Climate Literacy Conference

San Diego 18 Feb 2010

Carbon Dioxide, Chemistry and Climate
How do we know anything?

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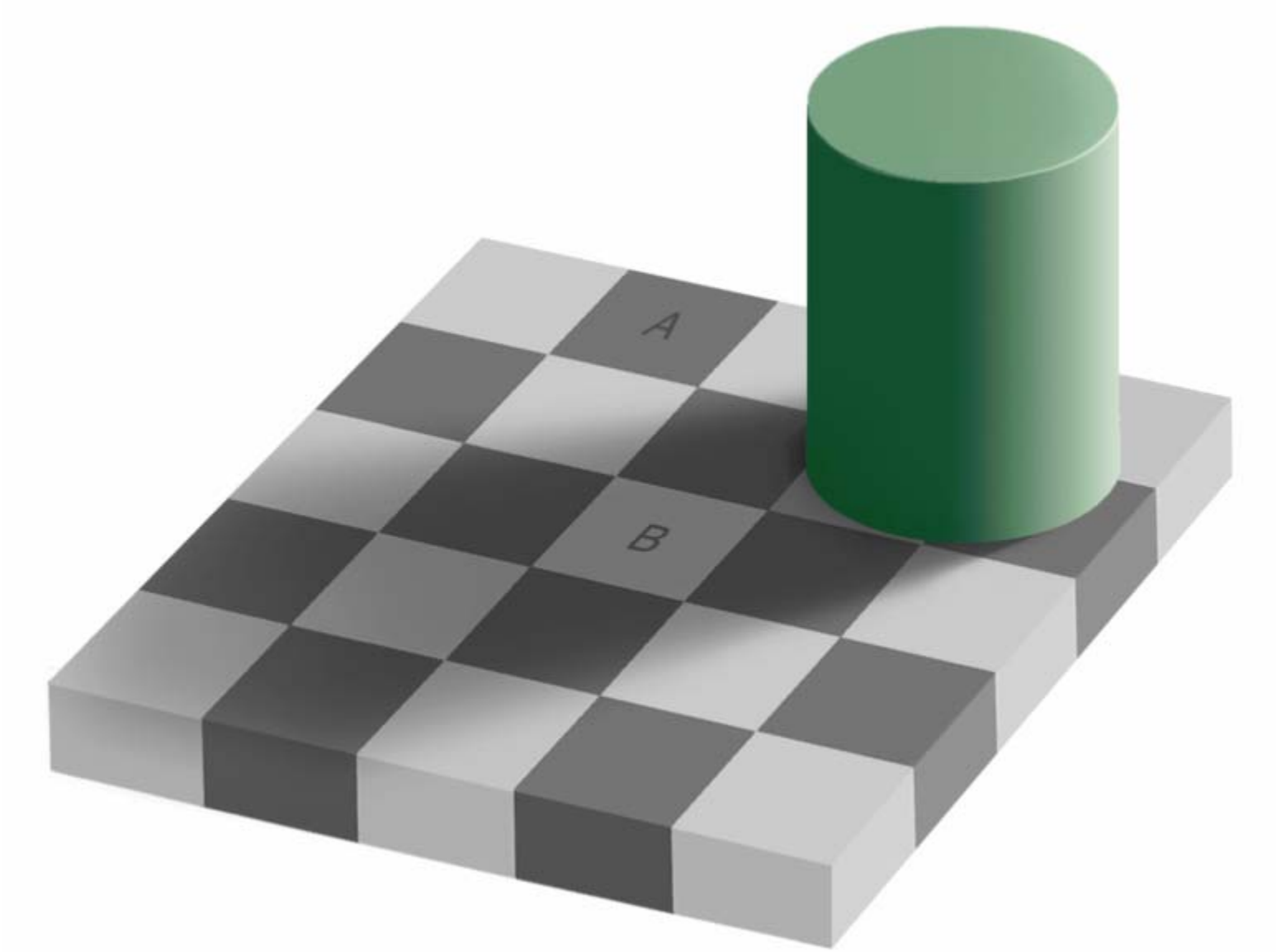
How do we know anything?

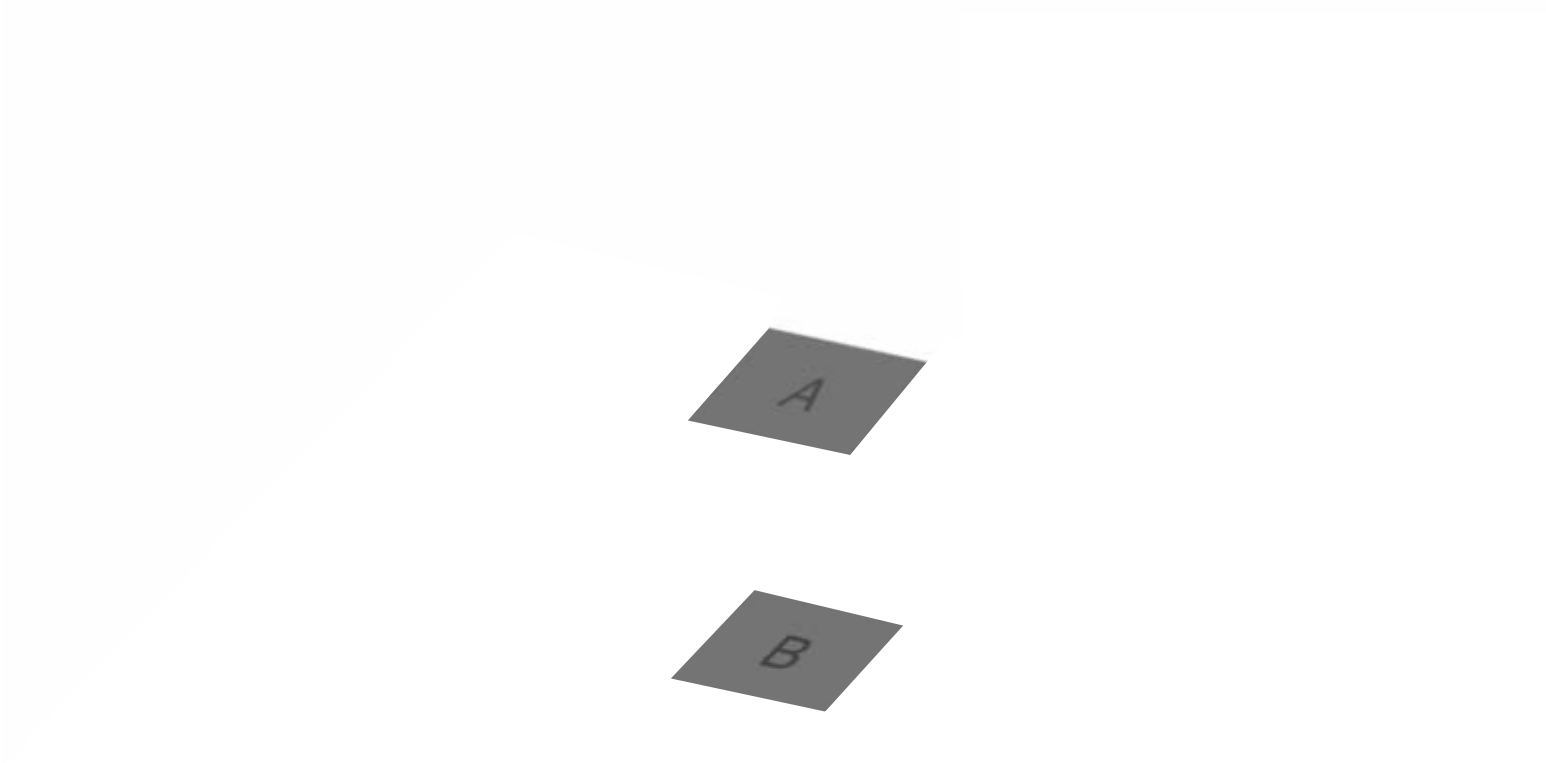
- Thought, intuition, interior reflection
- Unplanned direct experience
- Family, friends, etc
- TV, magazines, books, web sites, blogs, experts, idiots
- Planned empirical investigation
- Careful analysis and appraisal of multiple sources of information

Can we trust our own experience?



by Adrian Pingstone, based on the original created by Edward H. Adelson

Can we trust our own experience?



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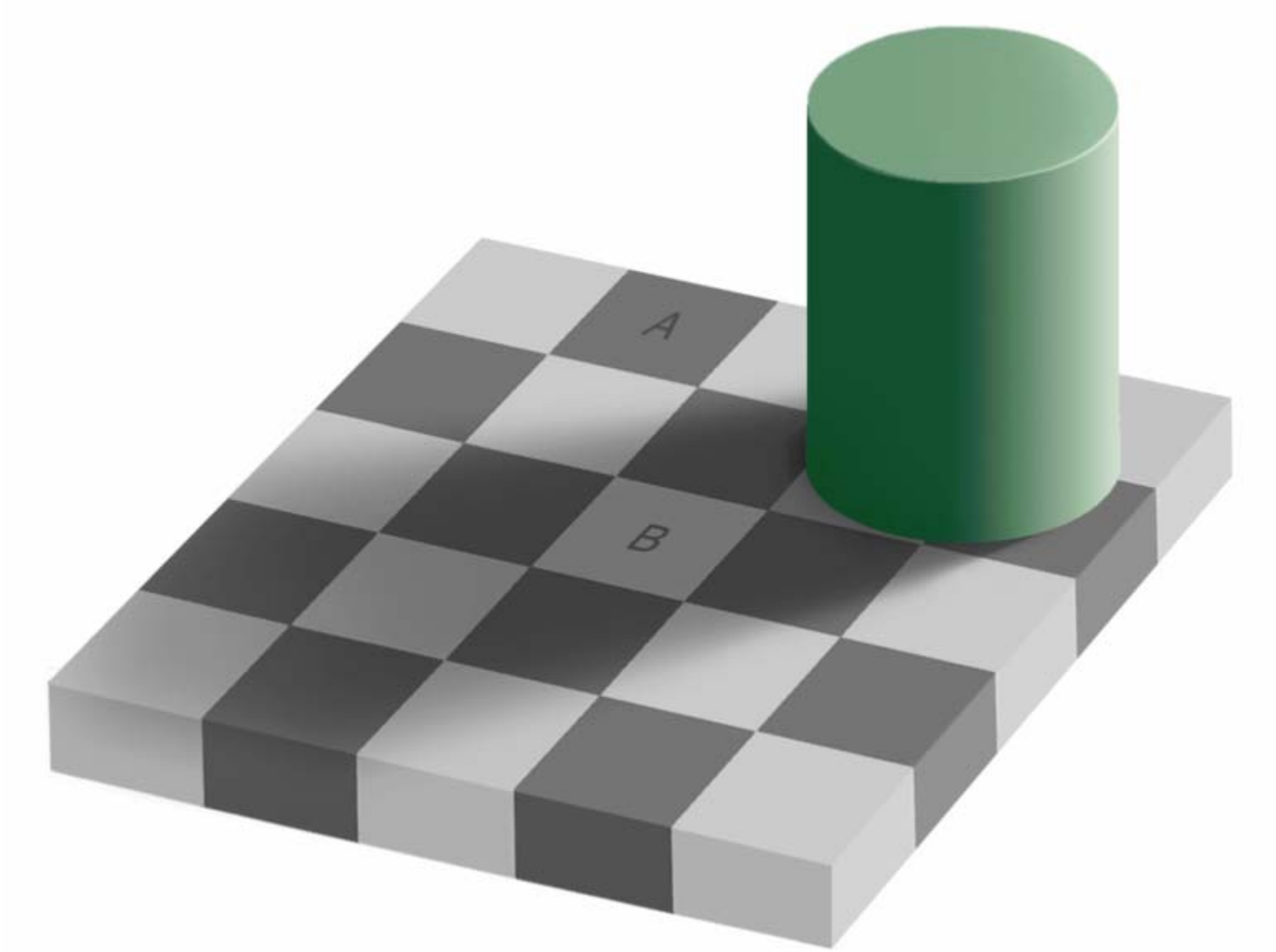
Can we trust our own experience?

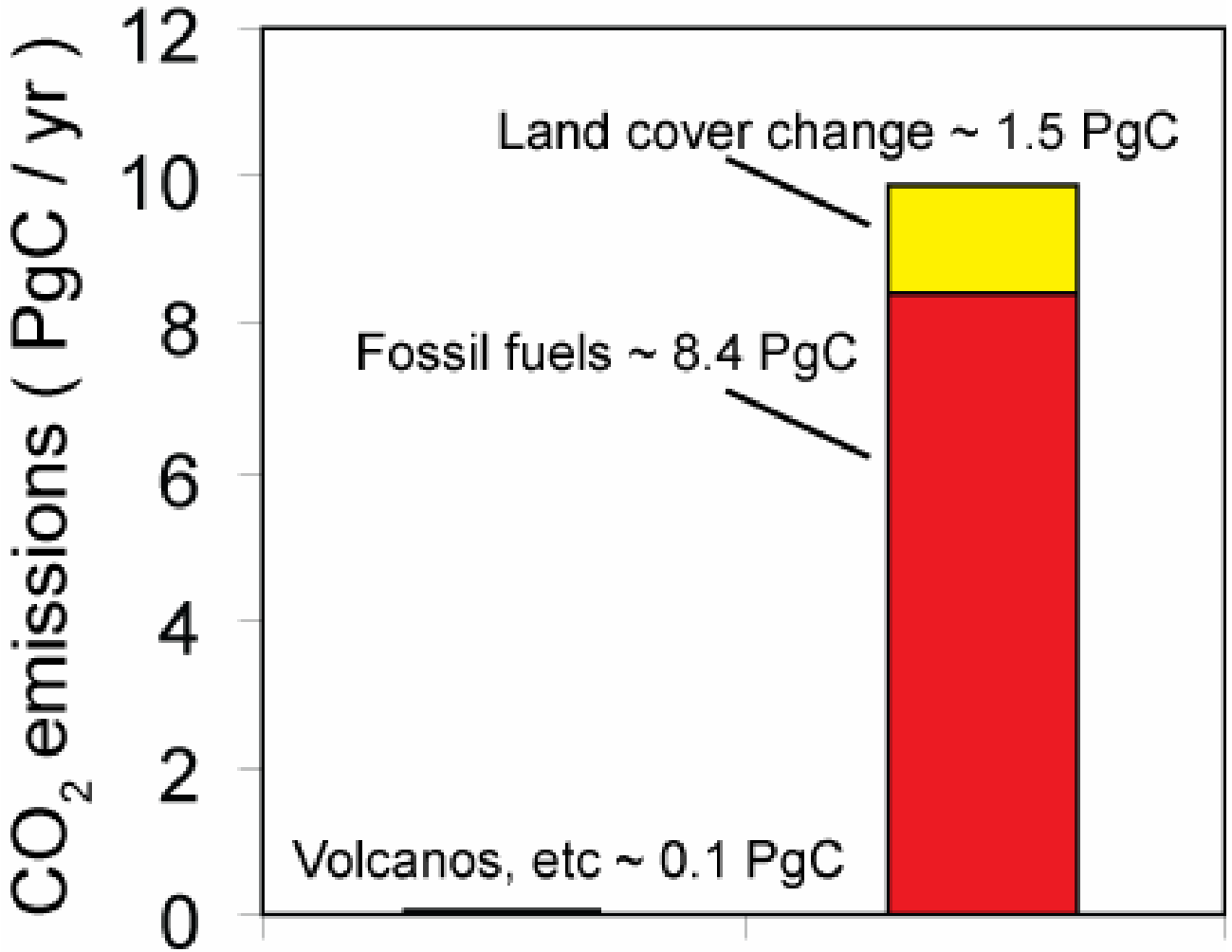


by Adrian Pingstone, based on the original created by Edward H. Adelson

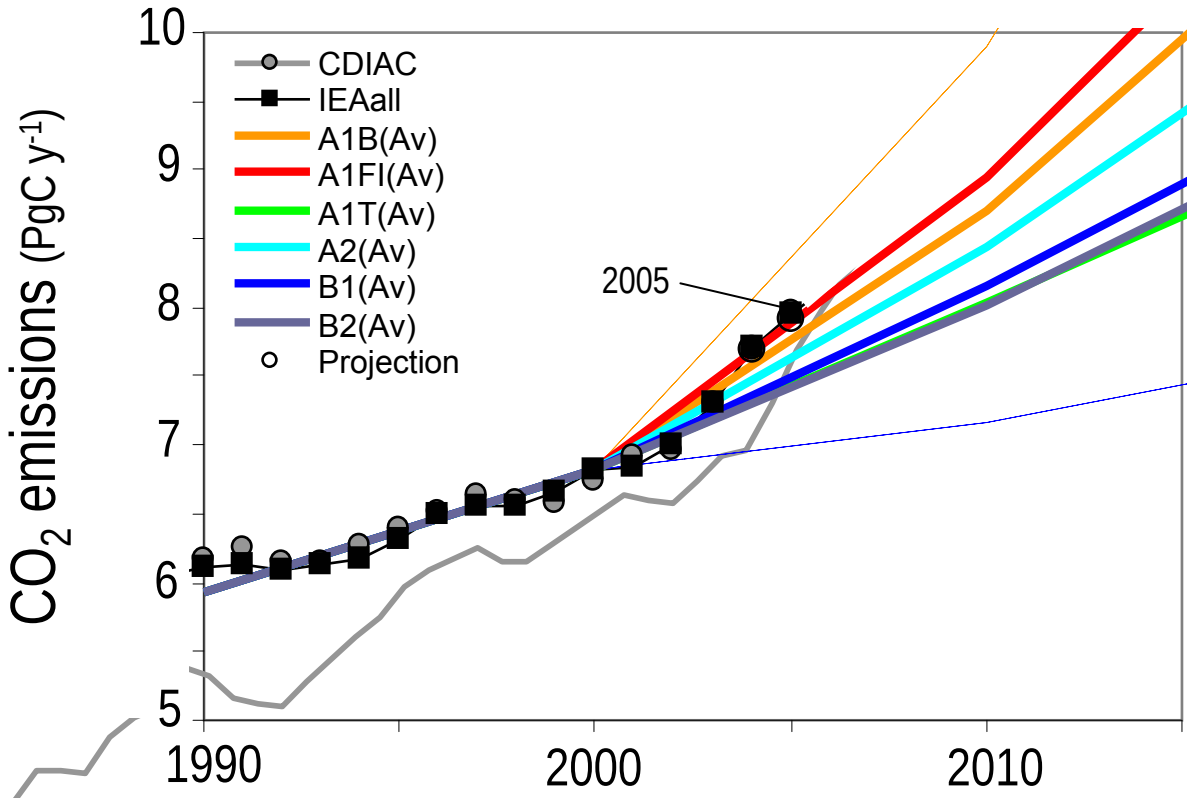
How do we know anything?

- What food to eat?
- Which things are really dangerous?
- Which investments are safe?
- Whether human-induced climate change is a real threat?
- Which energy technologies or approaches can really diminish climate risk?

Anthropogenic CO_2 emissions exceed natural emissions by a factor of about 100

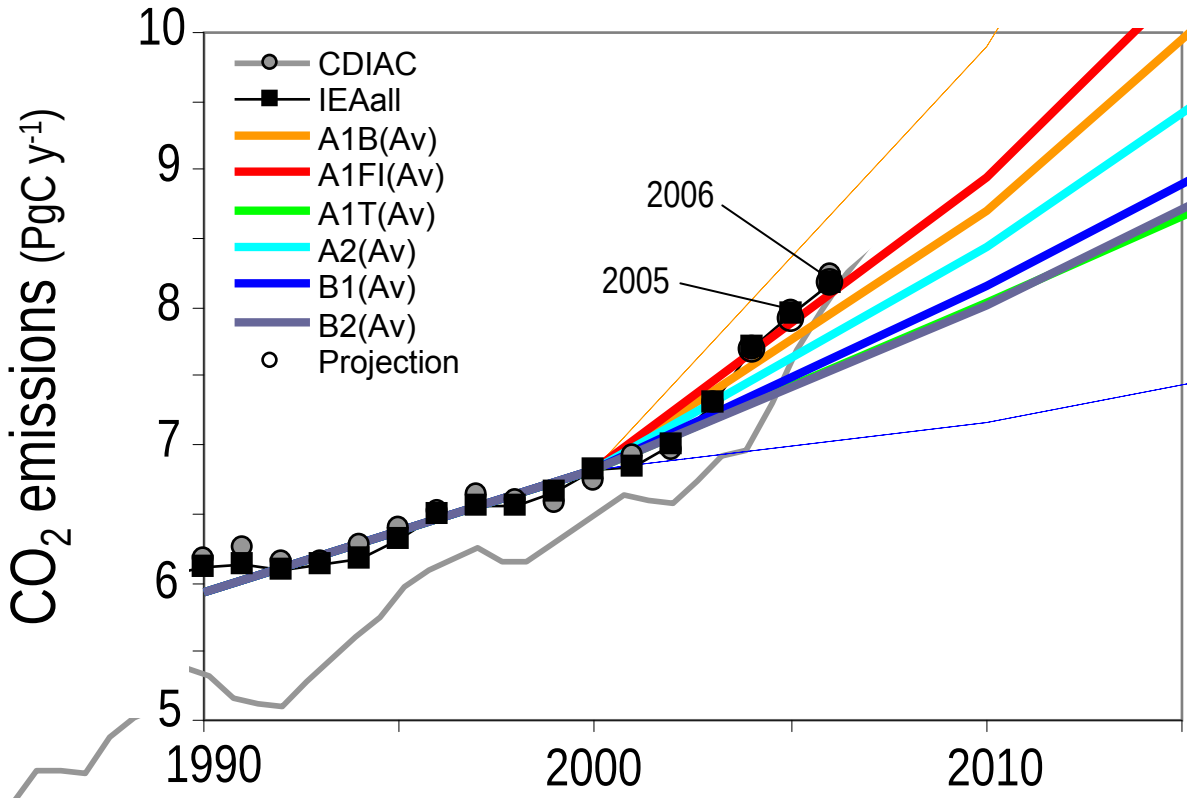


Fossil Fuel Emissions: Actual vs. IPCC Scenarios



Updated Raupach et al. 2007, PNAS

Fossil Fuel Emissions: Actual vs. IPCC Scenarios



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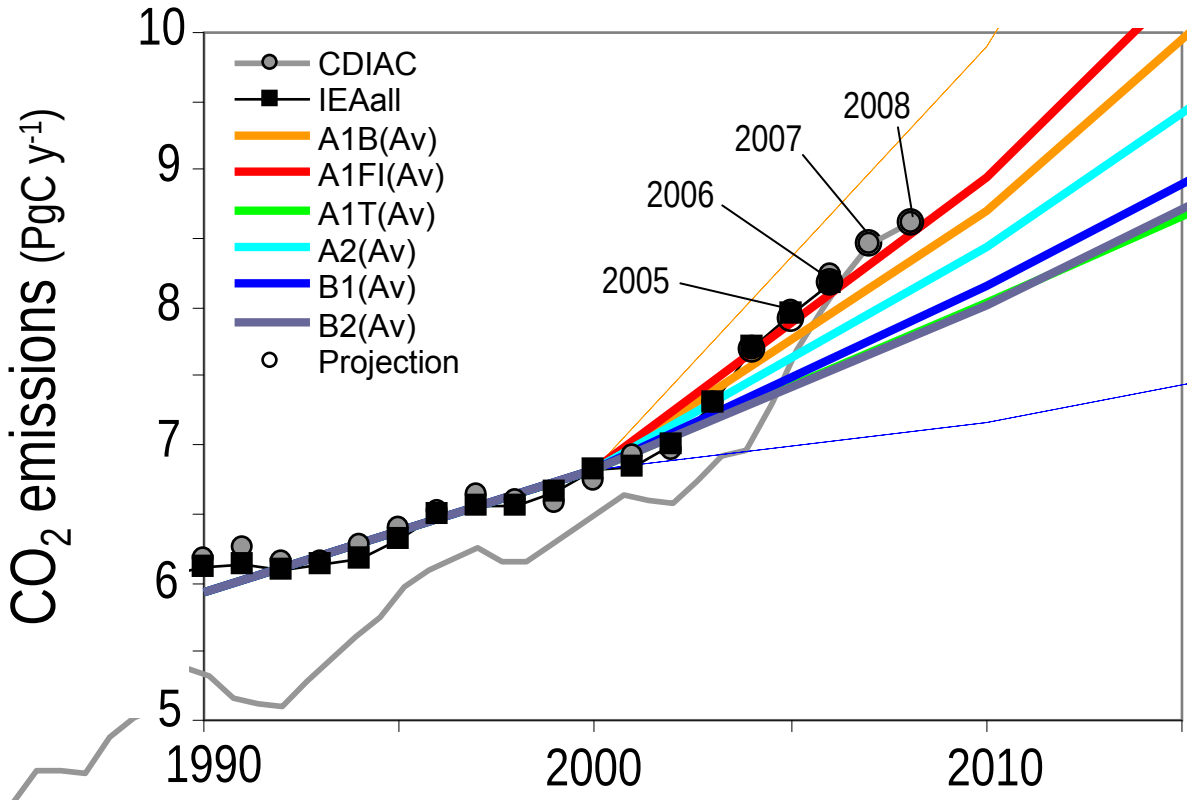
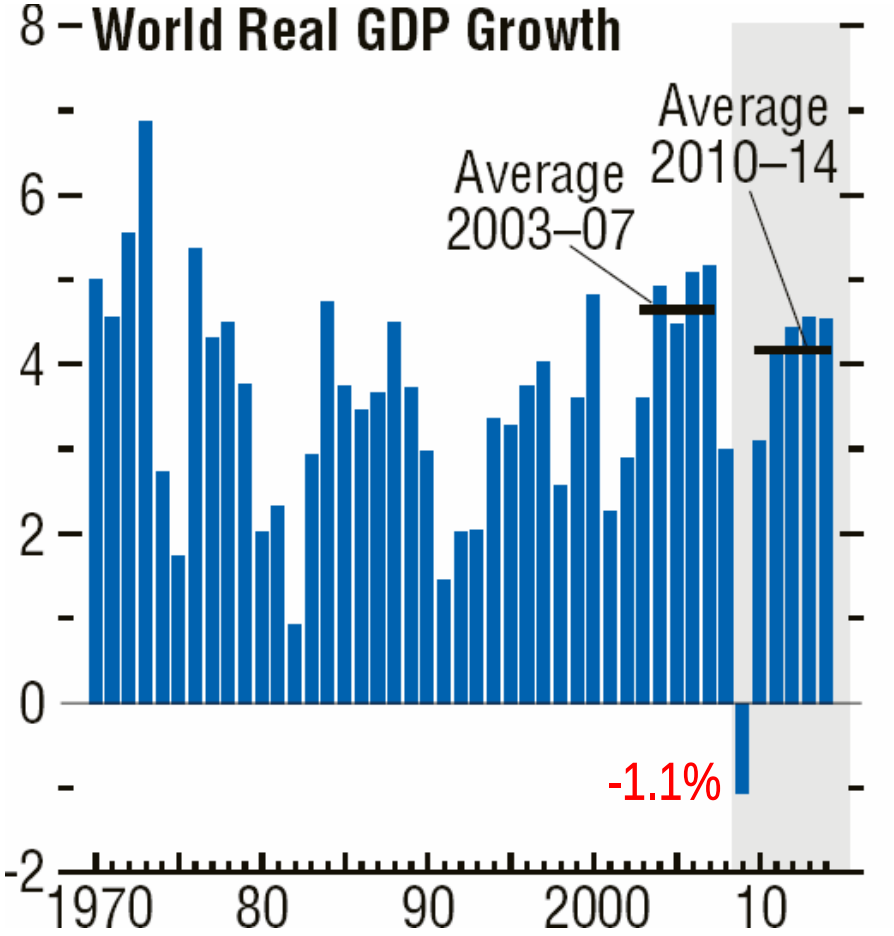
Fossil Fuel Emissions: Actual vs. IPCC Scenarios

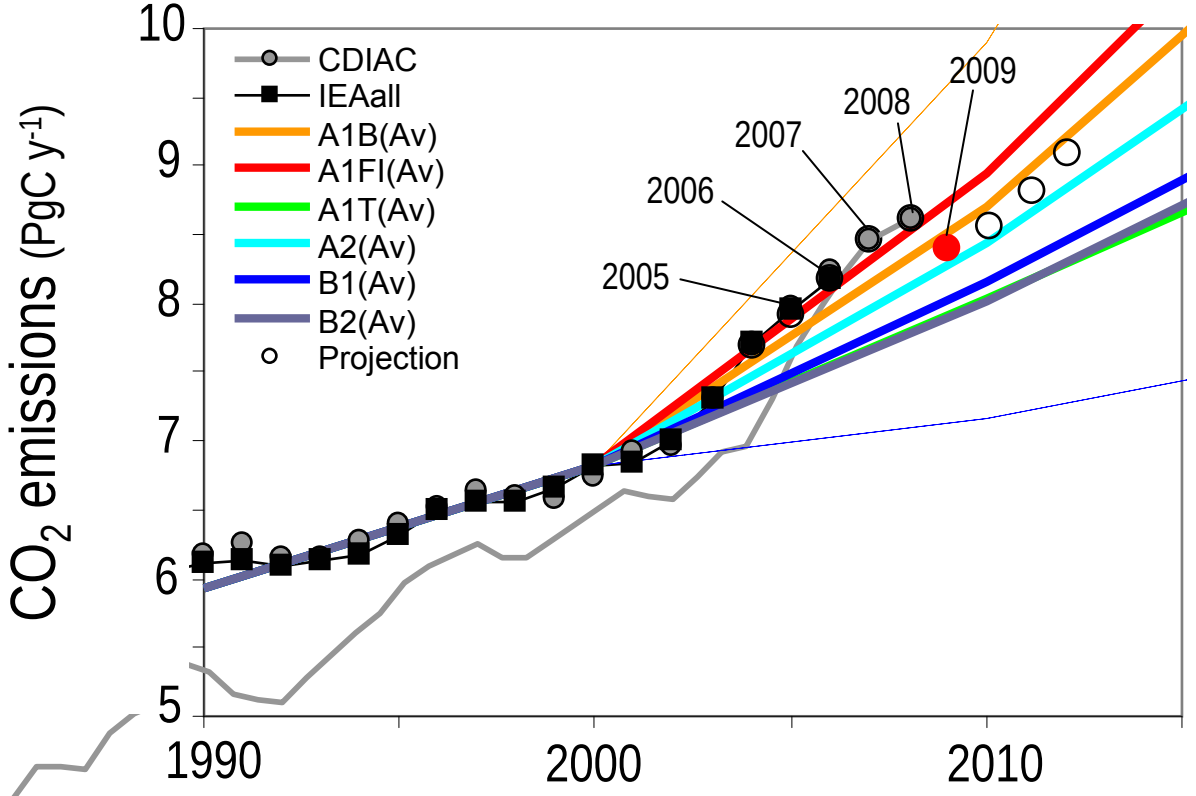


Updated Raupach et al. 2007, PNAS

Economic Crisis Impact on World GDP Growth



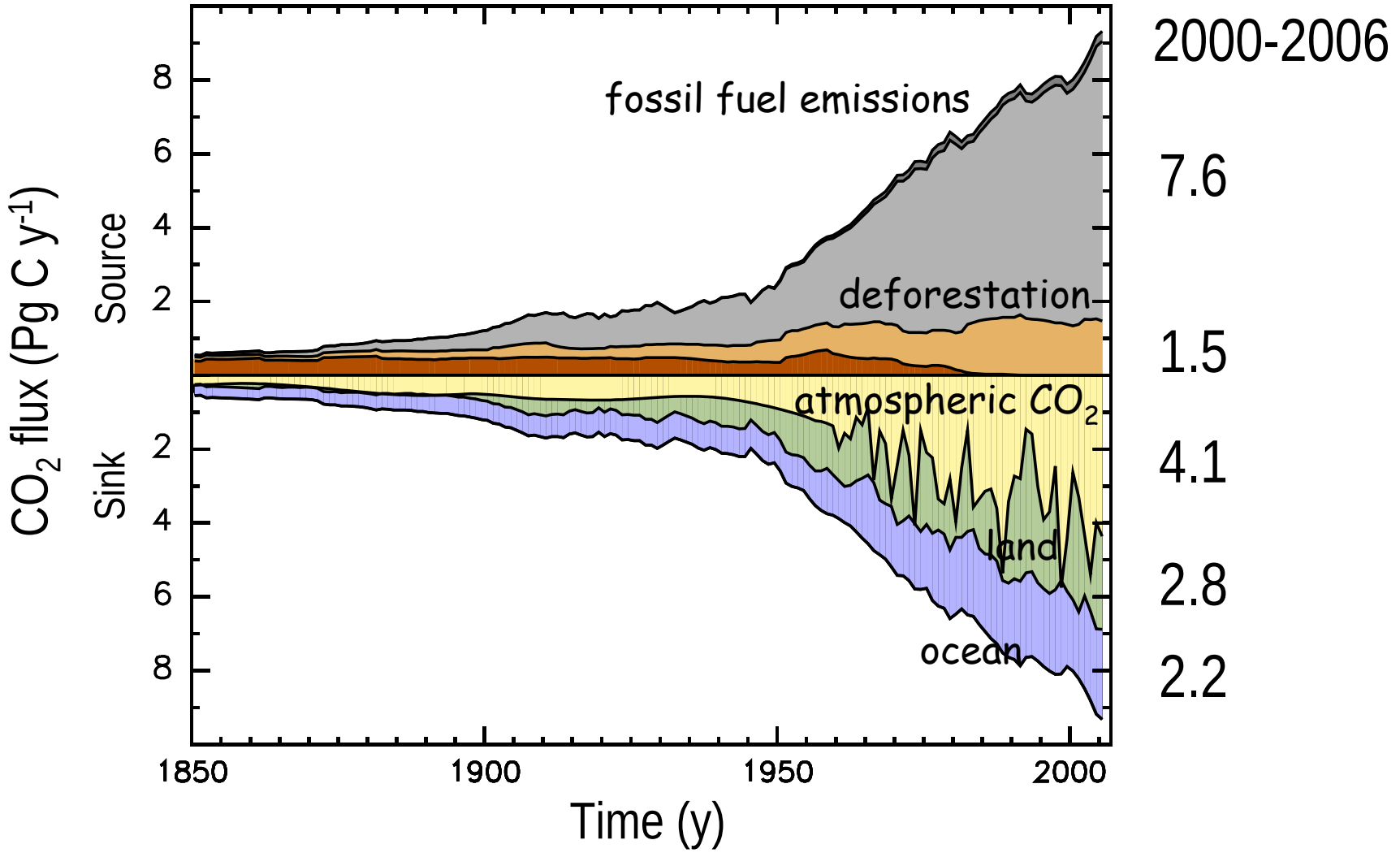
Fossil Fuel Emissions: Actual vs. IPCC Scenarios



Projection 2009:
Emissions: -2.8%
GDP: -1.1%
C intensity: -1.7%

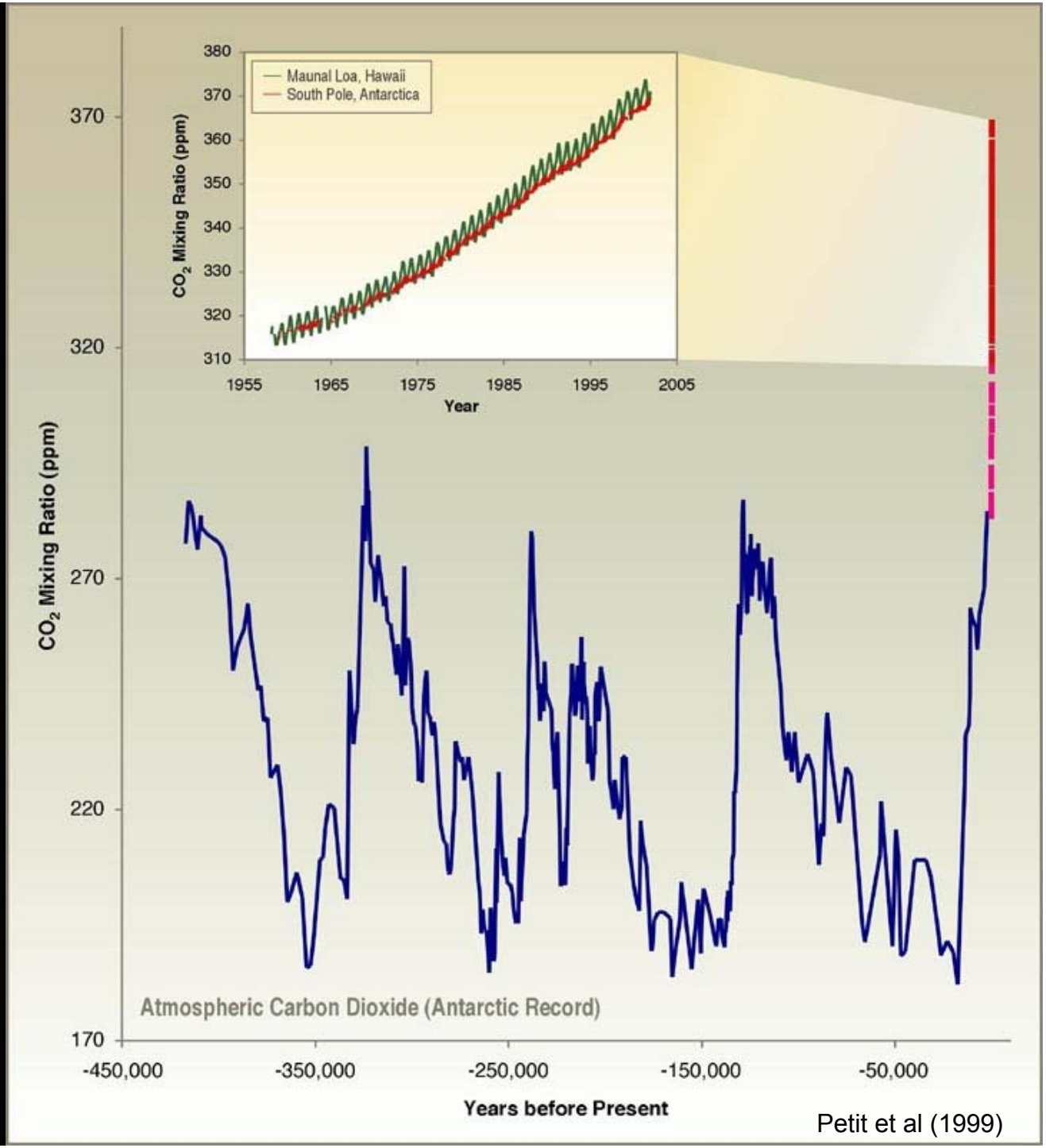
Raupach et al. 2007, PNAS; updated Raupach unpublished; Le Quéré et al. 2009, Nature-Geo, in press

Perturbation of Global Carbon Budget (1850-2006)



Le Quéré, unpublished; Canadell et al. 2007, PNAS

Ice core and instrumental records of atmospheric carbon dioxide concentrations



Petit et al (1999)

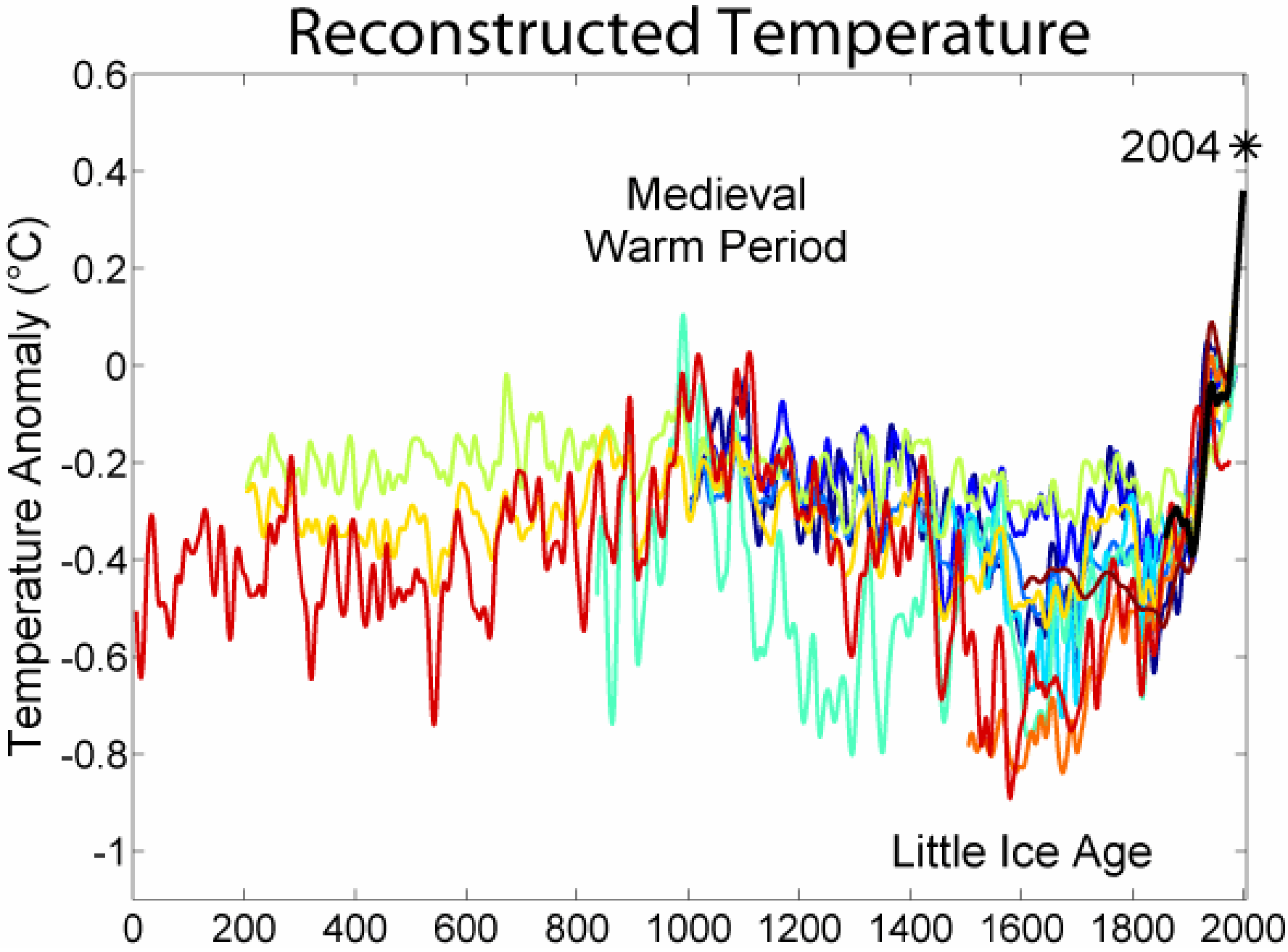
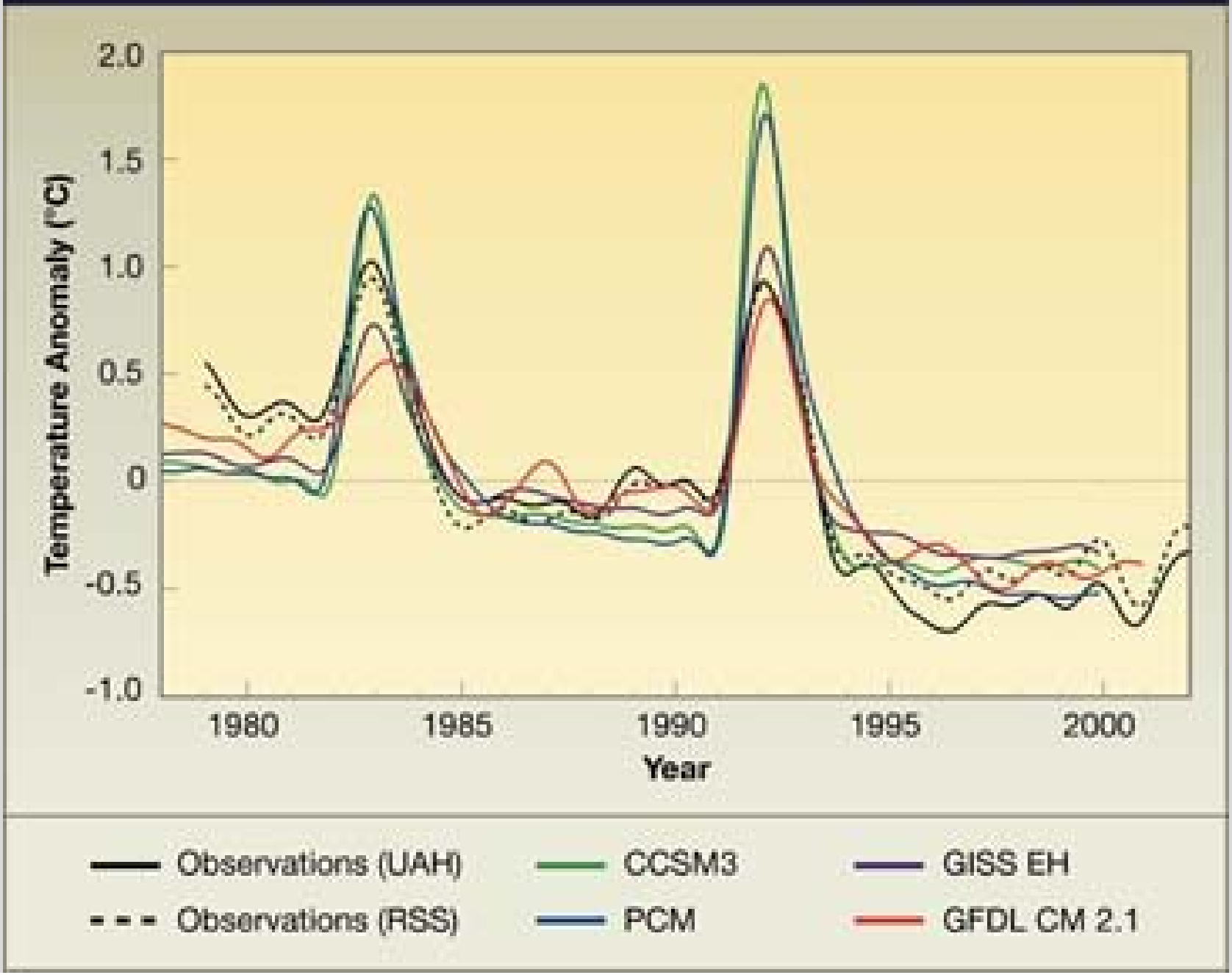
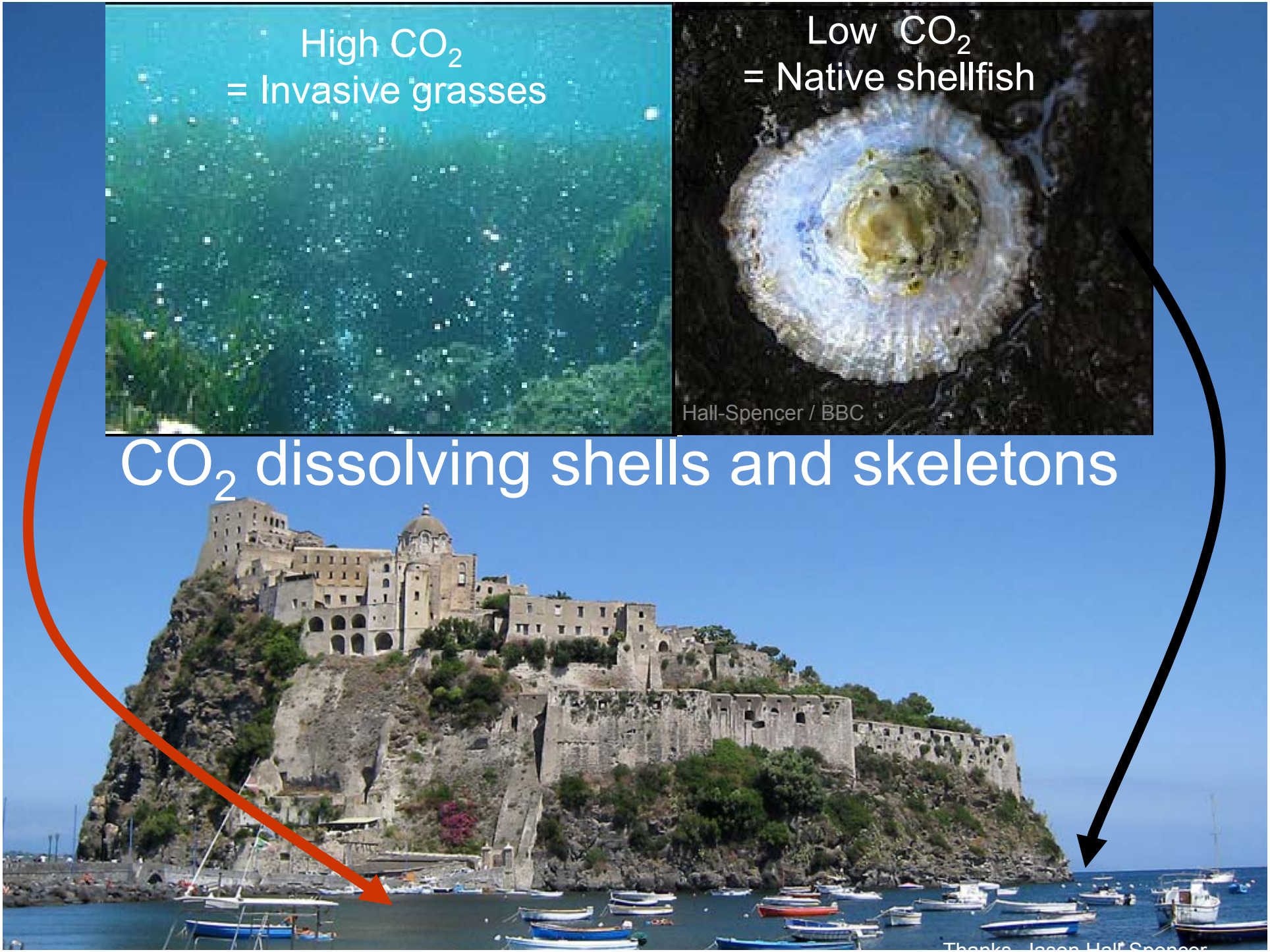


Fig by Robert A. Rohde

Simulated and Observed Stratospheric Temperature Changes

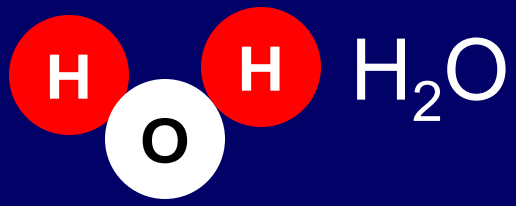


Ischia, Italy

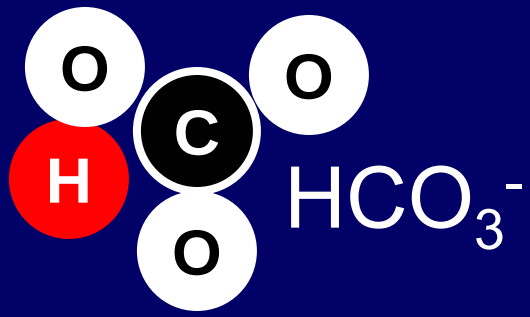

High CO_2
= Invasive grasses
Low CO_2
= Native shellfish
Hall-Spencer / BBC
CO_2 dissolving shells and skeletons

Chemistry of ocean acidification

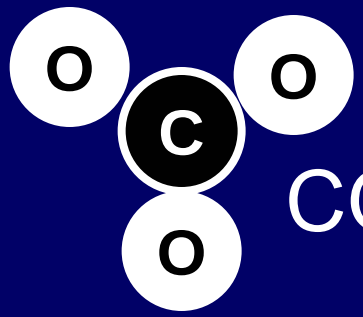
Formation of calcium carbonate shells and skeletons



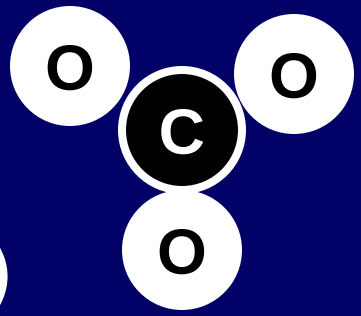
H_2O



HCO_3^-



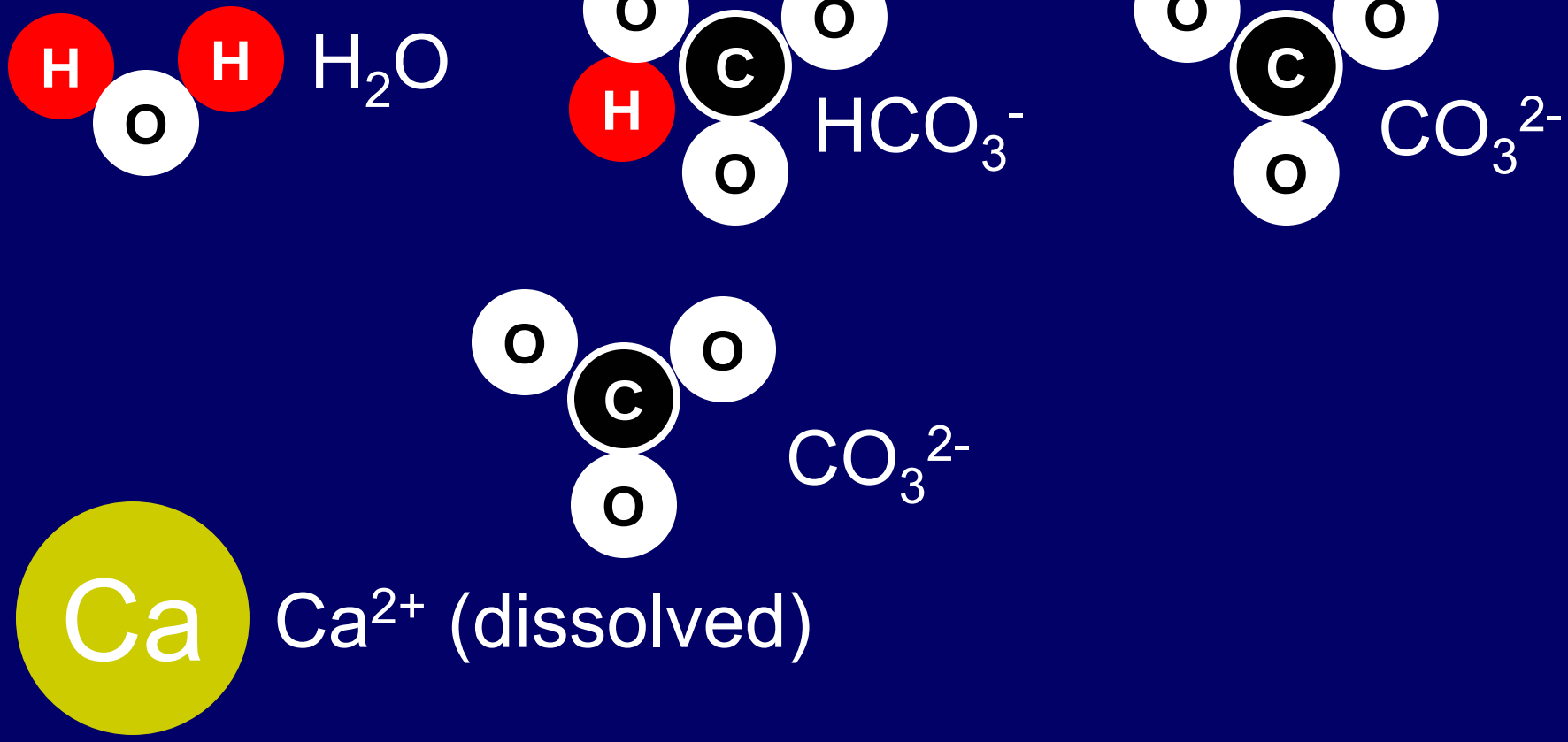
CO_3^{2-}



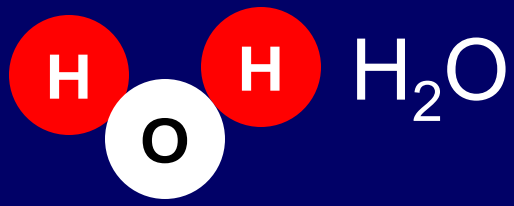
CO_3^{2-}

Ca^{2+} (dissolved)

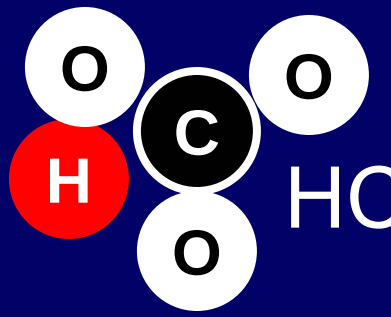
Formation of calcium carbonate shells and skeletons



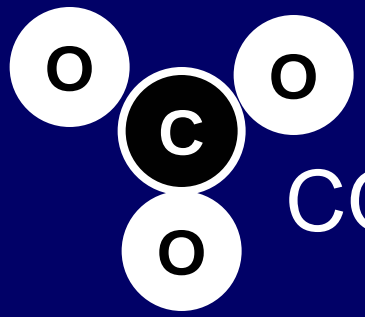
Formation of calcium carbonate shells and skeletons



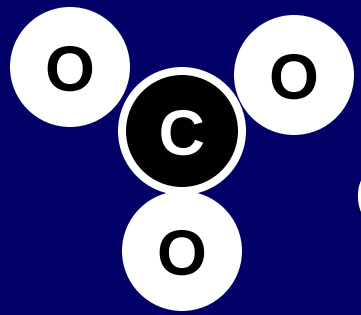
H_2O



HCO_3^-



CO_3^{2-}

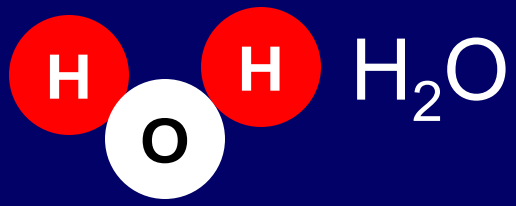


CO_3^{2-}

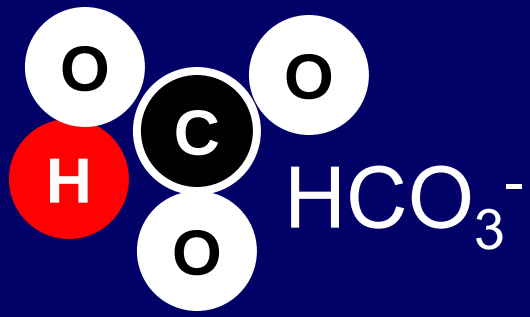
Ca

Ca^{2+} (dissolved)

Formation of calcium carbonate shells and skeletons



H_2O



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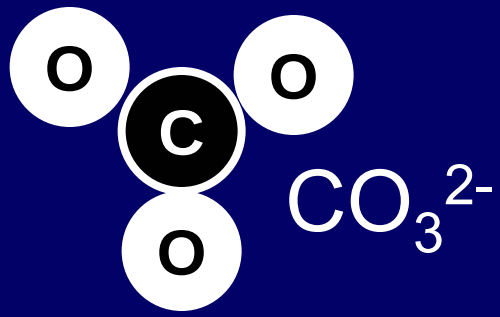
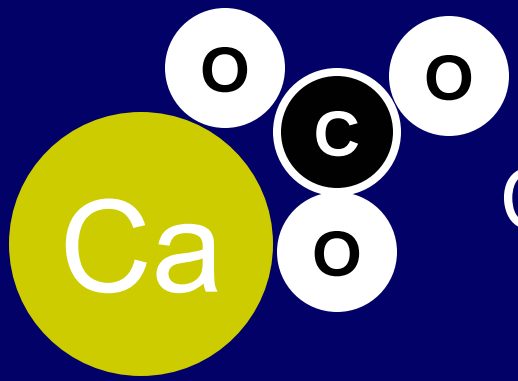
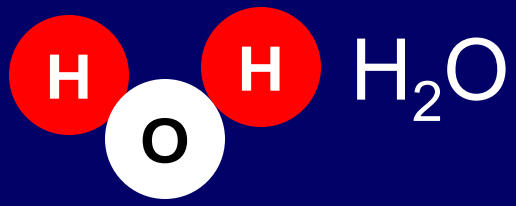


CO_3^{2-}

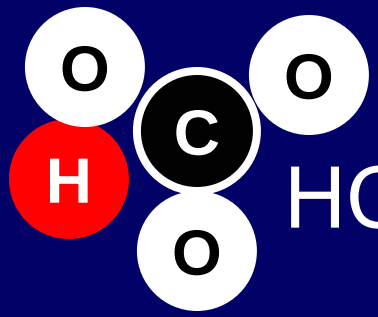


$CaCO_3$ (solid)

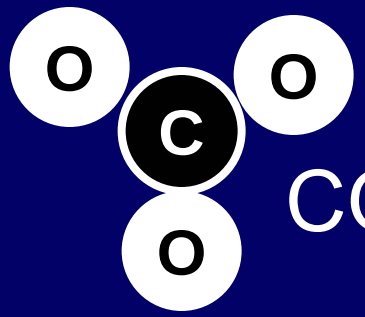
Water, dissolved carbon, and shells and skeletons



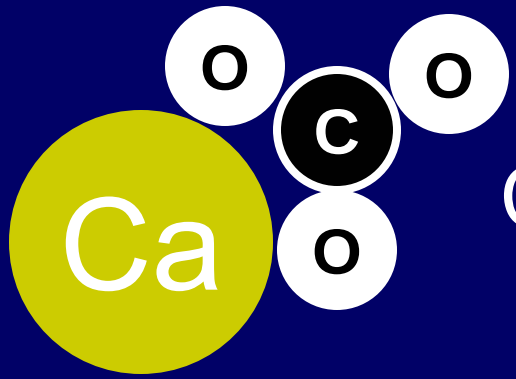
H_2O



HCO_3^-



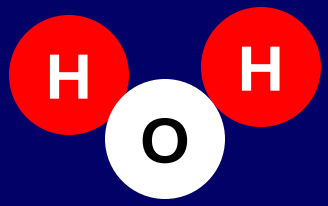
CO_3^{2-}



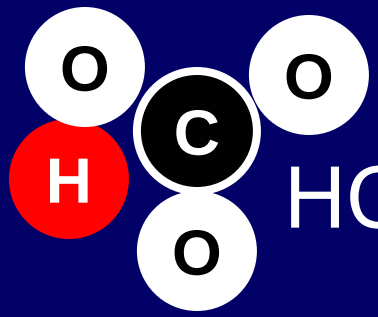
$CaCO_3$ (solid)

Addition of CO_2

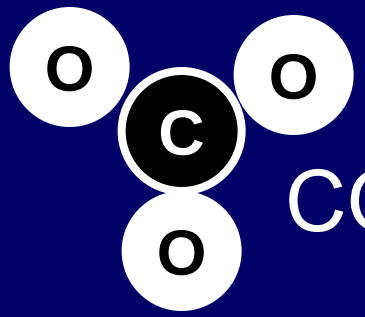
CO_2



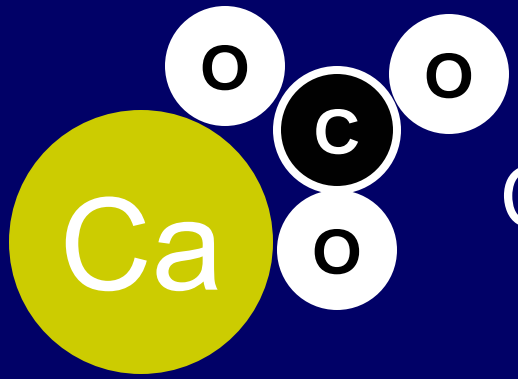
H_2O



HCO_3^-

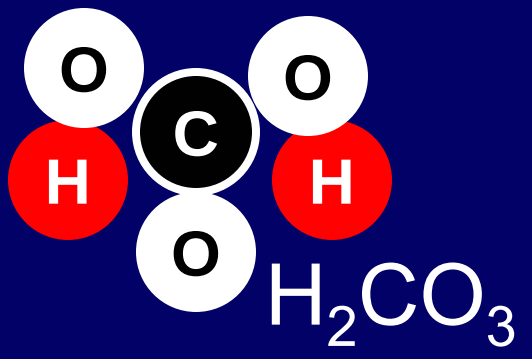


CO_3^{2-}

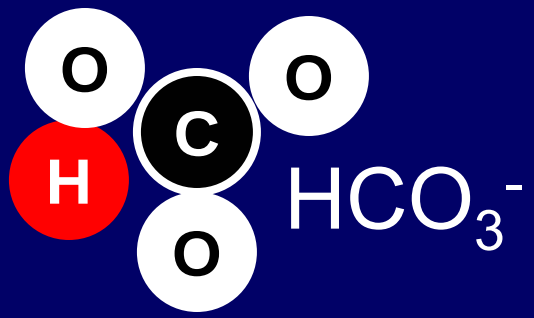


$CaCO_3$ (solid)

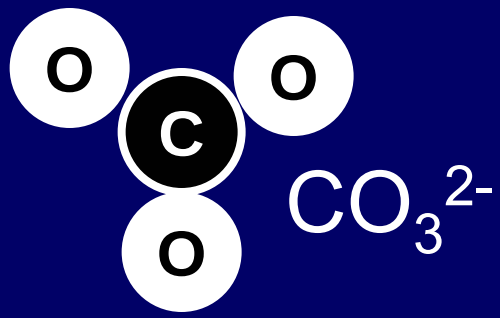
Formation of carbonic acid



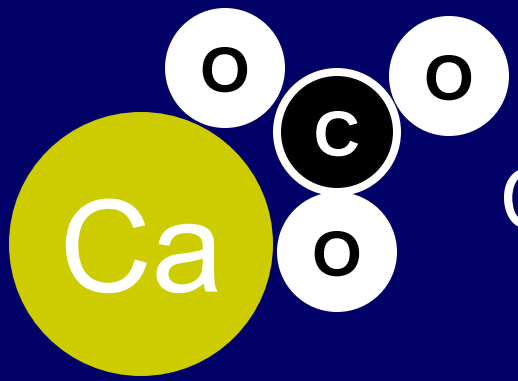
H_2CO_3



HCO_3^-

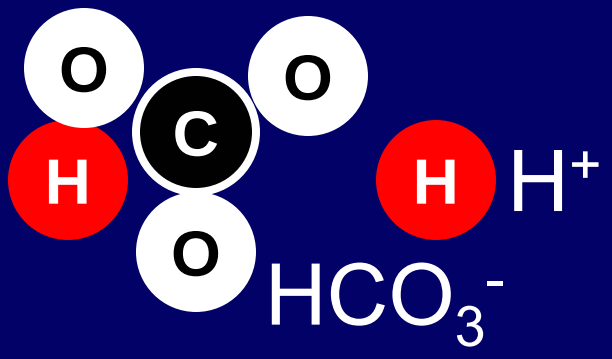


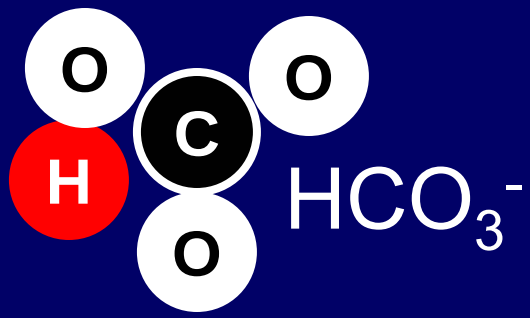
CO_3^{2-}

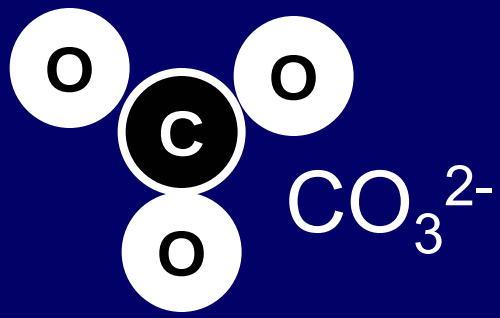


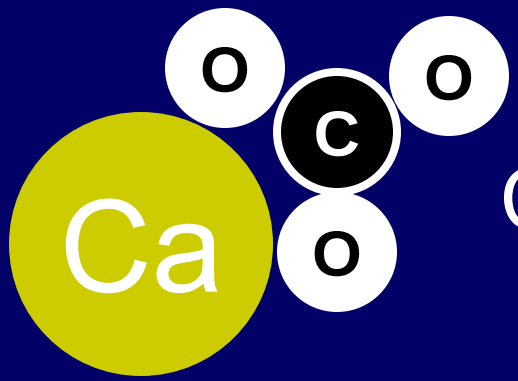
$CaCO_3$ (solid)

Increasing ocean acidity

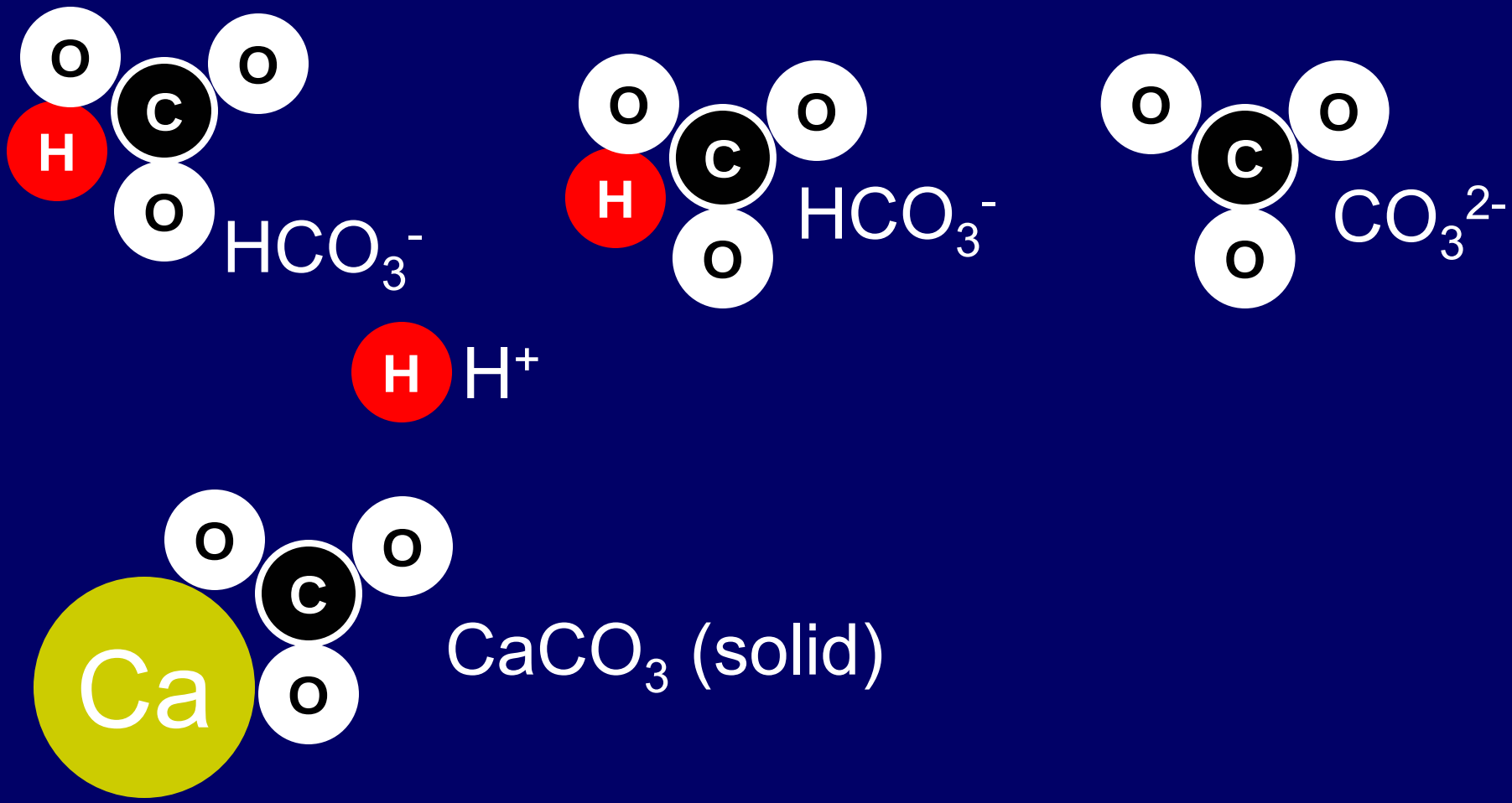




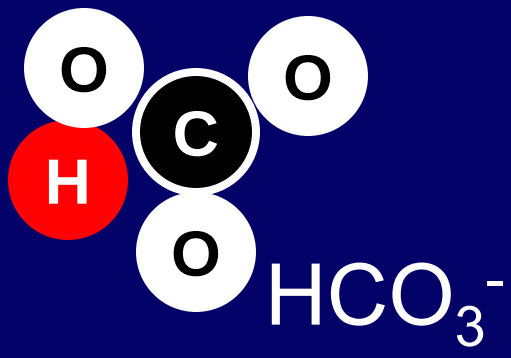




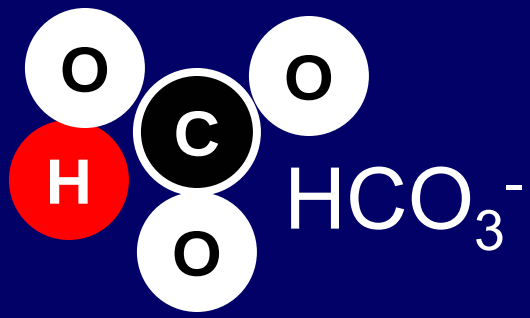
Increasing ocean acidity



Increasing ocean acidity



HCO_3^-



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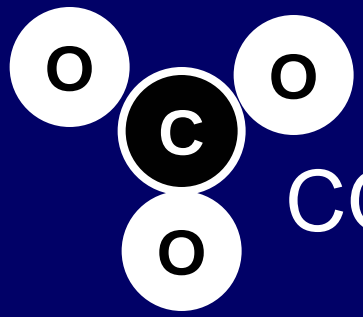
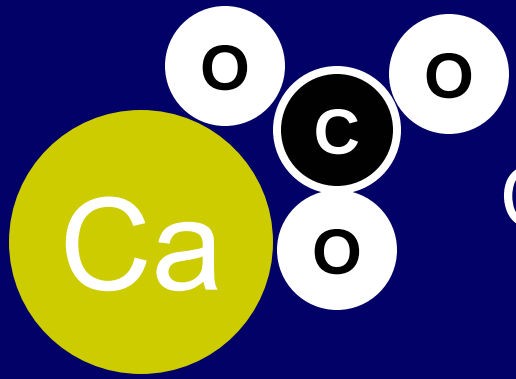


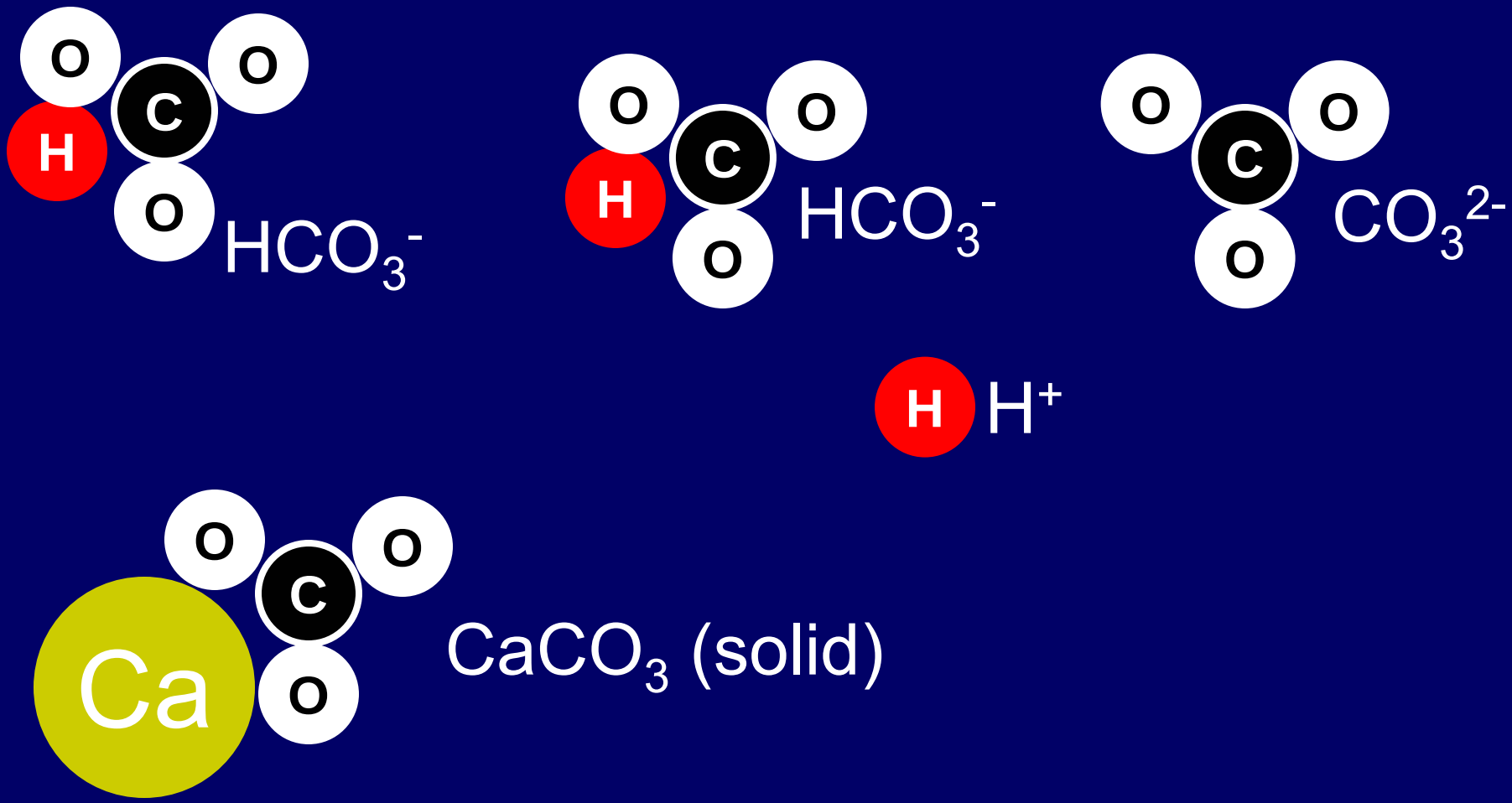
CO_3^{2-}

H^+

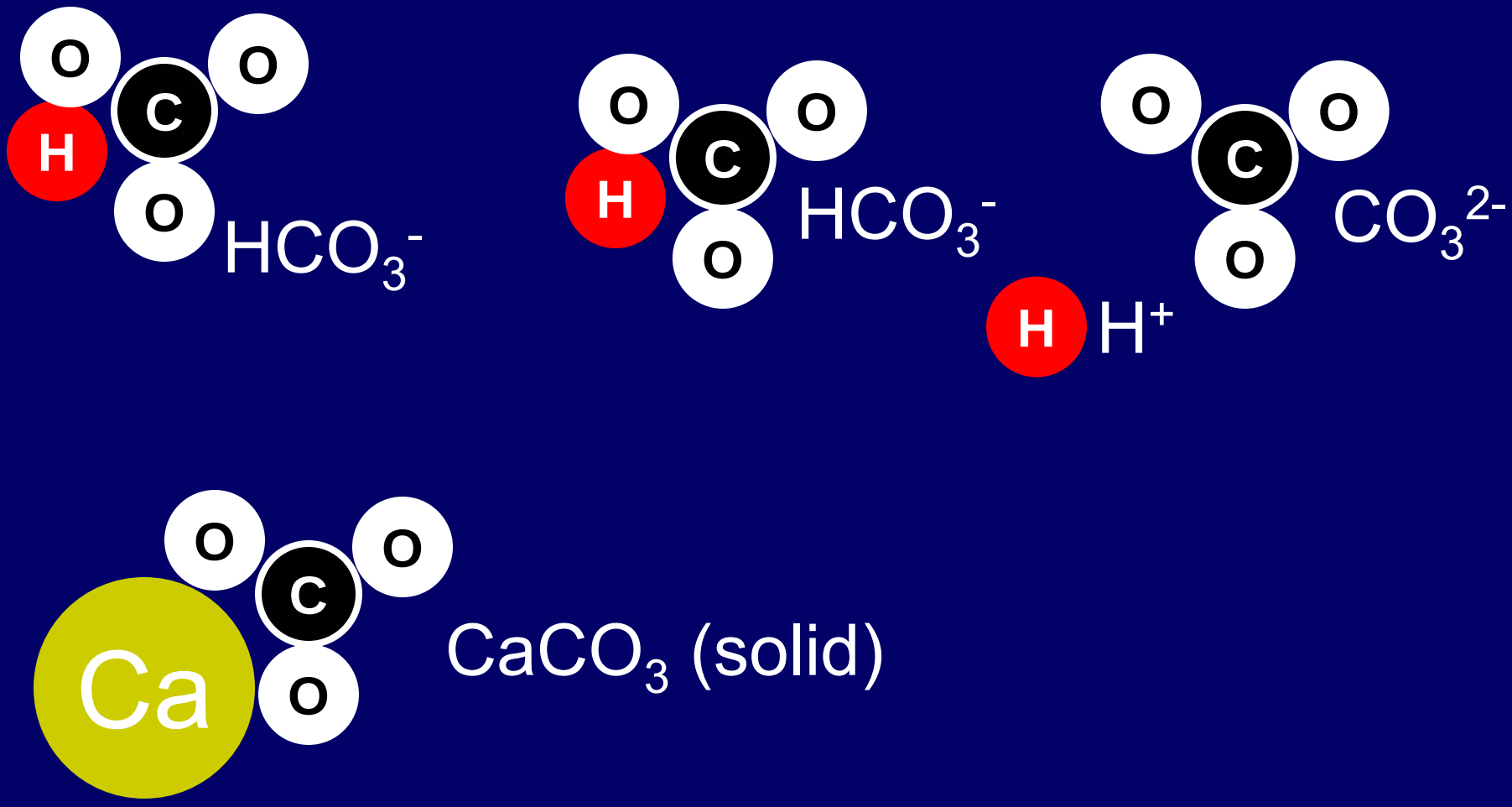


$CaCO_3$ (solid)

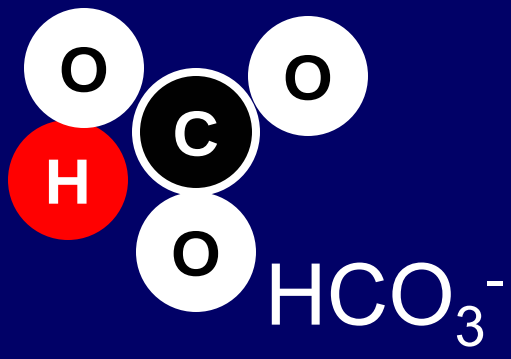
Increasing ocean acidity



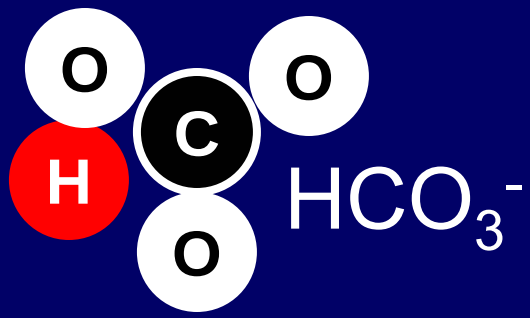
Attacking a building block for shells and skeletons



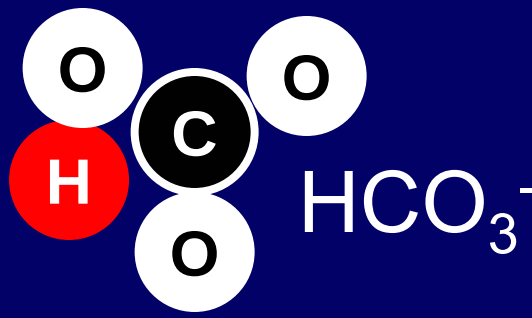
Attacking a building block for shells and skeletons



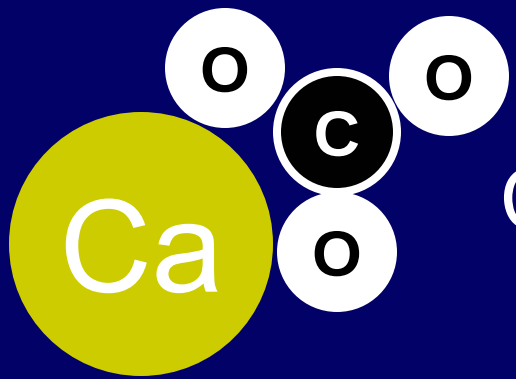
HCO_3^-



HCO_3^-

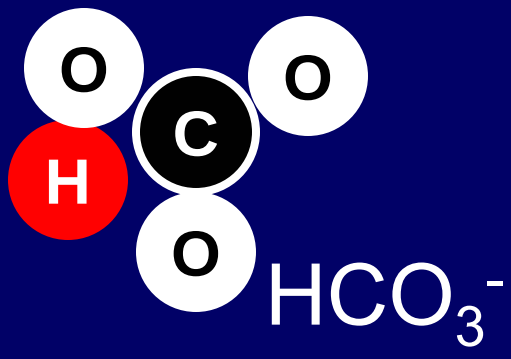


HCO_3^-

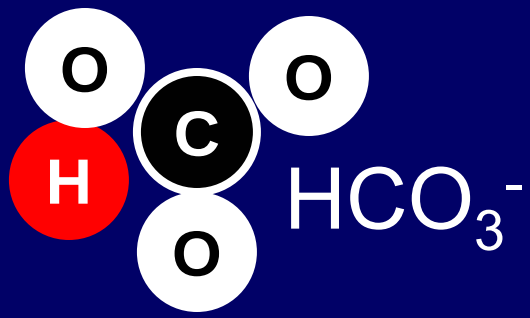


$CaCO_3$ (solid)

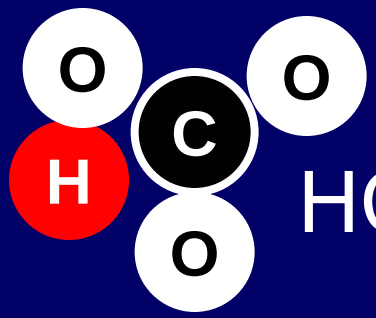
Dissolving shells and skeletons



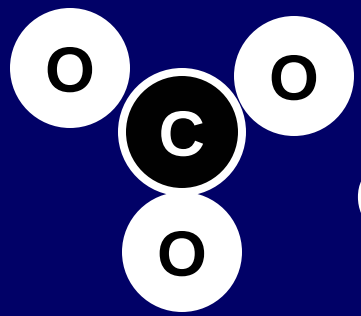
HCO_3^-



HCO_3^-



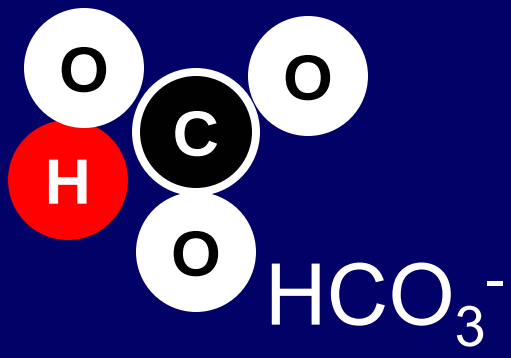
HCO_3^-



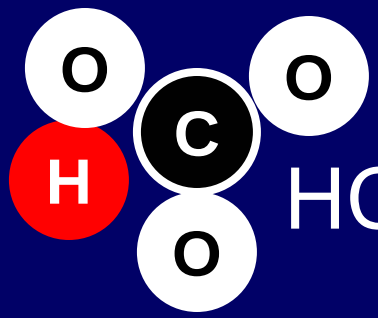
CO_3^{2-}

Ca^{2+} (dissolved)

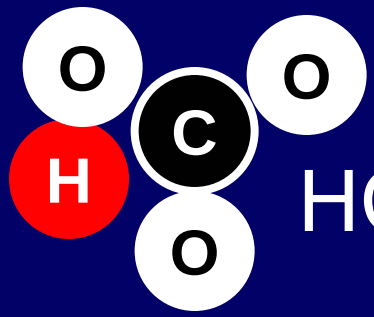
Dissolving shells and skeletons



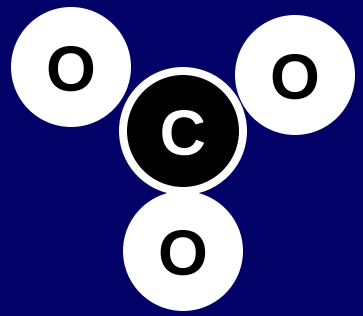
HCO_3^-



HCO_3^-



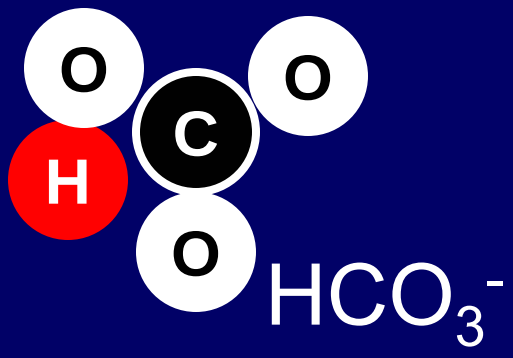
HCO_3^-



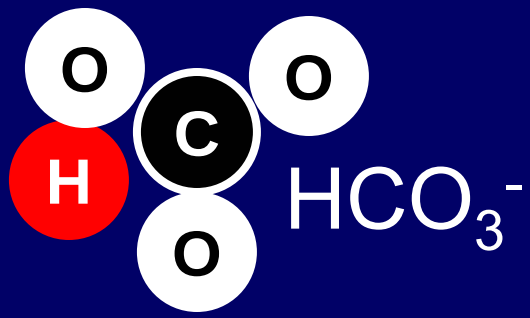
CO_3^{2-}

Ca Ca^{2+} (dissolved)

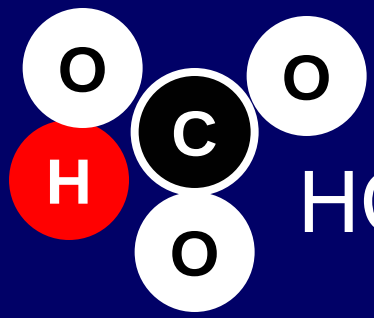
Dissolving shells and skeletons



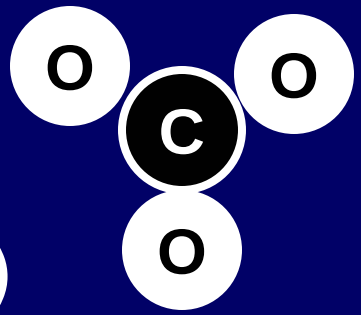
HCO_3^-



HCO_3^-



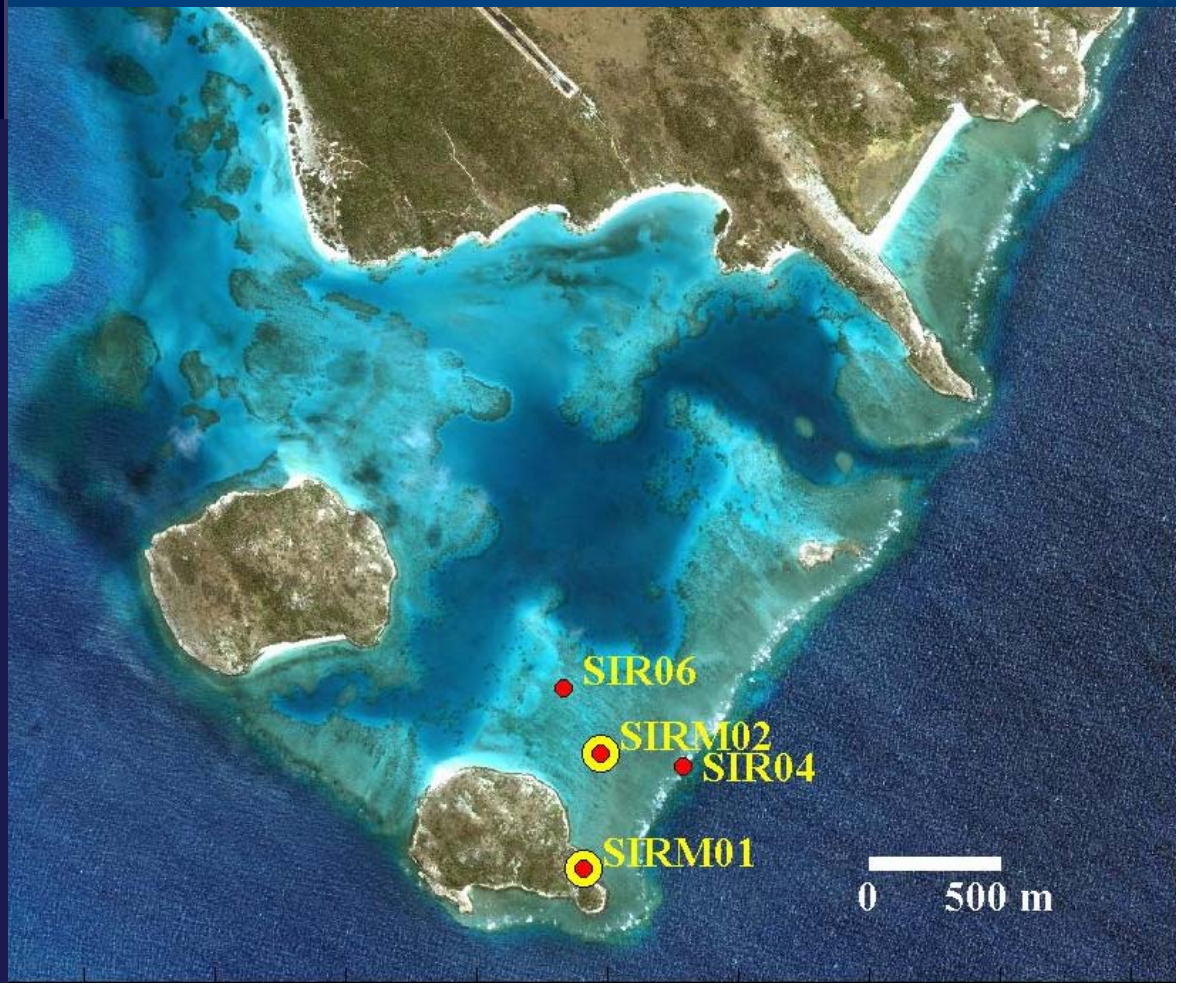
HCO_3^-

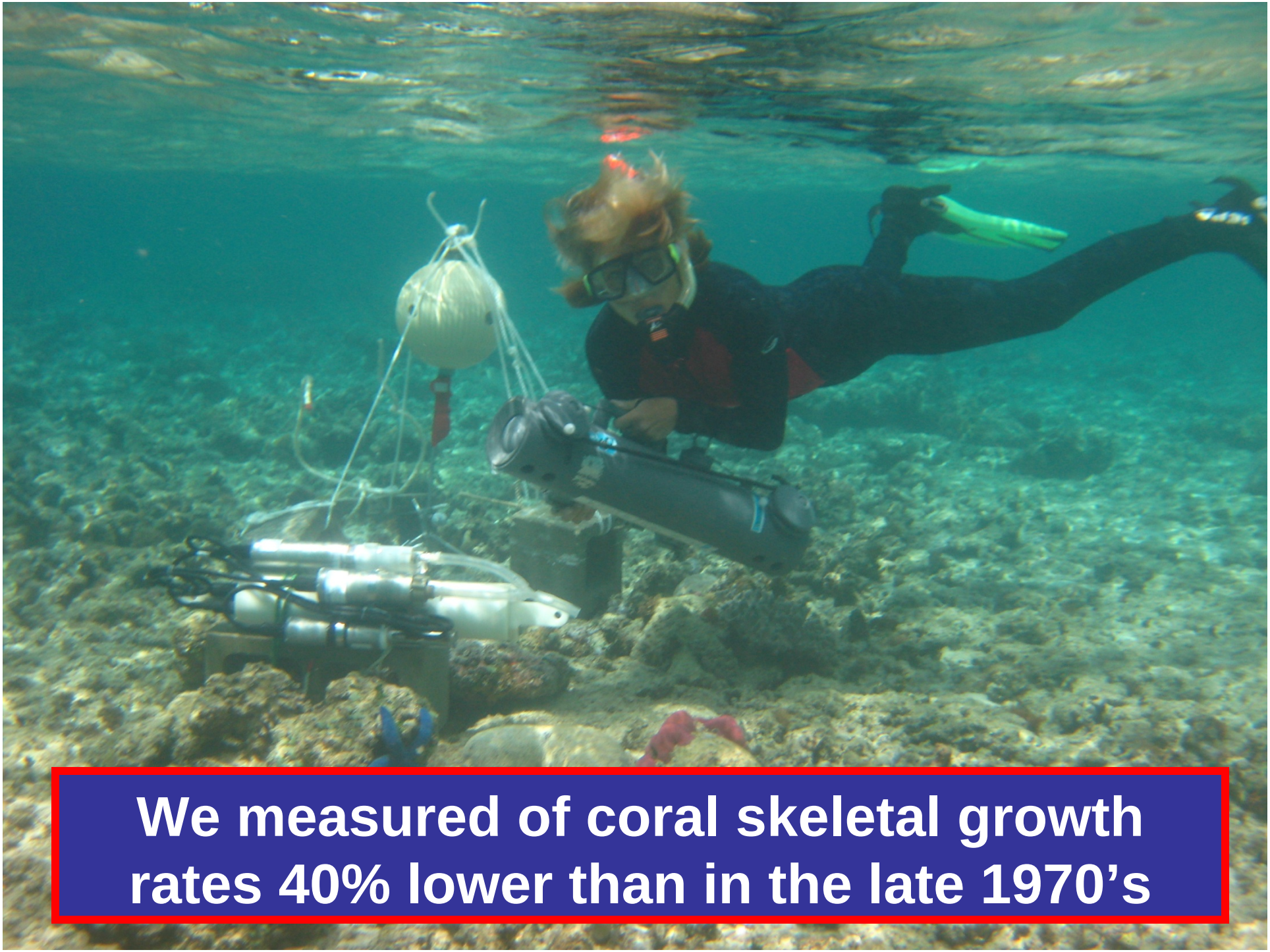


CO_3^{2-}

Ca^{2+} (dissolved)

Lizard Island Expedition September 2008





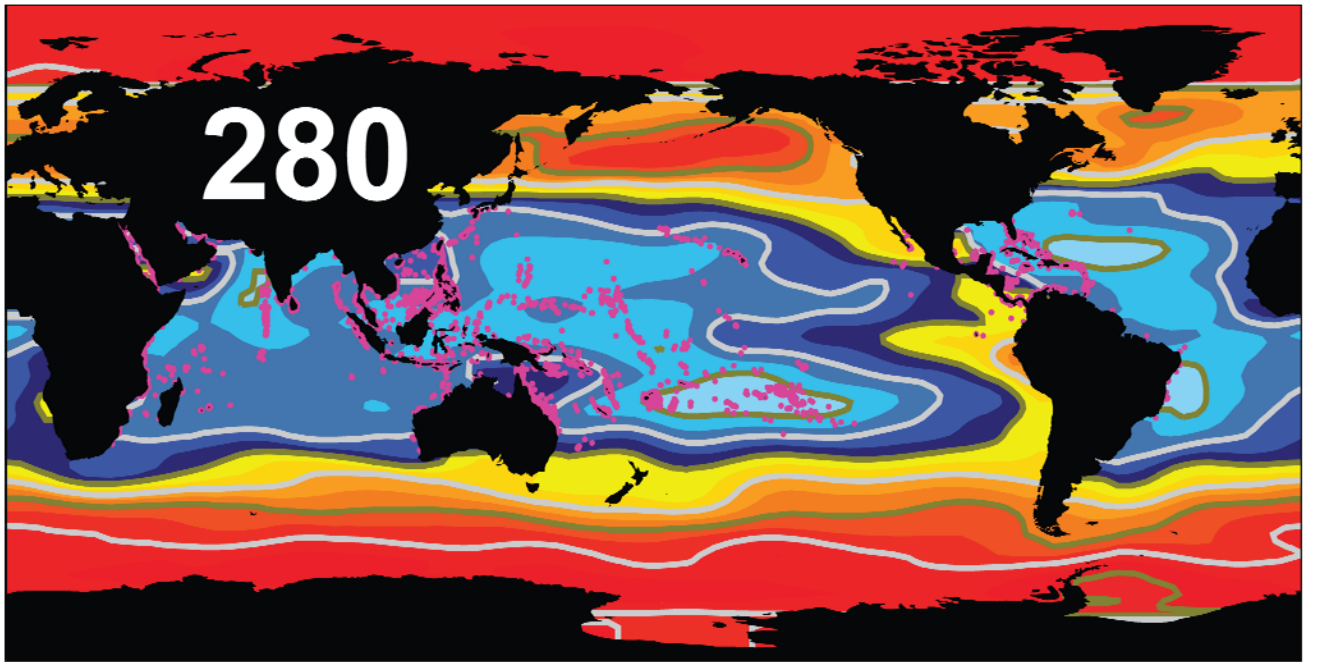
We measured of coral skeletal growth rates 40% lower than in the late 1970's

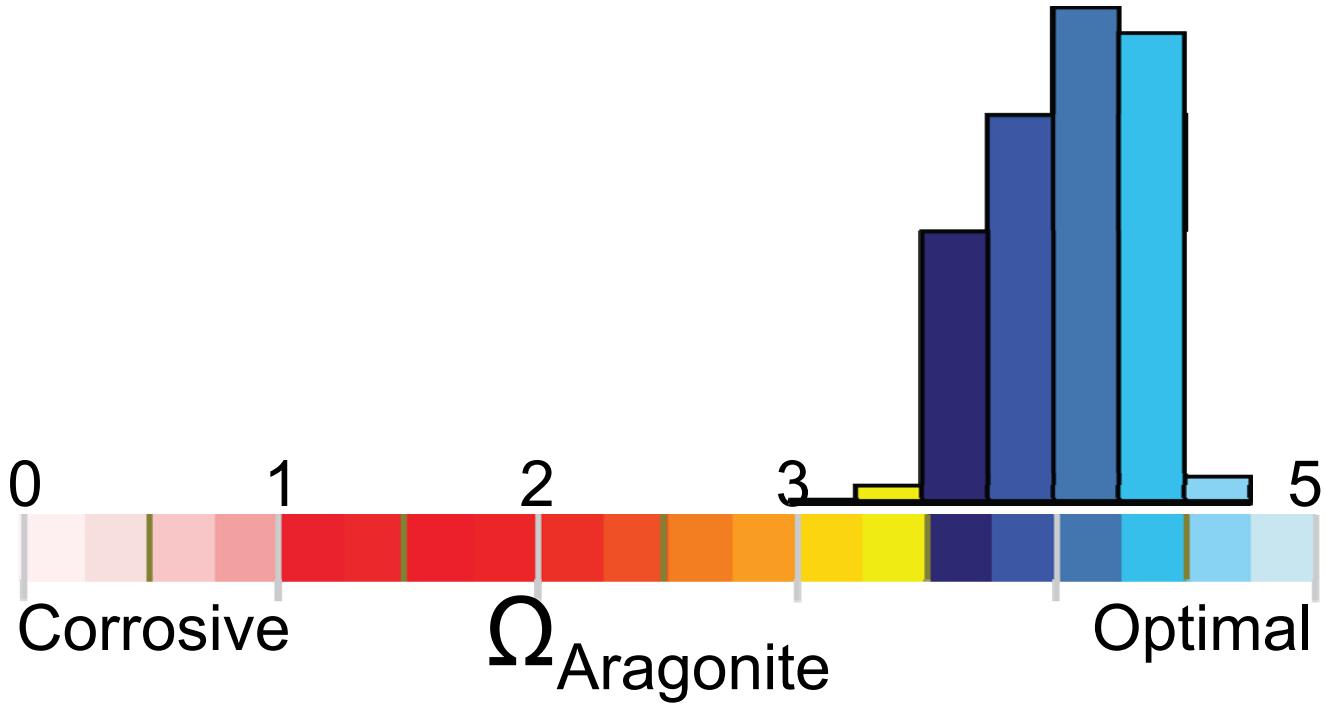
Distribution of corals and ocean acidification

Carbon dioxide level,

Coral reef distribution,

and chemical conditions helping drive reef formation



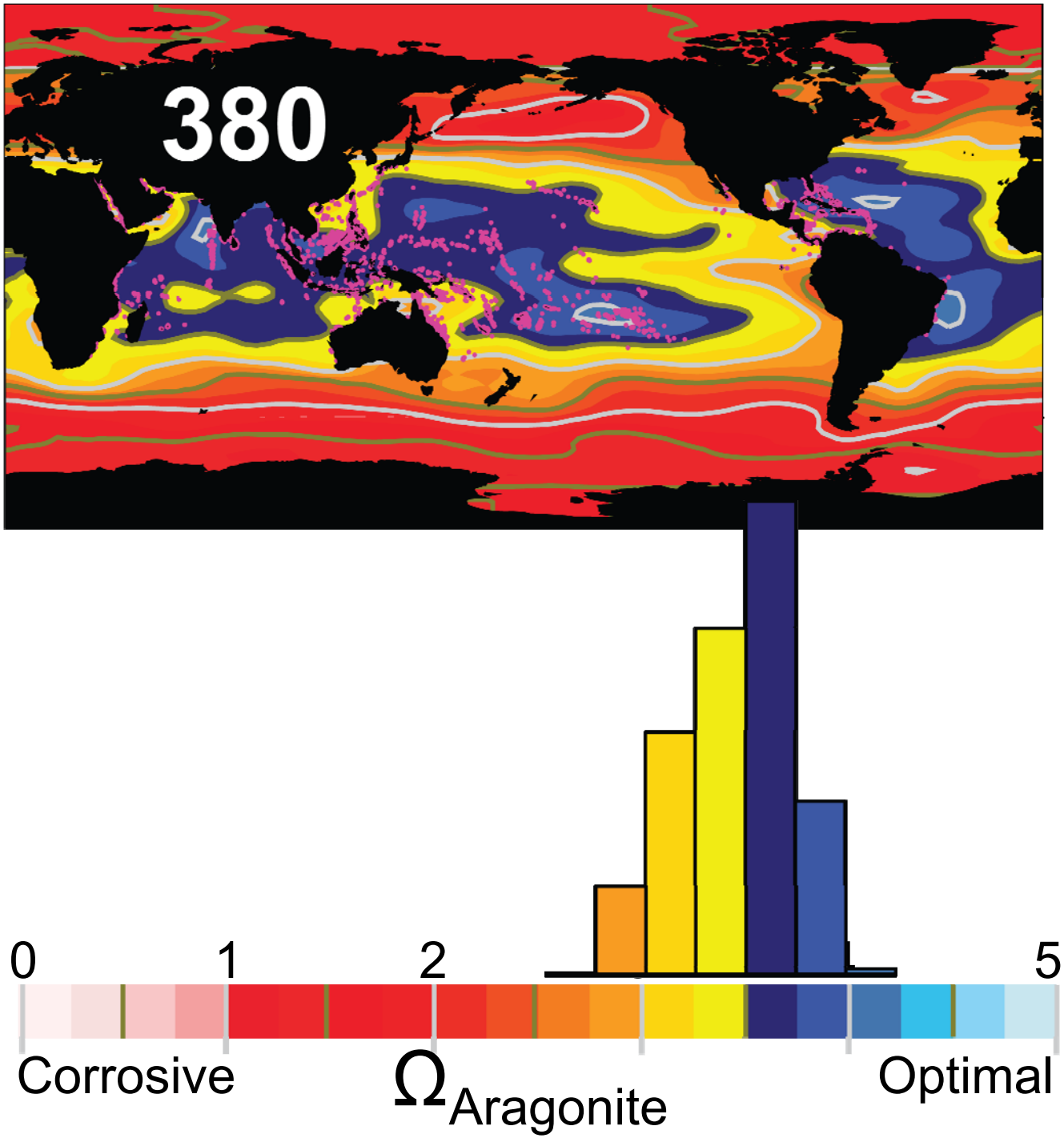


Cao and Caldeira, 2008

Carbon dioxide level,

Coral reef distribution,

and chemical conditions helping drive reef formation



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Carbon dioxide level,

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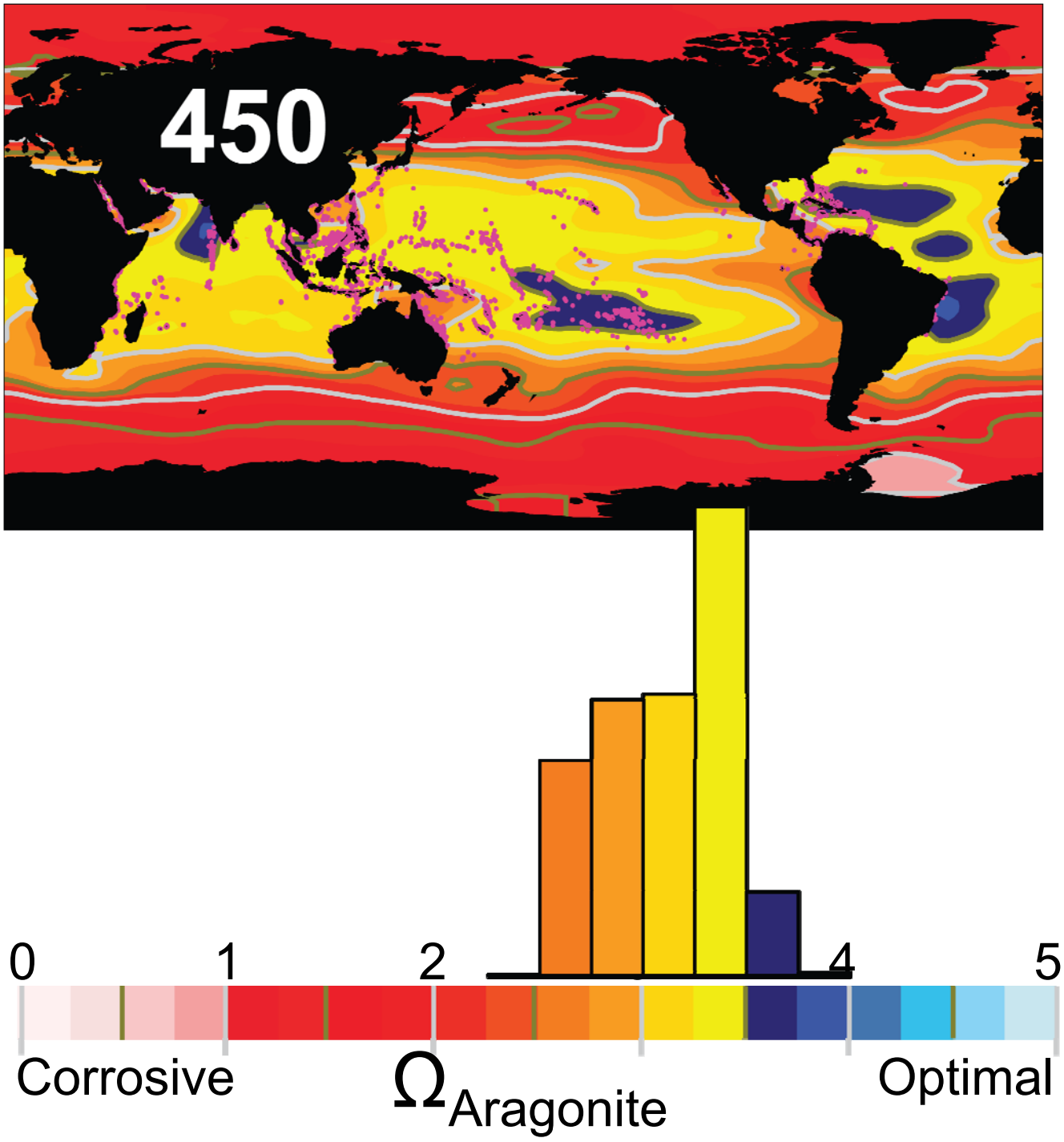
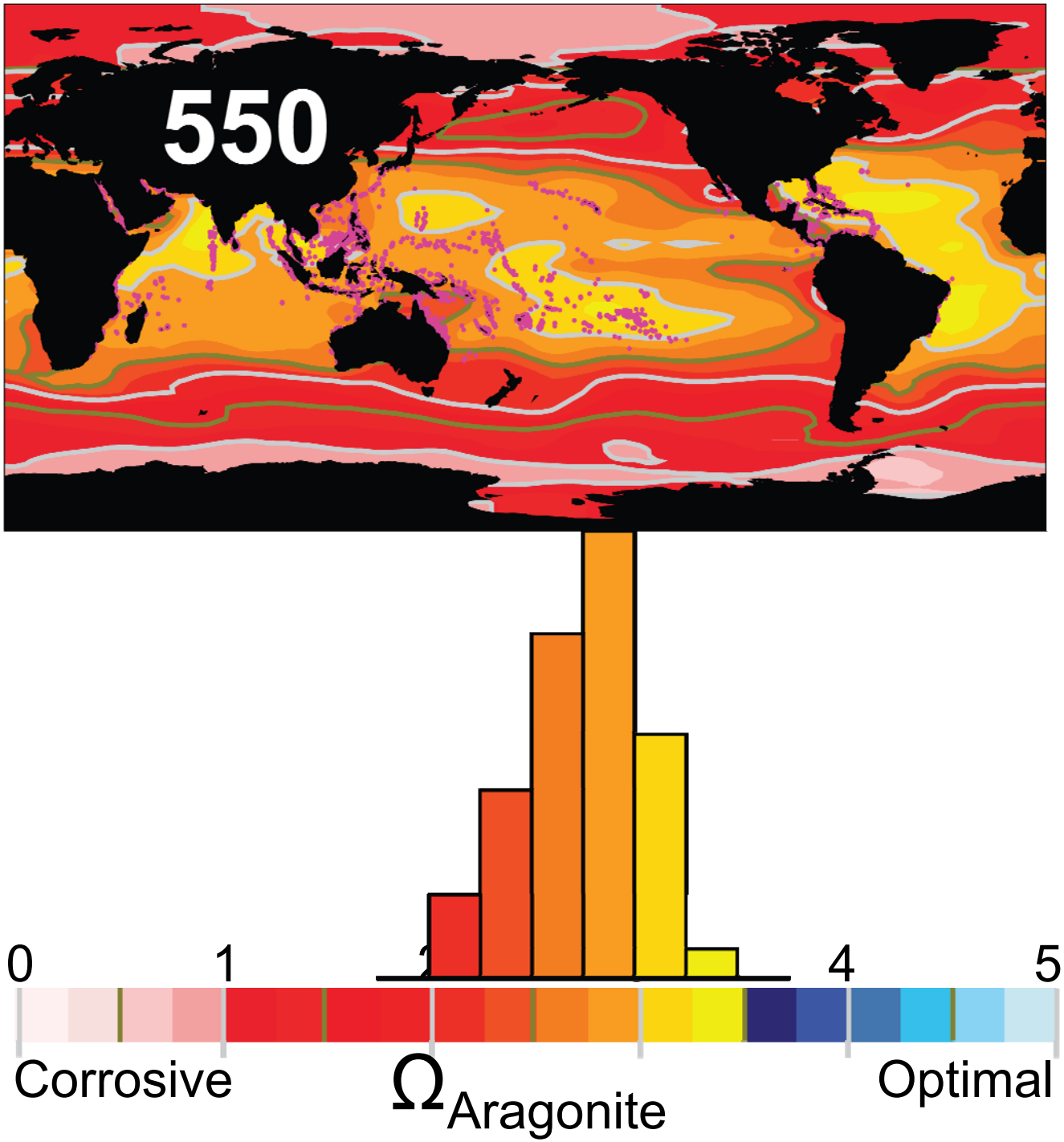


Cao and Caldeira, 2008

Carbon dioxide level,

Coral reef distribution,

and chemical conditions helping drive reef formation

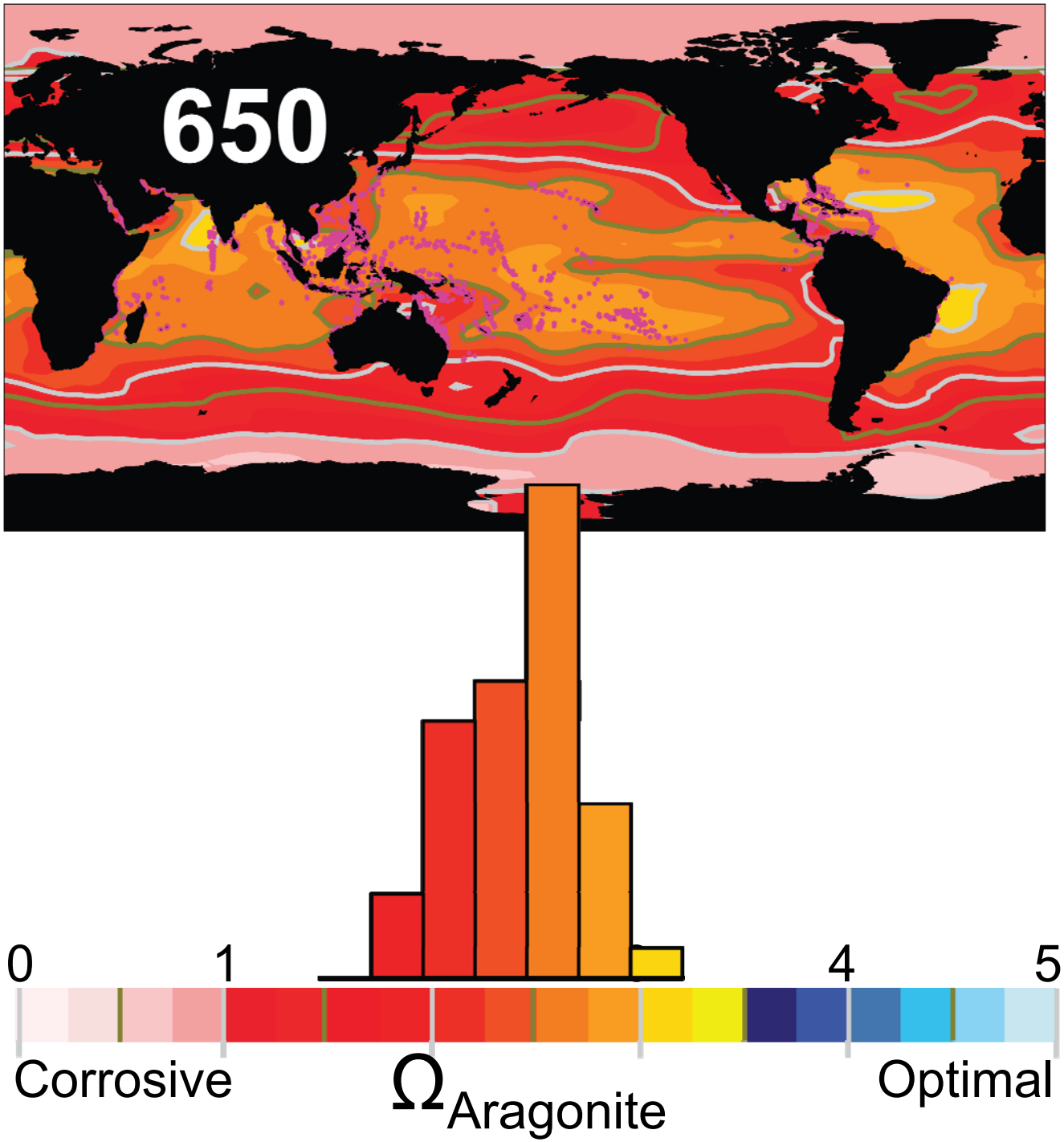


Cao and Caldeira, 2008

Carbon dioxide level,

Coral reef distribution,

and chemical conditions helping drive reef formation

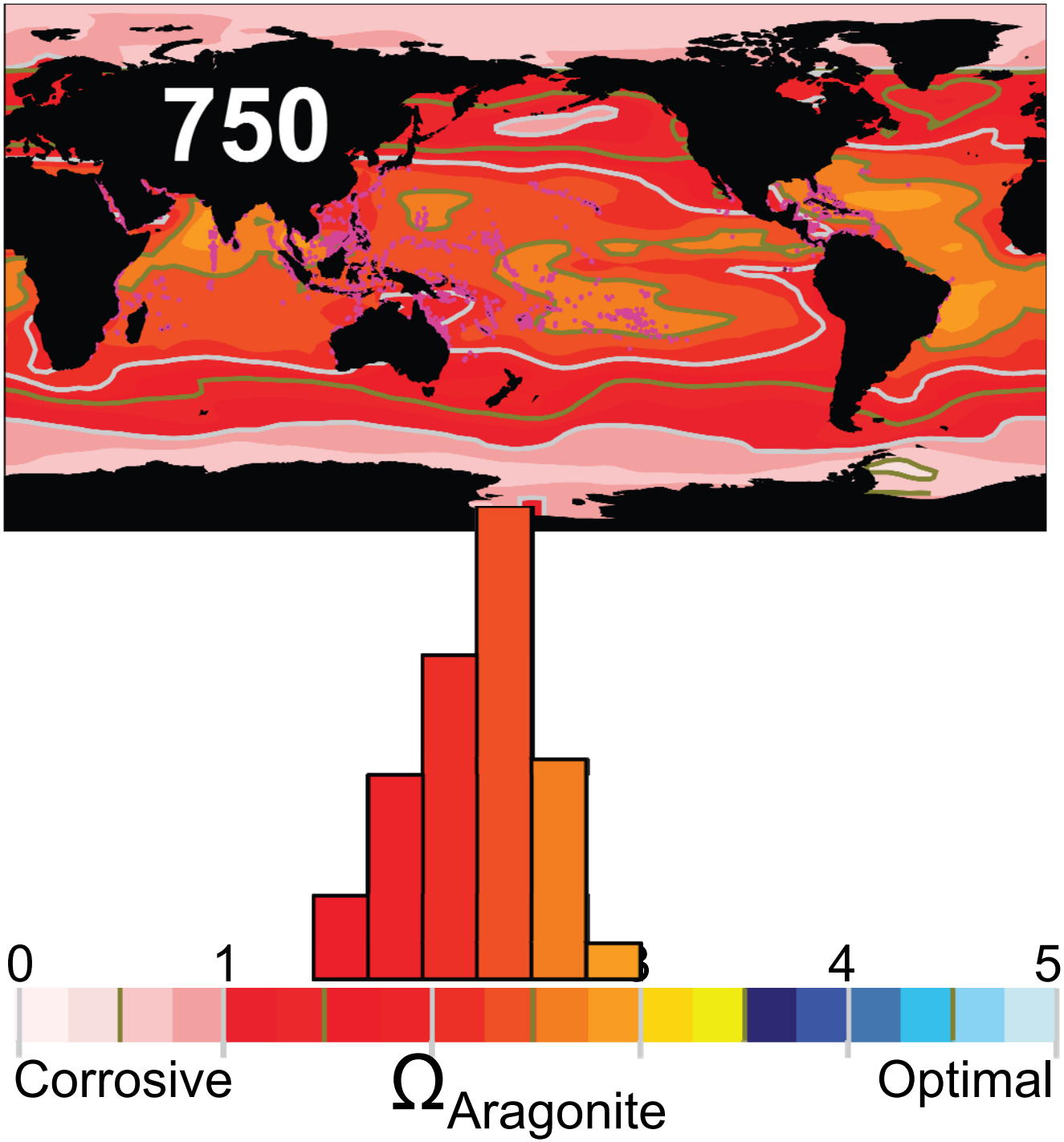


Cao and Caldeira, 2008

Carbon dioxide level,

Coral reef distribution,

and chemical conditions helping drive reef formation



Cao and Caldeira, 2008

McCall Glacier, Brooks Range, Alaska

Austin Post,1958

Matt Nolan, 2003

Courtesy Lonnie Thompson

Muir Glacier, SE Alaska

August, 1941 (photo by William Field)

August, 2004 (photo by Bruce Molnia)

Courtesy Lonnie Thompson

Glacier No. 1, China

1960

1990

2001

Lonnie G. Thompson, Byrd Polar Research Center, The Ohio State University

Courtesy Lonnie Thompson

Glacier National Park, Grinnel Glacier

Photo: Fred Kiser, Glacier National Park archives

Photo: Karen Holzer, US Geological Survey

Glacier National Park, Boulder Glacier

Photo: George Grant, Glacier National Park archives

Photo: Jerry DeSanto, National Park Service

Source: *BioScience*, Vol. 53 No. 2, Feb 2003

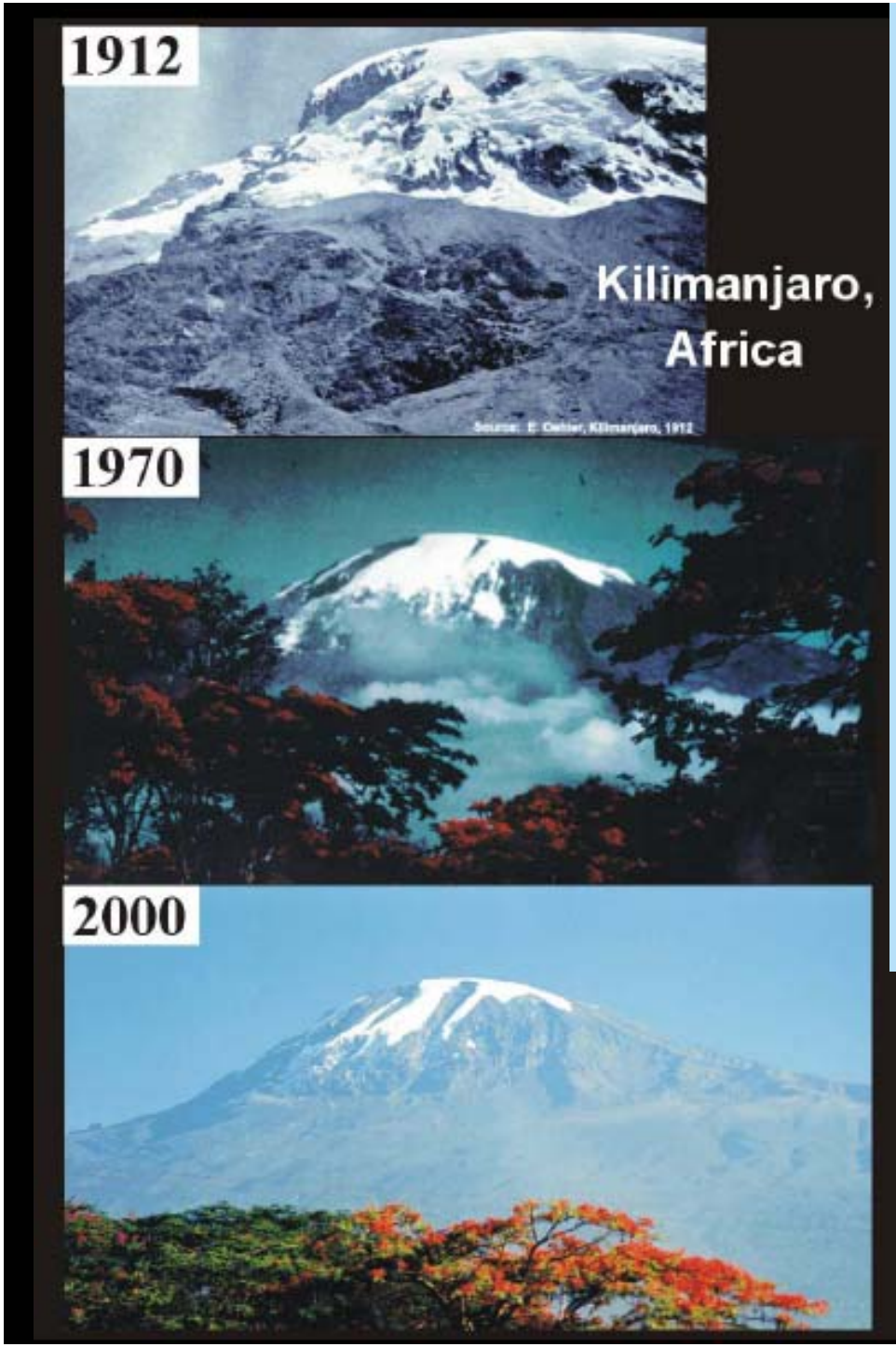
Courtesy Lonnie Thompson

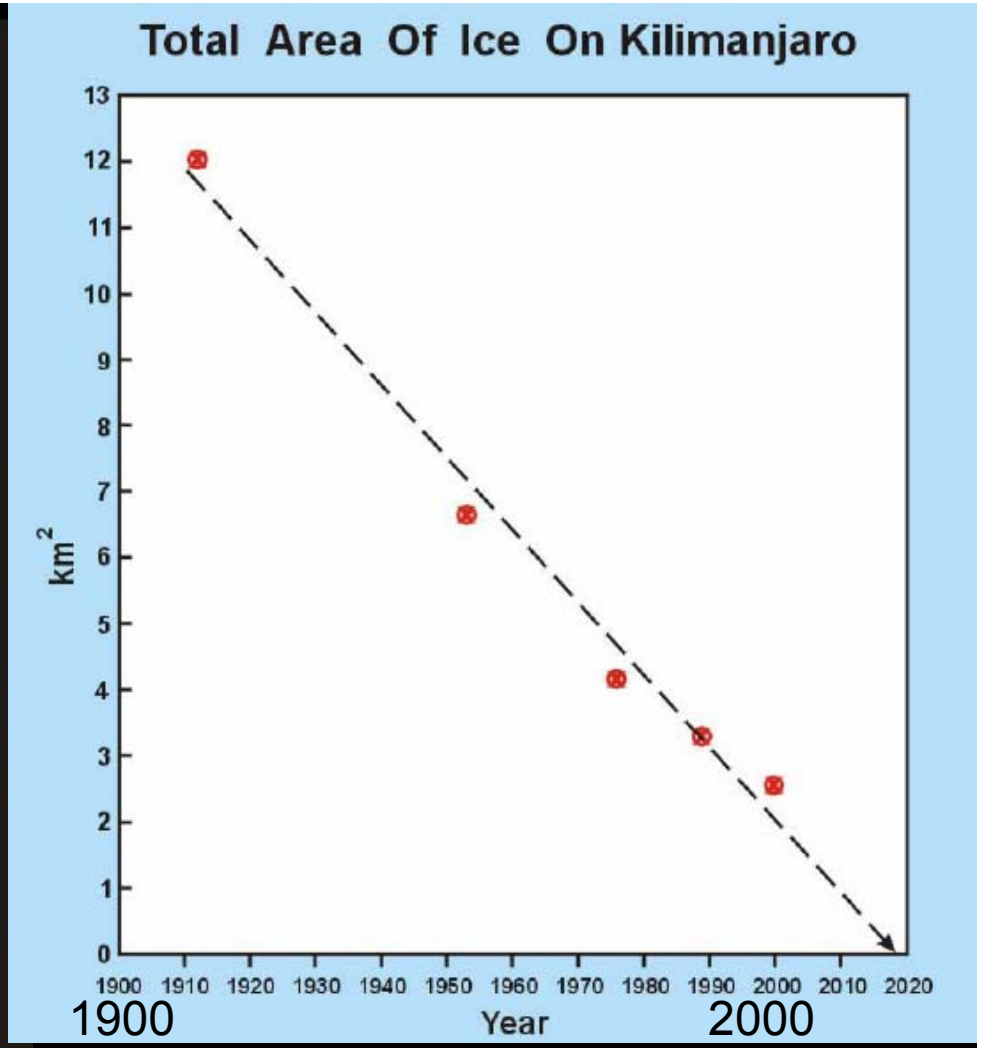
Qori Kalis, Peru 1978

Courtesy Lonnie Thompson

Qori Kalis, Peru 2002

Courtesy Lonnie Thompson





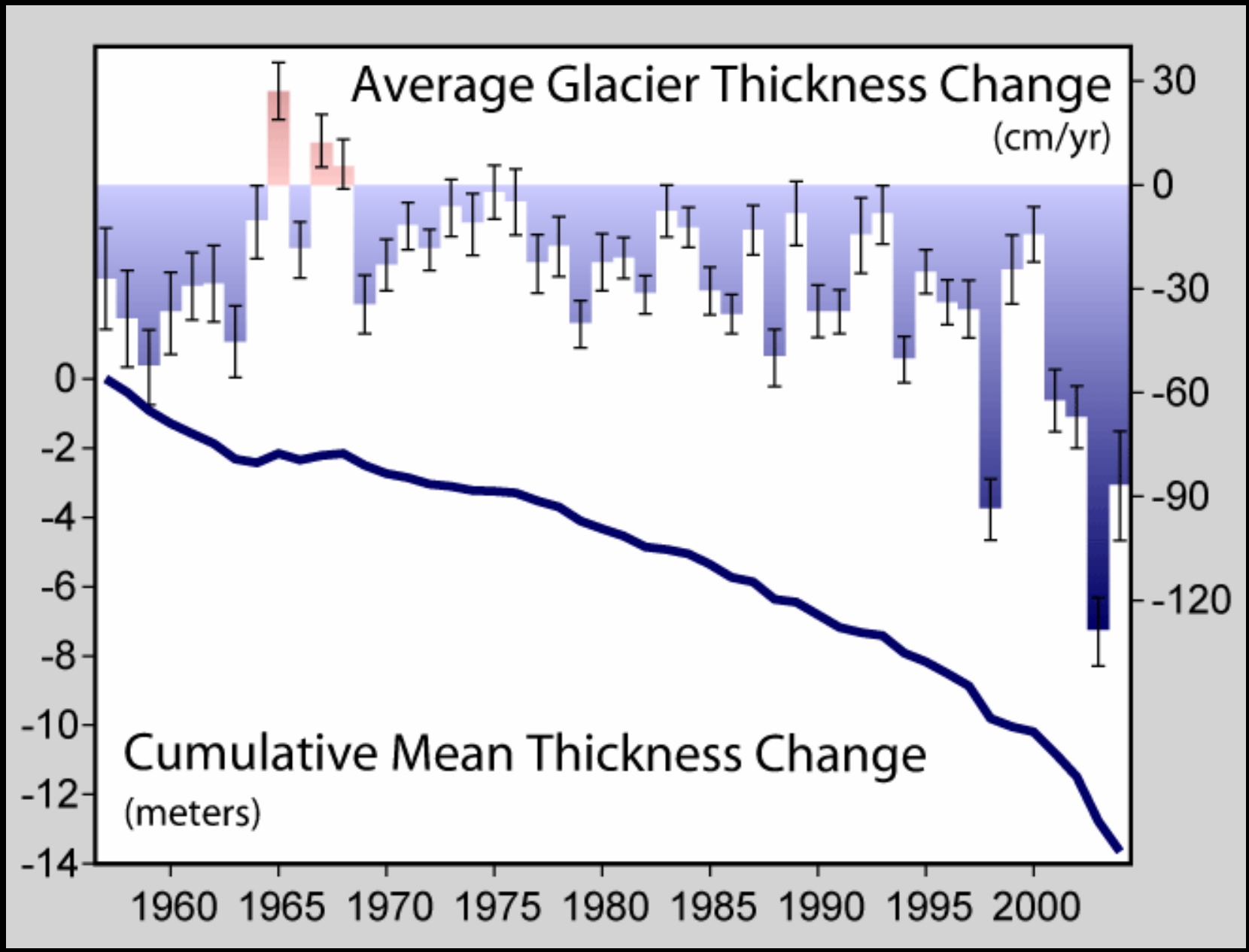
Courtesy Lonnie Thompson

Whitechuck Glacier
WA, USA

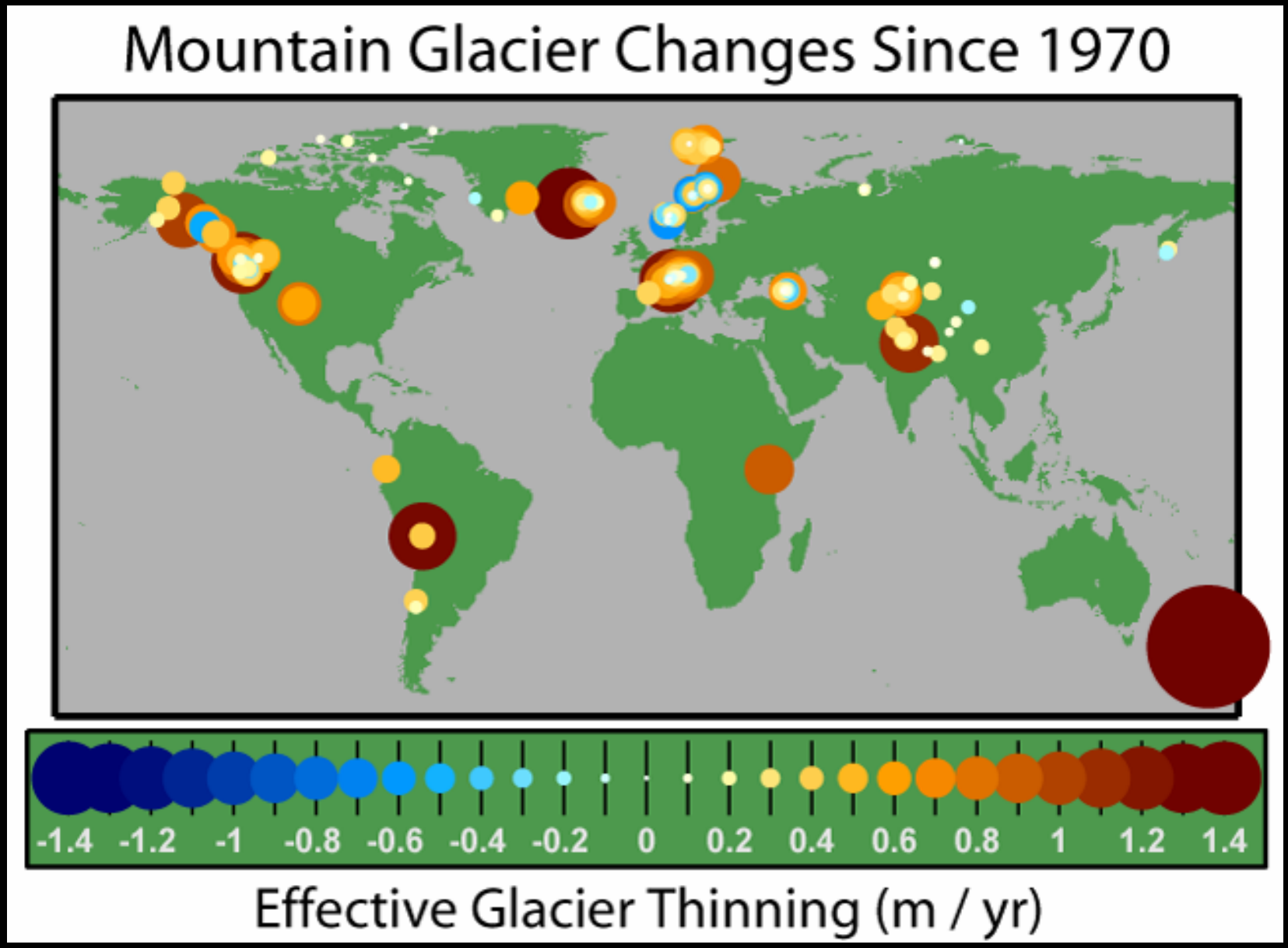
1973

2006

Anecdotes
&
Statistics



Dyurgerov (2002), Dyurgerov and Meier (2005) fig by Rhode



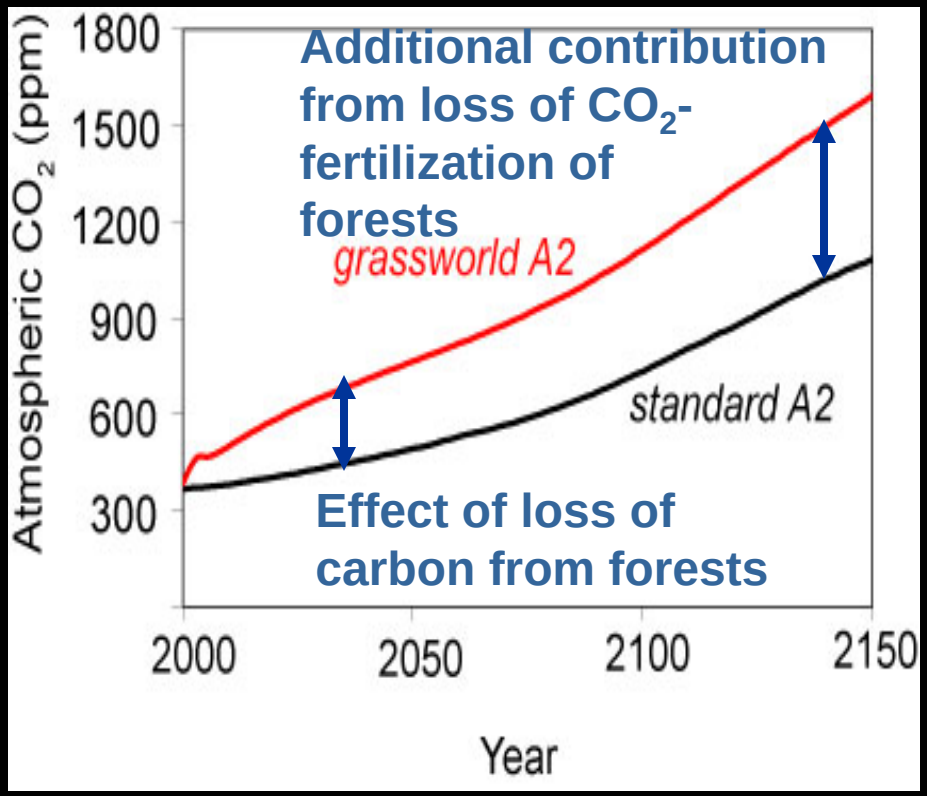
Dyurgerov and Meier (2005) fig by Rhode

What if things aren’t simple?

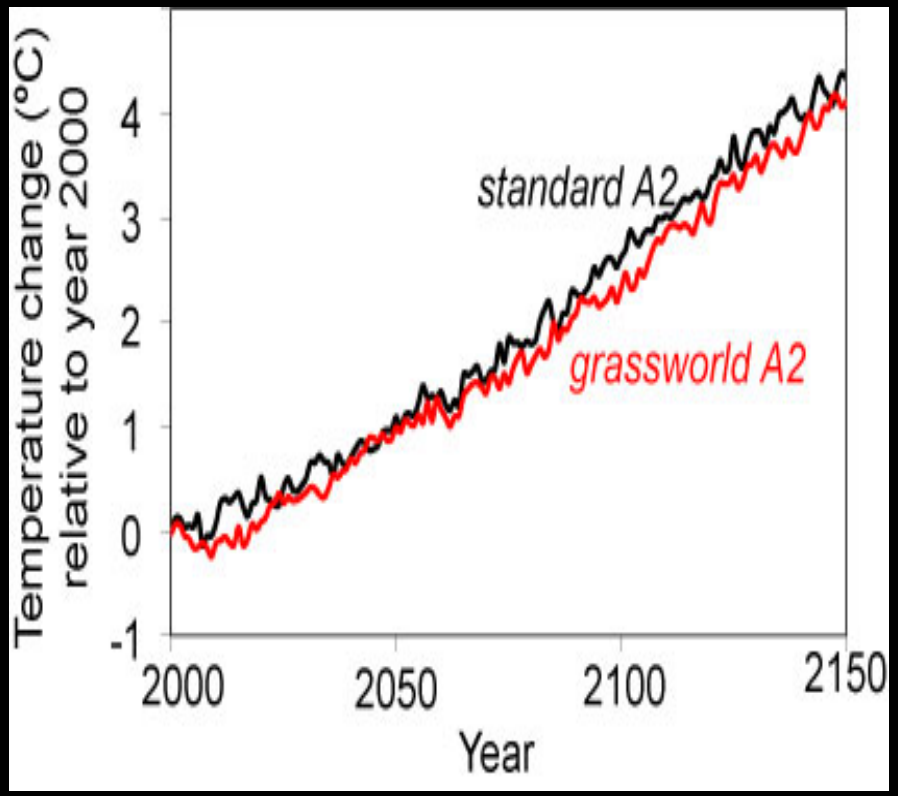
The case of forests

With deforestation, CO_2 is much higher but temperatures are slightly cooler

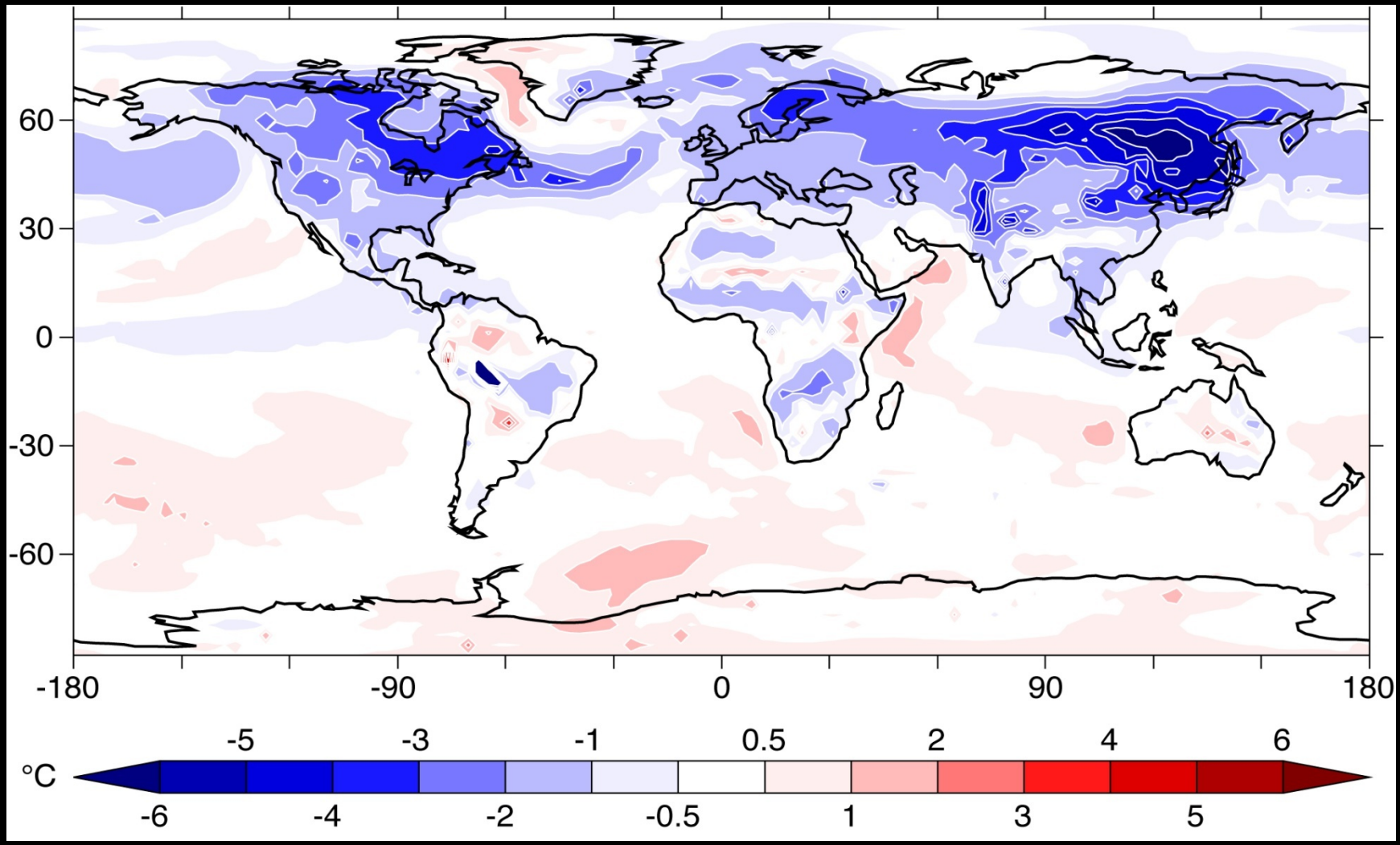
Atmospheric CO_2



Temperature



Global deforestation experiment: net temperature change (CO_2 + biophysical)

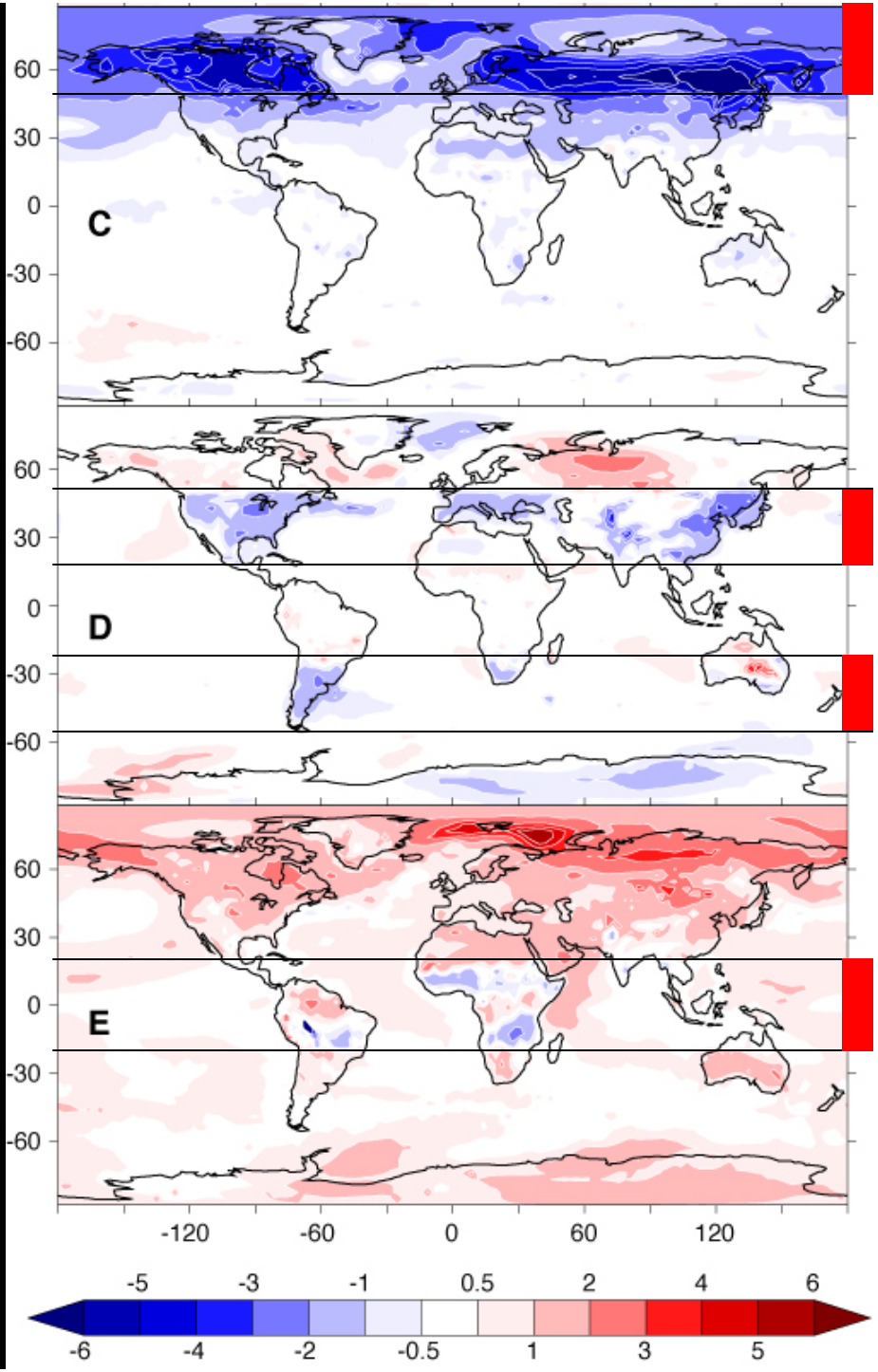


Boreal

Temperature change predicted in latitude-band deforestation simulations

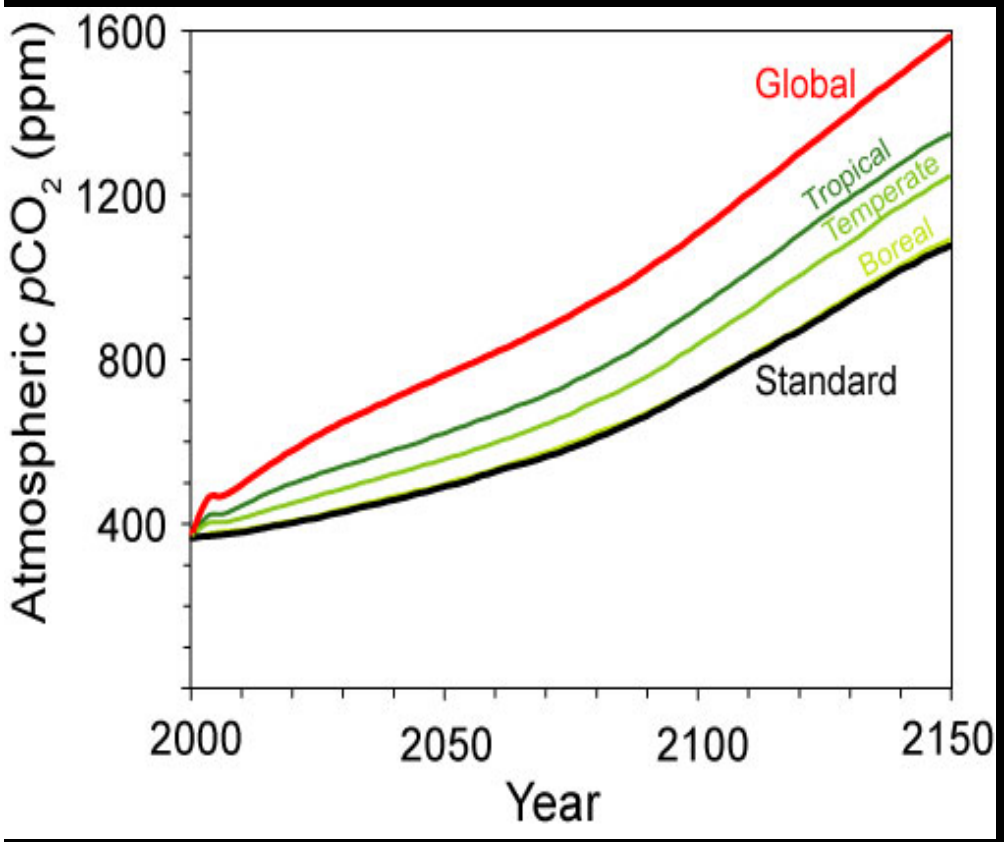
Temperate

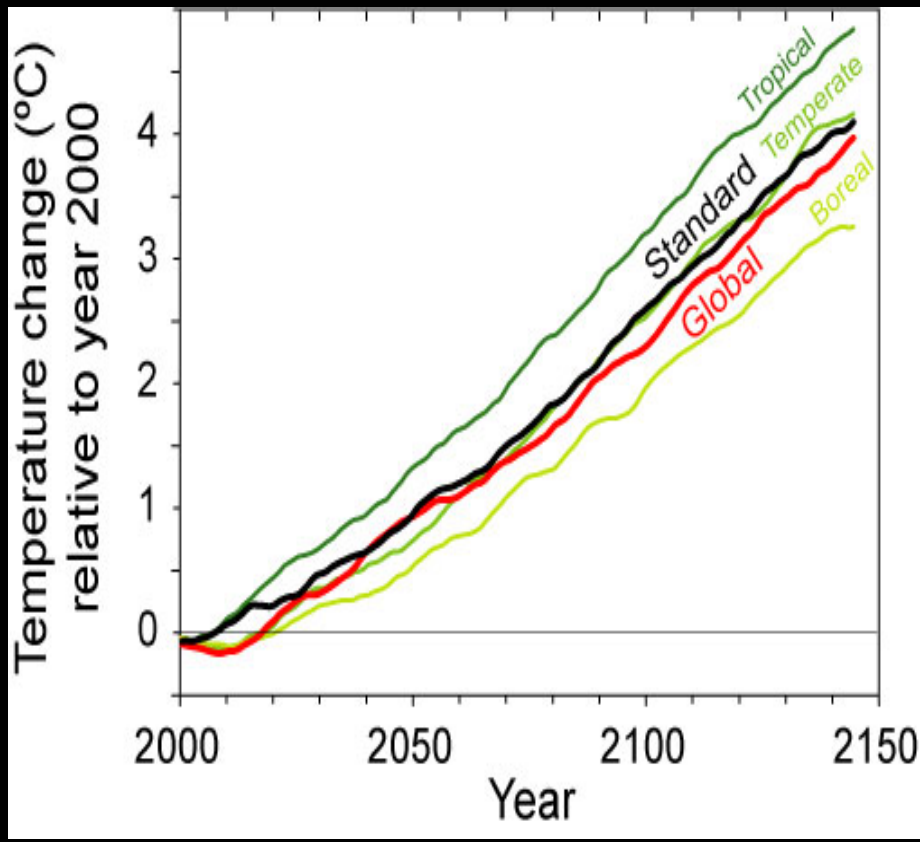
Tropical

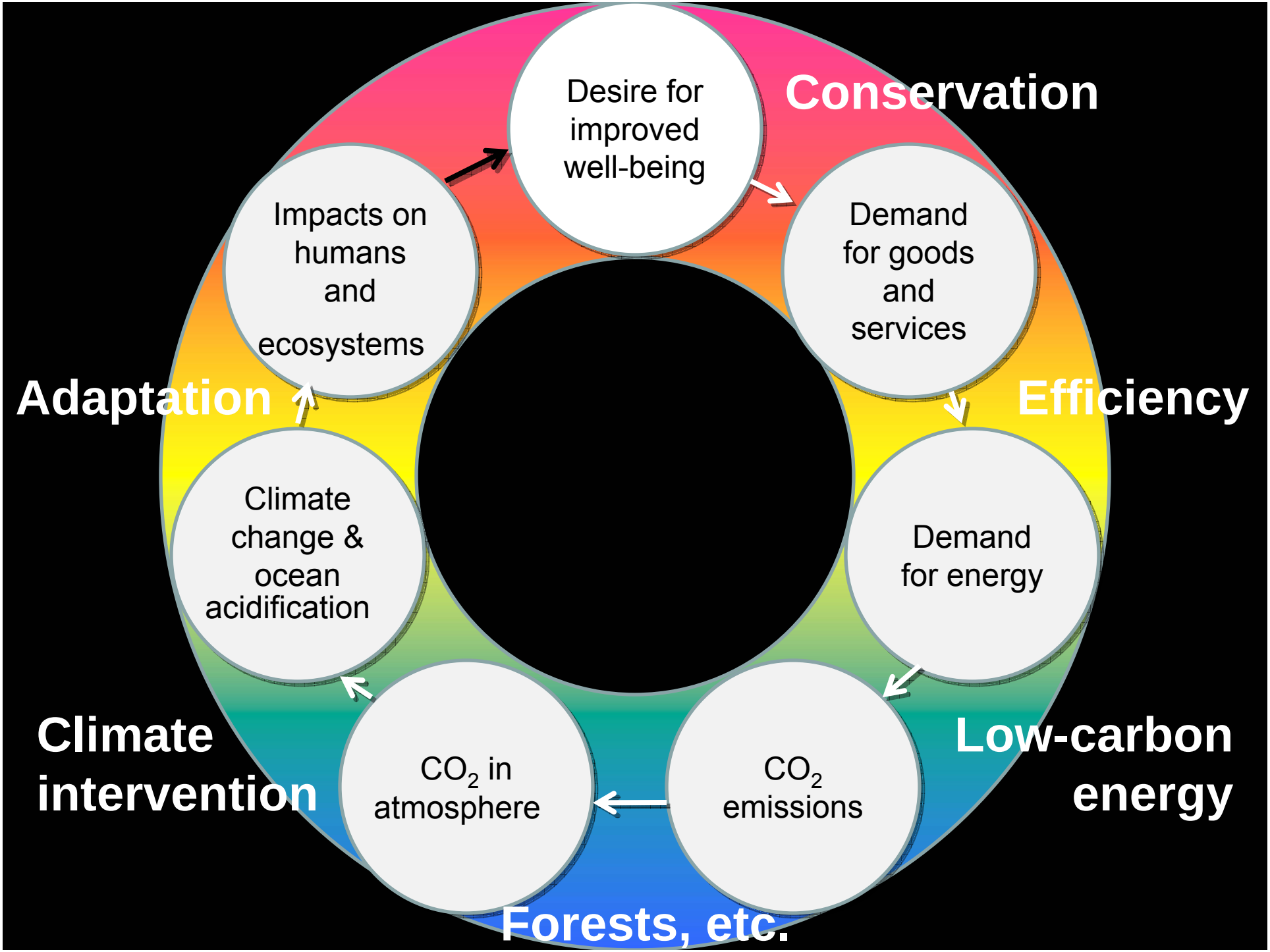


Predicted role of forests

Tropical forests cool the planet
Temperate (mid-latitude) forests do little
Boreal forests warm the planet






Desire for improved well-being
Conservation
Demand for goods and services
Efficiency
Demand for energy
Low-carbon energy
CO_2 emissions
Forests, etc.
CO_2 in atmosphere
Climate intervention
Climate change & ocean acidification
Adaptation
Impacts on humans and ecosystems

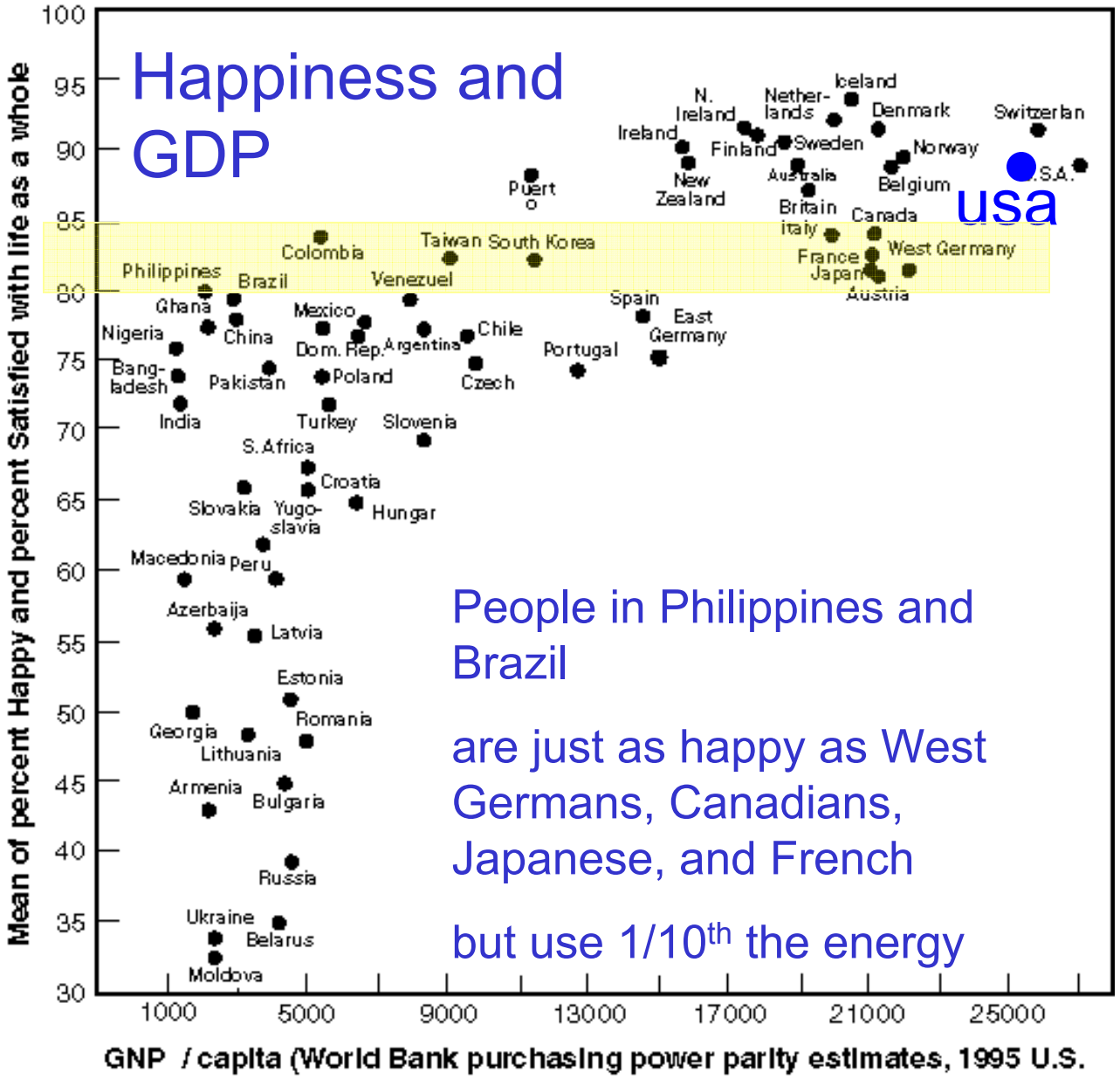
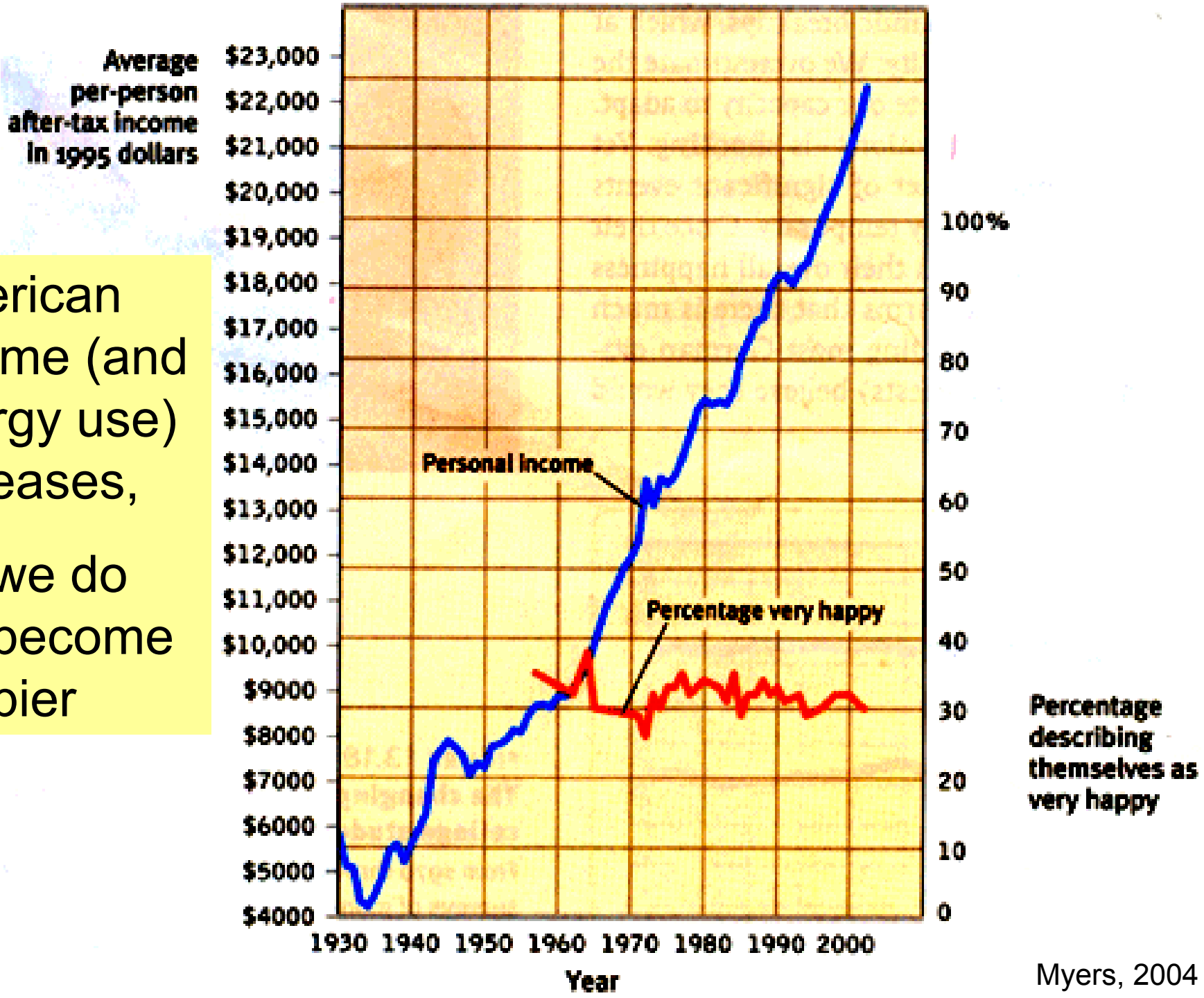


Figure 2. Subjective well-being by level of economic development.
Source: World Values Surveys; GNP/capita purchasing power estimates from World Bank, World Development Report, 1997.
R = .70 N = 65 p < .0000

Inglehart and Klingemann 2000.

American income (and energy use) increases,

but we do not become happier



Myers, 2004

How do we know anything?

- Thought, intuition, interior reflection
- Unplanned direct experience
- Family, friends, etc
- TV, magazines, books, web sites, blogs, experts, idiots
- Planned empirical investigation
- Careful analysis and appraisal of multiple sources of information