Climate Change Science Overview

Asset Management and Adaptation to Climate Change webinar

Robert Kafalenos
FHWA, Office of Natural & Human Environment
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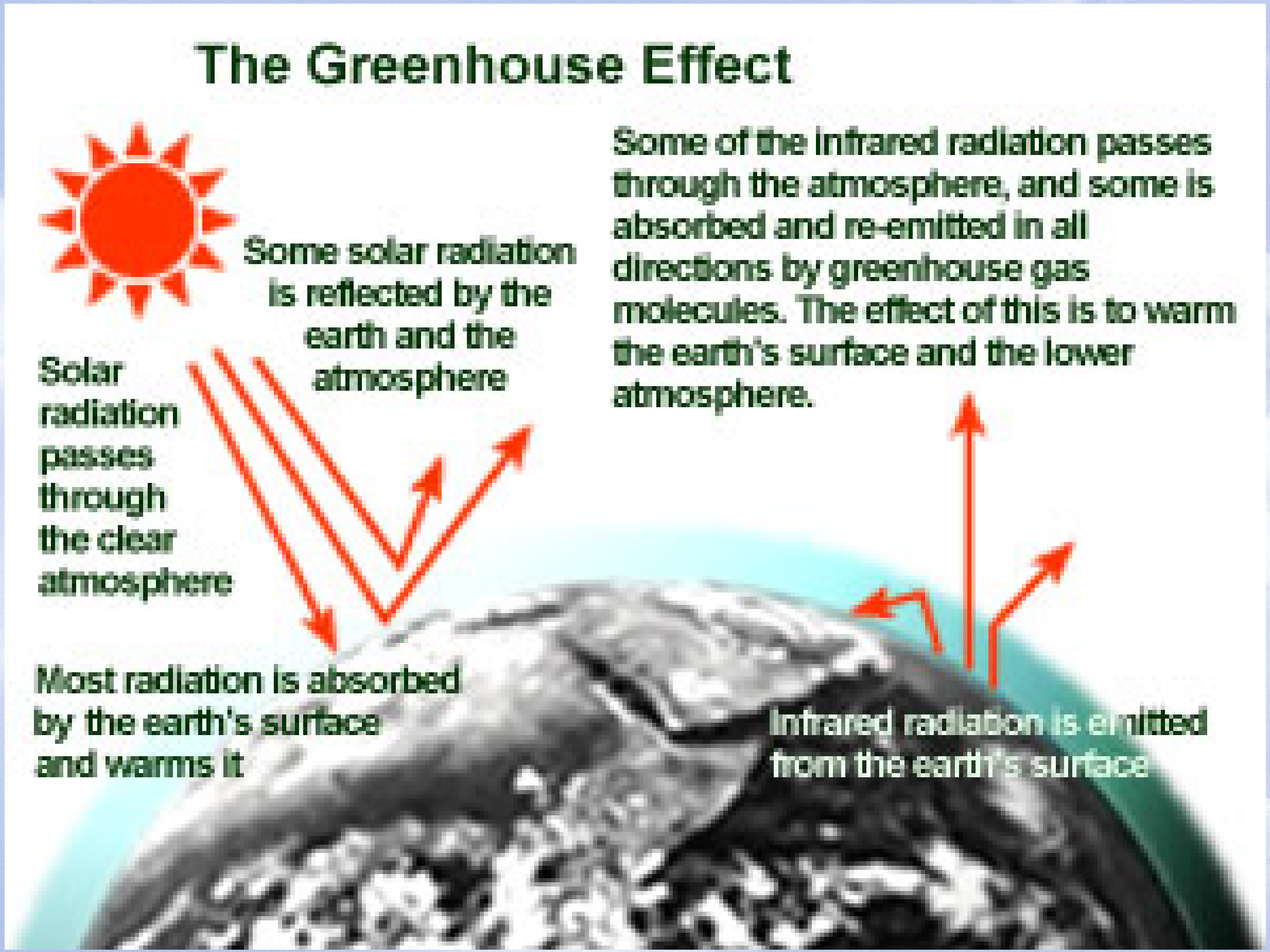
Climate Science - Introduction

- Climate change is an evolving field that involves continuing research and some uncertainty
- FHWA relies on the expertise of other federal agencies (particularly NOAA, NASA and USGS), as well as the IPCC, to help guide our decisions regarding which issues to focus on and where to target resources
- Is Climate Change real? Yes.

The Greenhouse Effect



The greenhouse effect keeps the Earth habitable, but recent changes to the atmosphere are causing it to warm.

Source: USEPA

What’s the difference between “global warming” and “climate change”?

- The global trend has been an increase in global average temperatures
- We are also concerned about impacts besides rising average temperatures, including temperature extremes, changes in sea level, precipitation, storm frequency and intensity—hence, “climate change”
- Small changes in global-average surface temperature can lead to large changes in climatic patterns. Difference between an ice age & an interglacial is ~5°C (9°F)

Why is FHWA Concerned about Climate Change?

Impacts on transportation infrastructure

- Higher temperatures, more intense precipitation events, stronger storms and higher sea levels are likely to have adverse effects on transportation systems

Transportation contribution to greenhouse gas emissions

- Transportation is the second-largest source of greenhouse gases in the US; the US highway system produces 1/20th of the *world's* CO_2 emissions

Influences on Global Climate

Natural Influences

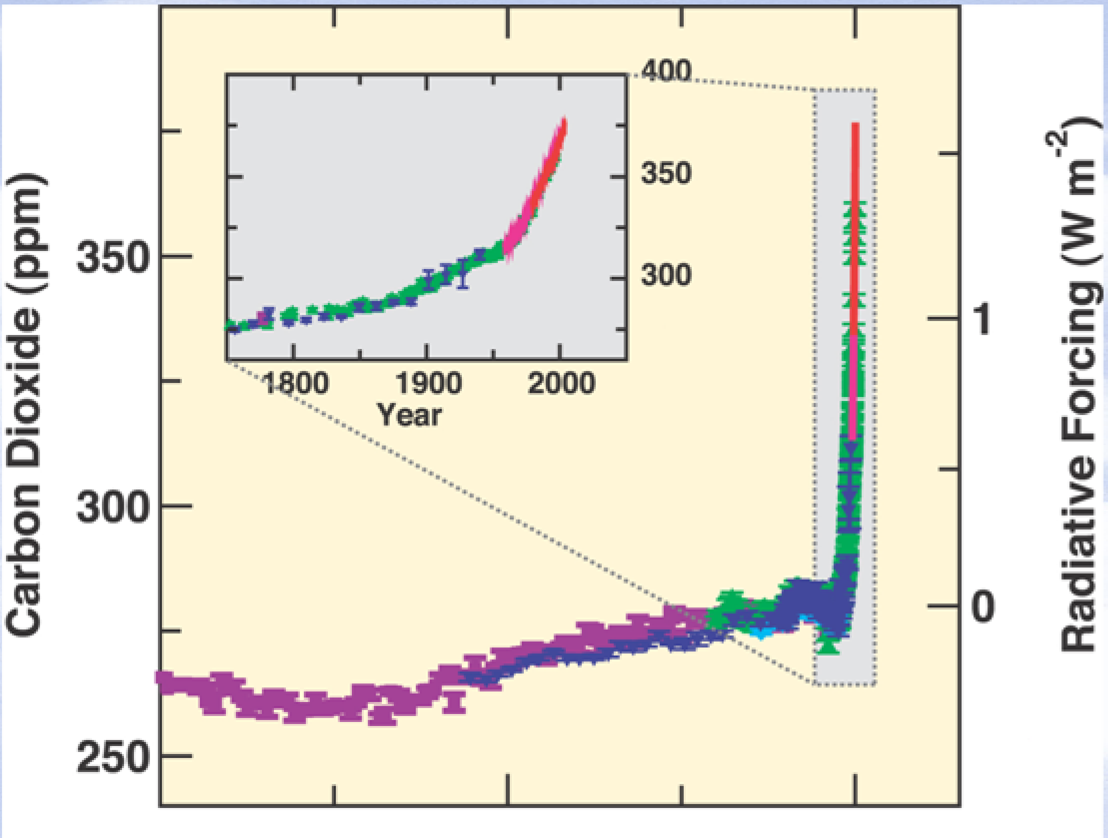
- Variations in the energy output of the Sun
- Variations in the Earth's orbit and tilt
- Continental drift
- Changes in atmospheric composition from volcanoes, biological activity, weathering of rocks

Human Influences

- Rising concentrations of greenhouse gases from fossil-fuel burning, deforestation, agriculture,
- Rising concentrations of particulate matter from agriculture, fossil-fuel burning
- Alteration of Earth's surface reflectivity by deforestation
- Increased high cloudiness from aircraft contrails

Trends in Key GHG Concentrations, Environmental Conditions

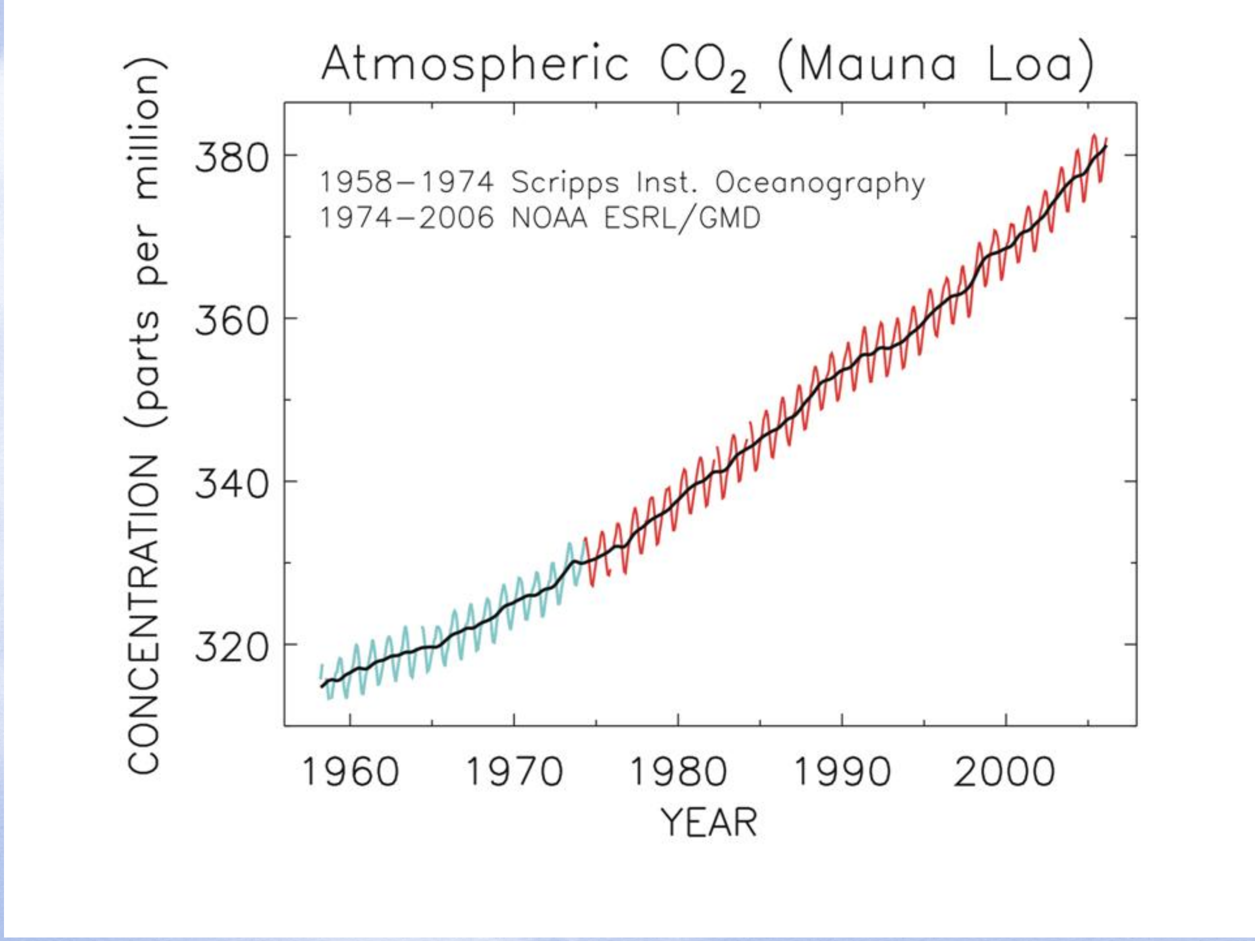
- CO_2 Concentrations:
  - 280 ppm in 1750
  - 379 ppm in 2005
- Temperature:
  - +0.74 C over the last century. Twice rate of previous century
- Sea Level Rise:
  - +1.8 mm /yr (1961-2003),
  - +3.1 mm/yr (1993-2003)



(X-axis: From 10,000 years ago to the year 2005)

Source: IPCC

Trends in CO_2 Concentrations: Recent History



Source: Pieter Tans, NOAA

Other Greenhouse Gases

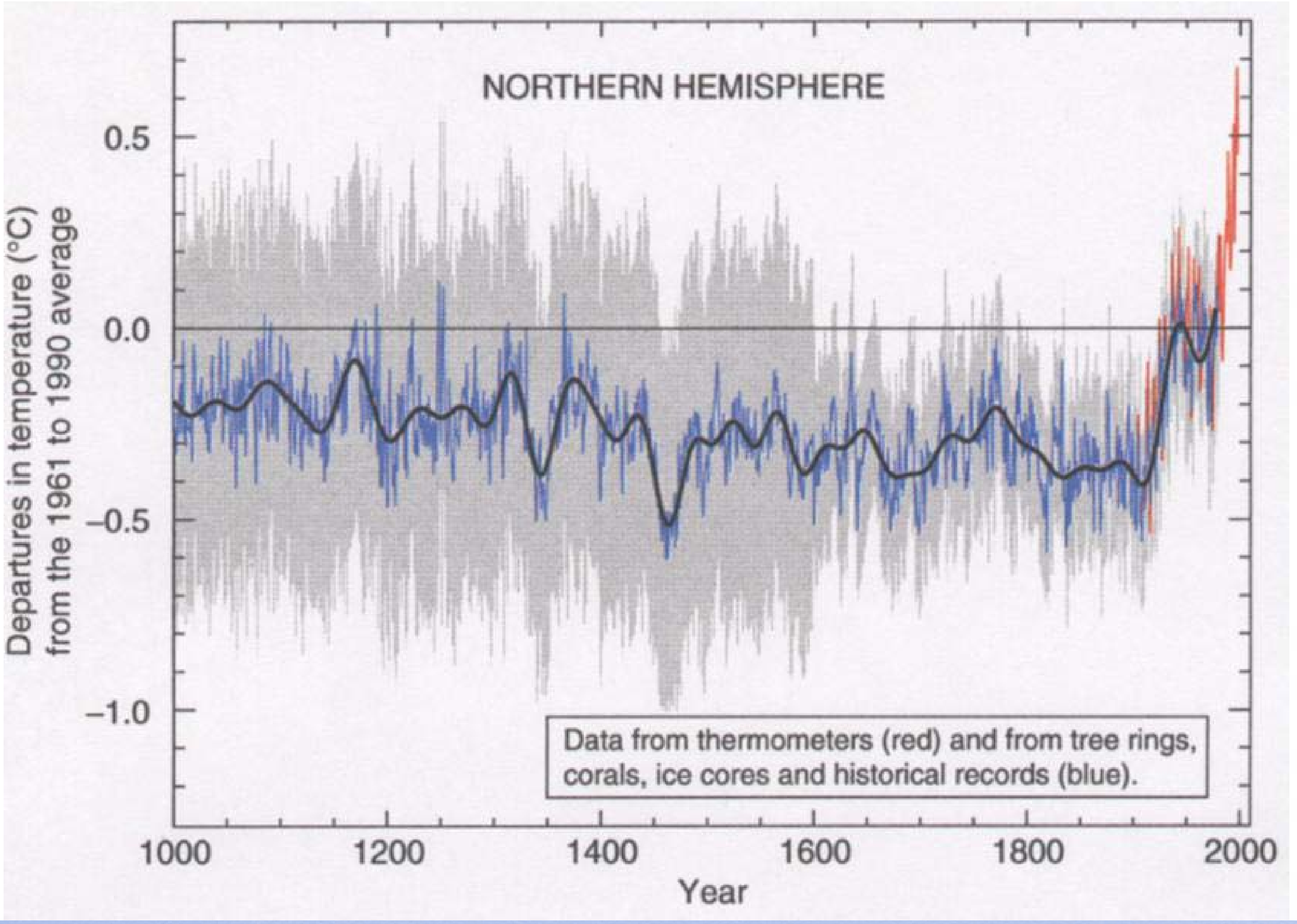
Other gases also have long atmospheric lifetimes and are more potent GHGs than CO_2 (they have a higher *global warming potential*):

Gas	Lifetime	GWP (relative to CO_2)
Methane (CH_4)	~12 years	21
Hydrofluorocarbons (HFCs)	1.5-264 years	140-11,700
Nitrous Oxide (N_2O)	~120 years	310
Sulfur Hexafluoride (SF_6)	~3200 years	23,900
Carbon Tetrafluoride (CF_4)	~50,000 years	6500

Source: USEPA

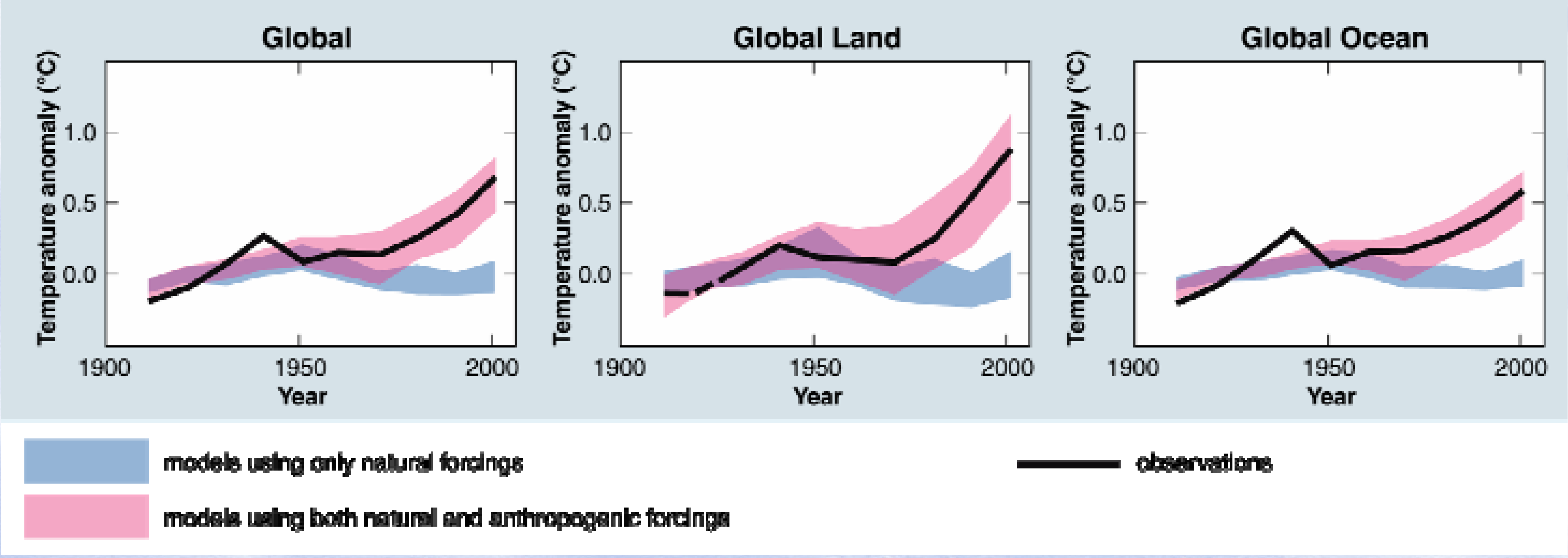
The net warming impact of each gas on the atmosphere (*forcing*) is a function of the amount of the gas released, and its global warming potential.

1000 years of "proxy" Surface Temperatures, 100+ from Thermometers



2007 IPCC Report Modeling Scenarios

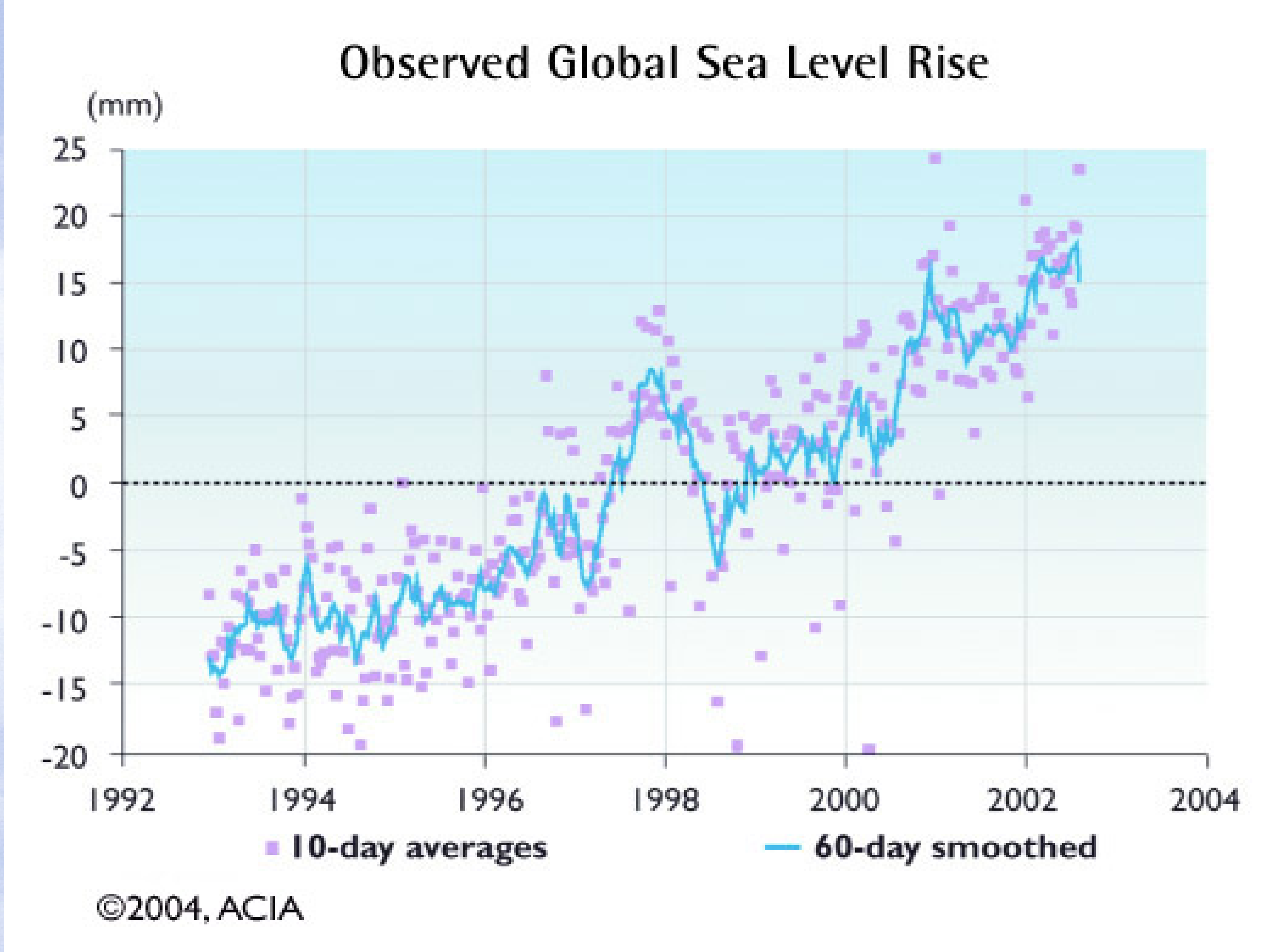
Black lines show actual temperature record; *blue area* shows modeled change with only natural forcings; *red area* shows modeled change with both natural and manmade forcings.



July 2008 USGCSP report concludes that “*modern models faithfully simulate continental to global scale temperature patterns and trends observed during the 20th century*.”

Sea Level is Rising

Global-average sea level rose about 6.7 inches over the last century; the rate of sea level rise has increased in recent years



1993-2003 ≈ 35 mm = 3.5 mm/yr; compare 1910-1990 = 1.5±0.5 mm/yr.

2007 IPCC Findings

- Ice loss from Greenland and Antarctica have *very likely (> 90% chance)* contributed to sea level rise (thermal expansion has also contributed); *High confidence (> 80% chance)* that the rate of sea level rise increased from the 19^{th} to the 20^{th} centuries

- *High confidence (> 80% chance)* that snow, ice and permafrost environments and hydrological systems (lakes and rivers) are already being impacted

Ocean Acidification

By 2050, falling ocean pH levels from CO_2 absorption will likely no longer support coral reefs in any US waters (USGCRP, 2000) and will jeopardize plankton production

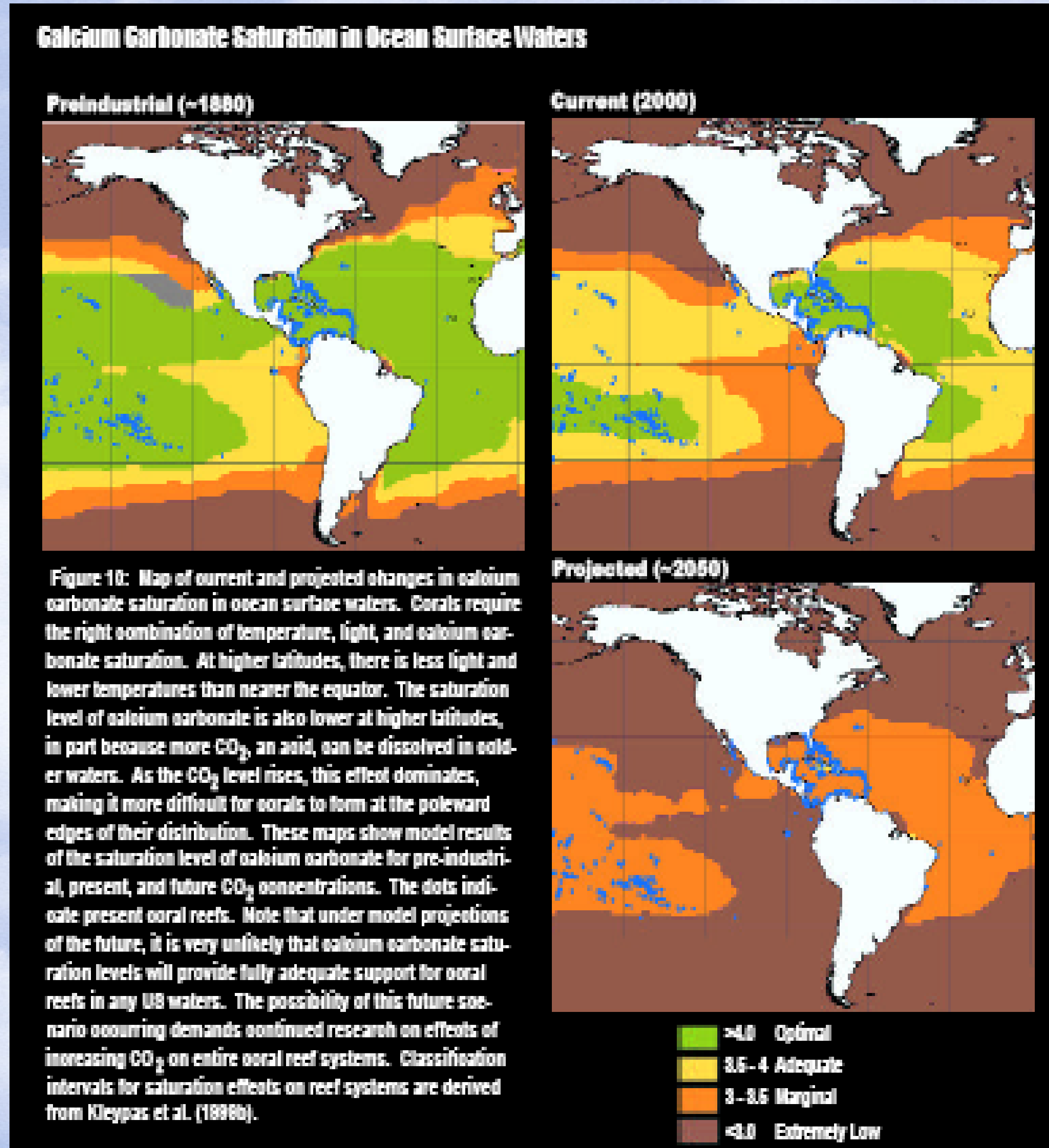
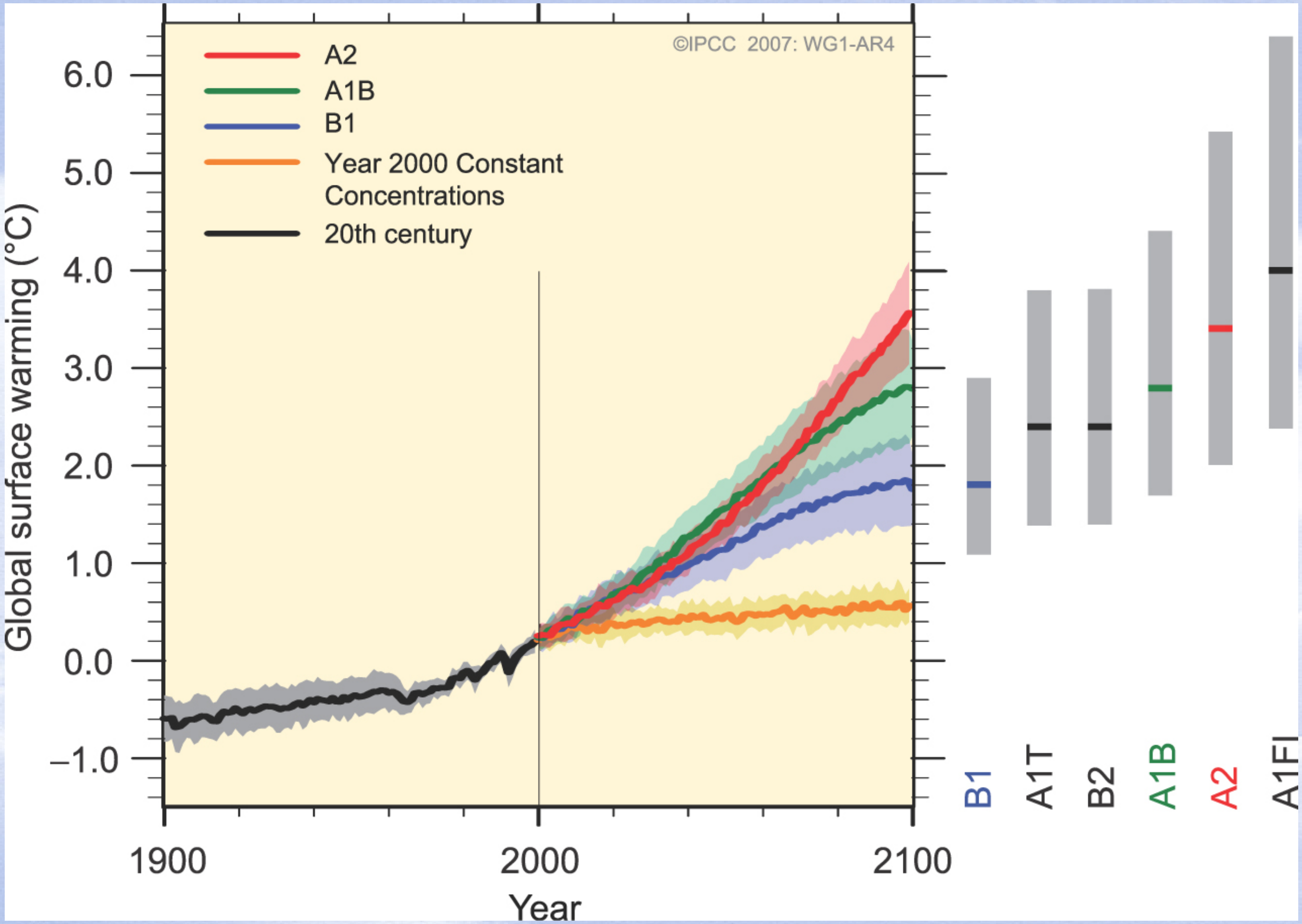


Figure 10: Map of current and projected changes in calcium carbonate saturation in ocean surface waters. Corals require the right combination of temperature, light, and calcium carbonate saturation. At higher latitudes, there is less light and lower temperatures than nearer the equator. The saturation level of calcium carbonate is also lower at higher latitudes, in part because more CO_2, an acid, can be dissolved in colder waters. As the CO_2 level rises, this effect dominates, making it more difficult for corals to form at the poleward edges of their distribution. These maps show model results of the saturation level of calcium carbonate for pre-industrial, present, and future CO_2 concentrations. The dots indicate present coral reefs. Note that under model projections of the future, it is very unlikely that calcium carbonate saturation levels will provide fully adequate support for coral reefs in any US waters. The possibility of this future scenario occurring demands continued research on effects of increasing CO_2 on entire coral reef systems. Classification intervals for saturation effects on reef systems are derived from Kleypas et al. (1999b).

Future Climate Projections



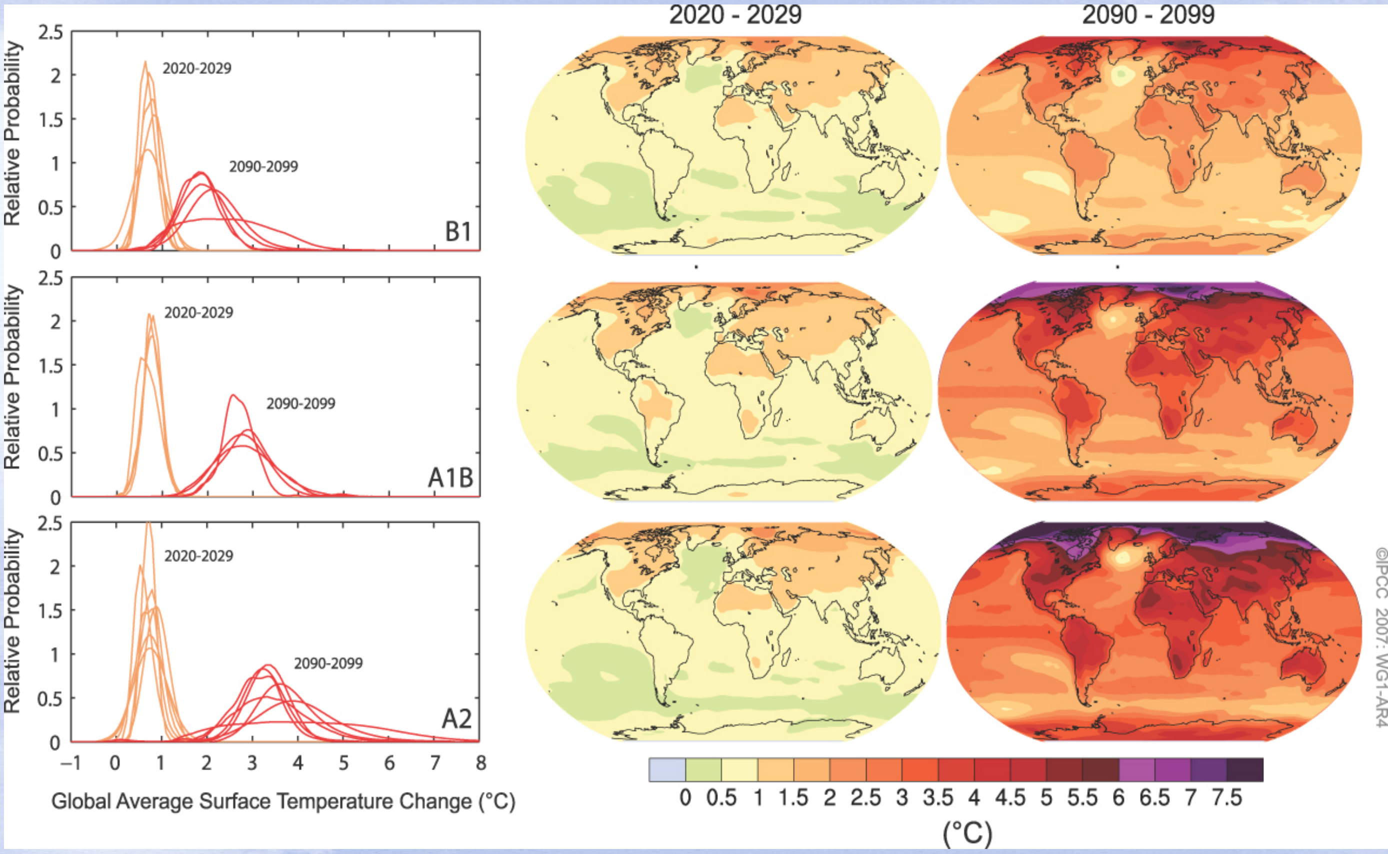
Source: IPCC

Note: the current growth rate in global CO_2 emissions is higher than these IPCC scenarios

Future Climate Projections: the Past is not a Good Predictor of the Future

Temperature increase projected for the US

- Short-term: 1-2 C [all scenarios]
- Long-term: 2-5 C [depends on scenario]



Source: IPCC

Greenhouse Gas Reduction Goals

- To prevent the more serious consequences of climate change, the IPCC suggests that temperature increases should be limited to 2 – 2.4°C (4 - 5°F)
  - This would require a 50-85% reduction in GHG emissions by 2050.

- Recent bills, the Administration have discussed reductions of about 80% by 2050.

Sea Level Rise Projections

Table TS.6. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Notes:
[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity (EMICs), and a large number of Atmosphere-Ocean Global Circulation Models (AOGCMs).
[b] Year 2000 constant composition is derived from AOGCMs only.

Source: IPCC, AR4, TS.6

Climate Change and Impacts on Transportation

Climate Change Effects

- Rising sea levels (virtually certain – 99%)
- Increases in intense precipitation events (very likely – 90%)
  - 20-yr peak precipitation events could occur every 6 to 8 years over much of the US
- Increases in hurricane intensity (likely – 66%)
  - Due to higher sea surface temperatures. Particularly in the Gulf, Tropical Atlantic
- Increases in very hot days and heat waves (very likely - 90% chance)
- Increases in Arctic temperatures (virtually certain – 99% chance)

Impacts on transportation infrastructure

- Permanent inundation, temporary flooding, higher maintenance levels, lower inland water levels, etc.

Gulf Coast Climate Change Impacts Study—Phase 1 (U.S. DOT)

Relative sea level rise (due to climate change and subsidence) of 4 feet could permanently flood:

- 24% of interstate miles, 28% of arterial miles
  - 2,400 miles of major highways
- 72% of freight, 73% of non-freight facilities at ports
- 9% of the rail miles operated, 20% of the freight facilities, no passenger stations

Other Impacts on North America

- 5-20% increase in yields for rain-fed agriculture; vulnerability of irrigated agriculture
- Western mountains: warmer winters mean less snowpack, winter flooding, reduced summer water availability
- Pest, diseases and fire impact forests, with an extended period of high fire risk and large increases in area burned
- Increased number and duration of urban heat waves

Source: IPCC

Resources

Intergovernmental Panel on Climate Change

http://www.ipcc.ch/

SR 290: Potential Impacts of Climate Change on US Transportation

http://www.trb.org/news/blurb_detail.asp?ID=8794

Impacts of Climate Variability and Change on Transportation Systems and Infrastructure – Gulf Coast Study

http://www.climatescience.gov/Library/sap/sap4-7/final-report/

U.S. DOT Climate Center Website

http://climate.dot.gov/