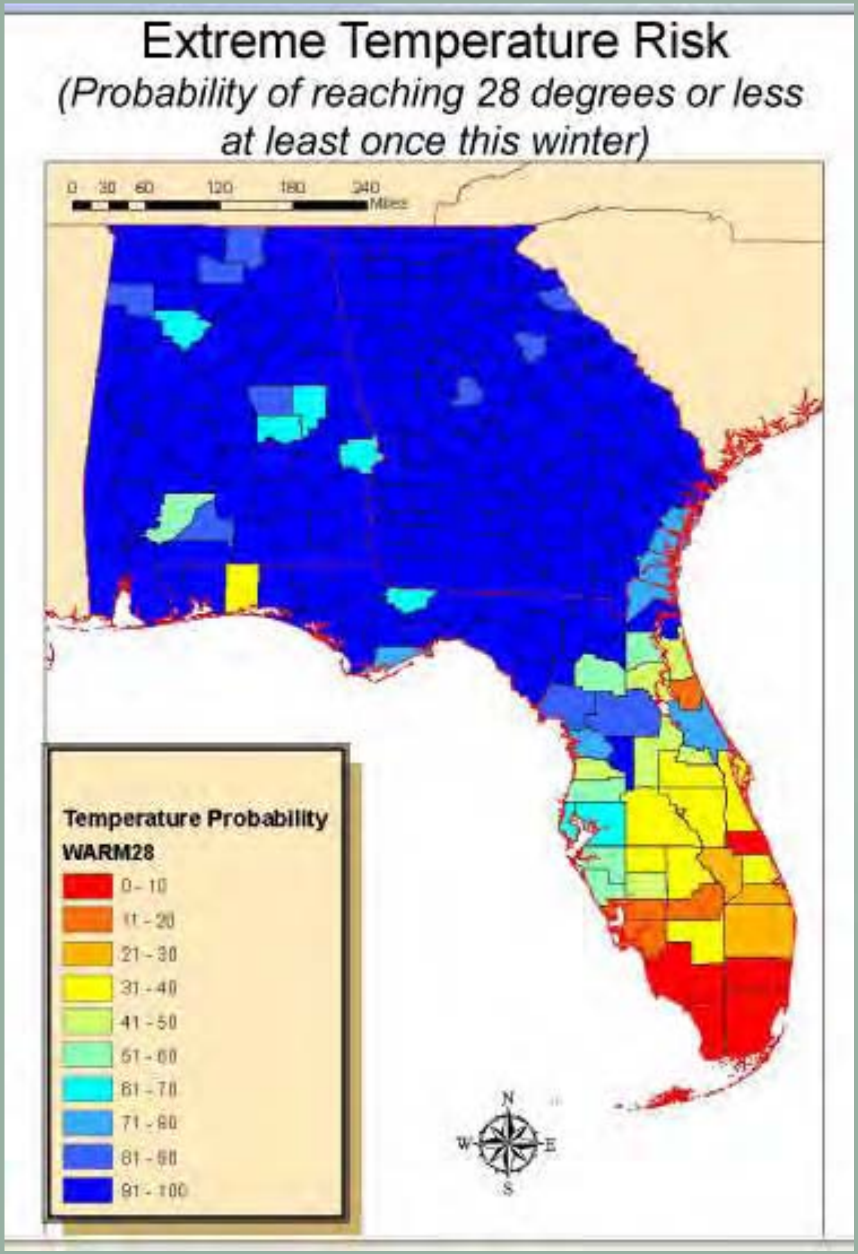
Farmers, Foresters, Land Managers want to Contribute

- Biofuel production
- Carbon sequestration in soils and forests
- More efficient energy use
- Environmental services
  - Water
  - Climate

Opportunities and Needs

- Interest is high in agriculture and forestry industries, historically in seasonal climate & hurricane forecasts
- Interest now high among community, urban, county managers and developers as well as ag and forestry
- Need climate projections at different time scales for use in decisions and policies, downscaled to state and local levels
- Want to know what they can do relative to longer term climate trends or climate change, concern is high
- Interested in economic opportunities associated with climate change
- Integrated climate, agriculture, and landscape models are needed for evaluating likely outcomes and risks associated with policies, decisions
- Partnerships among different commercial sectors, agencies, and universities

Risk of Freezing Temperatures



Nov 6, 2007

Opportunities and Needs

- Interest is high in agriculture and forestry industries, historically more so in seasonal climate & hurricane forecasts
- Need climate projections at different time scales for use in decisions and policies
- Want to know what they can do relative to longer term climate trends or climate change, concern is high
- Economic interests associated with climate change
  - Biofuel production from crops & forests
  - Carbon sequestration and energy use reduction
  - Land development and management that contribute to climate change goals (more energy efficient, less CO_2 emissions, etc.)
  - Interest high among community, urban, county managers and developers as well as ag and forestry
- Integrated climate, agriculture, and landscape models for evaluating likely outcomes and risks associated with policies, decisions
- Partnerships among different commercial sectors, agencies, and universities

W. David Montgomery

W. David Montgomery, Ph.D.

W. David Montgomery, Vice President, is the cohead of CRA International's Energy & Environment practice. Dr. Montgomery is an internationally recognized expert on economic issues associated with climate change policy, and his work on these topics has been published frequently in peer-reviewed journals. He was a principal lead author of the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Working Group III, and has authored a number of peer-reviewed publications on climate policy over the past 20 years.

Dr. Montgomery's current research deals with economic impacts of climate policies, design of R&D policy, and the relationship between institutional change and the reduction of greenhouse gas emissions in developing countries. He has led a number of strategic assessments for clients in the private sector, advising them on how future climate policies and other environmental regulations could affect their asset value, investment decisions, and strategic direction. He is the lead author of a major report on the design of California's policies to limit greenhouse gas emissions and recently testified at hearings on climate policy held by the Ways and Means and Foreign Relations committees of the U.S. House of Representatives.

Prior to joining CRA International, Dr. Montgomery held a number of senior positions in the United States Government. He was assistant director of the U.S. Congressional Budget Office and deputy assistant secretary for policy in the U.S. Department of Energy. He taught economics at the California Institute of Technology and Stanford University, and he was a senior fellow at Resources for the Future. Dr. Montgomery holds a Ph.D. in economics from Harvard University
and was a Fulbright Scholar at Cambridge University. He received the Association of Environmental and Resource Economists' 2005 award for a "Publication of Enduring Quality" for his pioneering work on emission trading.

Economic Costs of Mitigation At the State Level

CRA INTERNATIONAL

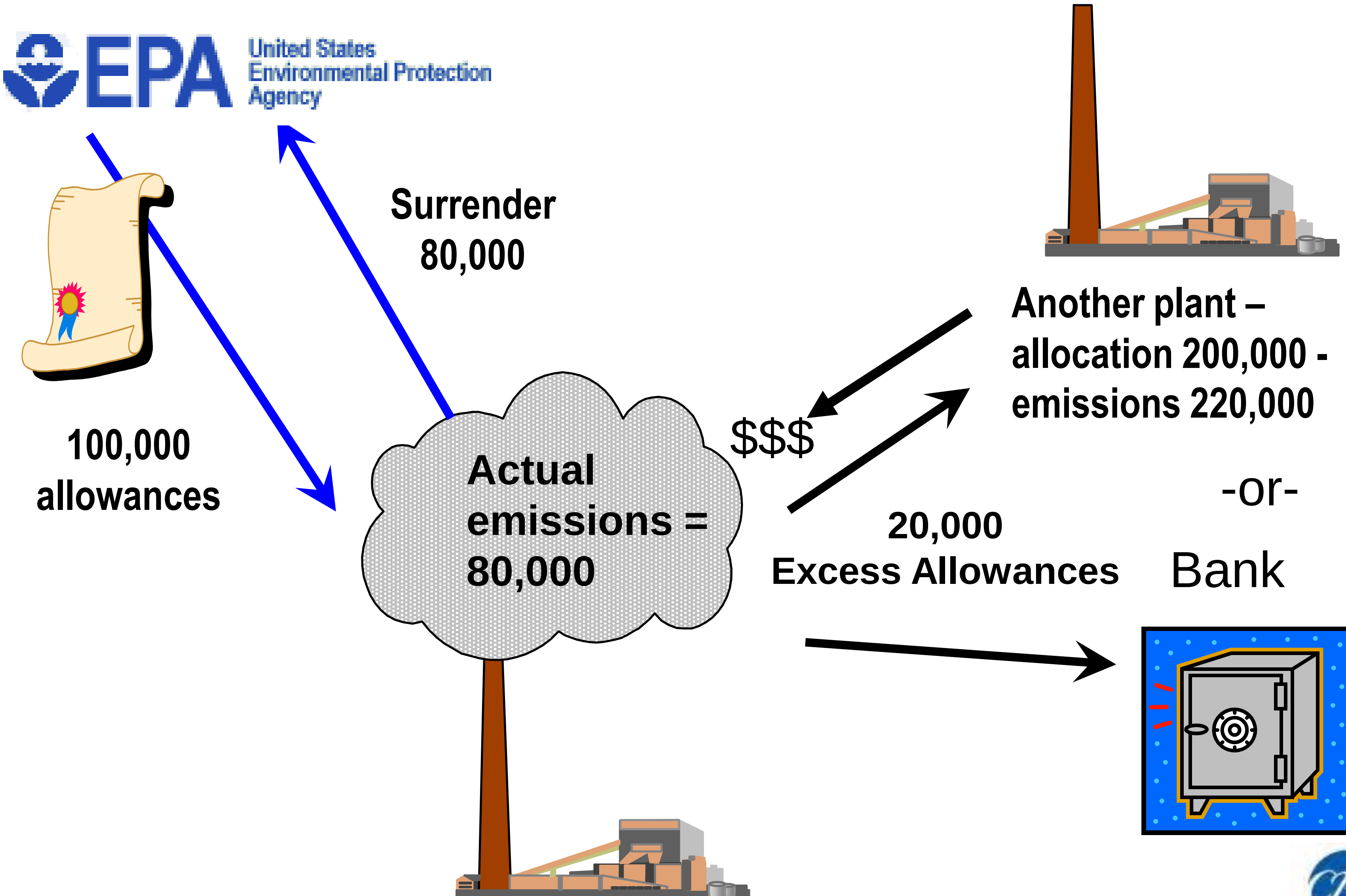
W. David Montgomery, Ph.D.
Vice President

Prepared for the:
Florida Legislature's Symposium on the Science and Economics of Climate Change
November 6 , 2007
Tallahassee, Florida

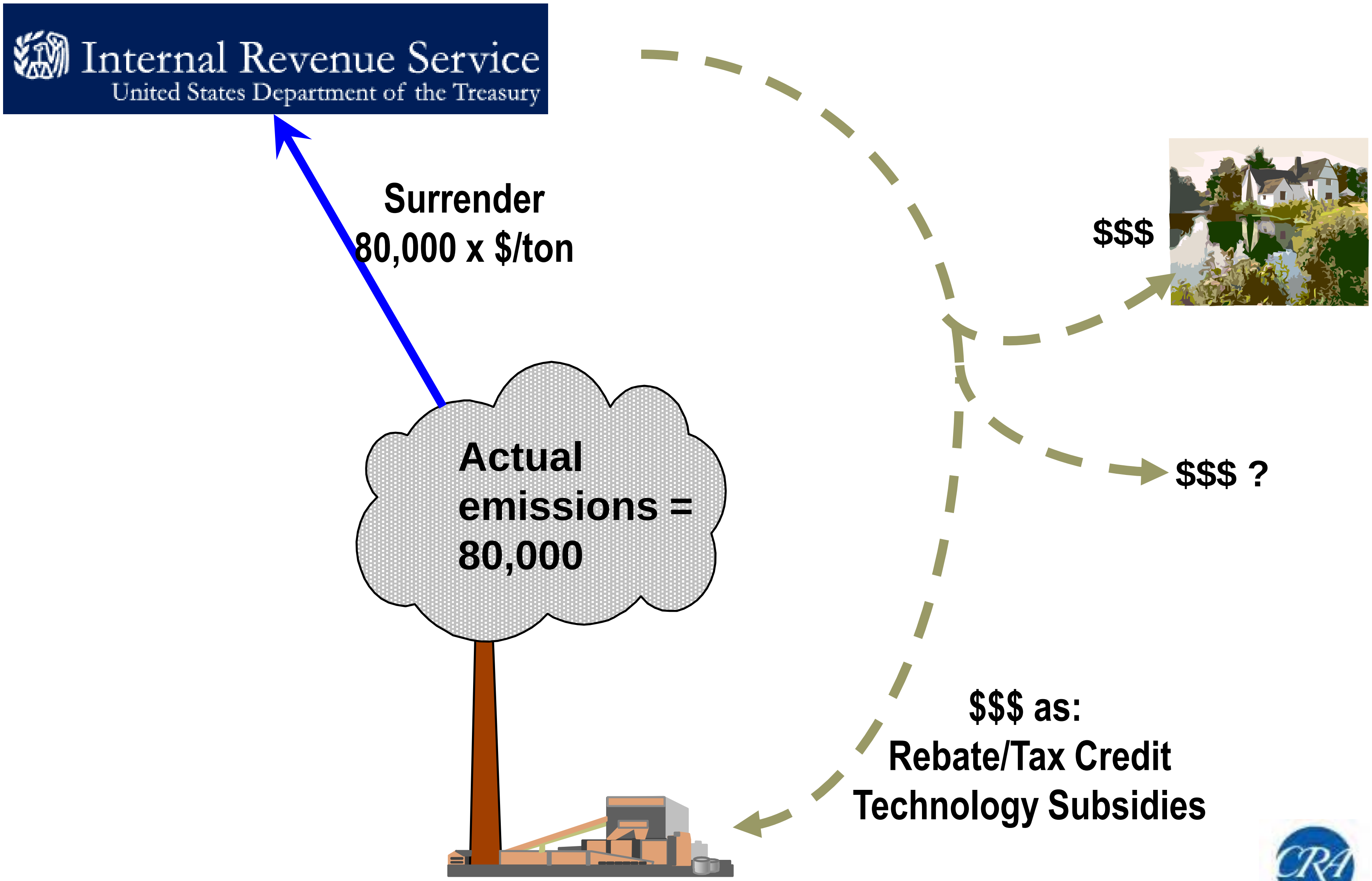
Design of a State Level Climate Policy

- **Governor Crist has issued executive orders that mirror some aspects of California's greenhouse gas policies**
  - A study of California's climate policy done by CRA for the Electric Power Research Institute provides insights into issues Florida will face
  - Florida differs in important ways, so the story will not be exactly the same
- **Many of the design issues are similar**
  - Need for market based measures versus command and control regulation
  - Need for provisions ("safety valve") to reduce price and cost risks
  - Point of regulation and extent of coverage
  - What constitutes a "cost containment" measure?
  - How relevant are targets for 2050?
- **Avoidable problems of a state-level approach**
  - Unrealistic expectations for what state-level policy can accomplish
  - Failure to consider economics, technology pace, how to meet future energy demand in setting targets
  - Restrictions on use of offsets or energy from outside the state
  - Leakage and market distortions from attempting to prevent leakage
  - Unanticipated effects of linkage to other trading systems

Emissions Cap & Trade Basics



Emissions Tax Basics

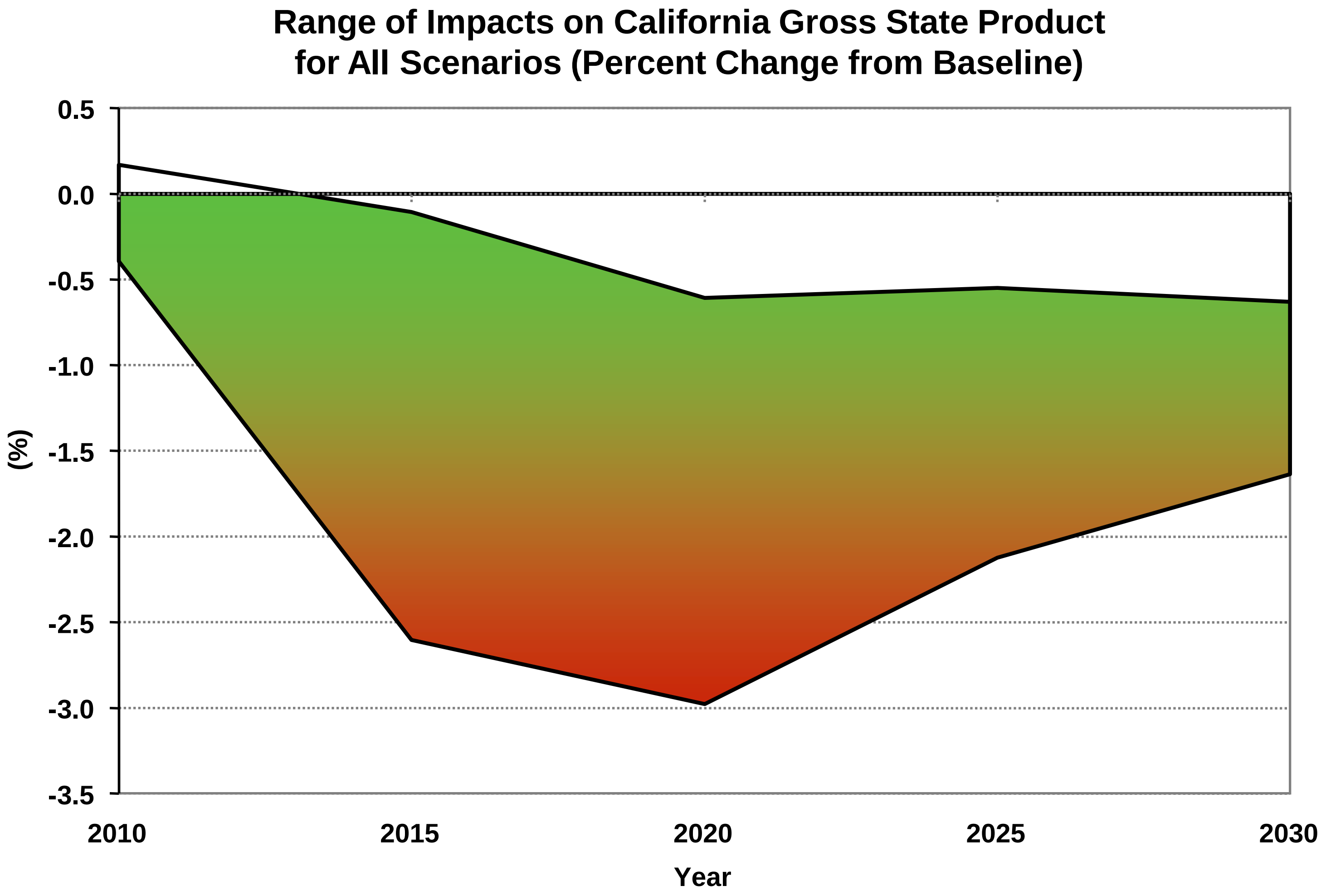


-- Findings From CRA's Studies of California Programs --

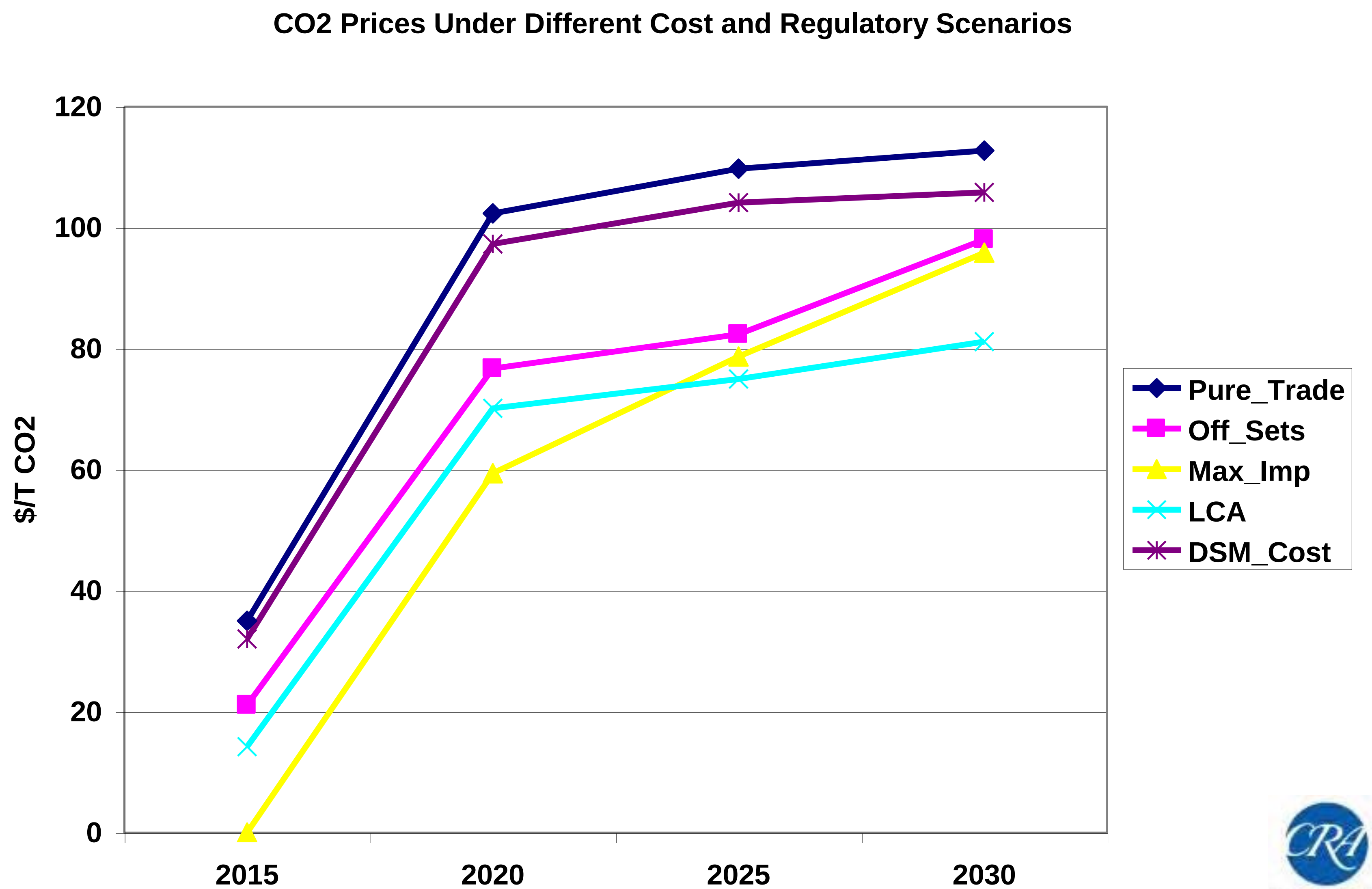
Principal Findings

- **Greenhouse gas controls will impose costs on any state that implements them**
- **Cap and trade beats command and control**
  - The high costs of sector specific regulation
  - Layering regulation on top of cap and trade increases cost
- **Cost risks are high without a price safety valve**
  - Risks of unexpectedly high abatement costs
  - Unnecessary carbon price volatility
- **Long-term targets set well below current emission levels are not feasible with current technology**
  - Unrestricted availability of nuclear power or development of cost-effective technologies that do not exist today are required
  - Without these techologies only “demand destruction” can get emissions down to 20% of 1990
- **Other cap and trade design issues**
  - Broad coverage is impossible with a downstream system
  - Offsets can reduce but not eliminate costs
  - Linkage to other systems can produce unexpected results
- **A state cannot efficiently regulate emissions outside its boundaries**
  - Importance and difficulty of policy toward electricity imports
  - Shifts of investment, economic activity, *and emissions* to other states
  - California’s current approach cannot avoid perverse consequences

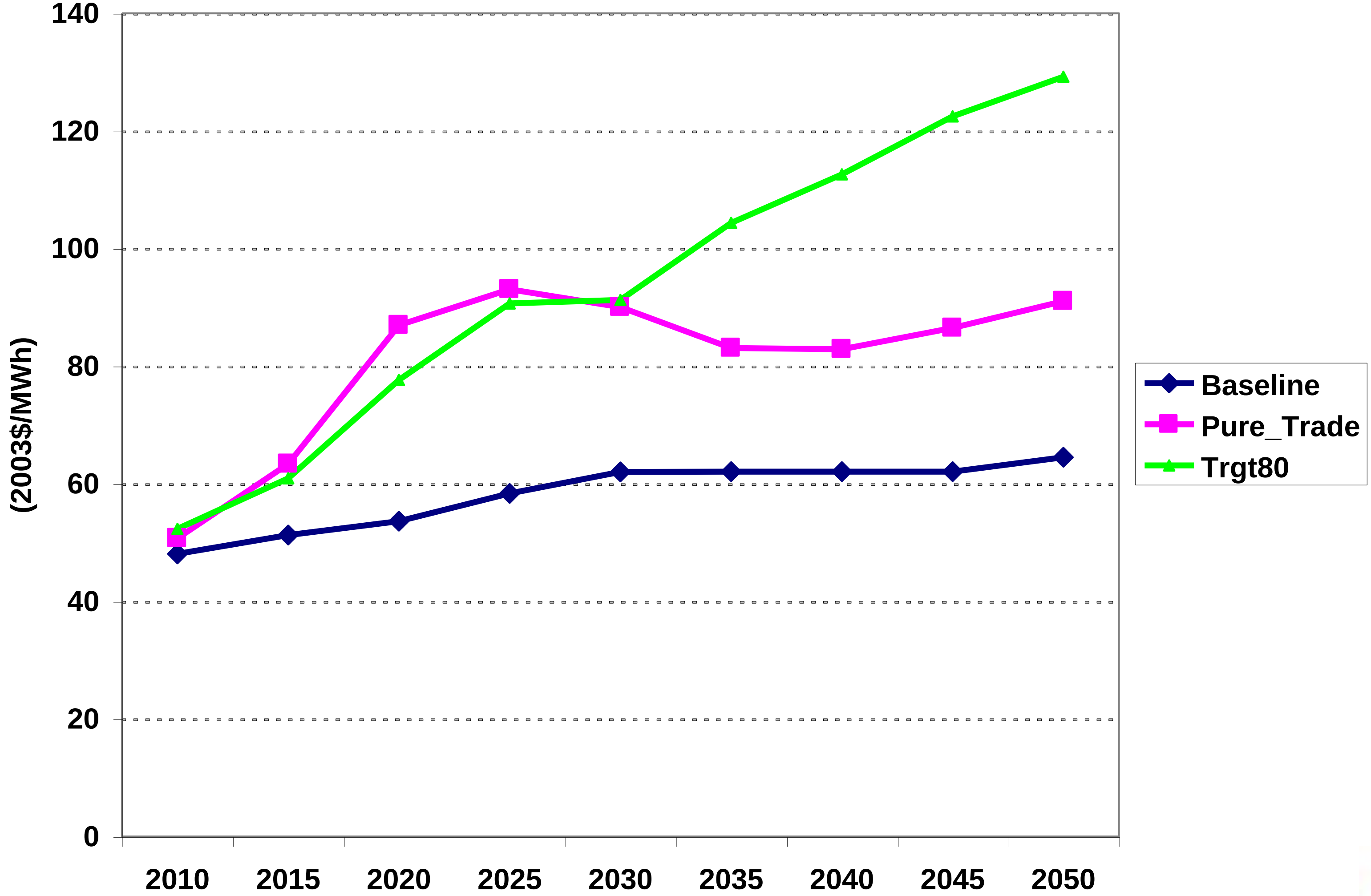
There Will Be A Cost



Carbon Prices Are Highly Uncertain Depending on Regulatory Design and What Abatement Really Costs

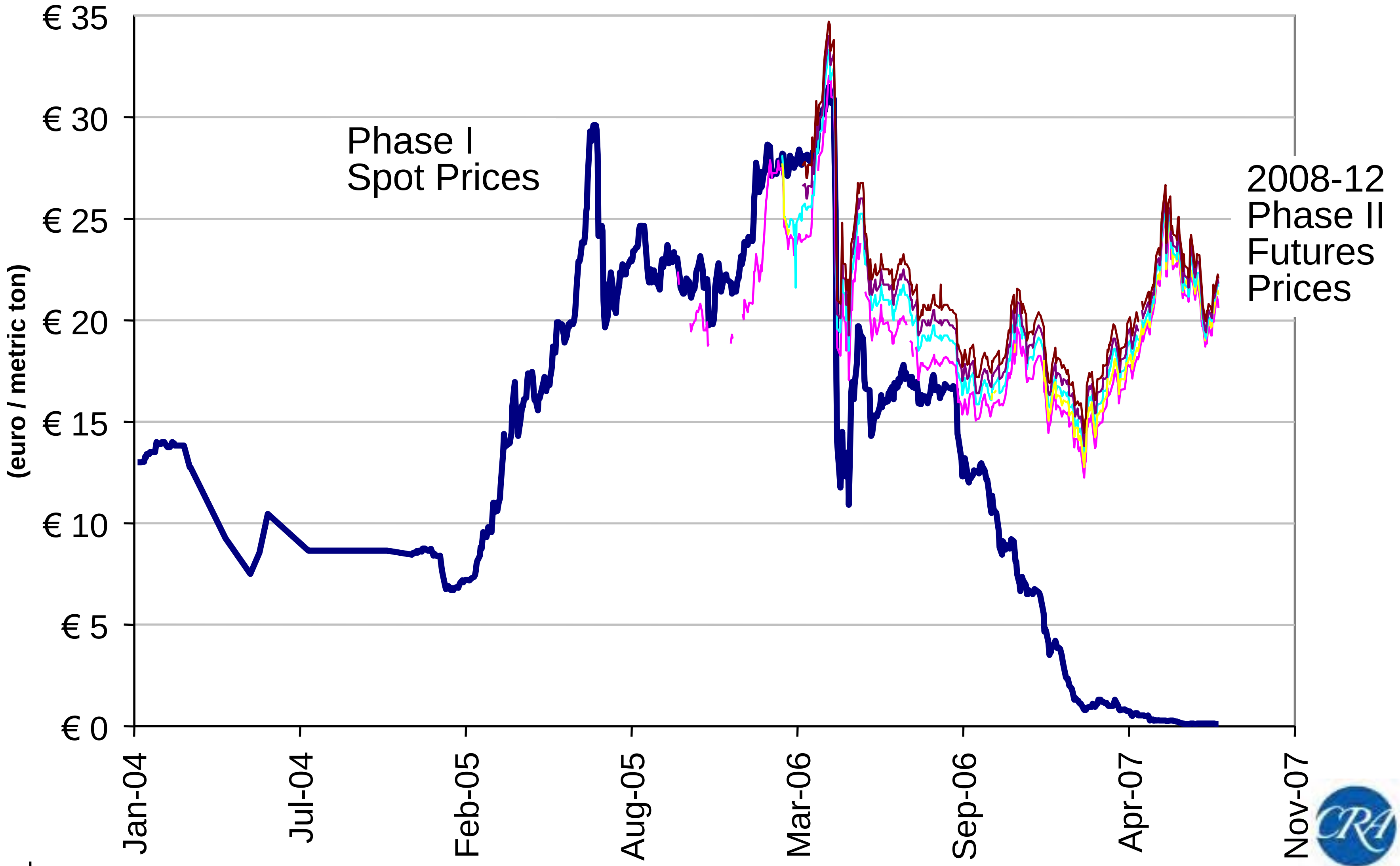


Electricity Prices Would Be Driven Up By More Than 50% In 2025



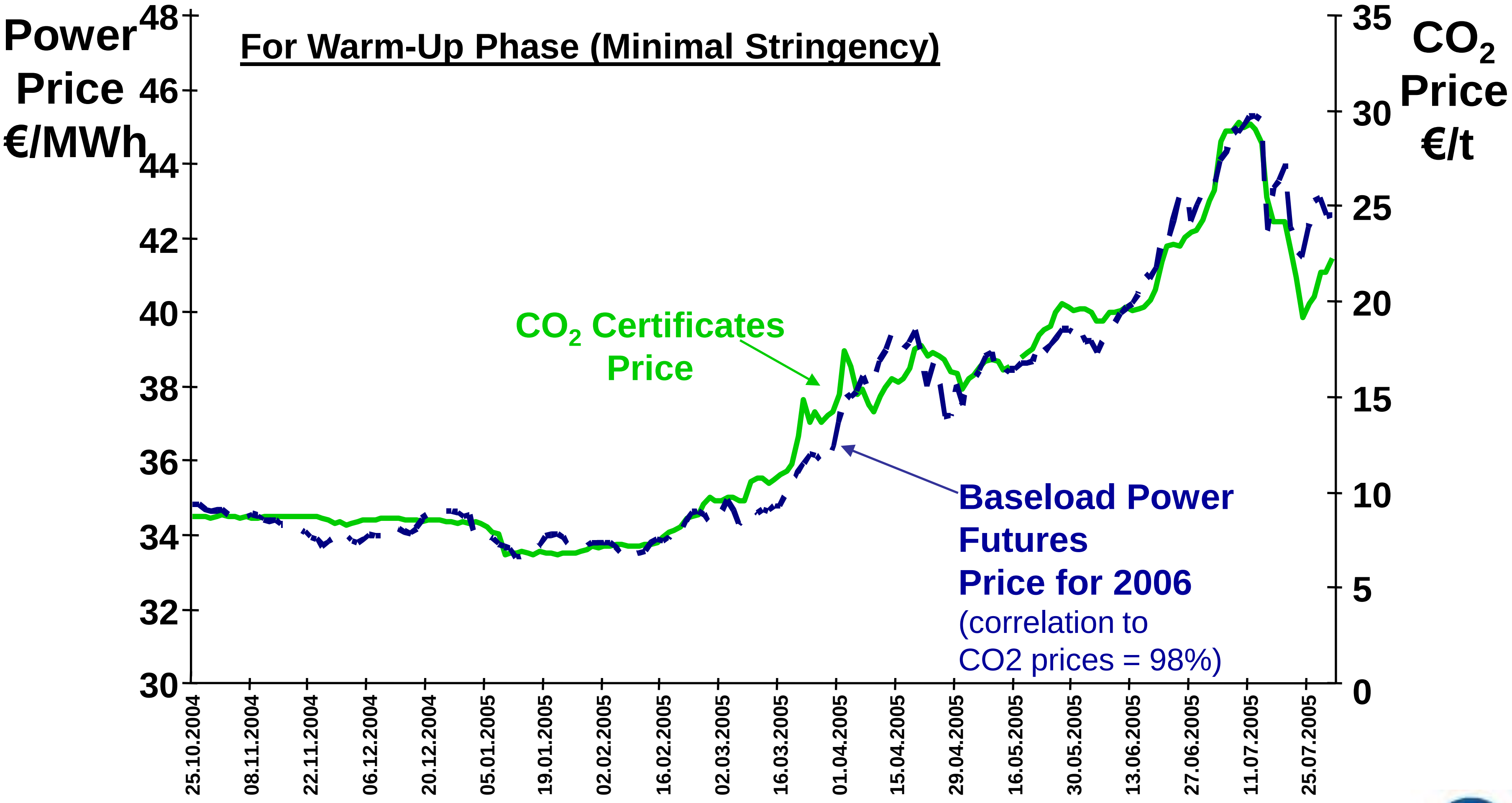
-- The EU ETS Also Has Demonstrated That Hard Caps Can Be Expected to Have Volatile Emissions Prices --

EU's ETS Experience Illustrates How Large Risks Are



Source: Bloomberg EU ETS Prices

The EU ETS Has Demonstrated that Energy Prices Become Volatile Along with GHG Prices



Source: IFIEC Europe "Correcting the failures in the EU-Emissions Trading Scheme" Brussels, June 28, 2005

The Answer Is Not A Retreat From Market Based Policies

- **Regulatory programs and efficiency standards adopted without regard to whether or not they efficiently correct an underlying market failure only increase costs**
- **Regulatory measures are not "cost-containment" – *they may reduce carbon prices but only at the expense of increasing overall costs***
- **No regulator can be sufficiently omniscient to manage all the decisions that a price-based system will motivate -- *thus a regulatory approach will ultimately fail to deliver sufficient reductions***
- ***LCFS and fuel economy standards for vehicles* that go beyond the emission reductions that would be economic with a uniform carbon price significantly increase costs**

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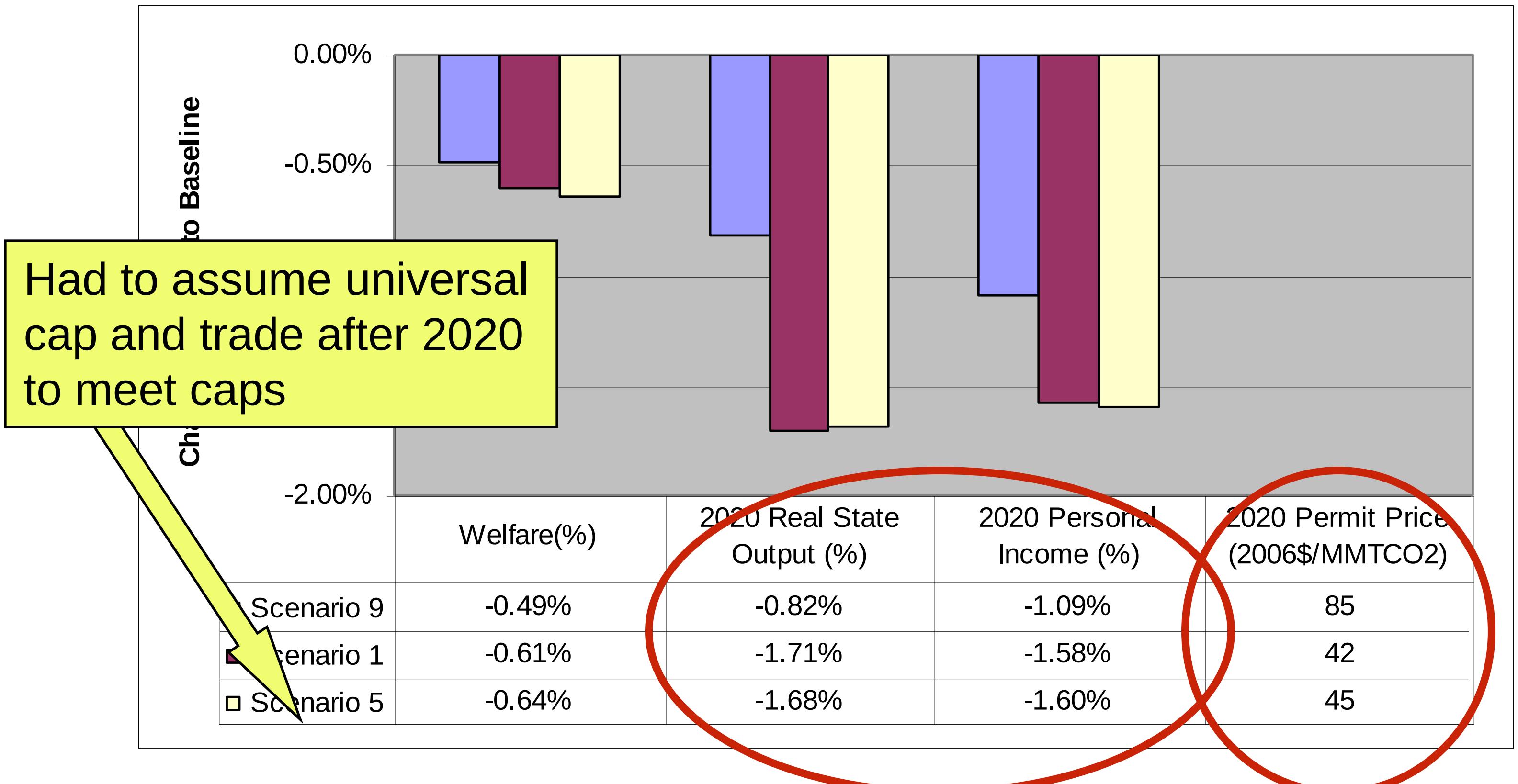
California Appears Increasingly Committed to Inefficient Regulatory Approaches That Raise Costs *Even Though They Appear to Lower CO2 Prices*

Layering Command-and-Control Strategies on Top of Market-Based Strategies Decreases Welfare, Economic Output, and Personal Income



	Welfare(%)	2020 Real State Output (%)	2020 Personal Income (%)	2020 Permit Price (2006$/MMTCO2)
Scenario 9	-0.49%	-0.82%	-1.09%	85
Scenario 1	-0.61%	-1.71%	-1.58%	42
Scenario 5	-0.64%	-1.68%	-1.60%	45

Scenario 9: Pure cap and trade
Scenario 1: Efficiency standards and regulation with universal cap and trade
Scenario 5: Efficiency standards and regulation with sector specific cap and trade

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EU-ETS Provides Concrete Evidence of Undesirability of a Mixed Regulatory and Cap-and-Trade Approach

- **EU-ETS covers less than 50% of EU GHG emissions**
- **Other sources of CO2 emissions have continued to grow unabated since start of EU-ETS**
- **Slow progress in efforts to impose technology and behavioral "standards" to address the uncovered but growing emissions**
- **Prediction:**
  - If the EU fails to meet its Kyoto Targets, it will be because of the >50% of emissions sources that went uncapped under its downstream approach.

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The Answer Could Be An Effective Safety Valve Based on Policymakers' Beliefs About The Cost of Meeting Caps

- **Basing targets on optimistic cost projections can produce a nasty surprise if the optimism is unfounded**
  - Accepting a safety valve based on the optimistic cost projections would guard against this possibility
  - If the optimistic cost projections seen thus far in California's economic assessments are right, the caps will be met
- **Our safety valve case did just this**
  - Accept a set of optimistic assumptions about cost of new technologies and energy efficiency
  - Calculate carbon price to meet targets based on these assumptions
  - Use this carbon price as a safety valve using standard cost assumptions and estimate emission reduction and economic losses
- **Result – safety valve**
  - Meets targets if optimism about costs is correct
  - Reduces costs by almost 50% if optimism turns out to be unfounded

-- Regional Policies Have No Effective Solutions to Leakage --

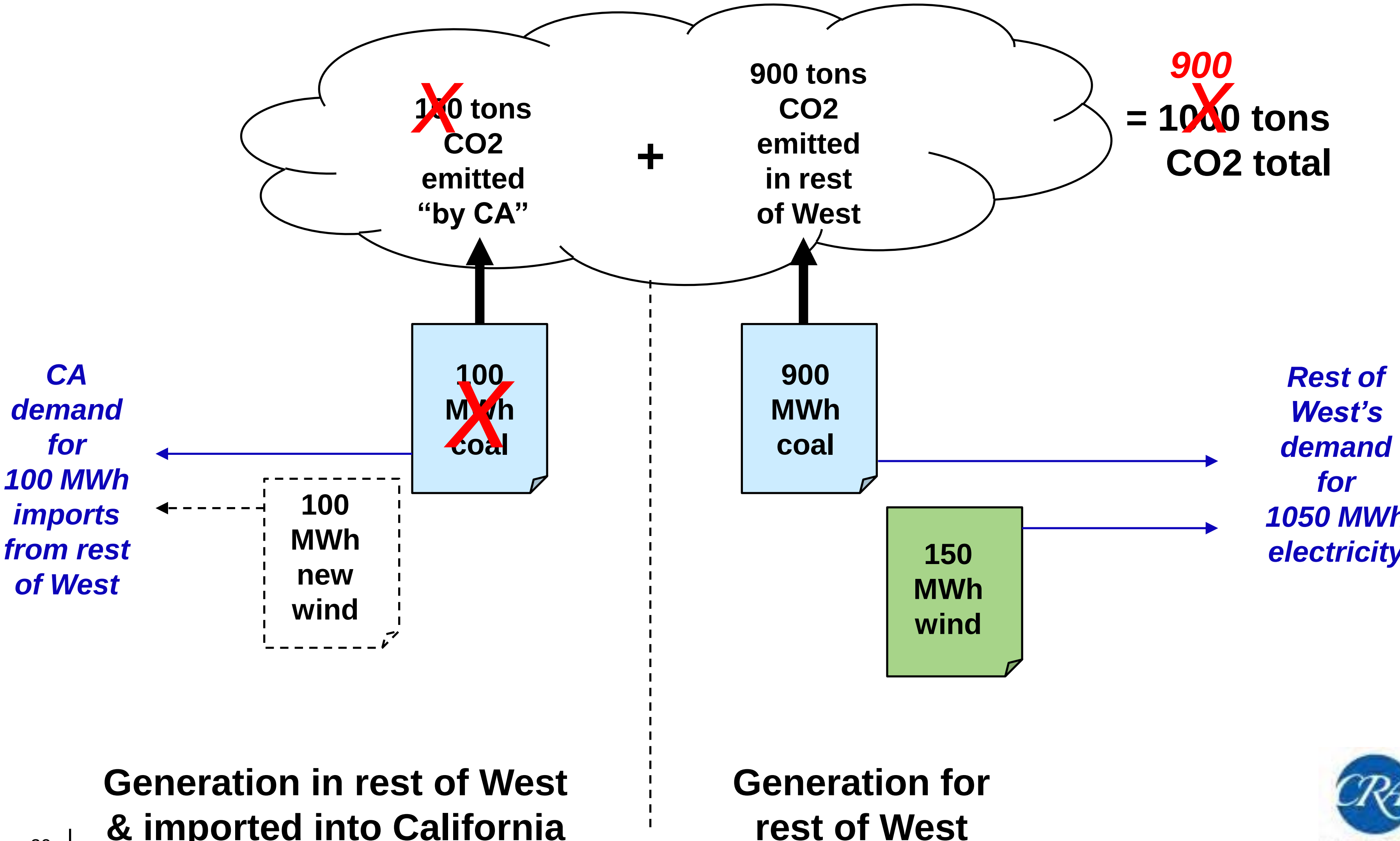
Imports are A Partial Safety Valve that Florida Lacks

- **California study shows that despite problems of leakage, imports are extremely important to control costs**
  - Limits on renewable capacity, deployment of nuclear power, and availability of sites for carbon capture and sequestration make imports the only way to get enough low carbon power
  - Restrictions on imports can make it costly or impossible to meet tight limits on emissions from power generation without relying on demand destruction from higher prices
  - Imports of electricity from low carbon sources outside the state are the only answer
- **Lack of transmission capacity could make tight limits very expensive for Florida**
  - Limited capacity for renewables inside the state
  - No excess capacity in current transmission links
  - High costs of transmission to and inside the state
  - High cost of adding natural gas transmission also makes switch to natural gas for generation in-state problematic
- **Then there's leakage and the unintended consequences of trying to prevent it**

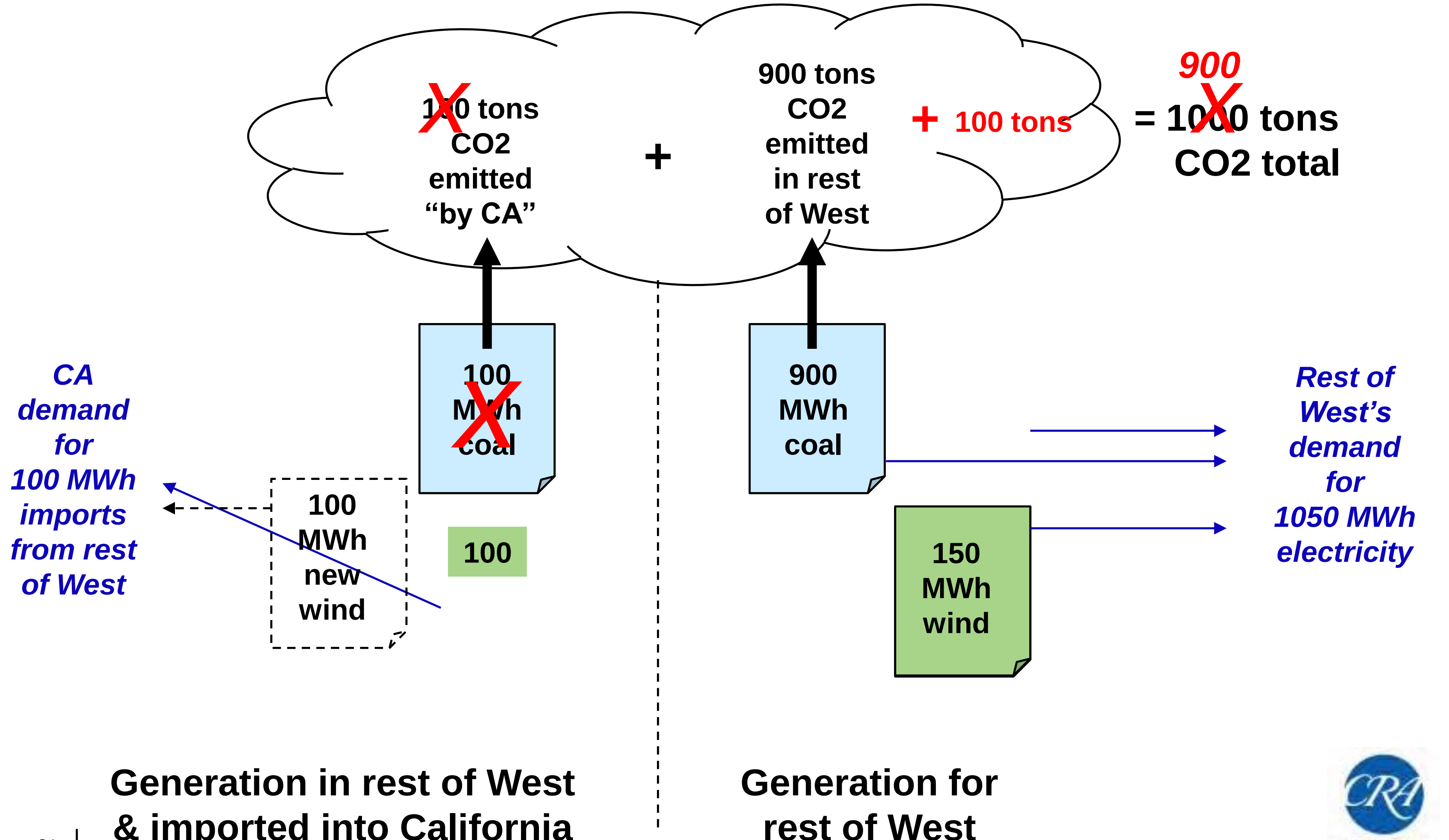
Dependence on Electricity Imports Creates Intractable Problems of Leakage

- **Electricity is a fundamentally fungible commodity so that carbon emissions can only be tracked at the source**
  - No state has jurisdiction over generators outside its borders
- **Sufficient low carbon electricity is now being generated in the West that simply reassigning contracts for this energy to California would easily meet import needs**
  - Existing and new coal fired generation replaces those contracts for states outside California
- **The result is leakage – apparent reductions in California's emissions balanced by increases in emissions from generation delivered to other states**
- **All unilateral efforts to stem this leakage impose additional costs on California and have the potential to disrupt Western power markets**
  - Only a WSCC or US wide carbon trading system can solve the leakage problem

Import Performance Standard Can Create "Contract Shuffling" with No Net GHG Emissions Change



Import Performance Standard Can Create "Contract Shuffling" with No Net GHG Emissions Change



California's Experiment Could Radically Alter Power Markets in the Western U.S.

- **The California PUC has issued rules for how utilities in California can contract for new power supplies**
  - Baseload contracts must be unit specific so that emissions can be calculated based on generation type
  - Sales in the short-term market are not identifiable so that emissions are attributed based on average emission factors
- **The result of these rules is likely to be**
  - Increased costs of power in California
  - Contract shuffling, in which California utilities try to shed their long term coal commitments and buy up all existing hydro, wind and nuclear generation
  - Long term contract markets dry up as California utilities "wash" emissions from coal-based imports by switching to short term purchases
  - Prices could therefore become much more volatile in the West, as they were in the California energy crisis
- **Contract shuffling and nearly 100% leakage is an ironic but likely result of California rules**

Critical Policy Insights from California

- **Only a comprehensive market-based approach can allow the most cost-effective actions to be identified, innovated, and applied**
- **Combining regulatory programs with cap-and-trade or carbon taxes only increases costs**
- **An effective "safety valve" is required to prevent unexpected costs and price volatility**
- **Long term goals are prohibitively costly without new technologies, including zero-carbon transportation fuels, nuclear power, and carbon capture and sequestration**
  - *and credible incentives for R&D into these technologies are required to make these technologies available*
- **Imposing disproportionate regulations on any sector is counterproductive**
- **Attempting to regulate emissions from electricity imports without a national or regional emissions trading system creates an unavoidable tradeoff between leakage and cost**

Implications for Florida

- **There's no getting around it, state-level climate policy is an uphill battle**
- **Greenhouse gases do not cause harm locally, so that there are near zero benefits from State action unless it induces others to come along**
  - Florida accounts for ~1% of global CO2 emissions so that even getting Florida to zero emissions causes NO change in impacts
- **Costs can be very high unless targets are set in light of expected demand growth, availability of low-carbon energy sources, and timing of technology**
- **Separate R&D incentives are needed to create new technologies and opportunities for new industries and innovation**
- **Problems of handling leakage and competitive impacts on trade-vulnerable industries at a state level are nearly intractable**

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Gilbert E. Metcalf is a Professor of Economics at Tufts University and a Research Associate at the National Bureau of Economic Research. Metcalf has taught at Princeton University and the Kennedy School of Government at Harvard University and has served as a Visiting Scholar at the Joint Program on the Science and Policy of Global Change at MIT. He has served as a consultant to various organizations including the Chinese Ministry of Finance, the U.S. Department of the Treasury, and Argonne National Laboratory. Metcalf's primary research area is applied public finance with particular interests in taxation, energy, and environmental economics. His current research focuses on policy evaluation and design in the area of energy and climate change. He has published papers in numerous academic journals, has edited two books, and has contributed chapters to several books on tax policy. Metcalf received a B.A. in Mathematics from Amherst College, an M.S. in Agricultural and Resource Economics from the University of Massachusetts Amherst, and a Ph.D. in Economics from Harvard University.

Policy Choices for Addressing Climate Change

Florida Legislature's Symposium on the Science and Economics of Climate Change

November 6 , 2007

Gilbert E. Metcalf
Department of Economics
Tufts University
and
National Bureau of Economic Research

Florida's CO_2 Emissions

2003 CO_2 Emissions (MMT)				
Sector	**Direct Emissions**	**Share**	**Total Emissions**	**Share**
Residential	1.9	0.8%	66.7	27.3%
Commercial	4.5	1.8%	53.5	22.0%
Transportation	98.2	40.3%	98.3	40.3%
Industrial	14.2	5.8%	25.4	10.4%
Electricity	125.1	51.3%		
Total	243.9		243.9	

7.4 percent of U.S. energy related emissions

Electricity and transportation shares higher than national average

Industrial share lower than national average

Policy Choices

- A carbon tax and a cap and trade system are examples of *market based instruments*
- Both put a price on carbon emissions
- Raising costs provides the incentive to reduce emissions

Key Points on Policy Choice

- Market based instruments more efficient than regulation
- Carbon pricing is an essential policy tool for reducing greenhouse gas emissions
- May want to supplement with other policies
  - model building codes
  - smart growth zoning
  - information programs
  - incentives to break down information asymmetries (e.g. landlord-tenant energy efficiency programs)

Not a substitute for a carbon pricing policy

Setting a Price on Carbon

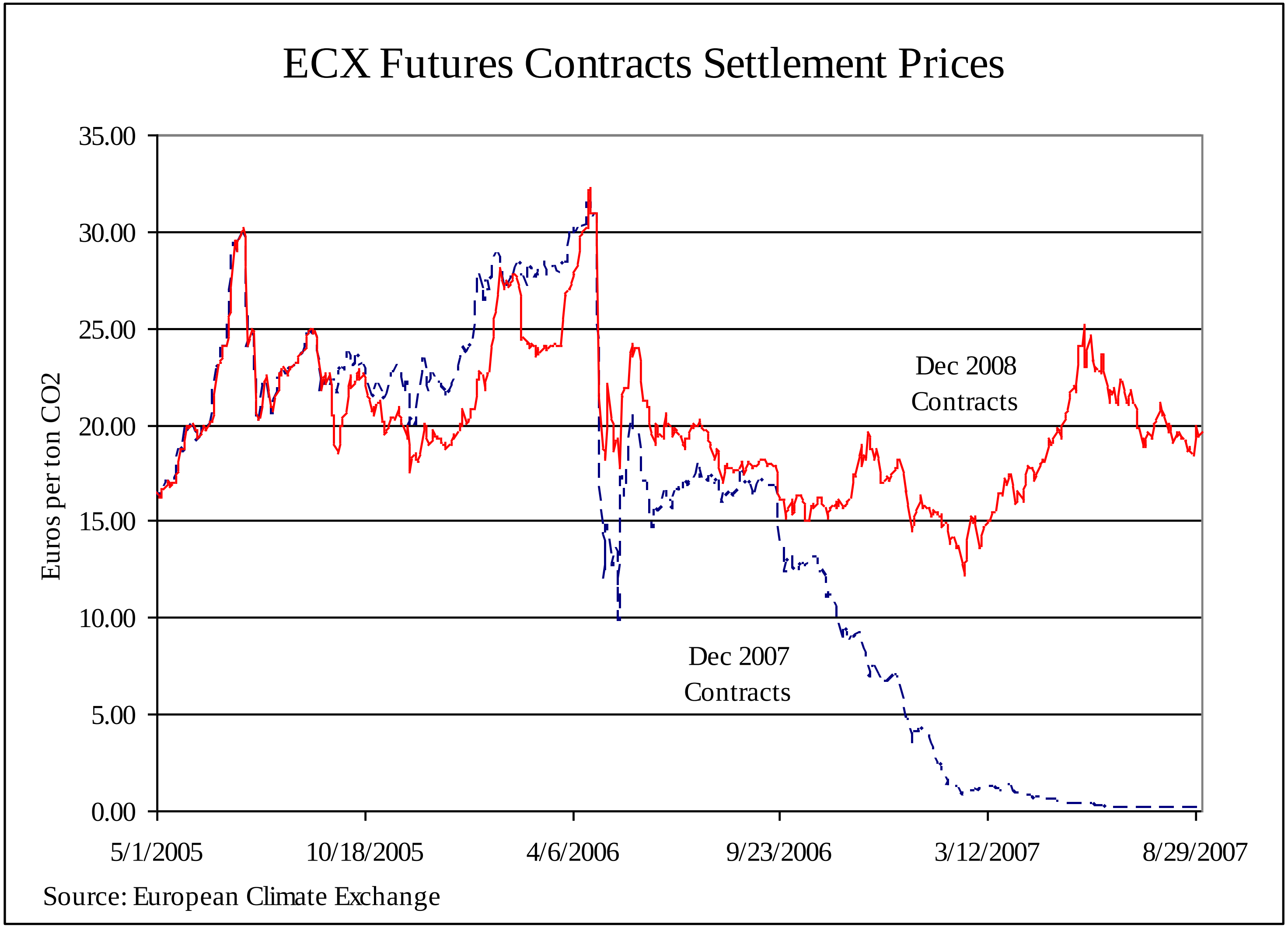
- Choice of instruments:
  - Cap and Trade
  - Carbon Tax
  - Hybrid instruments (safety valve)
- Points of similarity
  - both raise the price of carbon emissions
  - both raise the price of energy consumption

Factors Favoring Cap & Trade

- Experience with cap & trade
  - EU ETS
  - SO_2 trading among electric utilities
- Certainty of emissions
  - only if we are willing to tolerate high permit prices
- Politically appealing
  - does not appear to affect price of energy

Factors Favoring Carbon Tax

- No precedent for auctioning permits in cap and trade programs
  - value of Florida permits likely exceeds $3 billion with a $15 per ton permit price
- Permit allocation and rent seeking
- Administrative costs
- Efficiency
- Price volatility under cap & trade



ECX Futures Contracts Settlement Prices
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Euros per ton CO2
Dec 2008
Contracts
Dec 2007
Contracts
5/1/2005
10/18/2005
4/6/2006
9/23/2006
3/12/2007
8/29/2007
Source: European Climate Exchange

National Carbon Tax Scenario

- An upstream tax on carbon content of fossil fuels and other GHGs at an initial rate of $15 per metric ton of CO_2 equivalent.
- Tax rate should grow gradually over time.
- A rebate of the tax for sequestered GHGs as well as credits for approved sequestration activities.
- An environmental earned income tax credit linked to payroll taxes.

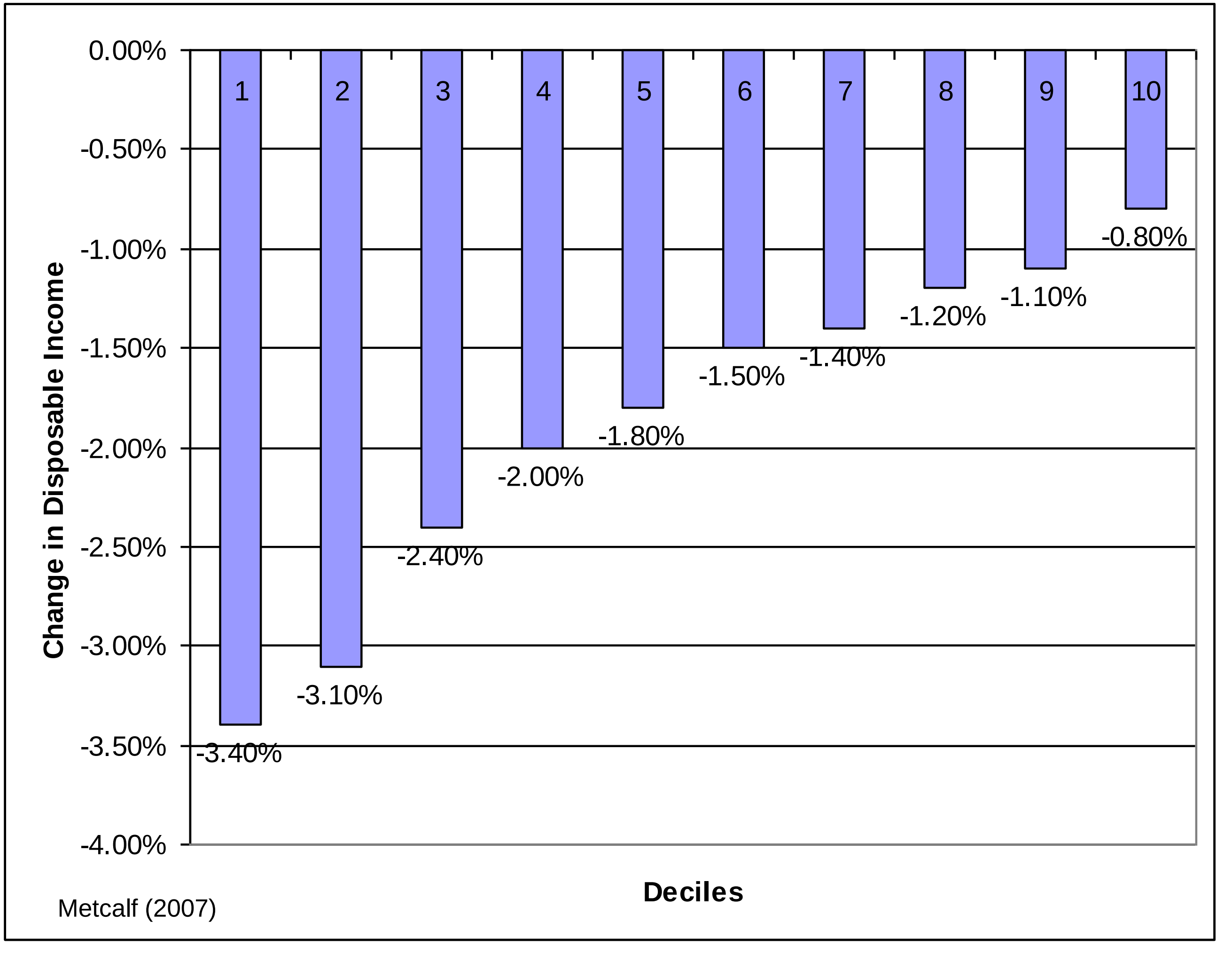
Consumer Price Impacts of a Carbon Tax	
Commodity	**Price Increase**
Electricity and Natural Gas	14.1%
Home Heating	10.9%
Gasoline	8.8%
Air Travel	2.2%
Other Commodities	0.3 to 1.0%

Source: Author's calculations using the Input/Output Accounts and the Consumer Expenditure Survey. A 2003 tax of $15 per metric ton of CO_2 (year 2005 dollars) is assumed to be passed fully forward to consumers.

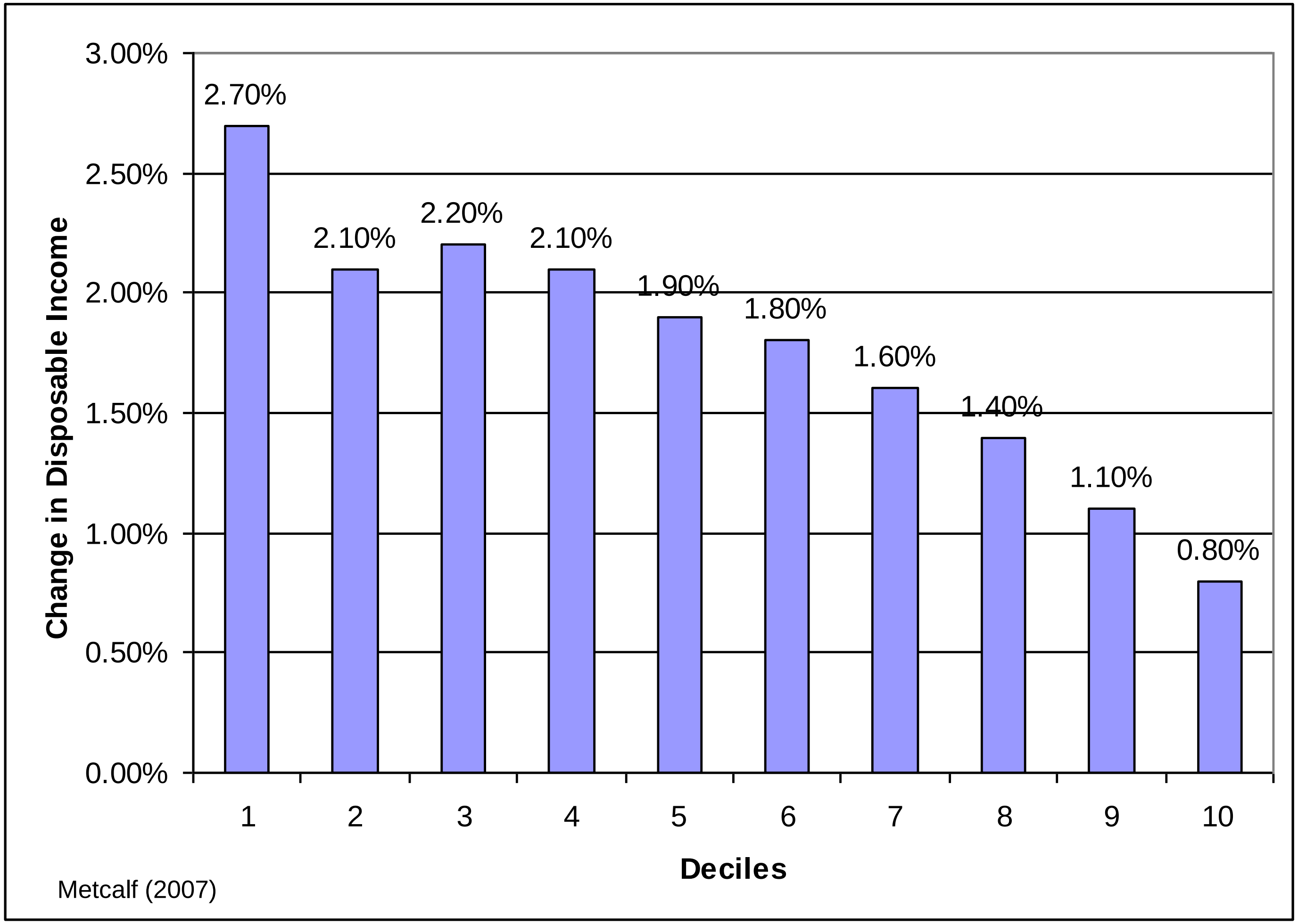
Short-Run Emissions Reductions With a Carbon Tax			
Source	**Reference**	**Carbon Tax**	**Percentage Reduction**
Emissions (mmt CO_2e)			
Greenhouse Gases	8201.5	7049.8	14.0%
CO_2 Emissions	6995.2	6408.8	8.4%
Other GHGs	1206.3	641.0	46.9%
Primary Energy Use (EJ)			
Coal	25.8	22.0	14.7%
Petroleum Products	49.6	46.8	5.6%
Natural Gas	26.8	25.9	3.4%

Source: Metcalf et al. (forthcoming). Results are for a $15 per ton CO_2e carbon tax in 2015. The tax is in year 2005 dollars.

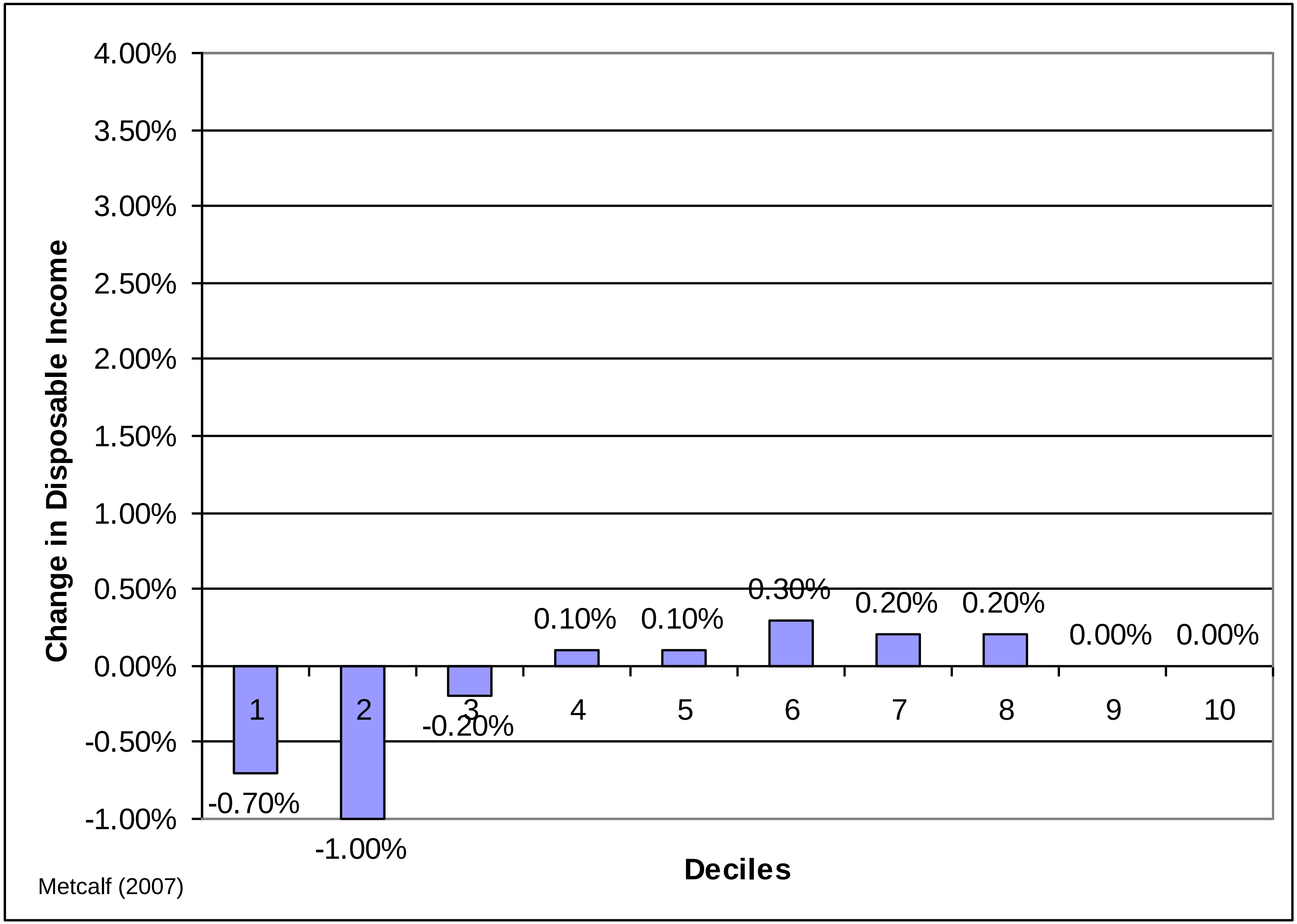
Carbon Tax Impact



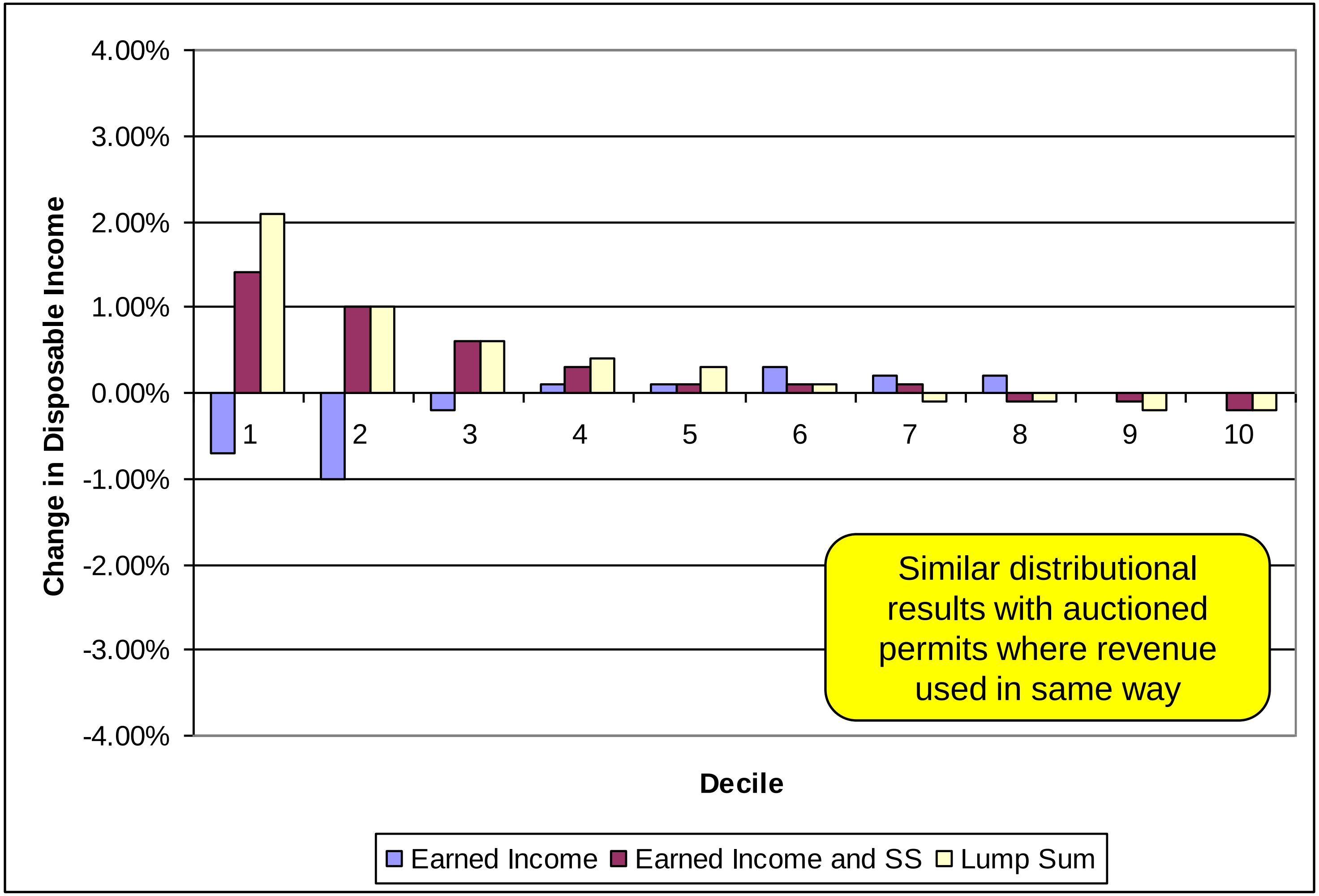
Environmental Tax Rebate Impact



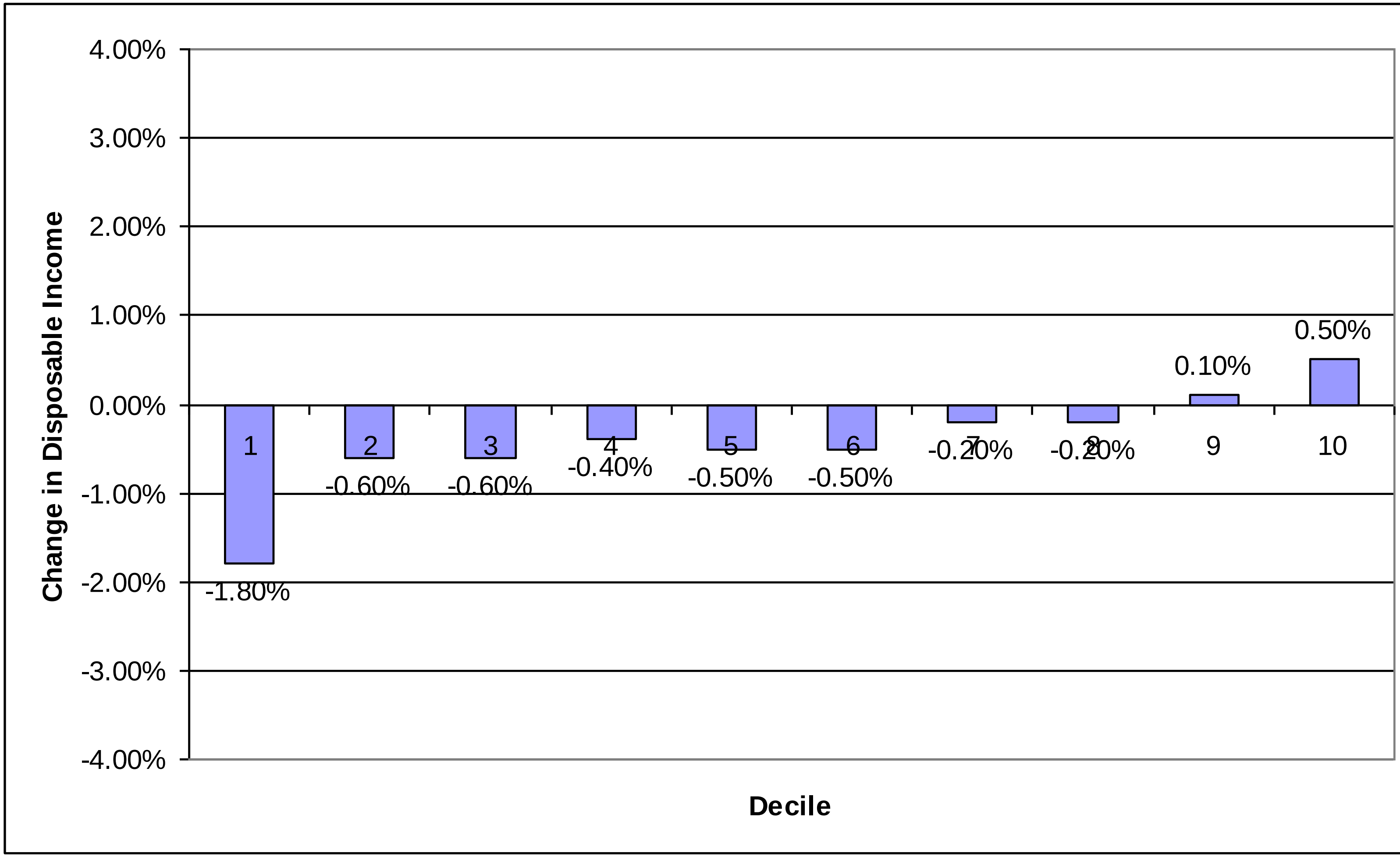
Net Impact on Income Distribution



Alternative Rebate Options



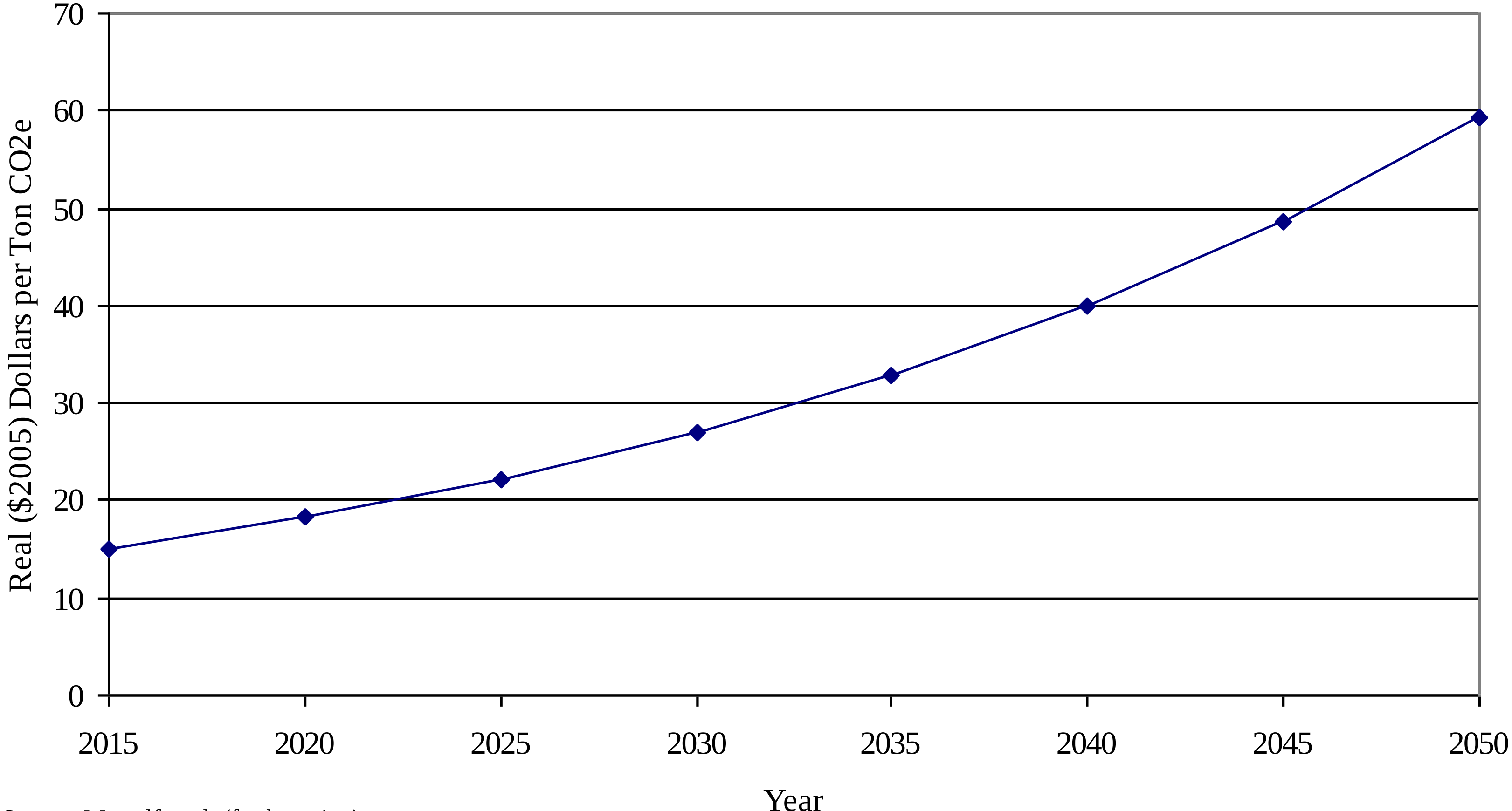
Grandfathered Cap and Trade



Concerns with a Carbon Tax

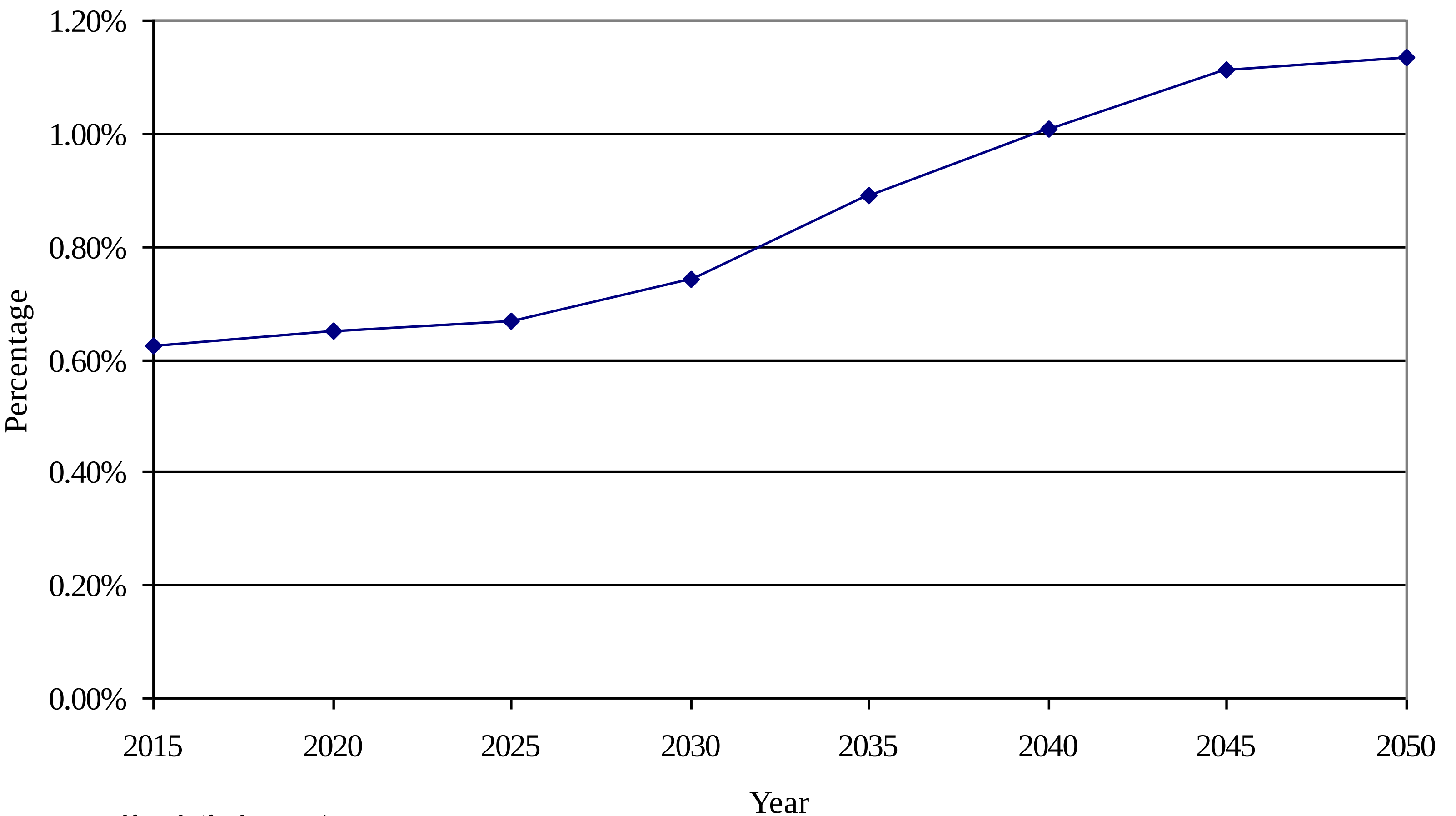
- Stability of tax base
- No guarantee of emission reductions
- Efficiency and expediency

Carbon Dioxide Tax Rates



Source: Metcalf et al. (forthcoming)

Carbon Tax Revenue As a Percentage of GDP



Source: Metcalf et al. (forthcoming)

No Guarantee Of Emission Reductions

- What matters are the economic and ecological consequences of higher concentrations of greenhouse gases in the atmosphere resulting from global emissions.
- As yet no definitive scientific evidence on the precise amount of emission reductions required to stabilize temperature and prevent large economic and ecological losses.
- To give primacy to specific emission reductions regardless of the cost is to suggest a greater certainty in the climate science than currently exists.
- We should balance reductions against the economic cost as represented by the marginal cost of abatement.

Efficiency and Expediency

- Proponents of a cap and trade system may feel the need to grandfather all of the permits in the interests of political expediency.
- Proponents of a carbon tax may feel the need to exempt certain sectors of the economy.
- Both should be avoided!

Summary

- Carbon tax and cap and trade examples of market based instruments
- A carbon tax can be designed to be revenue and distributionally neutral
- Economic efficiency and administrative advantages to a carbon tax
- Design issues affect efficiency and distribution:
  - upstream/downstream choice
  - cap & trade auctioning
  - sector coverage
  - rebate of carbon revenues