National Park Service
U.S. Department of the Interior

Climate Change and Ecological Impacts in the Southwestern U.S.

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Climate Change Scientist, U.S. National Park Service

Environmental and Energy Study Institute, briefing for U.S. Congressional staff
Washington, DC, April 2, 2014

Lodgepole pine trees killed by mountain pine beetles
Rocky Mountain National Park, Colorado
photo P. Gonzalez

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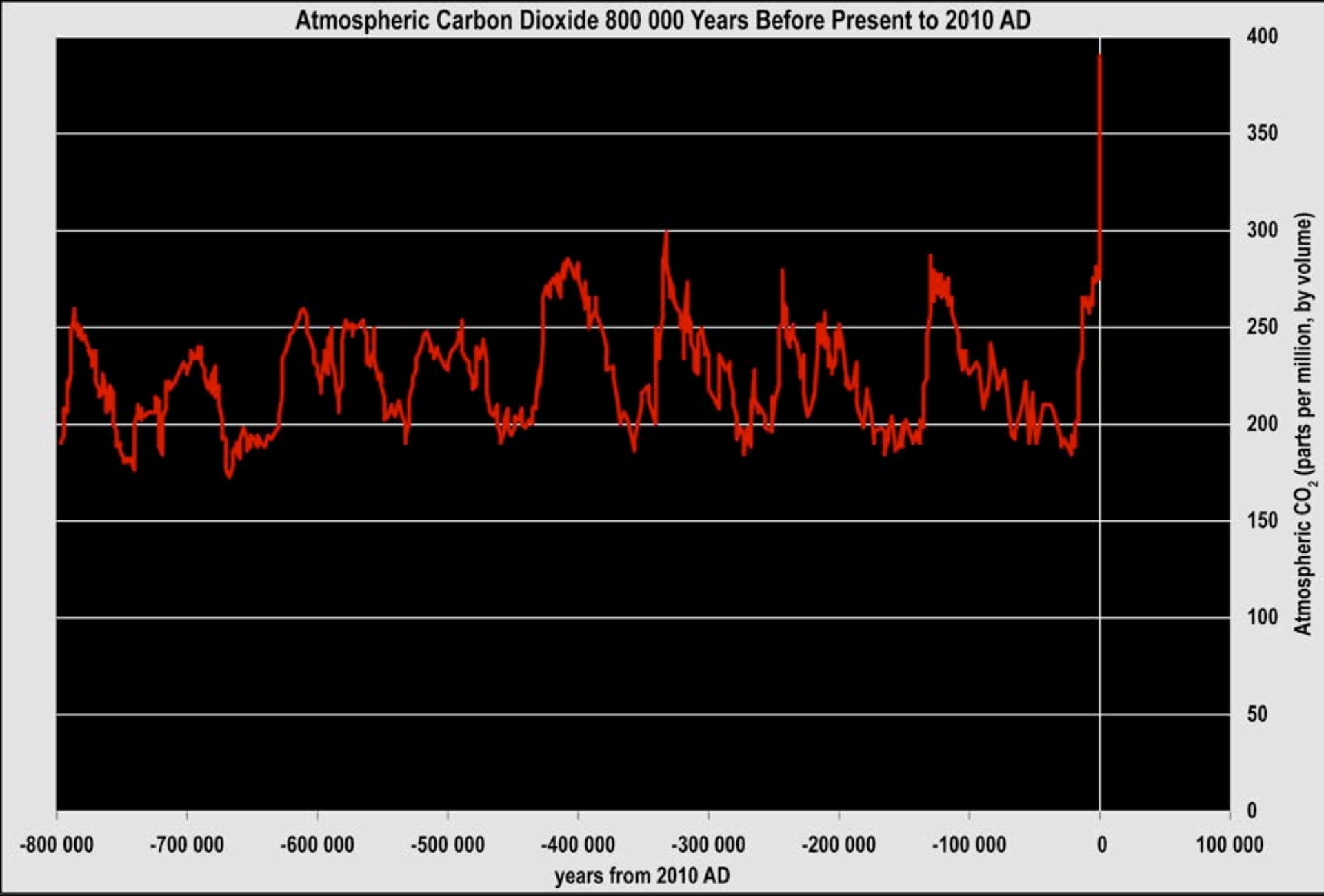
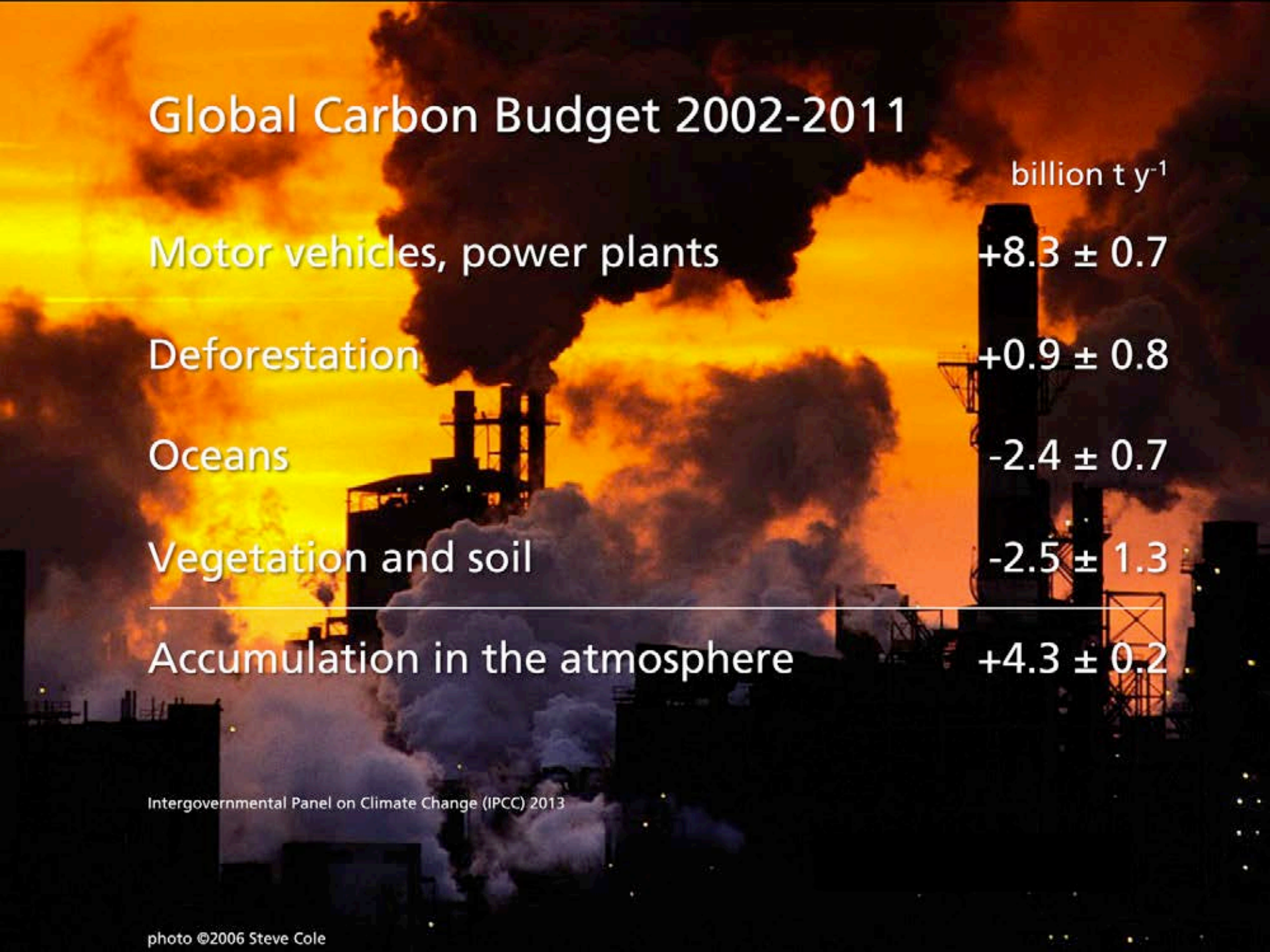
Outline

1. Historical climate trends
2. Historical ecological impacts
3. Future climate projections
4. Future ecological vulnerabilities

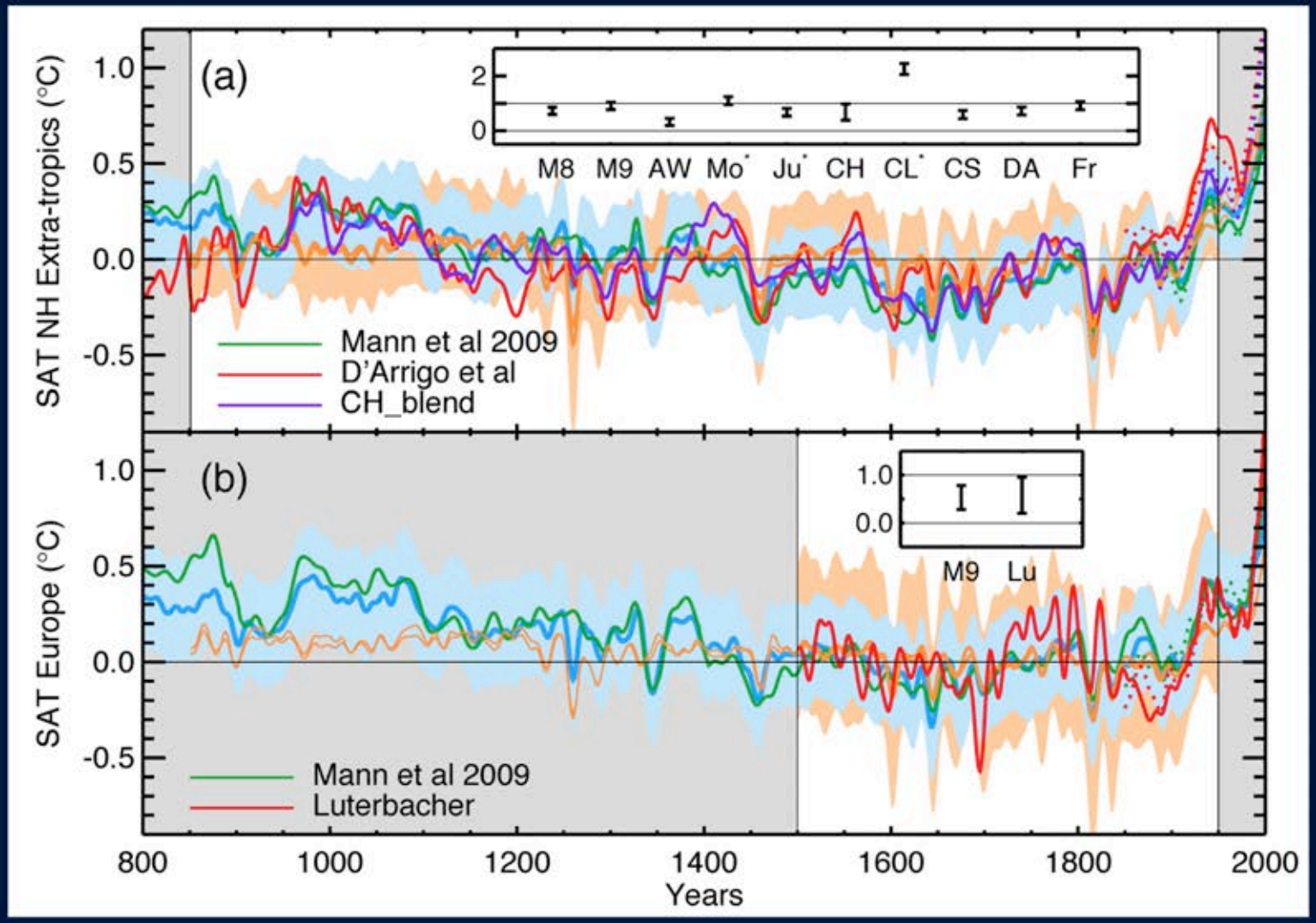


Data: Petit et al. 1999 Nature, Monnin et al. 2001 Science, Siegenthaler et al. 2005 Science, Lüthi et al. 2008 Nature, C.D. Keeling, National Oceanic and Atmospheric Administration

Graph: P. Gonzalez

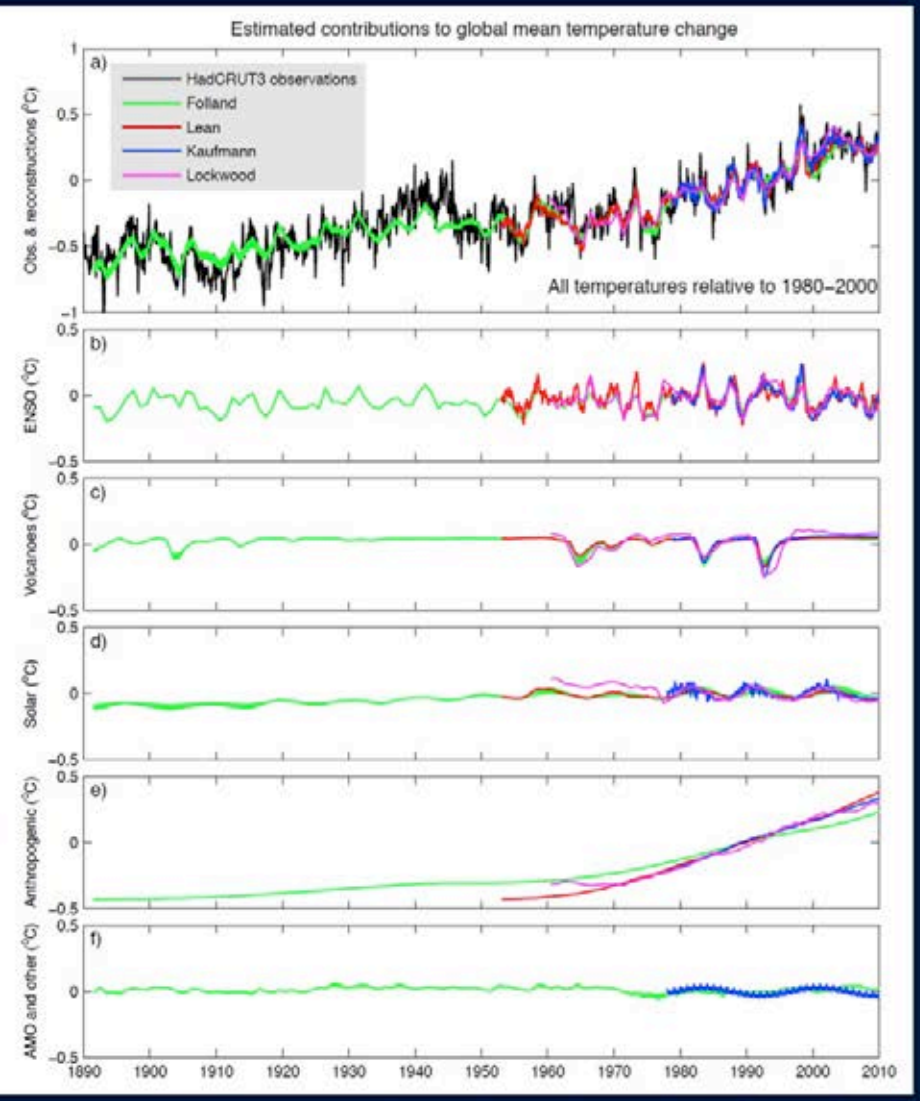

Global Carbon Budget 2002-2011
billion t y-1
Motor vehicles, power plants +8.3 ± 0.7
Deforestation +0.9 ± 0.8
Oceans -2.4 ± 0.7
Vegetation and soil -2.5 ± 1.3
Accumulation in the atmosphere +4.3 ± 0.2
Intergovernmental Panel on Climate Change (IPCC) 2013
photo ©2006 Steve Cole

Temperature has increased to its warmest level in 1200 years.



Intergovernmental Panel on Climate Change. 2013. Climate Change 2013: The Physical Science Basis. Cambridge University Press, Cambridge, UK.

Human activities are causing climate change.



Observed temperature

Influences of:

El Niño

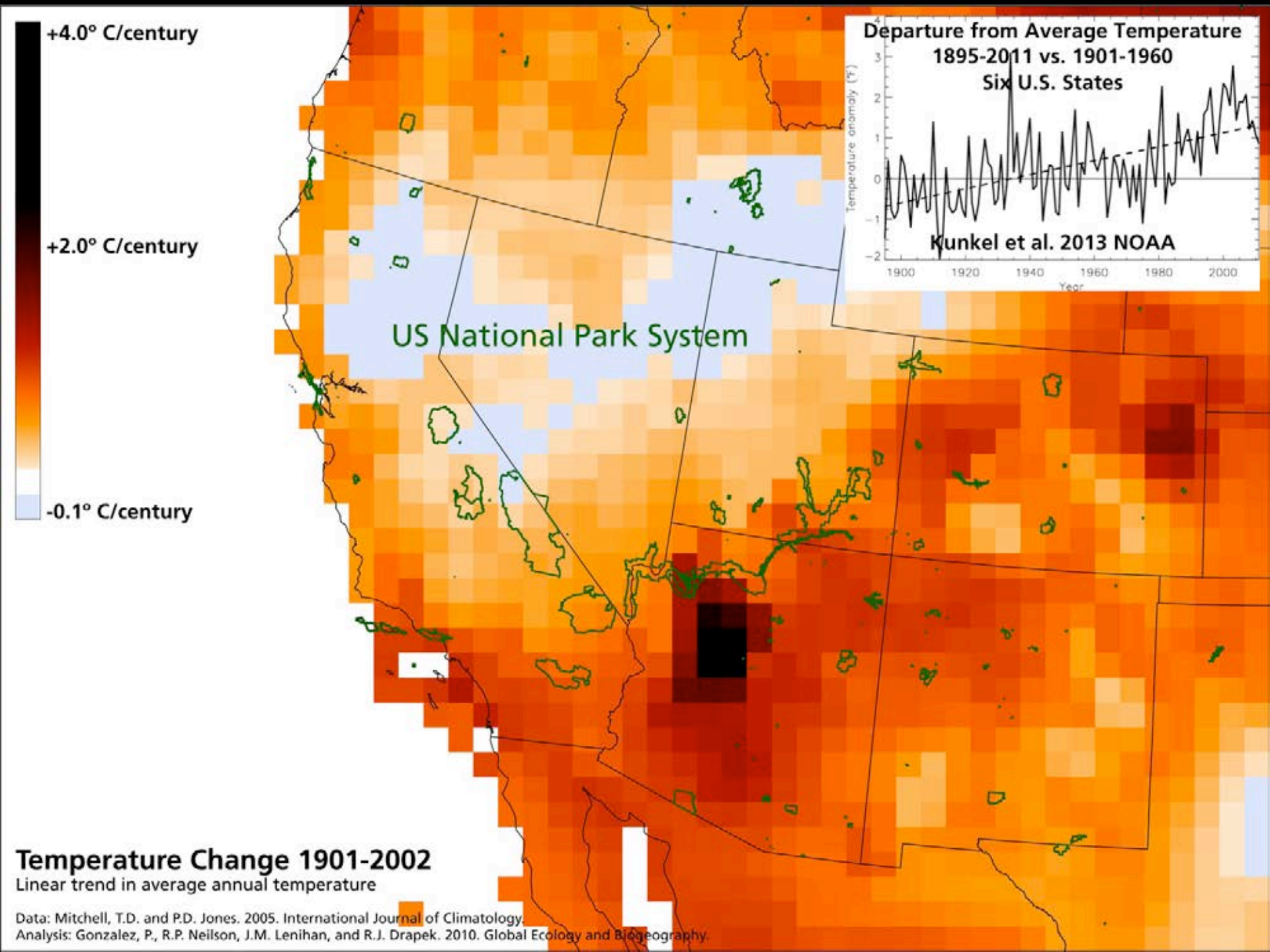
Volcanoes

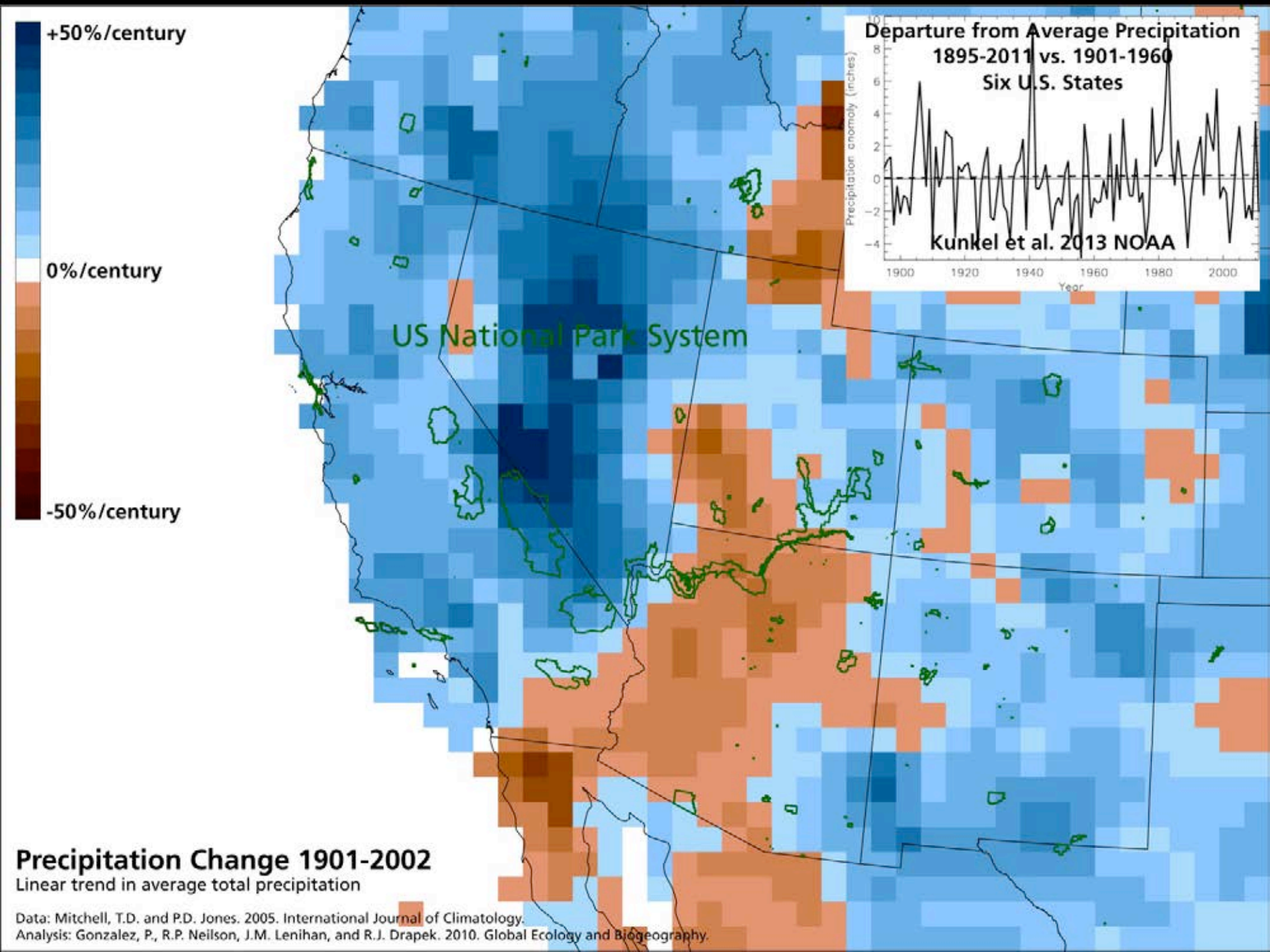
Solar cycles

Cars, power plants, deforestation

Atlantic Ocean

Intergovernmental Panel on Climate Change. 2013. Climate Change 2013: The Physical Science Basis. Cambridge University Press, Cambridge, UK.


+4.0° C/century
+2.0° C/century
-0.1° C/century
US National Park System
Departure from Average Temperature
1895-2011 vs. 1901-1960
Six U.S. States
Temperature anomaly (°F)
Year
Kunkel et al. 2013 NOAA
Temperature Change 1901-2002
Linear trend in average annual temperature
Data: Mitchell, T.D. and P.D. Jones. 2005. International Journal of Climatology.
Analysis: Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. Global Ecology and Biogeography.


+50%/century
0%/century
-50%/century
US National Park System
Departure from Average Precipitation
1895-2011 vs. 1901-1960
Six U.S. States
Kunkel et al. 2013 NOAA
Precipitation anomaly (inches)
Year
1900
1920
1940
1960
1980
2000
Precipitation Change 1901-2002
Linear trend in average total precipitation
Data: Mitchell, T.D. and P.D. Jones. 2005. International Journal of Climatology.
Analysis: Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. Global Ecology and Biogeography.

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Climate Change Response Program

Climate change has reduced winter snowfall in 53 national parks and across the western U.S.

Barnett et al. 2008 Science
Pierce et al. 2008 Journal of Climate

Rocky Mountain National Park, Colorado USA
photo P. Gonzalez

National Park Service
U.S. Department of the Interior

Climate Change Response Program

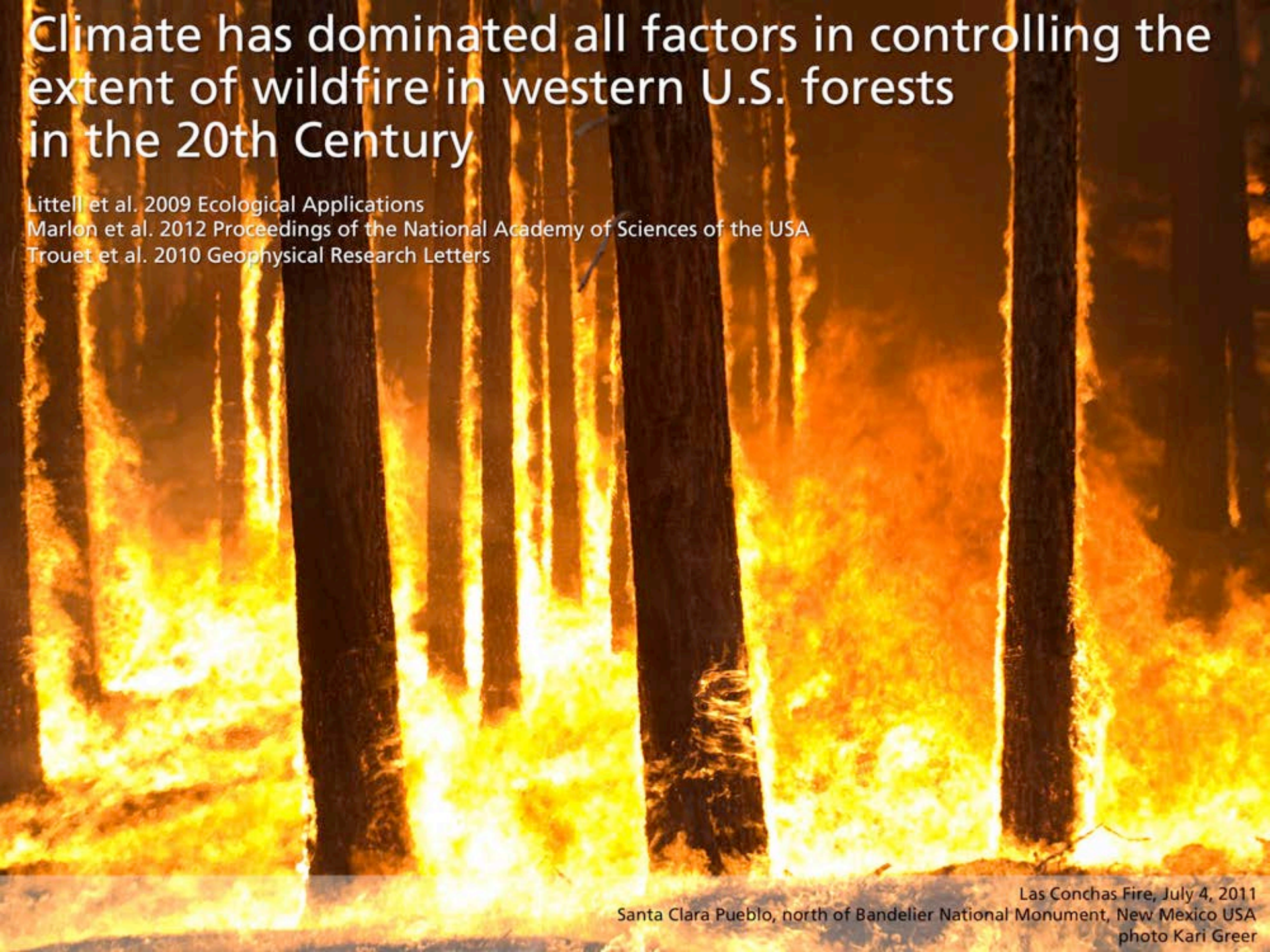
Climate change has advanced spring warmth in 53 western national parks and other areas

Ault et al. 2011 Journal of Climate

Sequoia National Park, California USA
photo P. Gonzalez

Climate has dominated all factors in controlling the extent of wildfire in western U.S. forests in the 20th Century

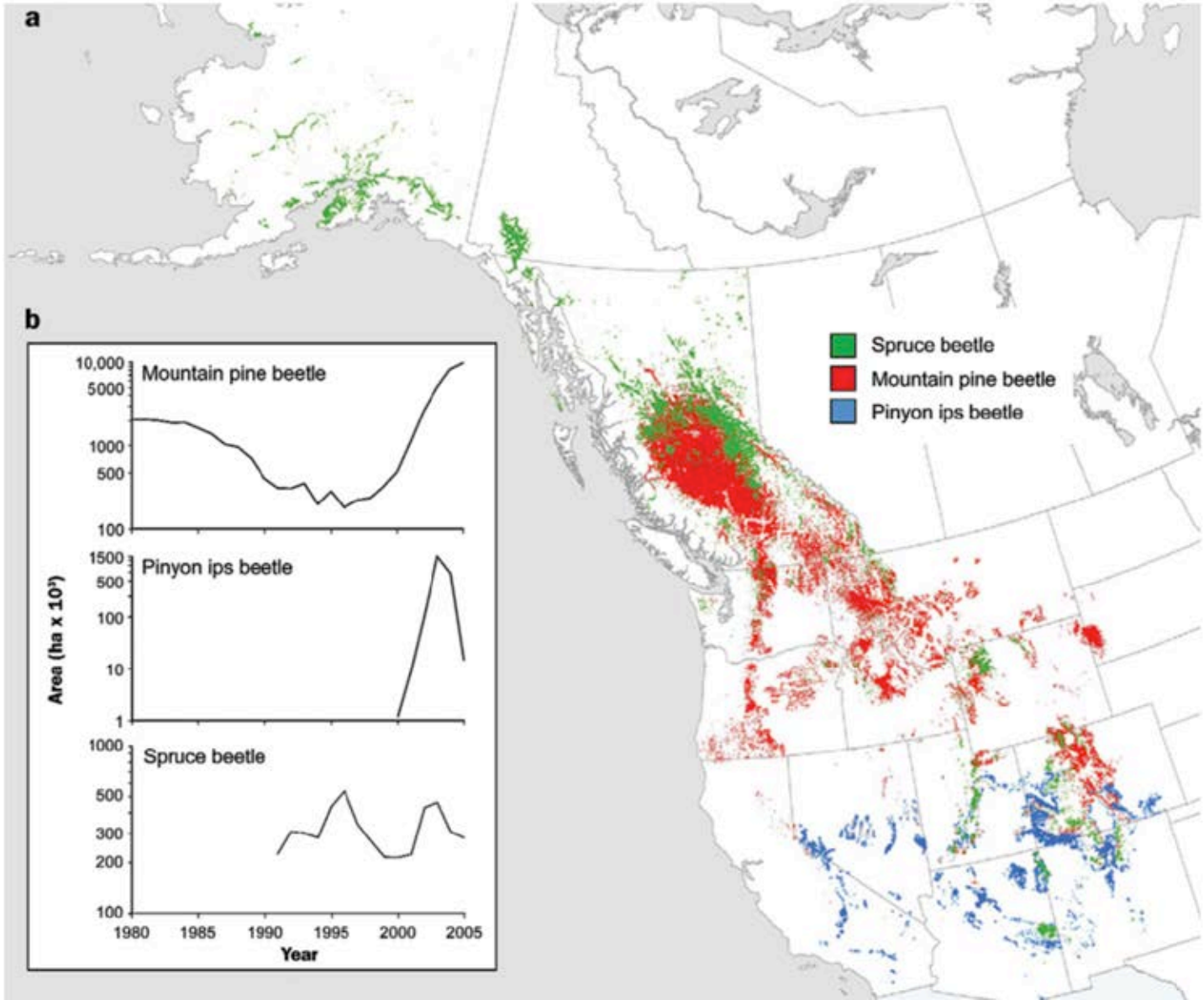
Littell et al. 2009 Ecological Applications
Marlon et al. 2012 Proceedings of the National Academy of Sciences of the USA
Trouet et al. 2010 Geophysical Research Letters



Las Conchas Fire, July 4, 2011
Santa Clara Pueblo, north of Bandelier National Monument, New Mexico USA
photo Kari Greer

Climate change has contributed to the most extensive bark beetle outbreak in 125 years

Raffa et al. 2008 BioScience



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Climate change doubled tree mortality in the western U.S. 1955-2007

van Mantgem et al. 2009 Science

Rocky Mountain National Park, Colorado USA
photo P. Gonzalez

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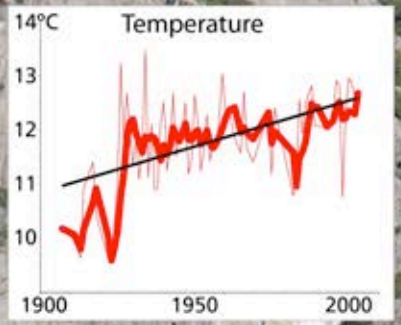
U.S. Department of the Interior

Climate Change Response Program

Climate change has shifted plant and animal species upslope at Yosemite 1914-2006

Moritz et al. 2008 Science
Millar et al. 2004 Arctic, Antarctic, and Alpine Research



Yosemite National Park, California, USA
photo P. Gonzalez

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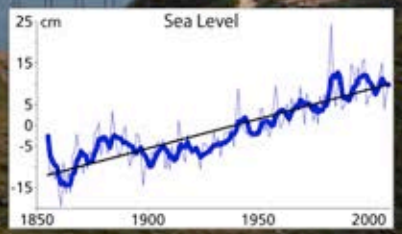
Climate change has increased sea-level at the Golden Gate 1855-2004

Church and White 2006 Geophysical Research Letters



Golden Gate National Recreation Area, California, USA
photo P. Gonzalez

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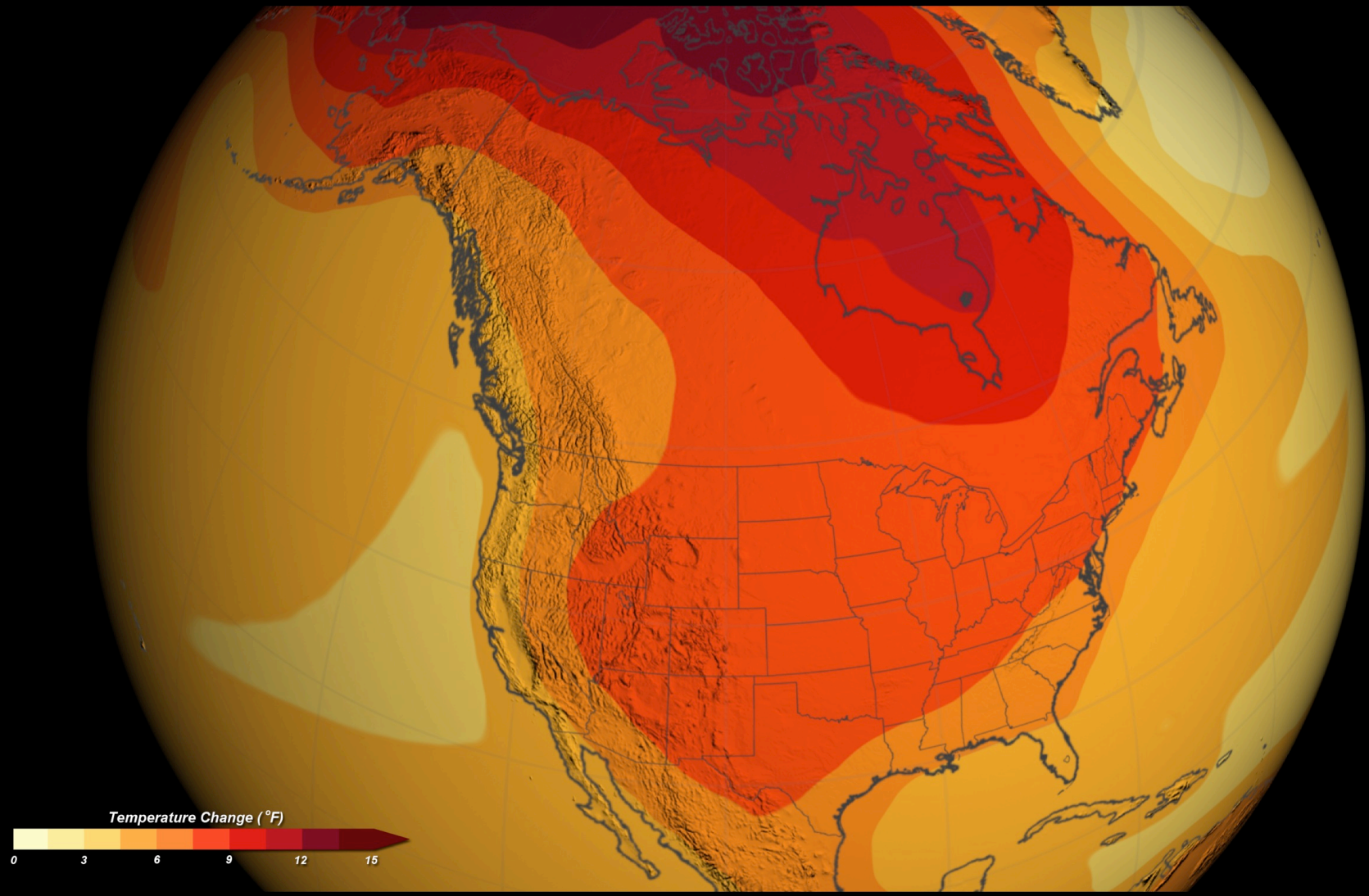
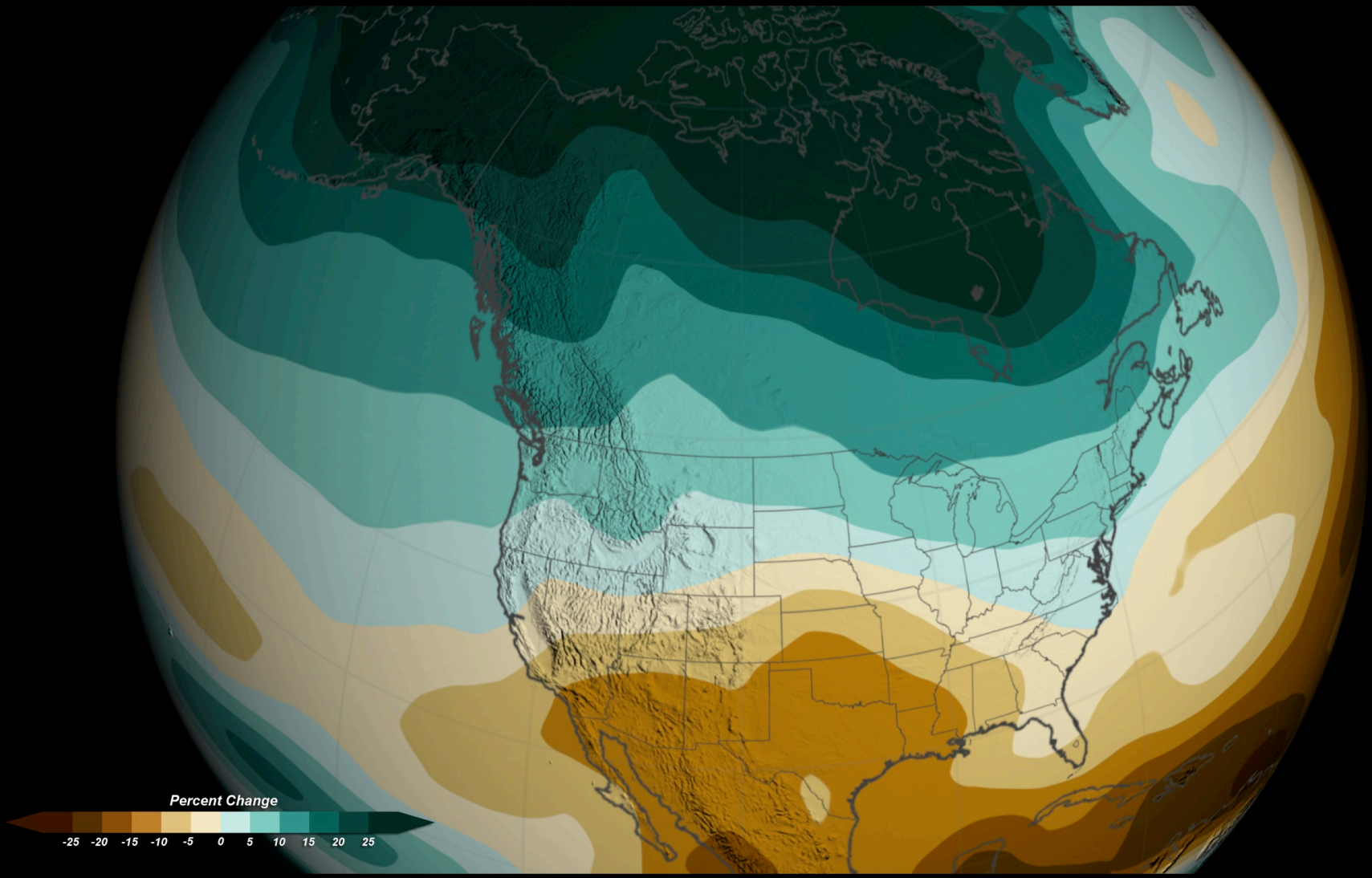
Projected temperature change



Projection: Emissions Scenario A2, difference of 2071-2100 and 1970-1999 annual average temperature
Data: Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, UK.
Analysis: National Oceanic and Atmospheric Administration
Visualization: National Aeronautics and Space Administration

Projected precipitation change



Projection: Emissions Scenario A2, fractional difference of 2071-2100 and 1970-1999 annual average precipitation
Data: Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, UK.
Analysis: National Oceanic and Atmospheric Administration
Visualization: National Aeronautics and Space Administration

U.S. National Climate Assessment Climate Trends

Six Southwestern States

years	temperature		precipitation
1895-2011	+0.9°C	(+1.7° F.)	~0
	statistically significant		not signif.
1999-2099 Lower emissions (B1)	+2.5 ± 0.5°C	(+4.5 ± 0.9°F.)	-2% ± 3%
1999-2099 Higher emissions (A2)	+4.6 ± 0.4°C	(+8.3 ± 0.8°F.)	-3% ± 6%

Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K.T. Redmond, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 5. Climate of the Southwest U.S. National Oceanic and Atmospheric Administration, Technical Report NESDIS 142-5, Washington, DC.

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Hotter summers are increasing wildfire in natural conifer forests of the western U.S.

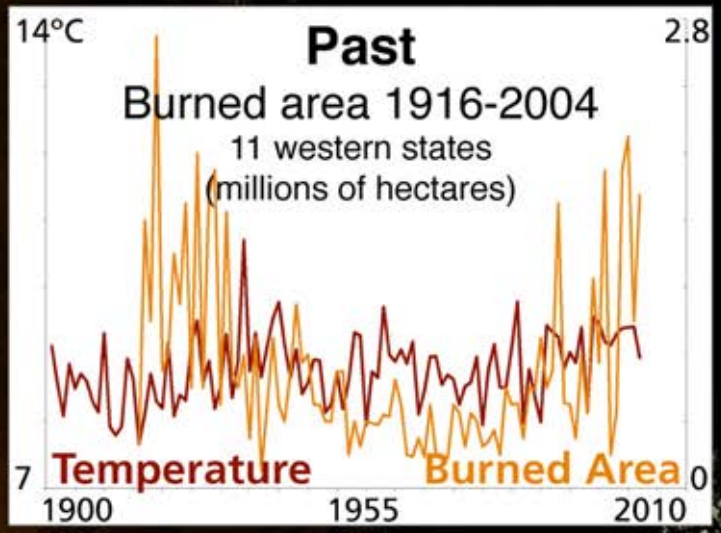
Westerling et al. 2006 Science

Whitewater-Baldy Complex fire, Gila National Forest, New Mexico USA
photo Kari Greer

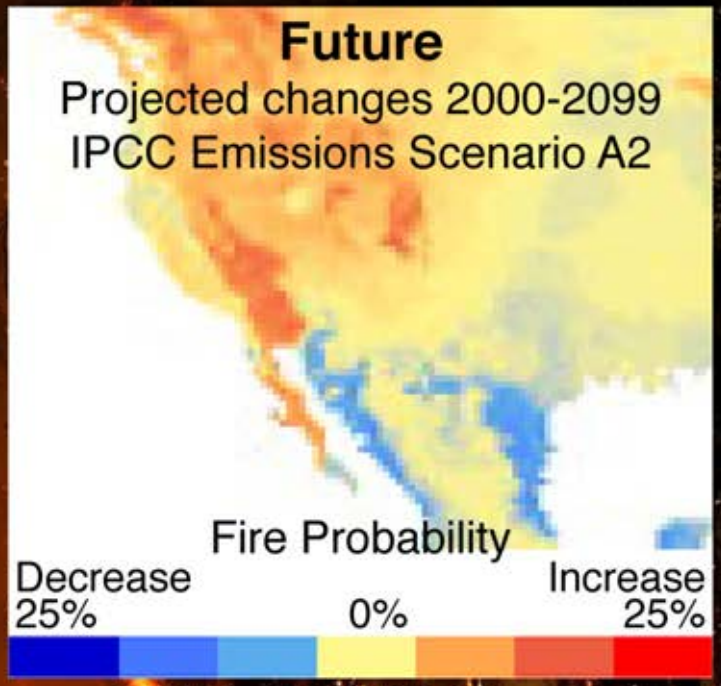
Wildfire

Present

August 21, 2013
Rim Fire
near Yosemite National Park, California
photo by Justin Sullivan/Getty Images



Littell et al. 2009 Ecological Applications
Gonzalez et al. 2010 Global Ecology and Biogeography



Moritz et al. 2012 Ecosphere

Climate change may reduce Colorado River streamflow 10-45% by 2055 AD

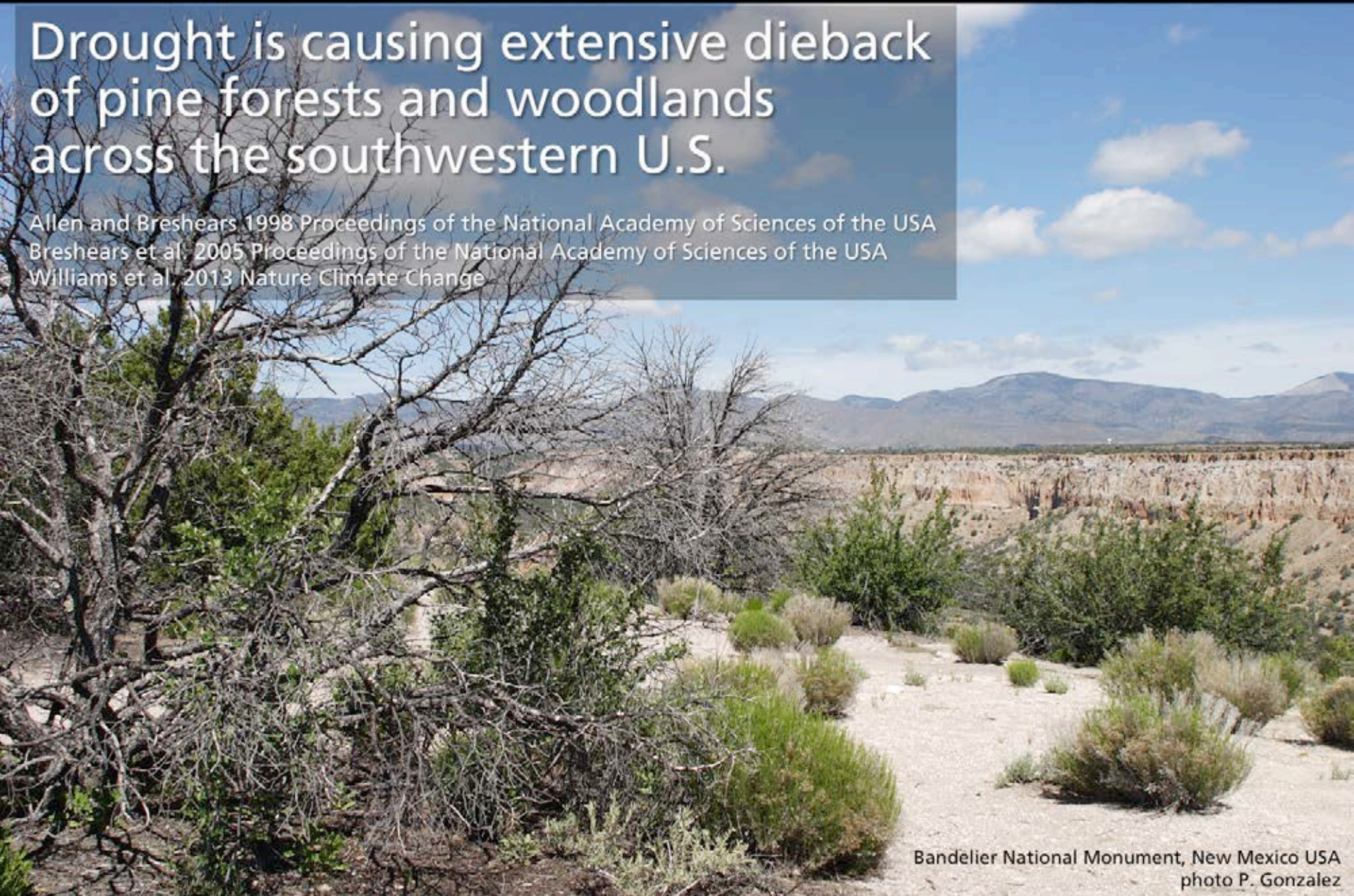
U.S. Bureau of Reclamation 2012 Colorado River Basin Water Supply and Demand Study

Vano et al. 2013 Bulletin of the American Meteorological Society

Grand Canyon National Park, Arizona USA
photo P. Gonzalez

Drought is causing extensive dieback of pine forests and woodlands across the southwestern U.S.

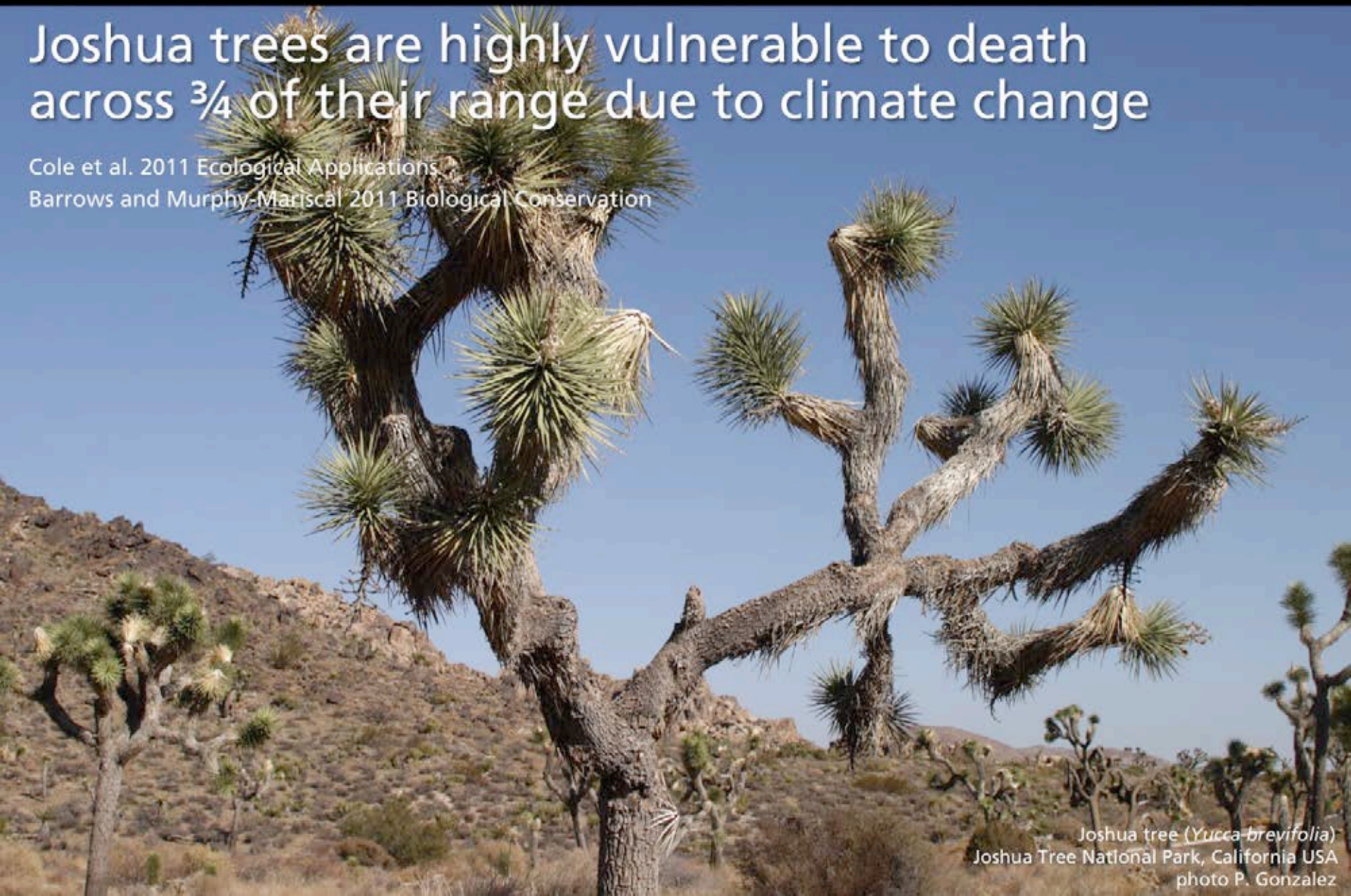
Allen and Breshears 1998 Proceedings of the National Academy of Sciences of the USA
Breshears et al. 2005 Proceedings of the National Academy of Sciences of the USA
Williams et al. 2013 Nature Climate Change



Bandelier National Monument, New Mexico USA
photo P. Gonzalez

Joshua trees are highly vulnerable to death across ¾ of their range due to climate change

Cole et al. 2011 Ecological Applications
Barrows and Murphy-Mariscal 2011 Biological Conservation



Joshua tree (*Yucca brevifolia*)
Joshua Tree National Park, California USA
photo P. Gonzalez

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Climate Change Response Program

Cultural resources for American Indians are vulnerable to climate change

Voggesser et al. 2013 Climatic Change

Bandelier National Monument, New Mexico USA
photo P. Gonzalez

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Climate Change Response Program

The pika is vulnerable to losing its habitat from warming in Great Basin National Park and other areas

Beever et al. 2011 Global Change Biology

American pika (*Ochotona princeps*)
photo NPS

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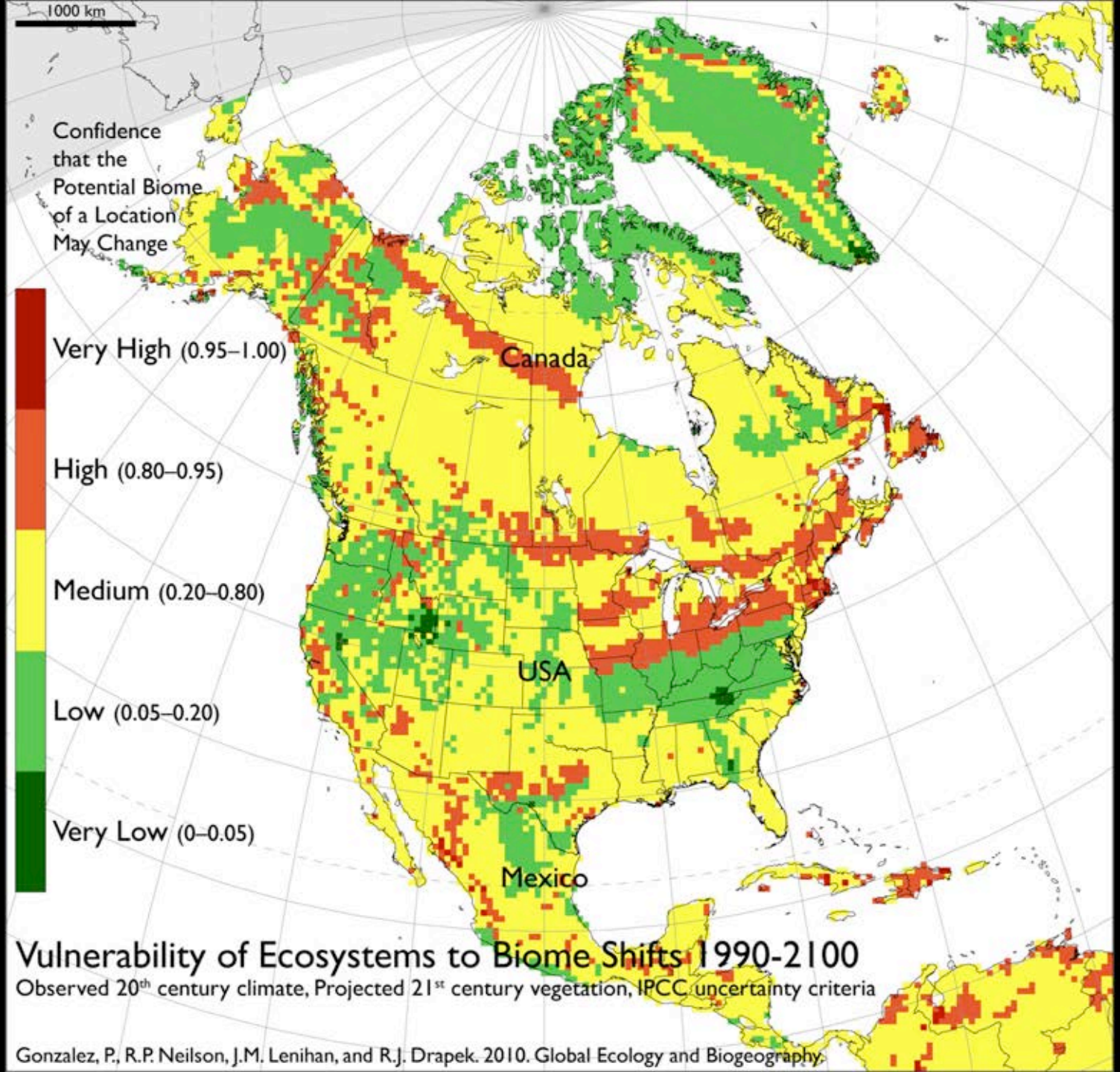
Climate Change Response Program

Desert plants in Saguaro National Park are vulnerable to death from hotter and drier conditions

Munson et al. 2012 Global Change Biology

Saguaro National Park, Arizona USA
photo P. Gonzalez


1000 km
Confidence that the Potential Biome of a Location May Change
Very High (0.95–1.00)
High (0.80–0.95)
Medium (0.20–0.80)
Low (0.05–0.20)
Very Low (0–0.05)
Canada
USA
Mexico
Vulnerability of Ecosystems to Biome Shifts 1990-2100
Observed 20th century climate, Projected 21st century vegetation, IPCC uncertainty criteria
Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. Global Ecology and Biogeography.

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Climate Change Response Program

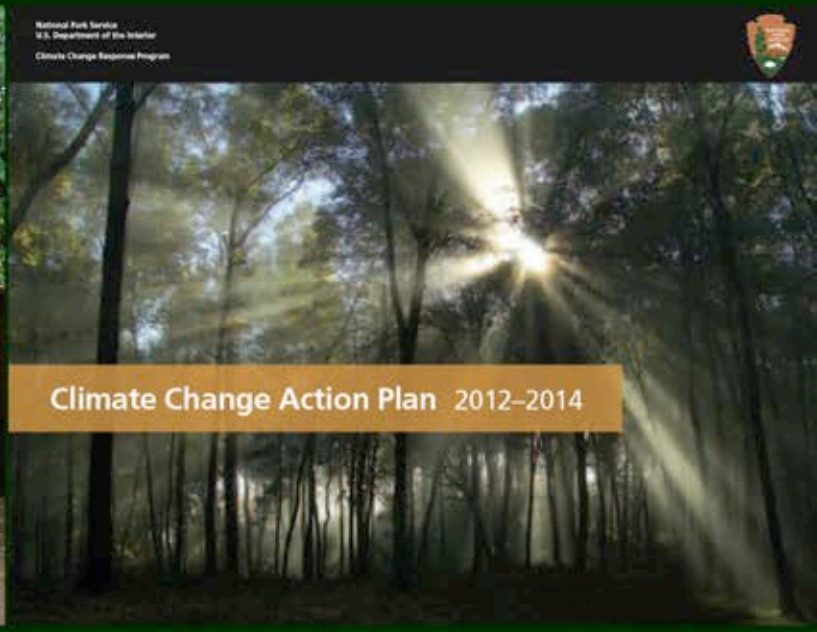
National Park Service Responding to Climate Change

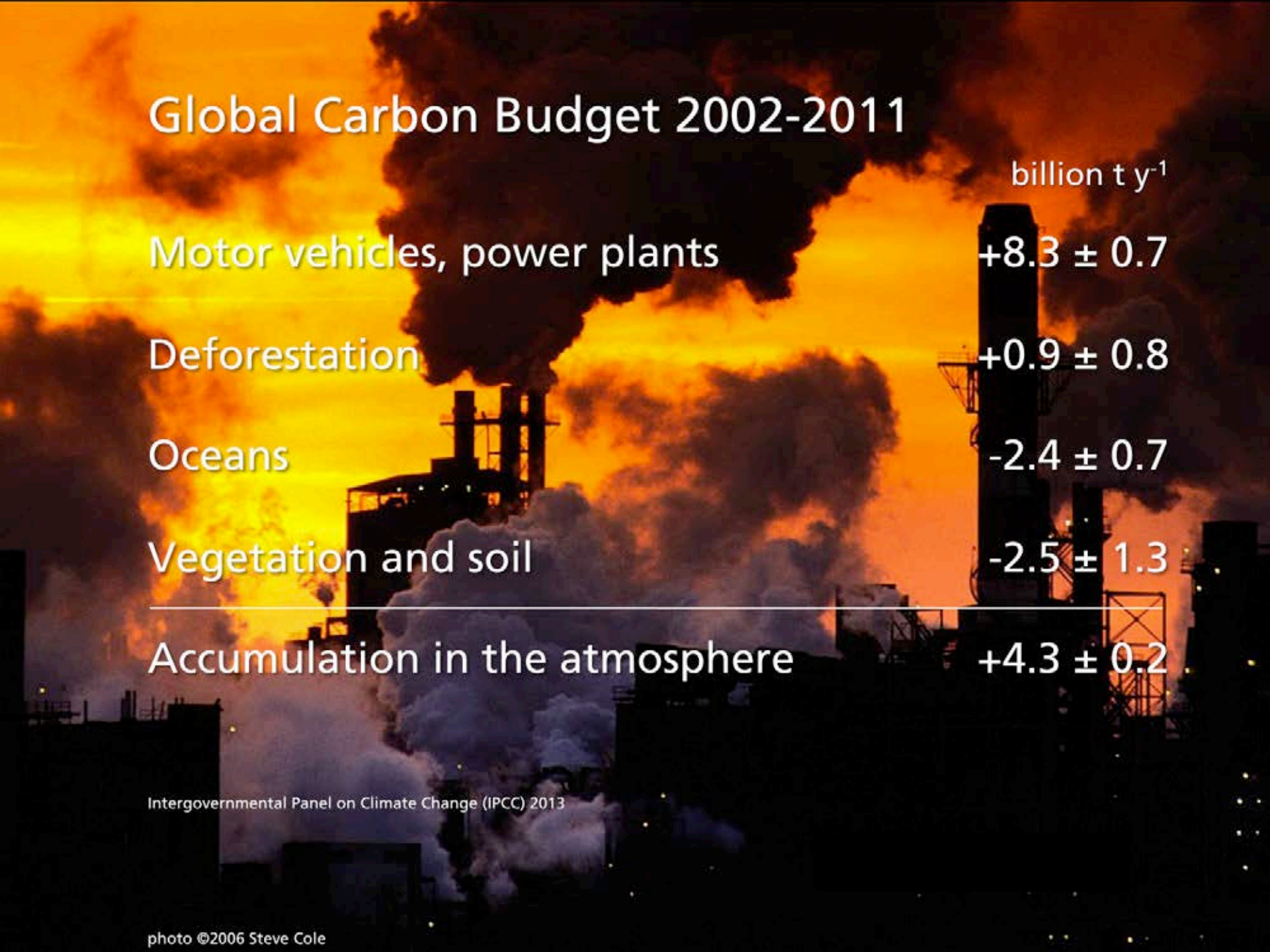
Science
Answer resource management questions
Contribute to published knowledge

Mitigation
Reduce operations emissions
Manage forest carbon

Adaptation
Improve resilience of resources
Explore management scenarios

Communication
Interpretation for visitors
Training for staff

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billion t y-1
Motor vehicles, power plants +8.3 ± 0.7
Deforestation +0.9 ± 0.8
Oceans -2.4 ± 0.7
Vegetation and soil -2.5 ± 1.3
Accumulation in the atmosphere +4.3 ± 0.2
Intergovernmental Panel on Climate Change (IPCC) 2013
photo ©2006 Steve Cole