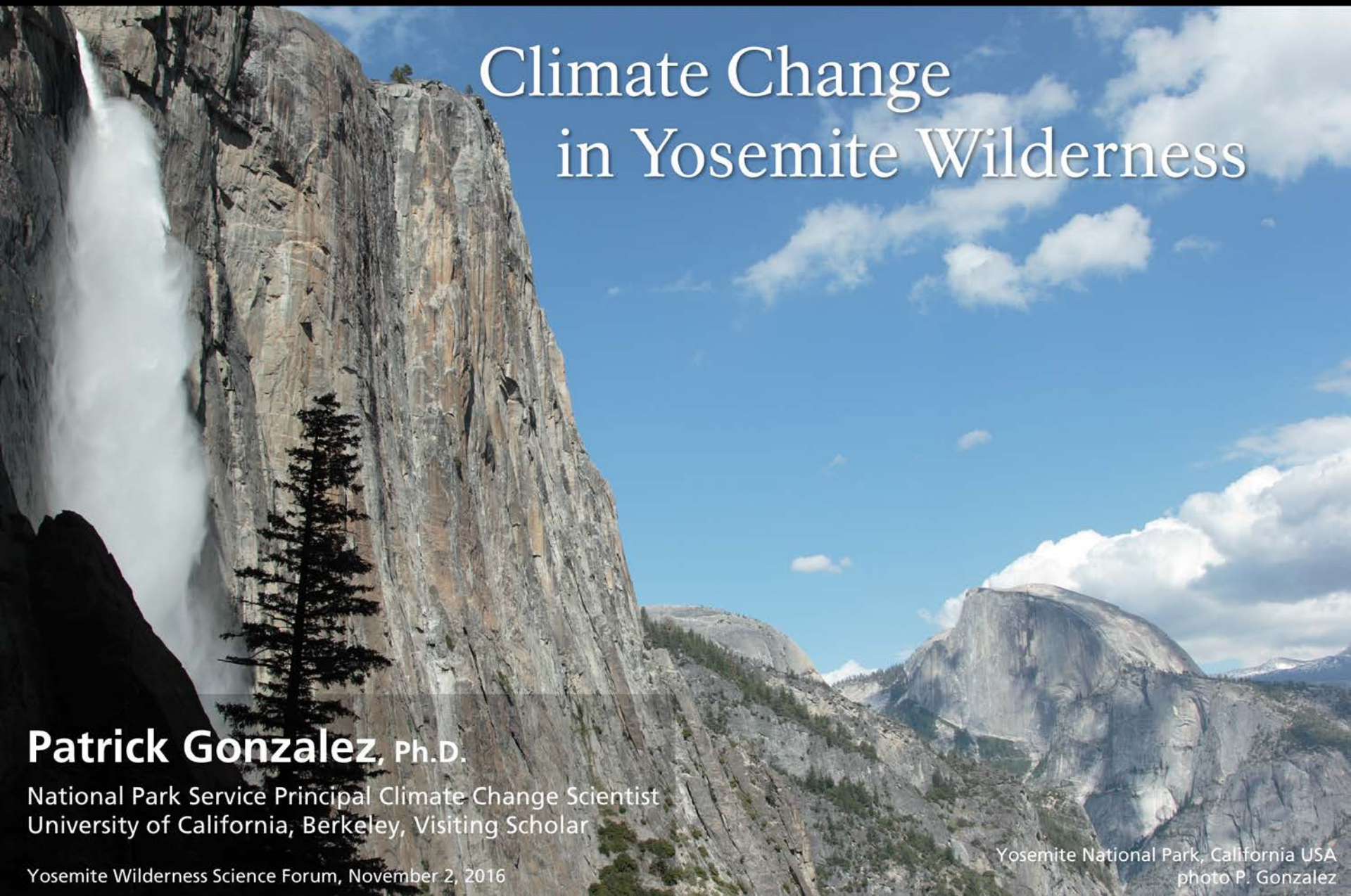
National Park Service
U.S. Department of the Interior

Climate Change in Yosemite Wilderness



Patrick Gonzalez, Ph.D.

National Park Service Principal Climate Change Scientist
University of California, Berkeley, Visiting Scholar

Yosemite Wilderness Science Forum, November 2, 2016

Yosemite National Park, California USA
photo P. Gonzalez

Climate Change in Yosemite Wilderness

Outline

1. Historical climate change has altered wilderness
2. Projected climate change increases future vulnerabilities
3. Ecosystem carbon storage reduces climate change
4. Adaptation of stewardship can protect ecosystems

National Park Service
U.S. Department of the Interior

Yosemite Valley, El Capitan (left), and Half Dome (center), Yosemite National Park (photo P. Gonzalez)

Climate Change Trends, Vulnerabilities, and Carbon in Yosemite National Park, California, USA

Patrick Gonzalez, Ph.D.

Natural Resource Stewardship and Science
U.S. National Park Service
130 Mulford Hall
University of California, Berkeley
Berkeley, CA 94720-3114 USA

February 9, 2016

Climate Change in Yosemite Wilderness

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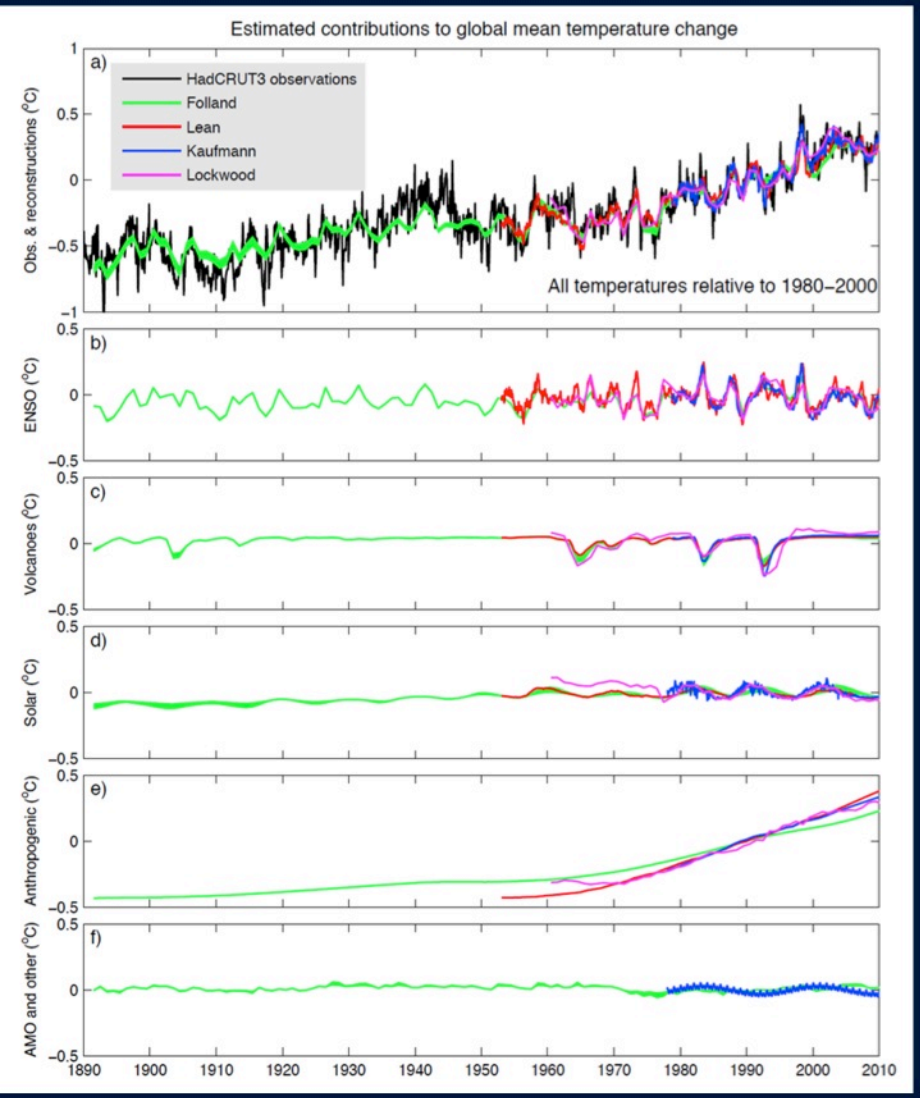
Human activities are causing climate change.



Observed temperature

Influences of:

El Niño

Volcanoes

Solar cycles

Cars, power plants, deforestation

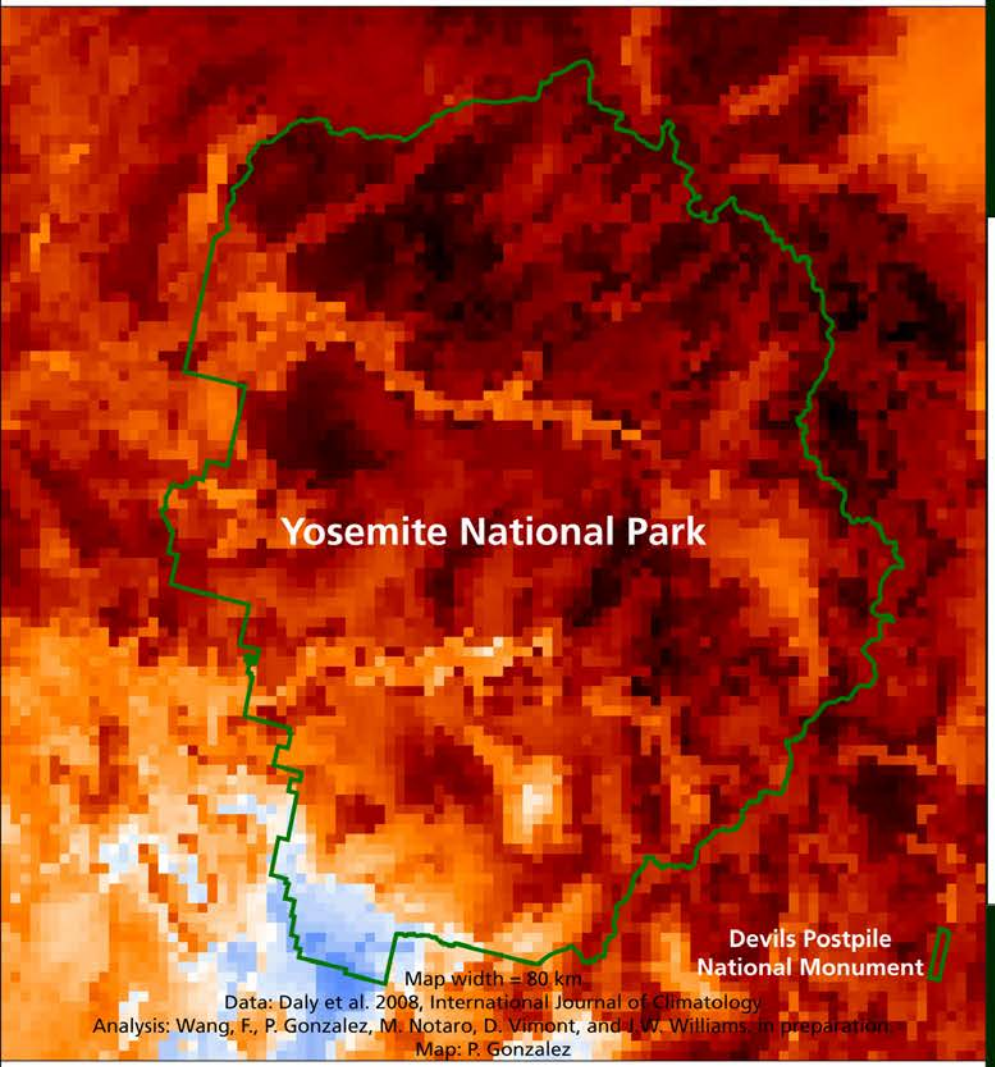
Atlantic Ocean

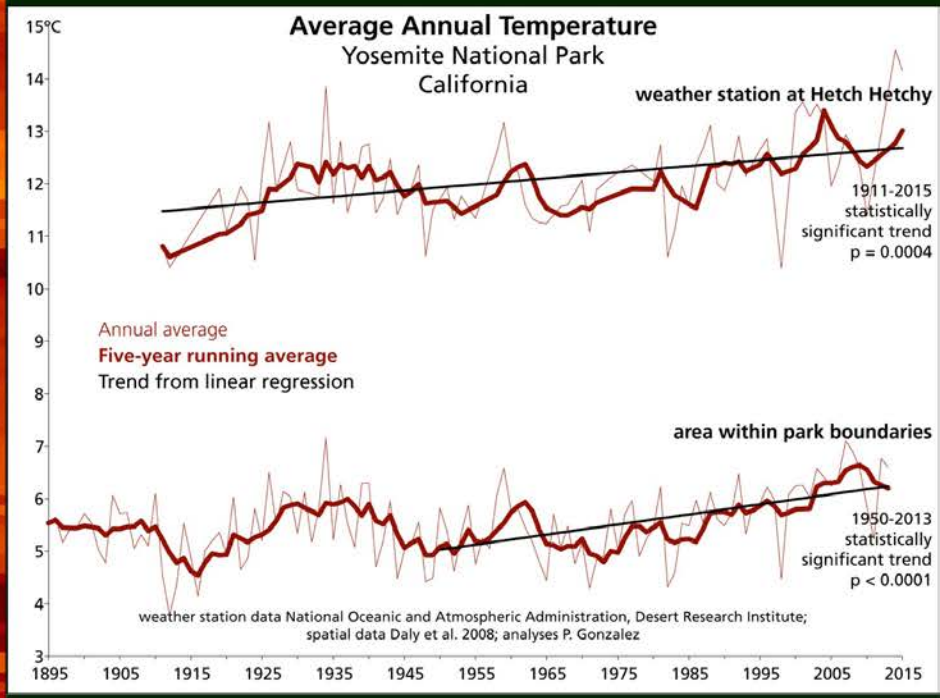
Intergovernmental Panel on Climate Change. 2013. Climate Change 2013: The Physical Science Basis. Cambridge University Press, Cambridge, UK.

National Park Service
U.S. Department of the Interior

Climate Change Response Program

Historical Trend, Annual Average Temperature, 1950-2010

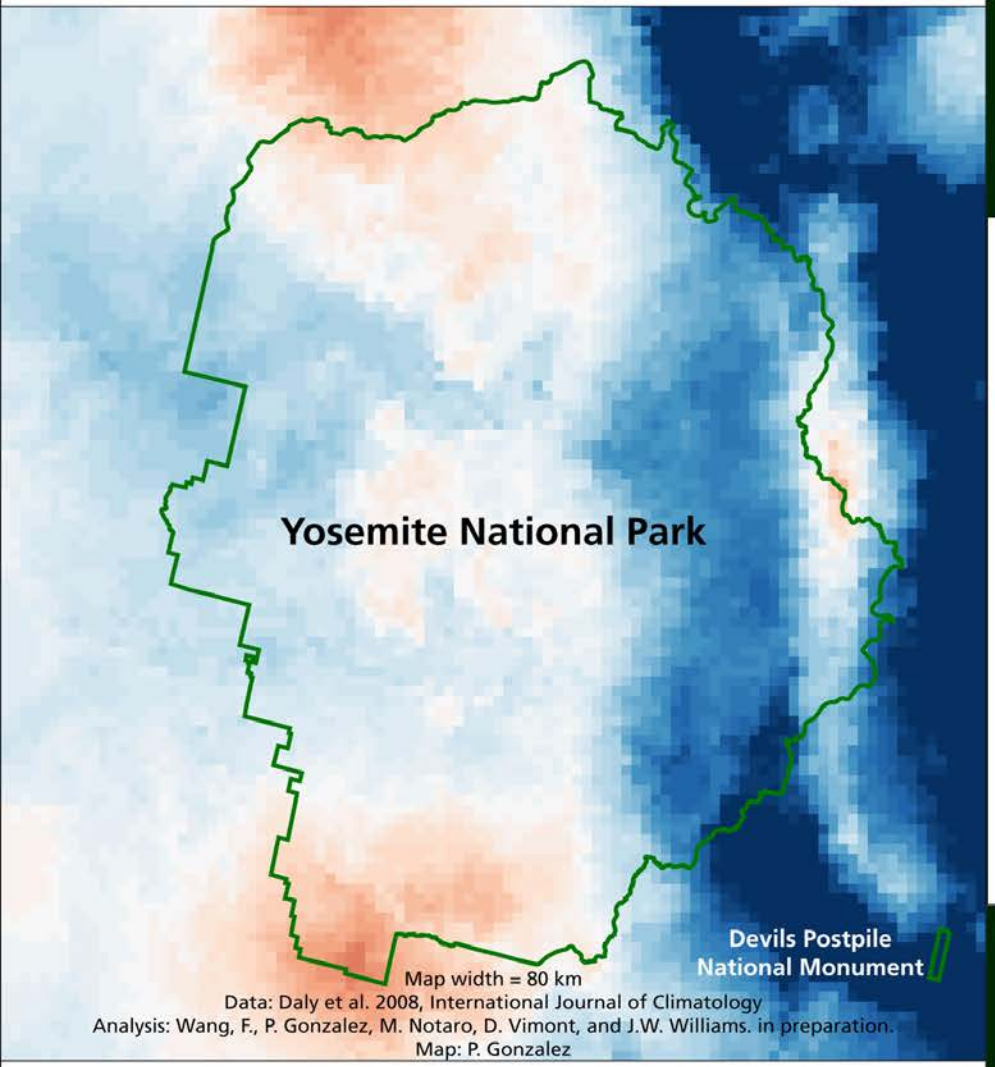


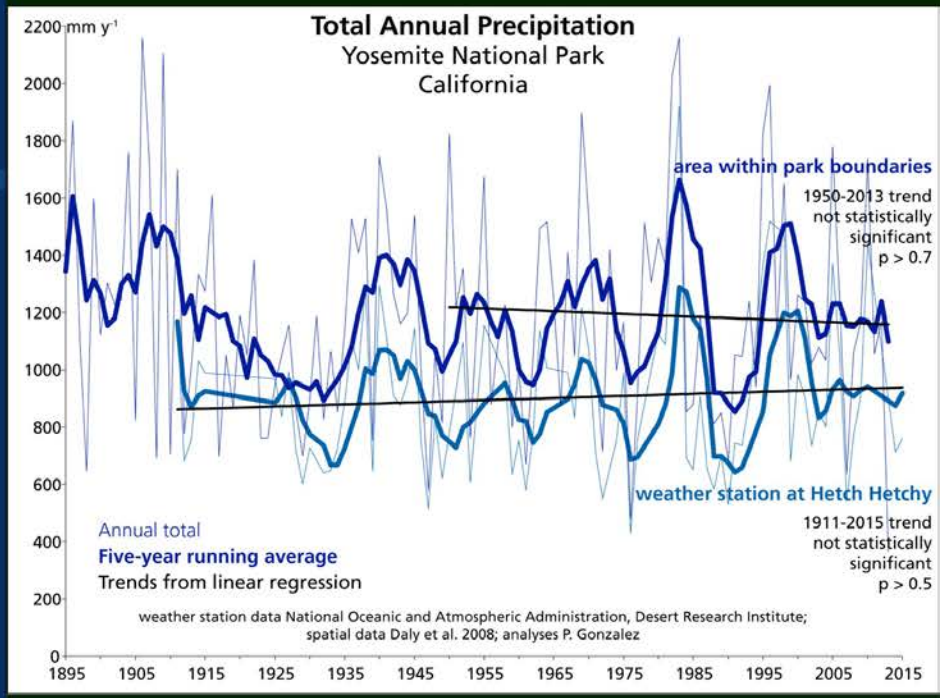


National Park Service
U.S. Department of the Interior

Climate Change Response Program

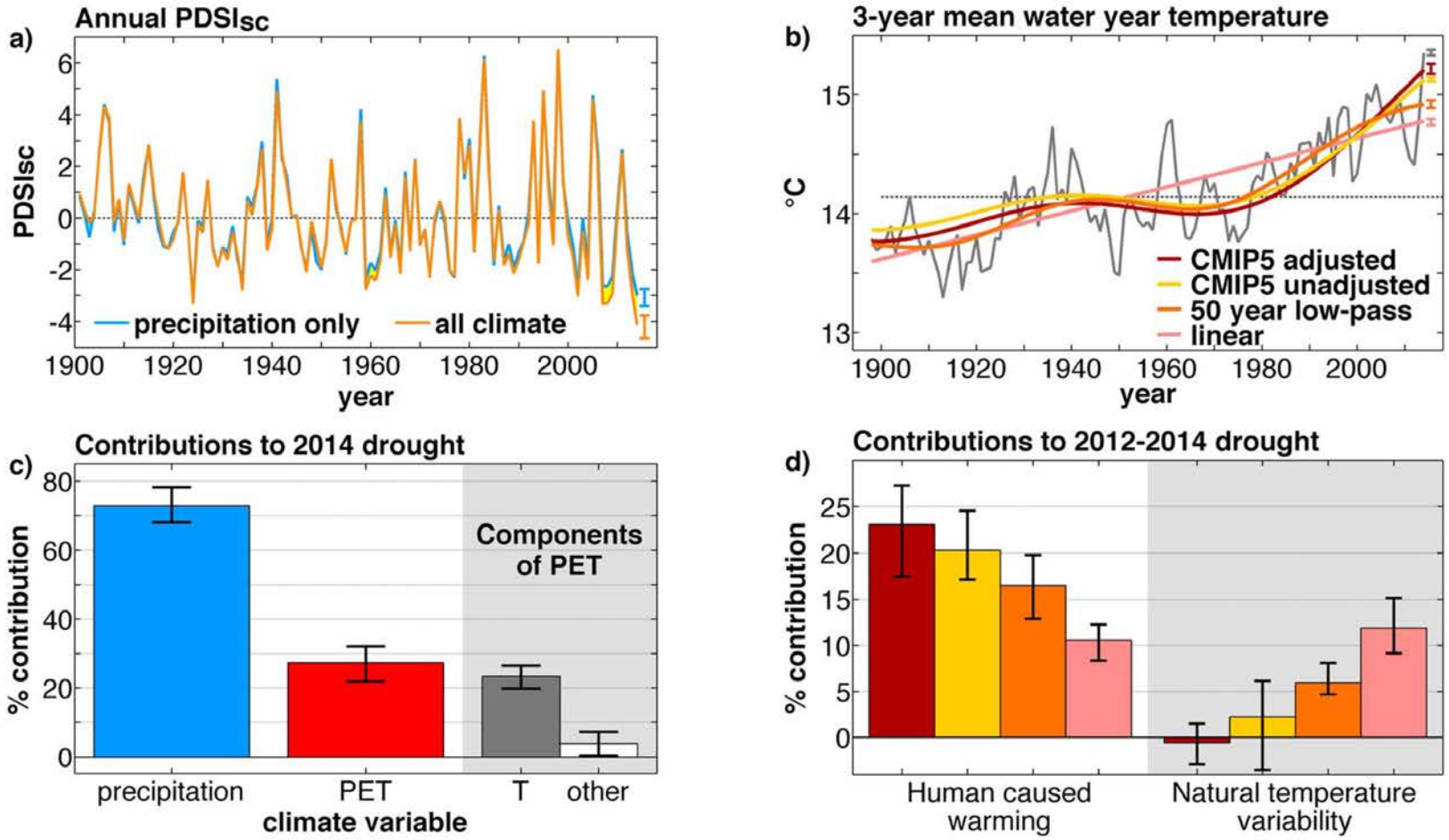
Historical Trend, Total Annual Precipitation, 1950-2010





Record heat and lower precipitation caused historic California drought

Williams et al. 2015 Geophysical Research Letters



Detection of Changes and Attribution of Causes

Detection

Finding of statistically significant changes from natural variability

Attribution

Determination of relative importance of different factors; generally for at least 30 years data, not for single events

National Park Service
U.S. Department of the Interior

Climate Change Response Program

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

van Mantgem et al. 2009 Science

Yosemite National Park, California USA
photo P. Gonzalez

National Park Service
U.S. Department of the Interior

Climate Change Response Program

Climate change has advanced spring warmth across the western US and Yosemite 1950-2005

Ault et al. 2011 Journal of Climate

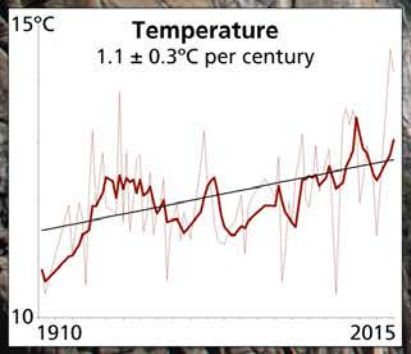
Yosemite National Park, California USA
photo P. Gonzalez

National Park Service
U.S. Department of the Interior

Climate Change Response Program

Climate change shifted trees into alpine meadows in Yosemite 1914-2006

Millar et al. 2004 Arctic, Antarctic, and Alpine Research



Weather station at Hetch Hetchy
Data NOAA, Graph P. Gonzalez

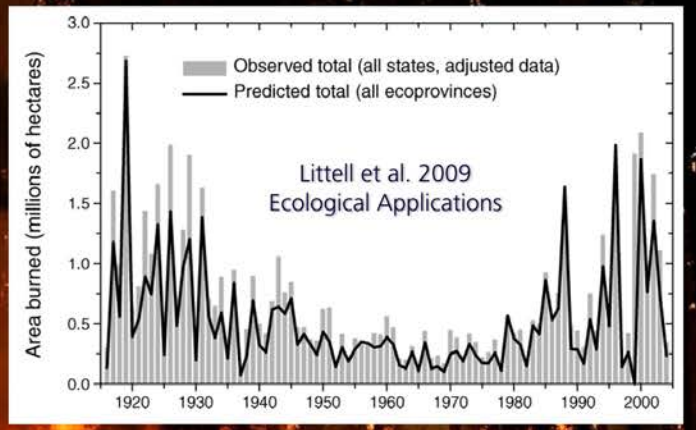
Yosemite National Park, California USA
photo P. Gonzalez

National Park Service
U.S. Department of the Interior

Climate Change Response Program

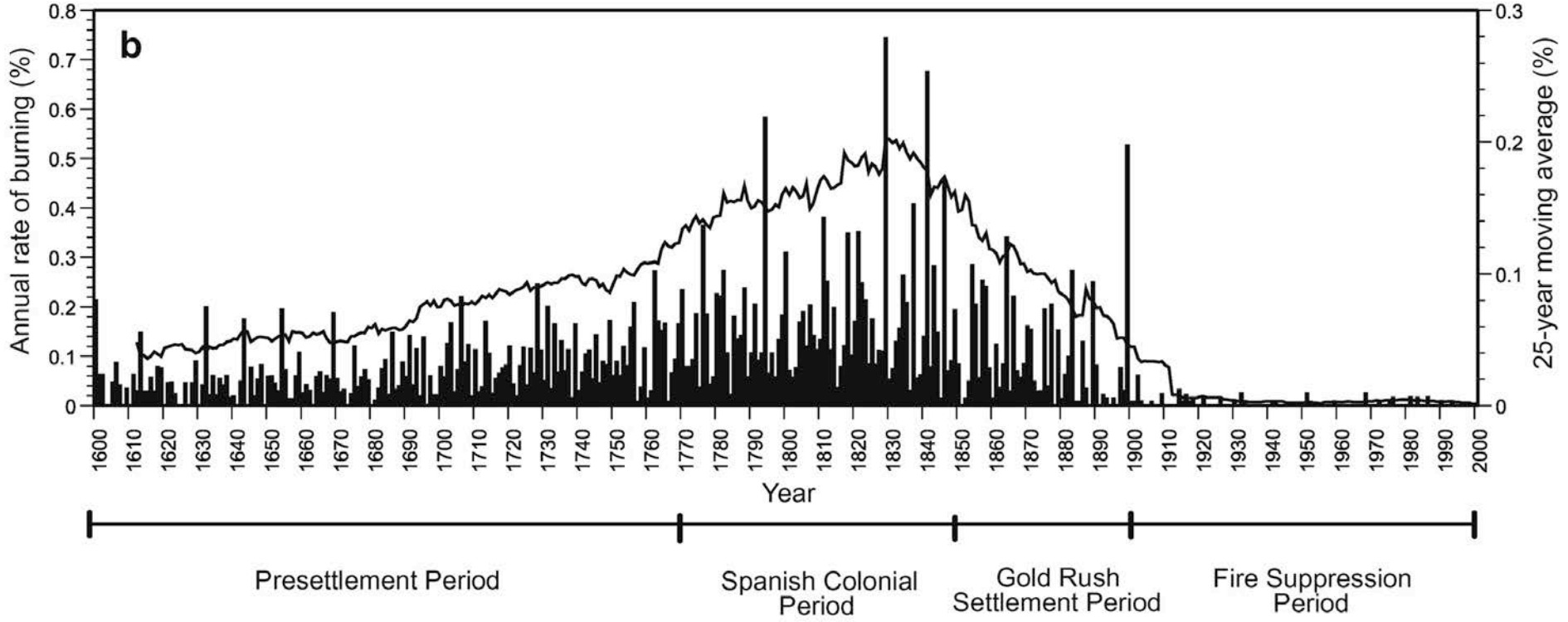
Climate has controlled the extent of wildfire in western US forests 1916-2003

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



Rim Fire, August 21, 2013
west of Yosemite National Park, California USA
photo Justin Sullivan/Getty Images

Yosemite National Park Wildfire 1600-2000 AD



Taylor and Scholl 2012 Forest Ecology and Management

Climate change shifted ranges of small mammals upslope in Yosemite 1920-2006

Moritz et al. 2008 Science

Sierra Golden-mantled (*Spermophilus lateralis*) and Belding ground squirrels (*Spermophilus beldingi*)
Yosemite National Park, California USA
Drawing by Major Allan Brooks, ca. 1928

National Park Service
U.S. Department of the Interior

Climate Change Response Program

Climate change shifted winter bird ranges northward 0.5 ± 0.3 km per year in Yosemite and across the U.S. 1975-2004

La Sorte and Thompson 2007 Ecology

Yosemite National Park, California USA
photo P. Gonzalez

Brown Creeper (*Certhia americana*)
photo Danilo Hegg

Changes in Yosemite consistent with, but not formally attributed to climate change

1. Glaciers melting (Stock et al. field work)
2. Higher-elevation tree shift (Bunn et al. 2005, Dolanc et al. 2013)
3. Large tree decline (Lutz et al. 2009a, McIntyre et al. 2015)
4. Upslope fire shift (Schwartz et al. 2015)
5. Earlier spring (Monahan et al. 2016)
6. Elevation shifts of bird ranges (Tingley et al. 2009, 2012)

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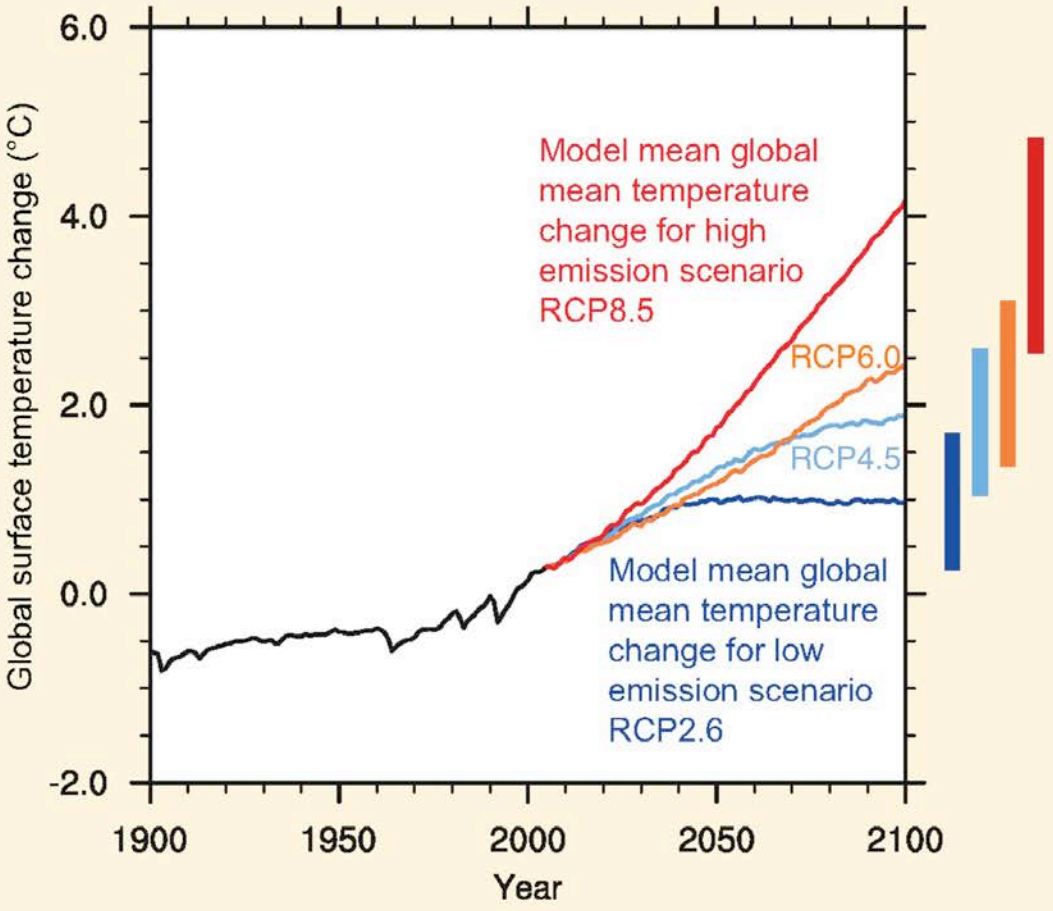
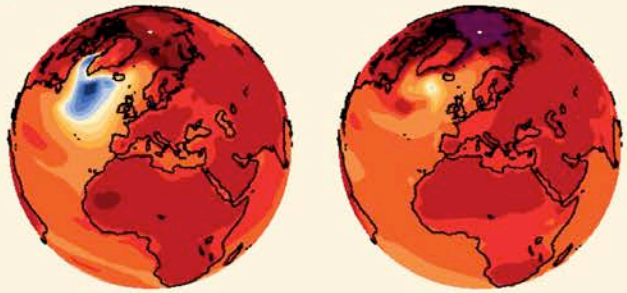
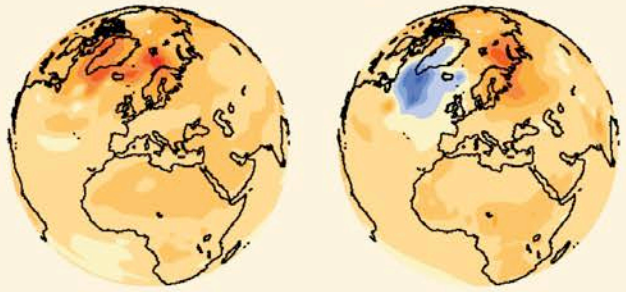
Representative Concentration Pathways (Emissions Scenarios)

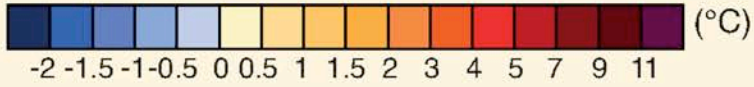


Possible temperature responses in 2081-2100 to high emission scenario RCP8.5



Possible temperature responses in 2081-2100 to low emission scenario RCP2.6



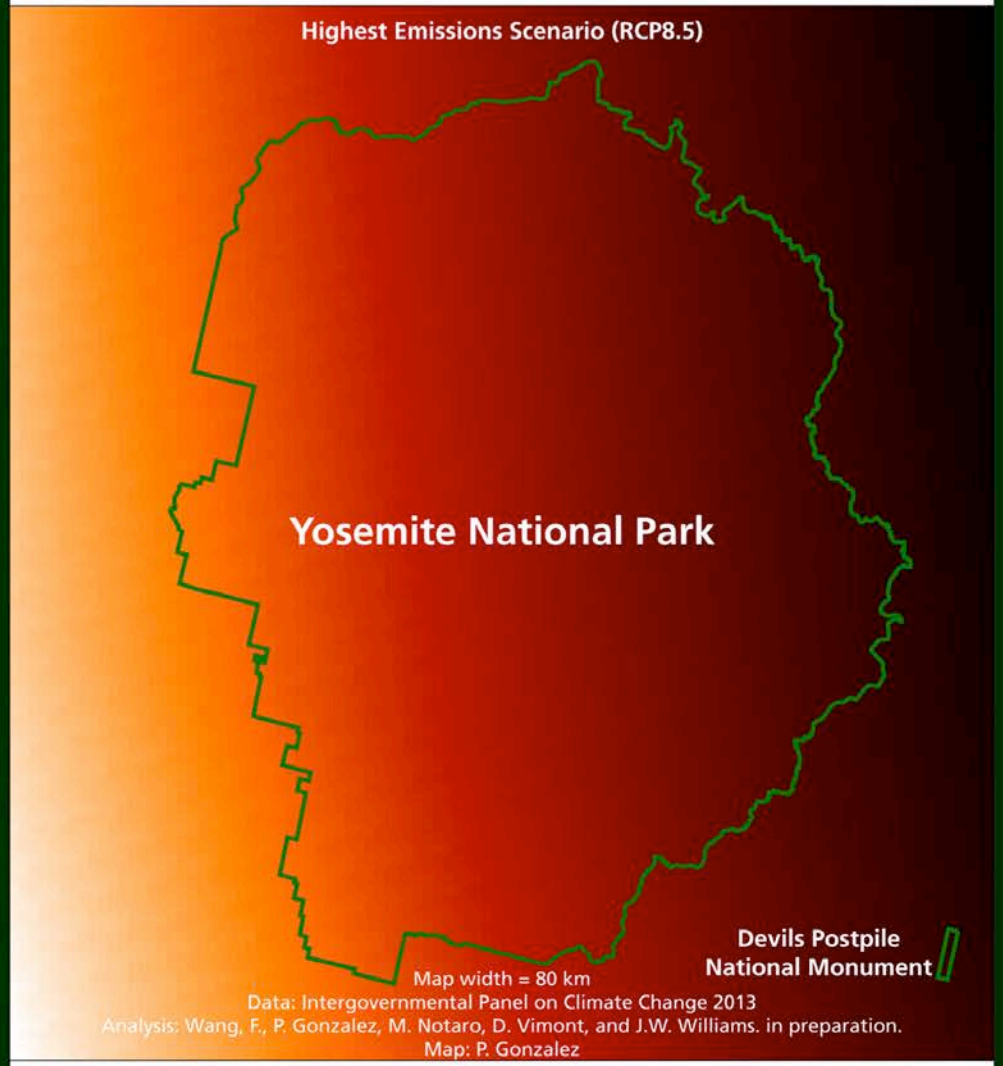


Intergovernmental Panel on Climate Change. Climate Change 2013: The Physical Science Basis. Cambridge University Press, Cambridge, UK.

National Park Service
U.S. Department of the Interior

Climate Change Response Program

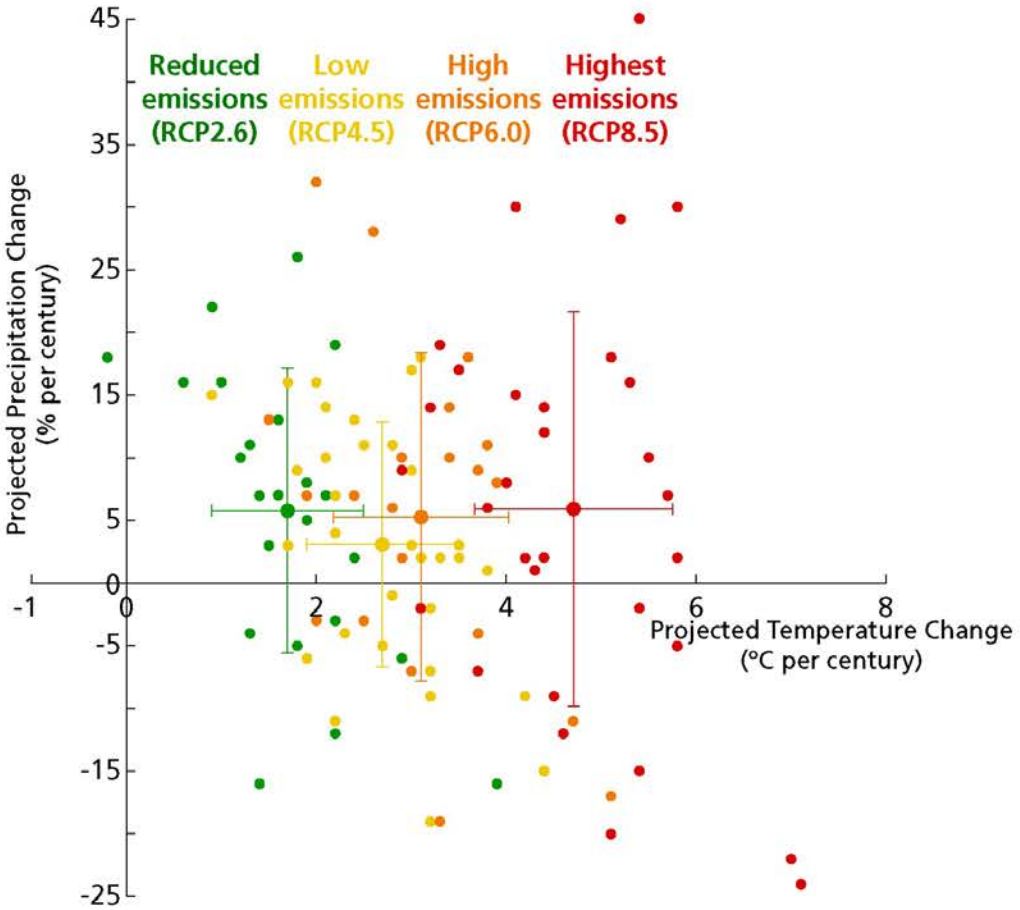
Projected Increase, Annual Average Temperature, 2000-2100



Climate Change Projections

Yosemite National Park, California, USA

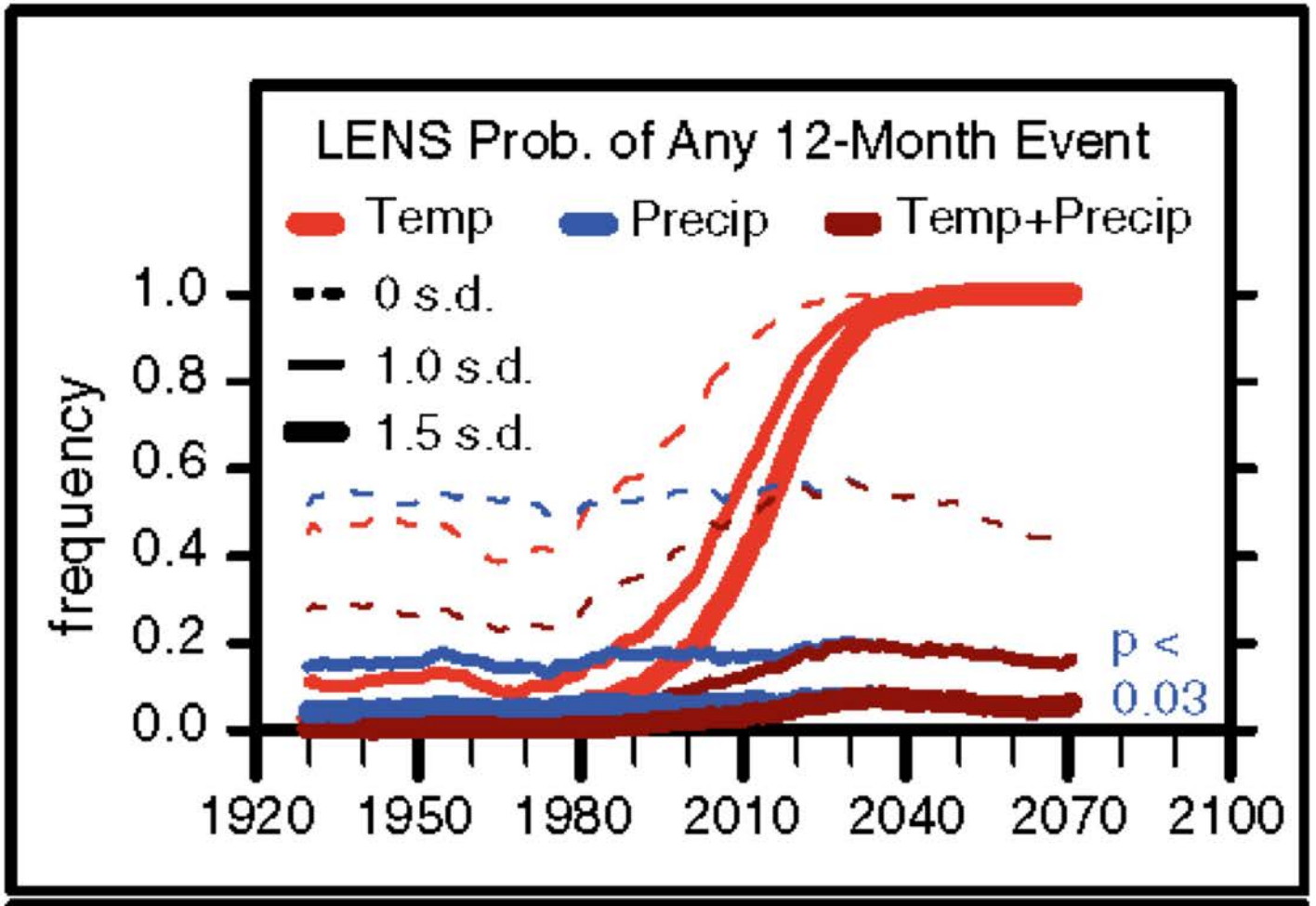
Difference between 1971-2000 and 2071-2100 averages



Data: Intergovernmental Panel on Climate Change 2013, Daly et al. 2008
Analysis: F. Wang, P. Gonzalez, M. Notaro, D. Vimont, J.W. Williams; Graph P. Gonzalez

Climate change may increase severe drought probability for California to near 100% by ~2030

Diffenbaugh et al. 2015 Proceedings of the National Academy of Sciences of the USA



Tuolumne River is vulnerable to earlier spring stream flow of up to a month from earlier snow melt

Cristea et al. 2014 Hydrological Processes

Tuolumne River
Yosemite National Park, California USA
photo NPS

National Park Service
U.S. Department of the Interior

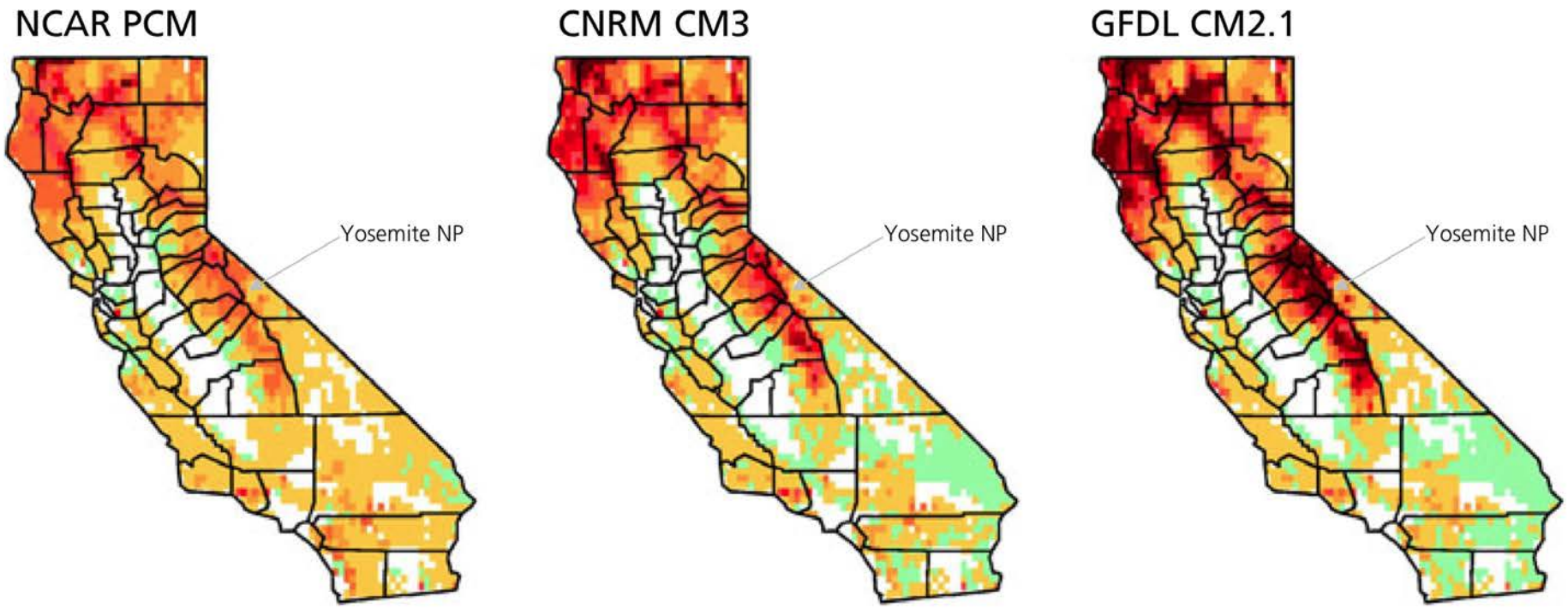
Climate Change Response Program

The pika is vulnerable to extirpation from Yosemite National Park due to upslope habitat shifts

Stewart et al. 2015 Journal of Biogeography

American pika (*Ochotona princeps*)
photo NPS

Yosemite ecosystems vulnerable to 100-300% increase in fire



Westerling et al. 2011 Climatic Change

Merced River is vulnerable to warming above the 21°C tolerance threshold for some fish species

Null et al. 2013 Climatic Change

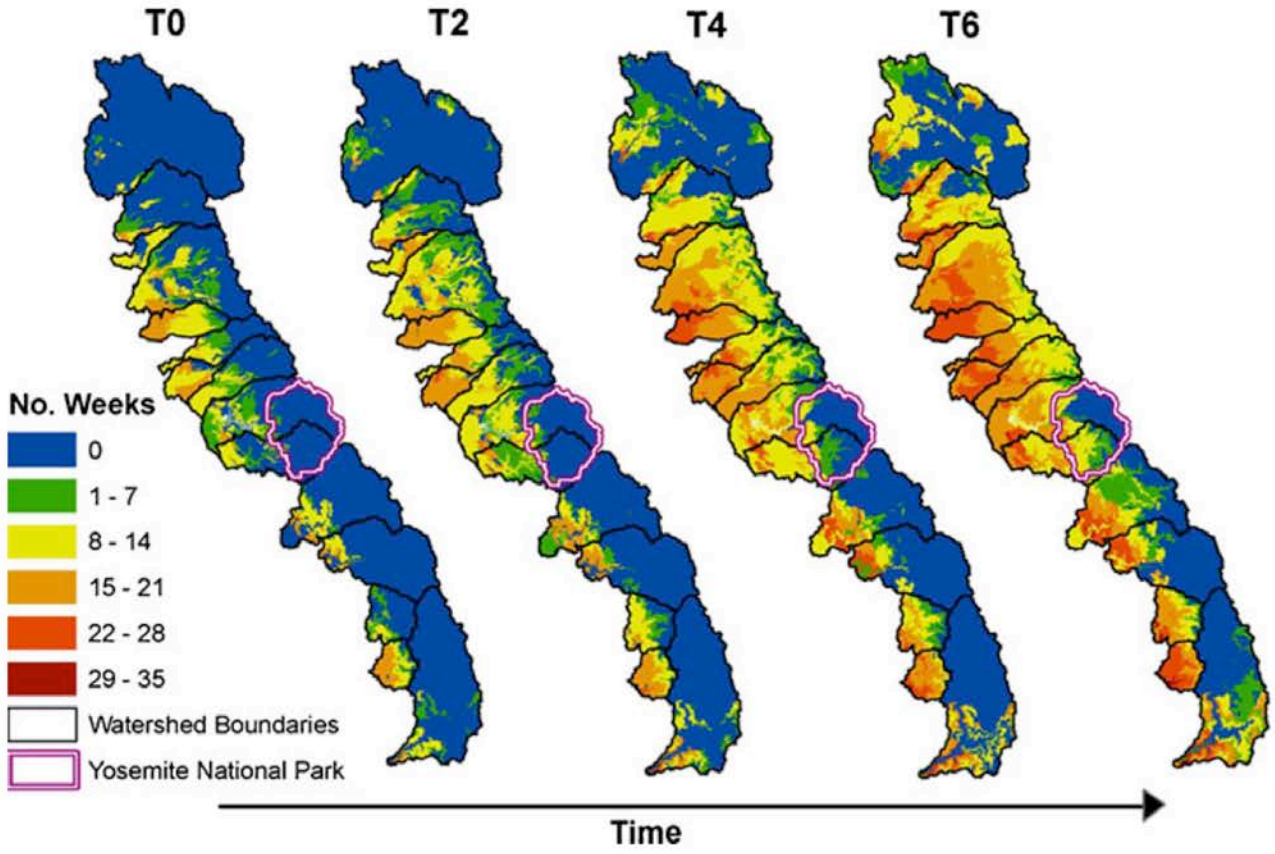


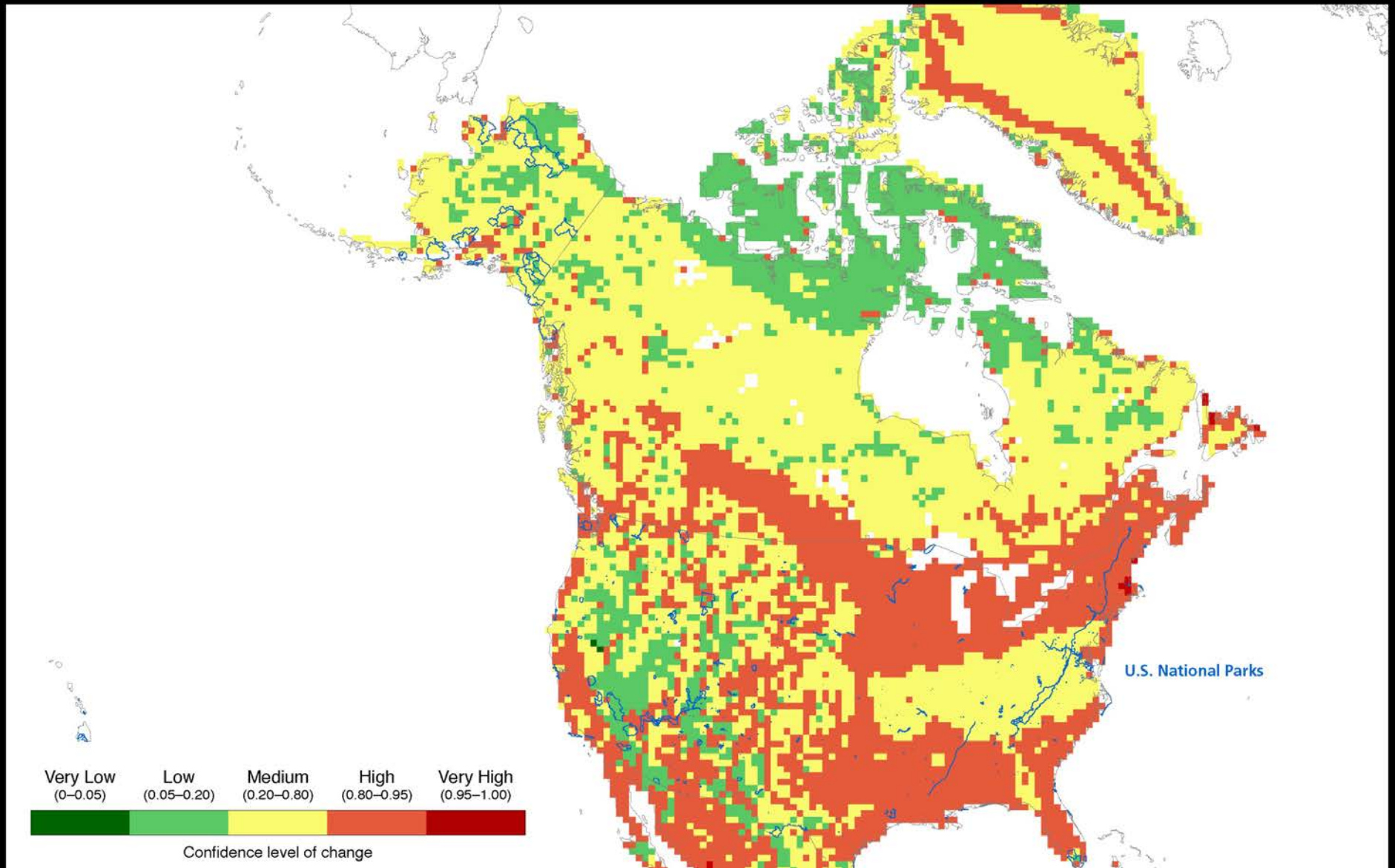
Fig. 5 Average annual number of weeks stream temperature exceeds 21°C with incremental uniform 2°C air temperature increases (T0, T2, T4, and T6 represent climate warming of 0°C, 2°C, 4°C, and 6°C, respectively)

Biomes of the Sierra Nevada, California, USA

Sequoia National Park
Inyo National Forest
Alabama Hills Recreation Lands
California, USA
photo P. Gonzalez

Vulnerability to Climate Change Biome Shifts and Habitat Loss

National Park Service
U.S. Department of the Interior



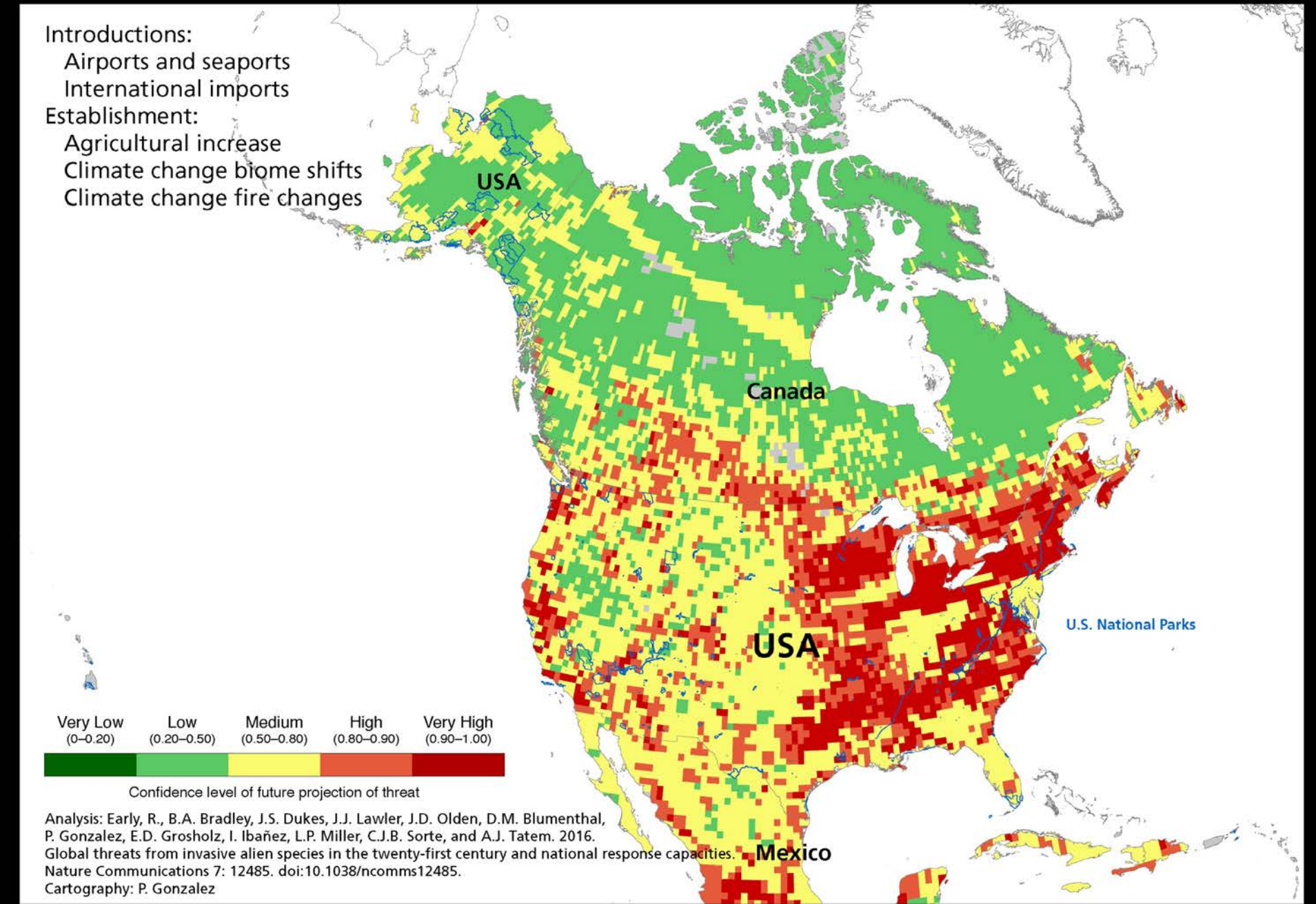
Vulnerability of ecosystems to biome shifts (1990-2100), mediated by habitat loss (2009).

Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. Global Ecology and Biogeography 19: 755-768.

Eigenbrod, F., P. Gonzalez, J. Dash, and I. Steyl. 2015. Vulnerability of ecosystems to climate change moderated by habitat intactness. Global Change Biology 21: 275-286.

Invasive Species Threat 2000-2100

National Park Service
U.S. Department of the Interior



Analysis: Early, R., B.A. Bradley, J.S. Dukes, J.J. Lawler, J.D. Olden, D.M. Blumenthal, P. Gonzalez, E.D. Grosholz, I. Ibañez, L.P. Miller, C.J.B. Sorte, and A.J. Tatem. 2016. Global threats from invasive alien species in the twenty-first century and national response capacities. Nature Communications 7: 12485. doi:10.1038/ncomms12485.
Cartography: P. Gonzalez

Climate Change in Yosemite Wilderness

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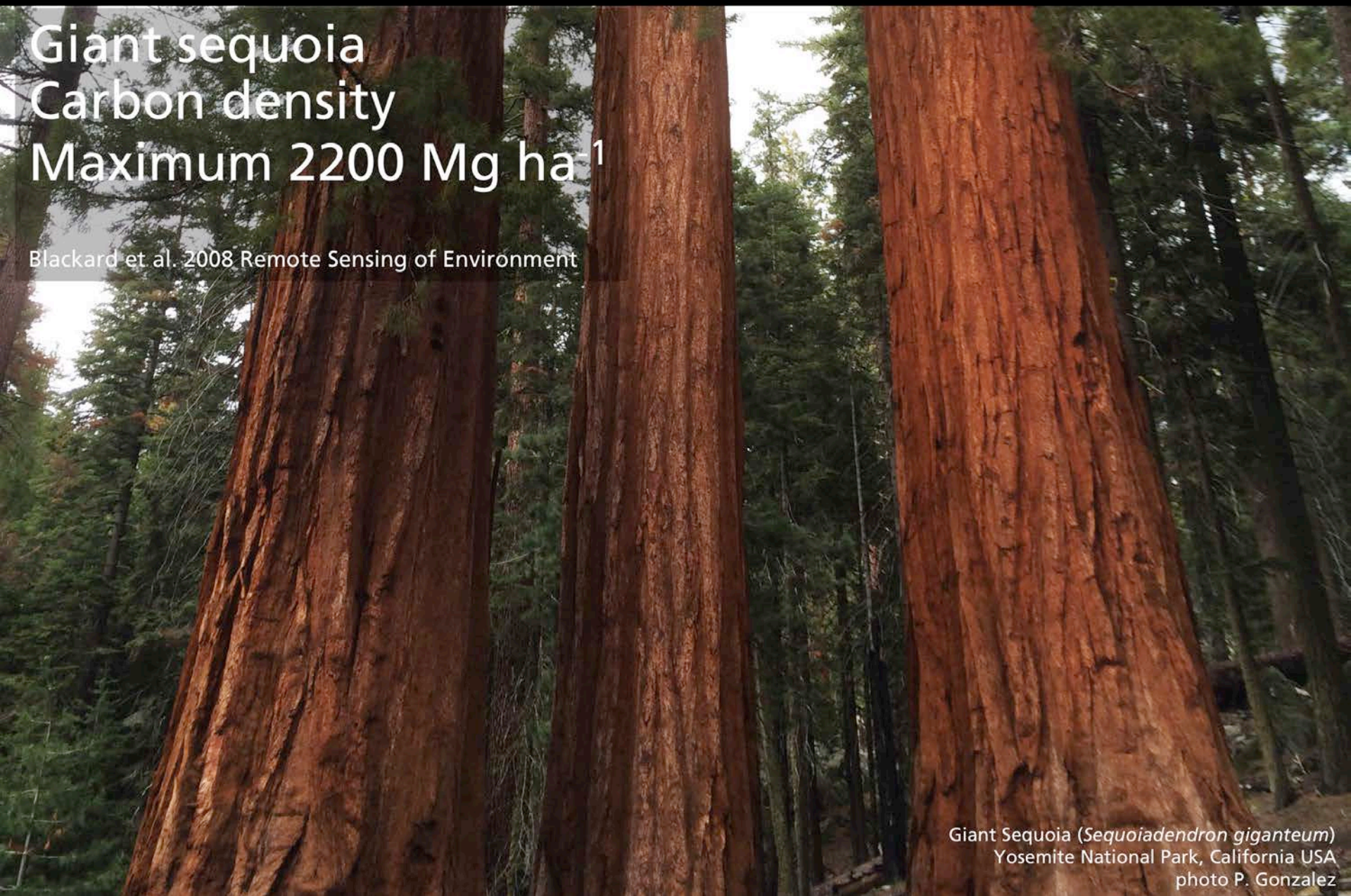
Giant sequoia Carbon density Maximum 2200 Mg ha^{-1}

Blackard et al. 2008 Remote Sensing of Environment

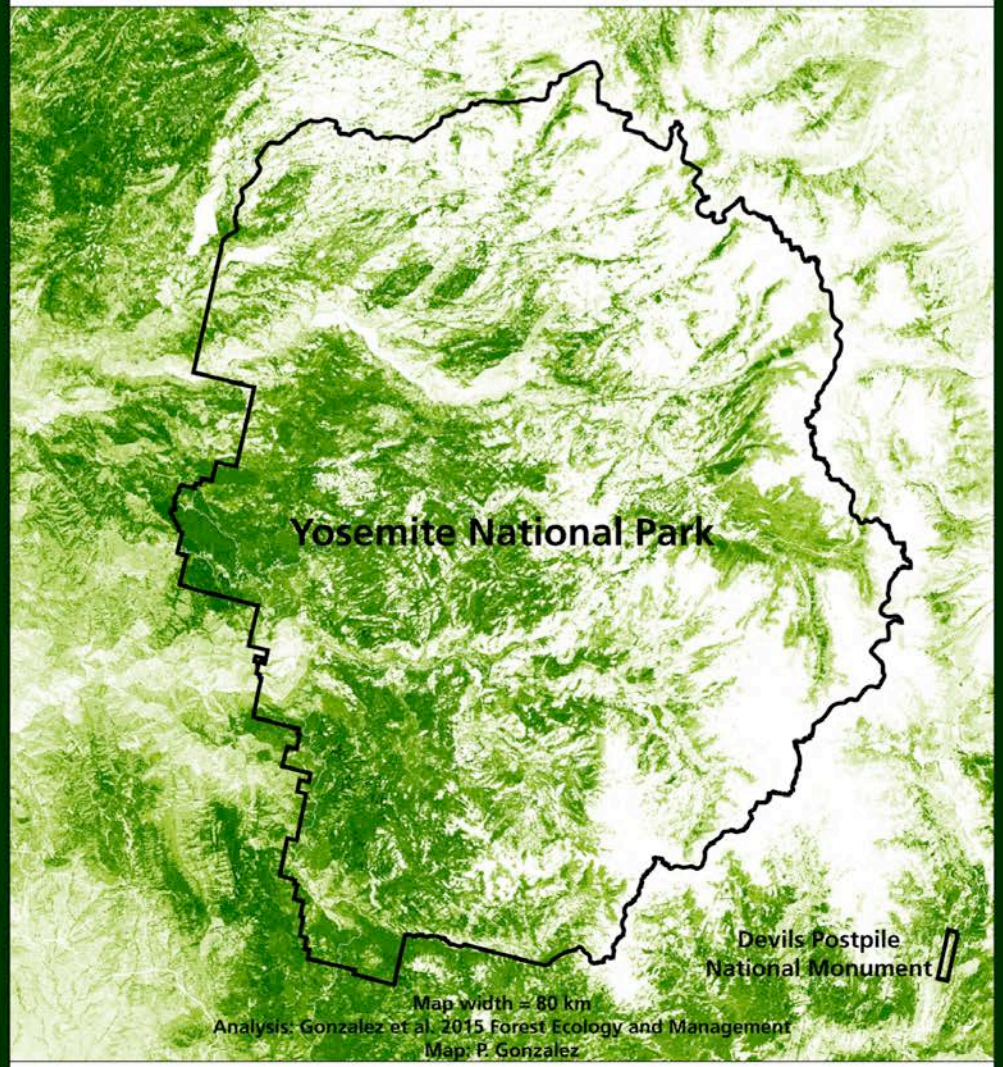


Giant Sequoia (*Sequoiadendron giganteum*)
Yosemite National Park, California USA
photo P. Gonzalez

National Park Service
U.S. Department of the Interior

Climate Change Response Program

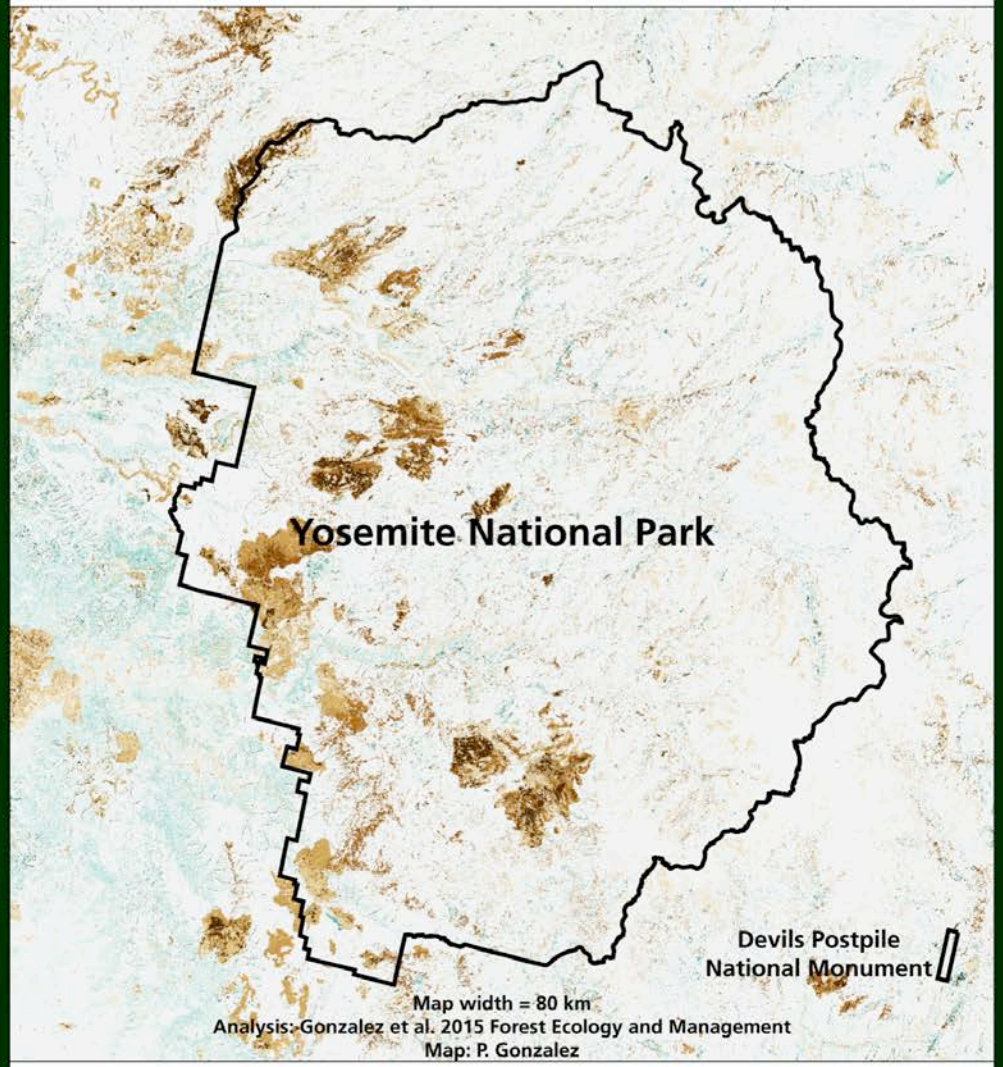
Aboveground Vegetation Carbon 2010



National Park Service
U.S. Department of the Interior

Climate Change Response Program

Aboveground Vegetation Carbon Change 2001-2010

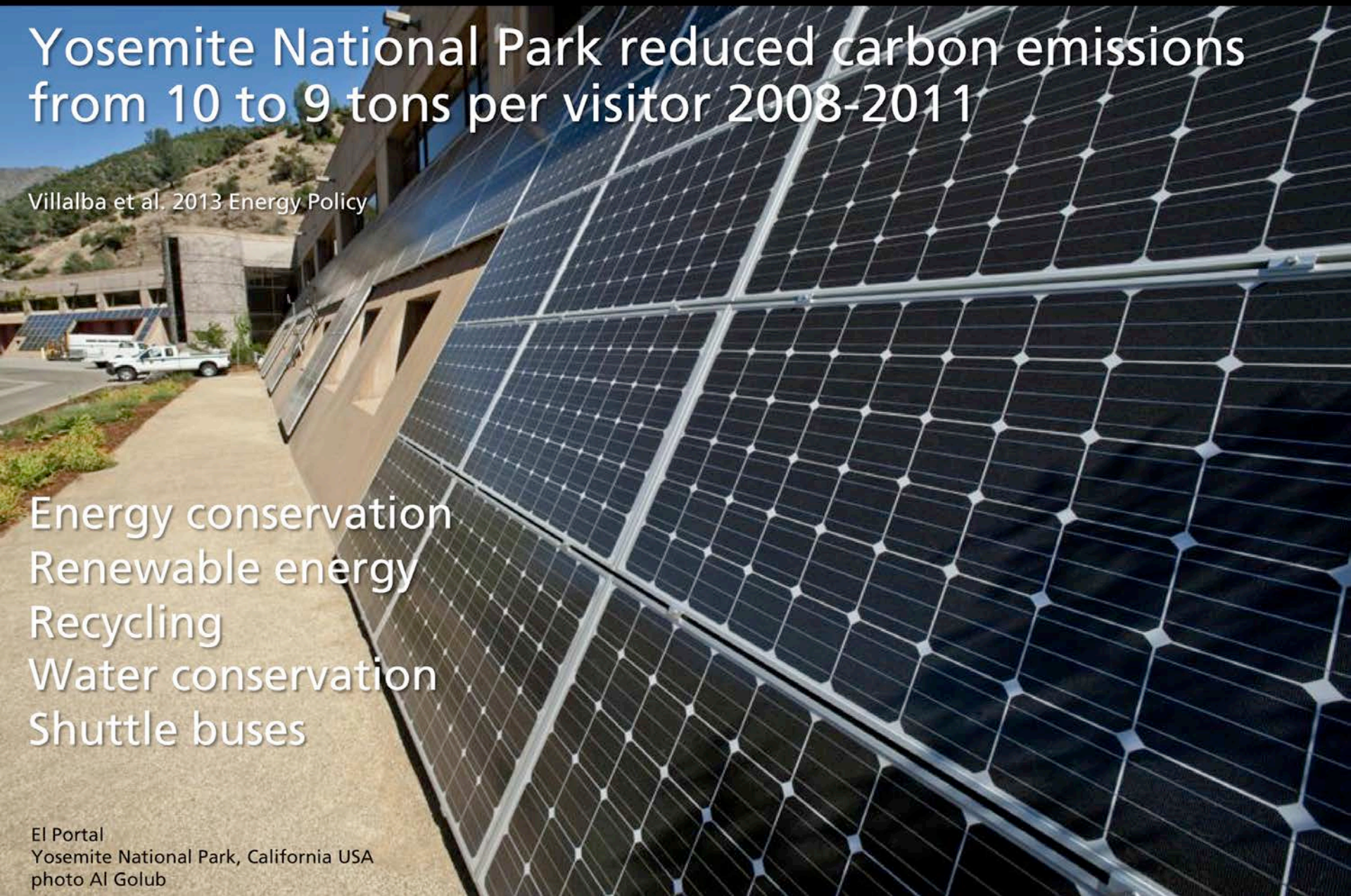


National Park Service
U.S. Department of the Interior

Climate Change Response Program

Yosemite National Park reduced carbon emissions from 10 to 9 tons per visitor 2008-2011

Villalba et al. 2013 Energy Policy



Energy conservation
Renewable energy
Recycling
Water conservation
Shuttle buses

El Portal
Yosemite National Park, California USA
photo Al Golub

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Goals of National Park Management

Leopold Report (1963)

"…biotic associations be maintained, or where necessary recreated, as nearly as possible to the condition that prevailed when the area was first visited …A national park should represent a vignette of primitive America."

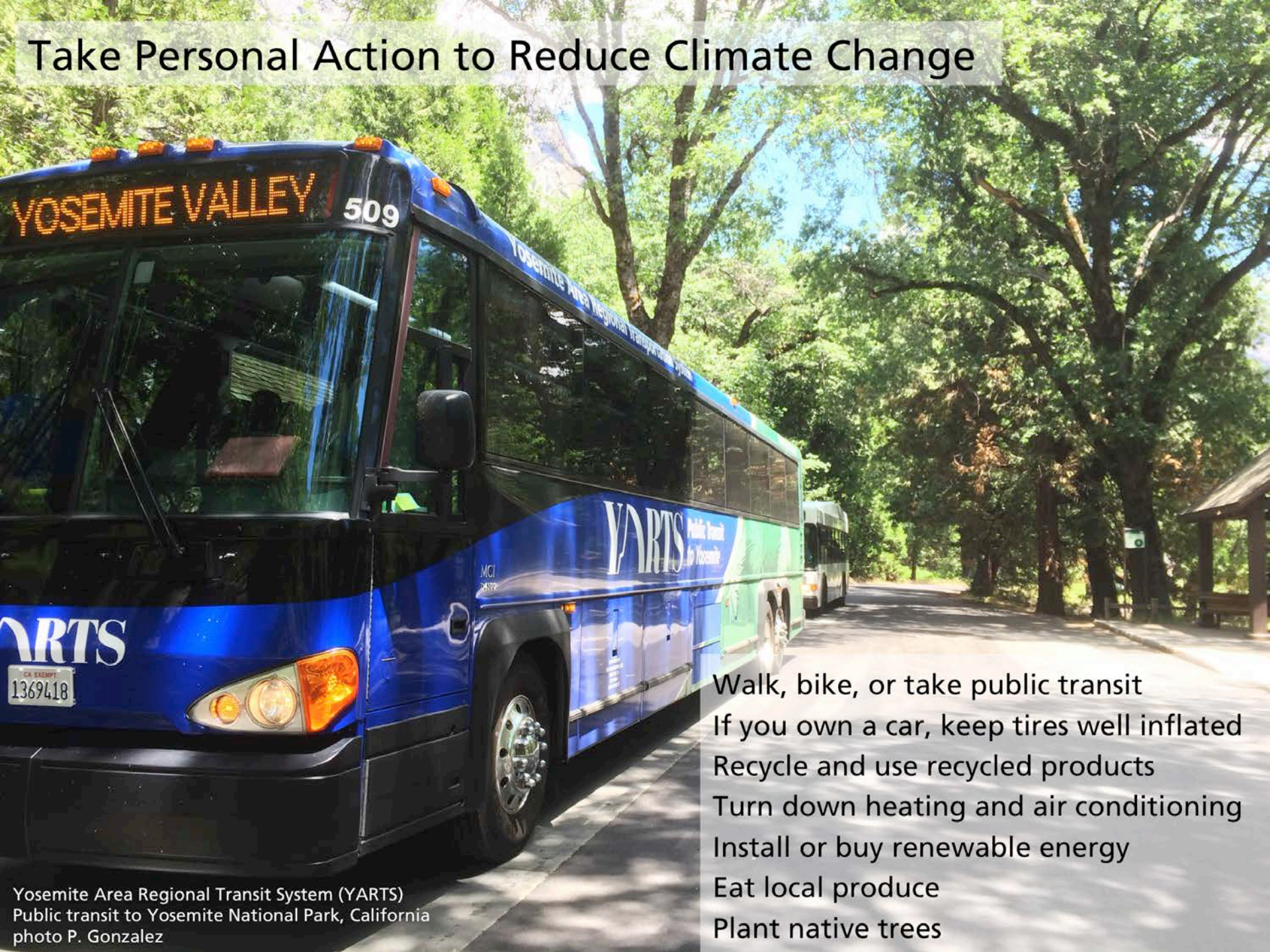
Revisiting Leopold (2012)

"to steward NPS resources for continuous change that is not yet fully understood, in order to preserve ecological integrity and cultural and historical authenticity, provide visitors with transformative experiences, and form the core of a national conservation land- and seascape."

Adaptation for ecological integrity under climate change

1. Conservation of refugia to biome shifts
   (Gonzalez et al. 2010 Global Ecology and Biogeography)
2. Targeted fire management to avoid catastrophic fire
   (Stephens et al. 2013 Science)
3. Ecological restoration of natural resilience of altered areas
   (Harris et al. 2006 Restoration Ecology)
4. Conservation of corridors across landscapes
   (McGuire et al. 2016 Proceedings of the National Academy of Sciences of the USA)
5. Targeted invasive species removal
   (Early et al. 2016 Nature Communications)
6. Thermal refugia for fish, amphibians, and other wildlife
   (Morelli et al. 2016 PLoS One)
7. Other measures…

Take Personal Action to Reduce Climate Change



Yosemite Area Regional Transit System (YARTS)
Public transit to Yosemite National Park, California
photo P. Gonzalez

Walk, bike, or take public transit
If you own a car, keep tires well inflated
Recycle and use recycled products
Turn down heating and air conditioning
Install or buy renewable energy
Eat local produce
Plant native trees