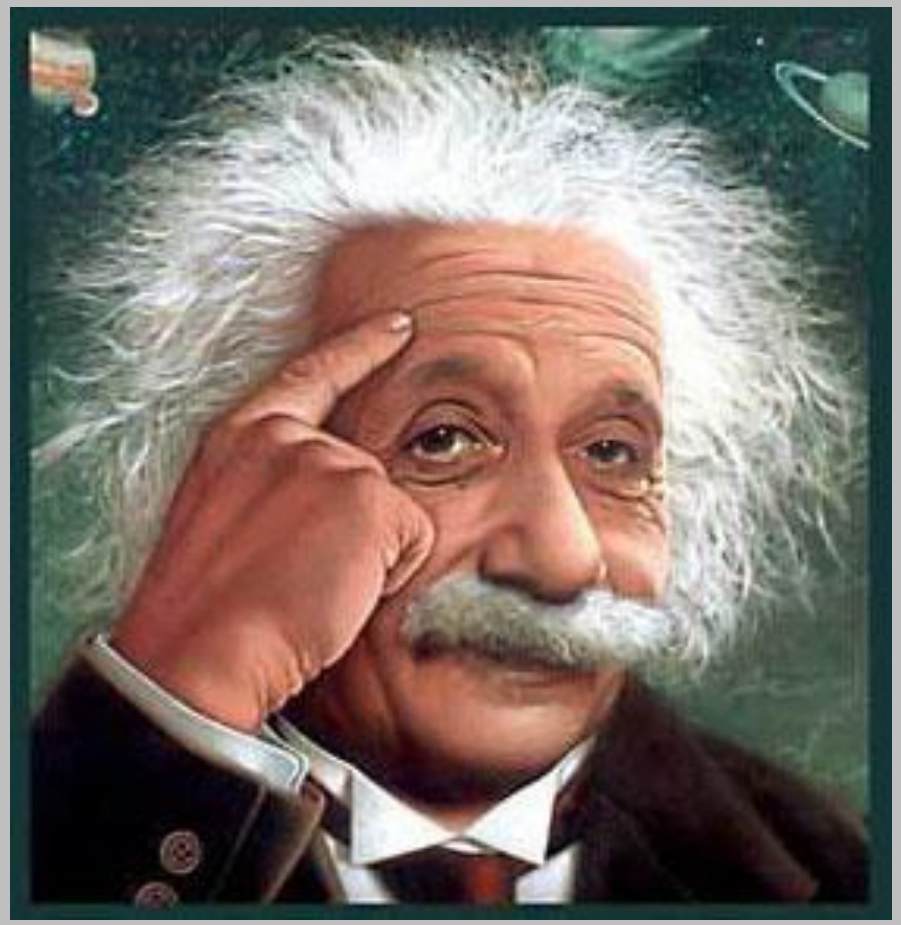
Climate Change and Texas 2017
By Jim Blackburn



"The world we have created to date as a result of our thinking thus far has problems that cannot be solved by thinking the way we were thinking when we created them."

Albert Einstein

Climate Change

- The Earth's Climate Is Changing
- Humans Are Causing This Change

IPCC 2013 AR-5 Finding #1

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased

IPCC 2013 AR-5 Finding #11

Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes . . . This evidence for human influence has grown since AR4. It is *extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century*.

Organizations That Concur With Findings That (1) Climate Is Changing and (2) Humans Are Causing It

Scientific organizations worldwide affirm:
Climate change is real, human-caused & urgent¶

American Chemical Society

AGU
American Geophysical Union

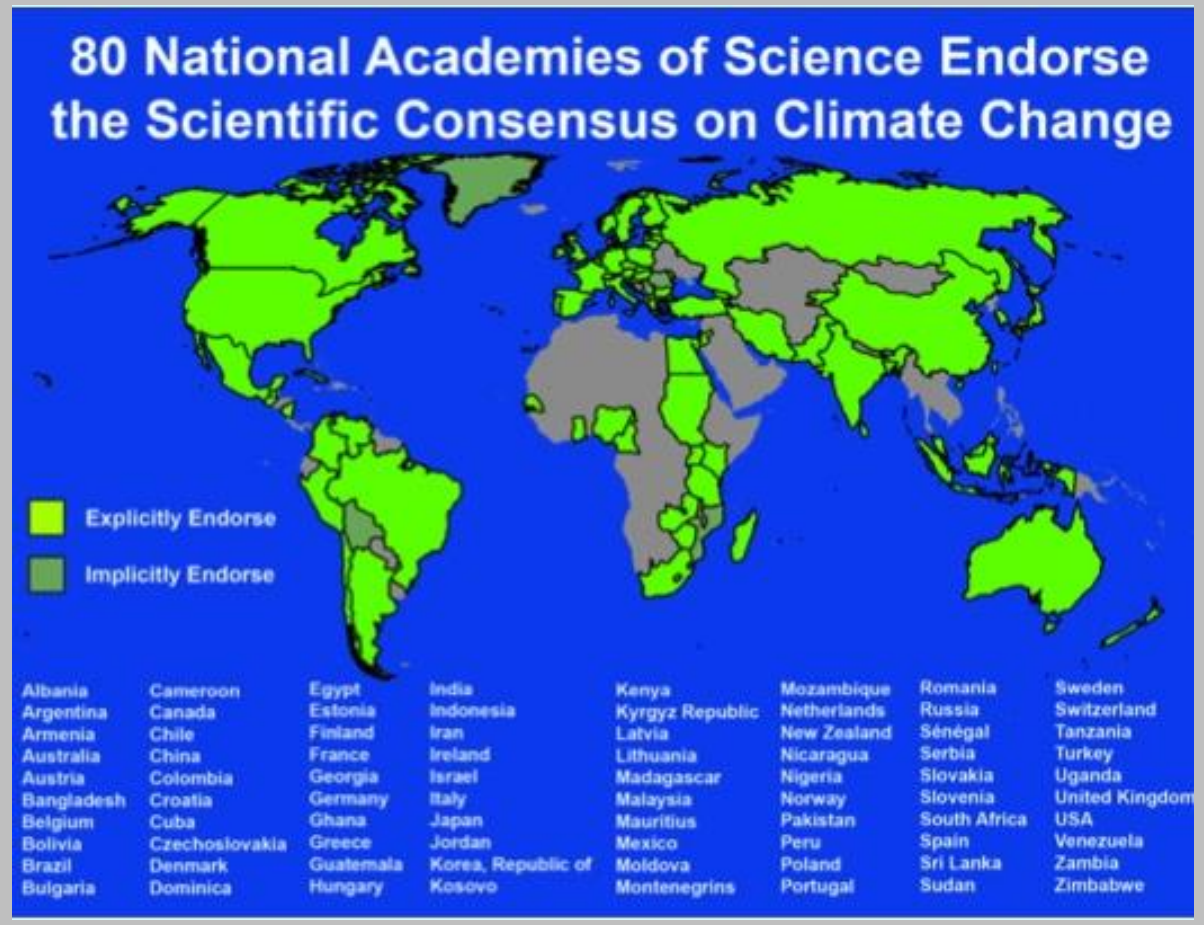
APS
AMERICAN PHYSICAL SOCIETY

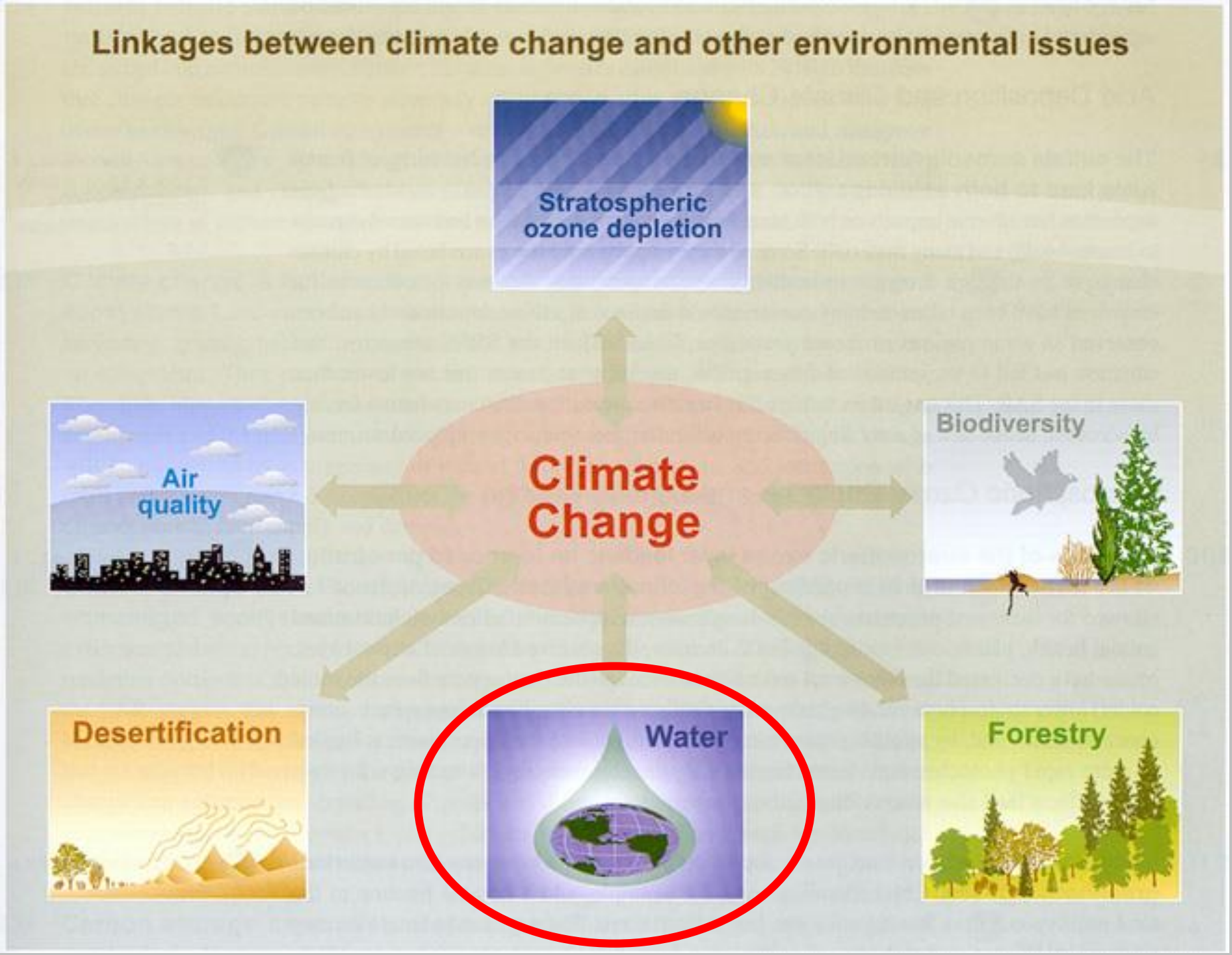
AMERICAN METEOROLOGICAL SOCIETY 1919

THE GEOLOGICAL SOCIETY OF AMERICA®

AAAS
ADVANCING SCIENCE, SERVING SOCIETY

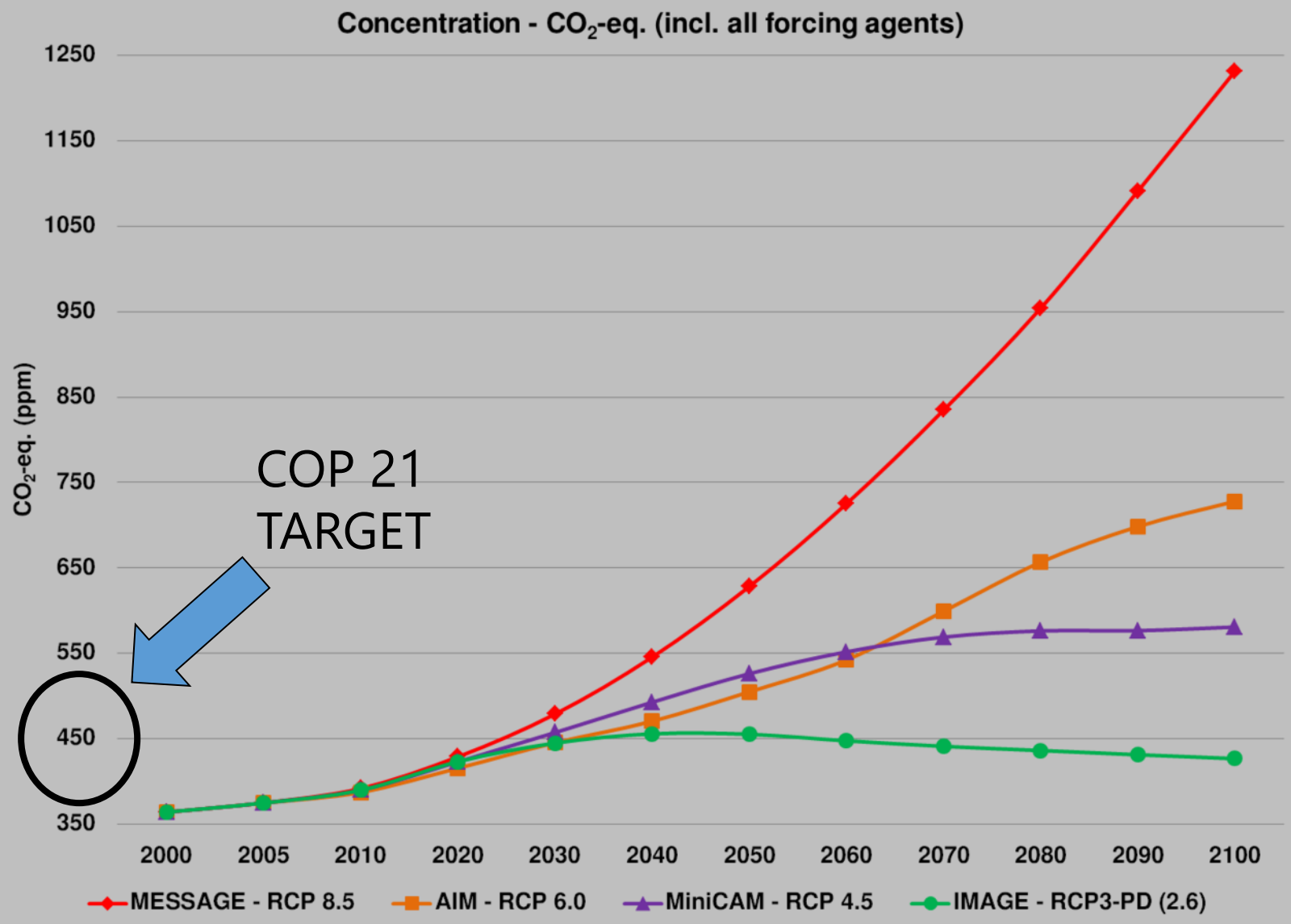
G8+5 Academies' joint statement:
Climate change and the transformation of energy technologies for a low carbon future

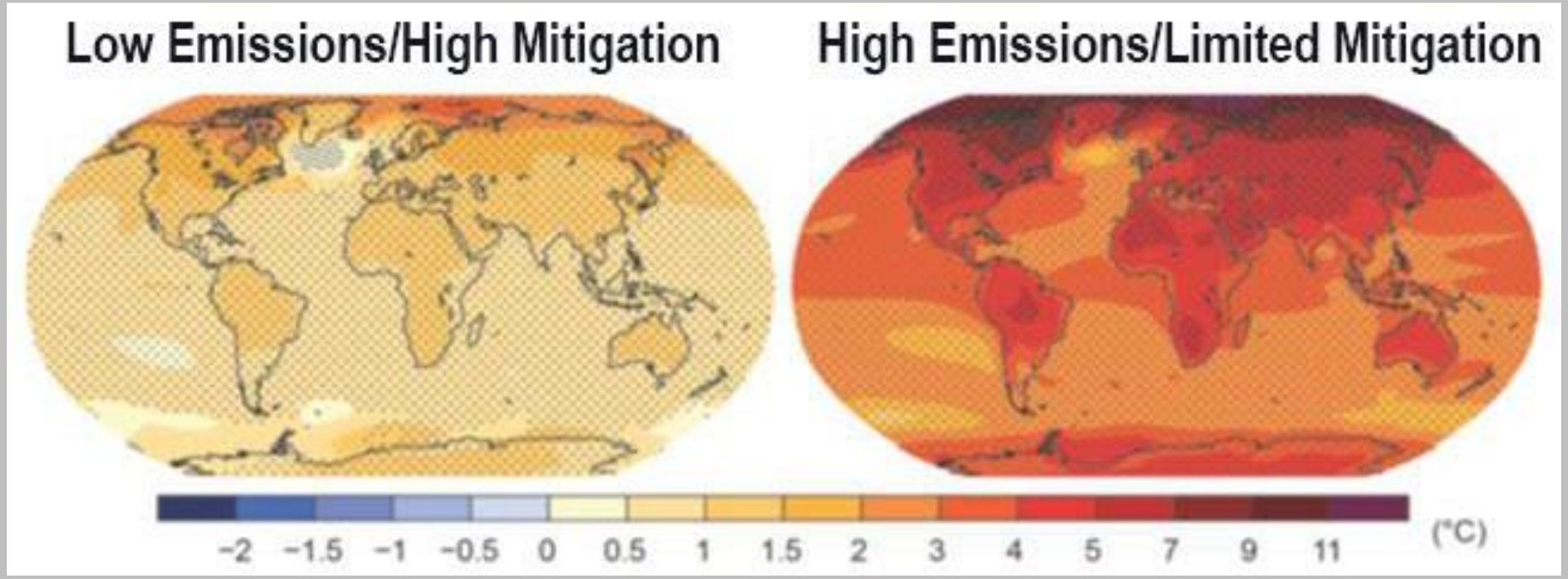


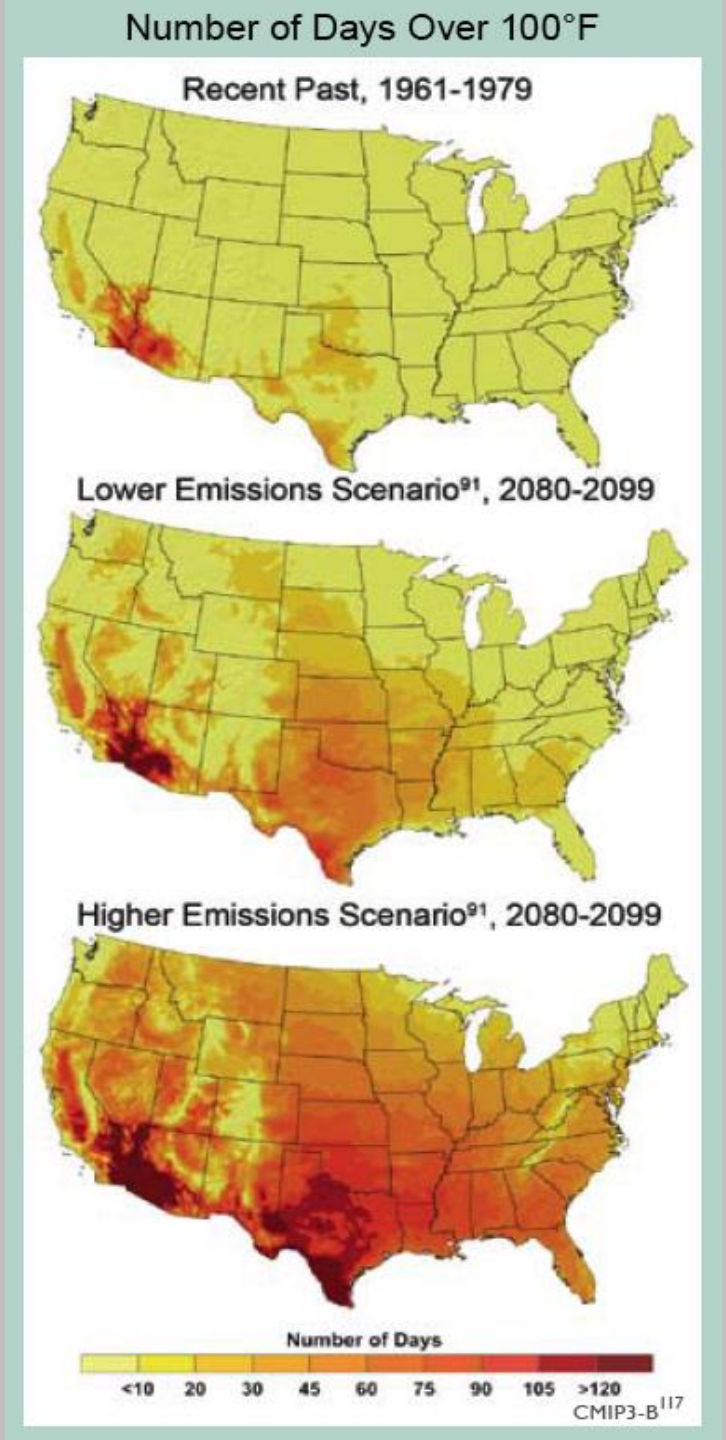


No Issue Quite Like Climate Change

Climate Change Scenarios




Low Emissions/High Mitigation
High Emissions/Limited Mitigation
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
(°C)



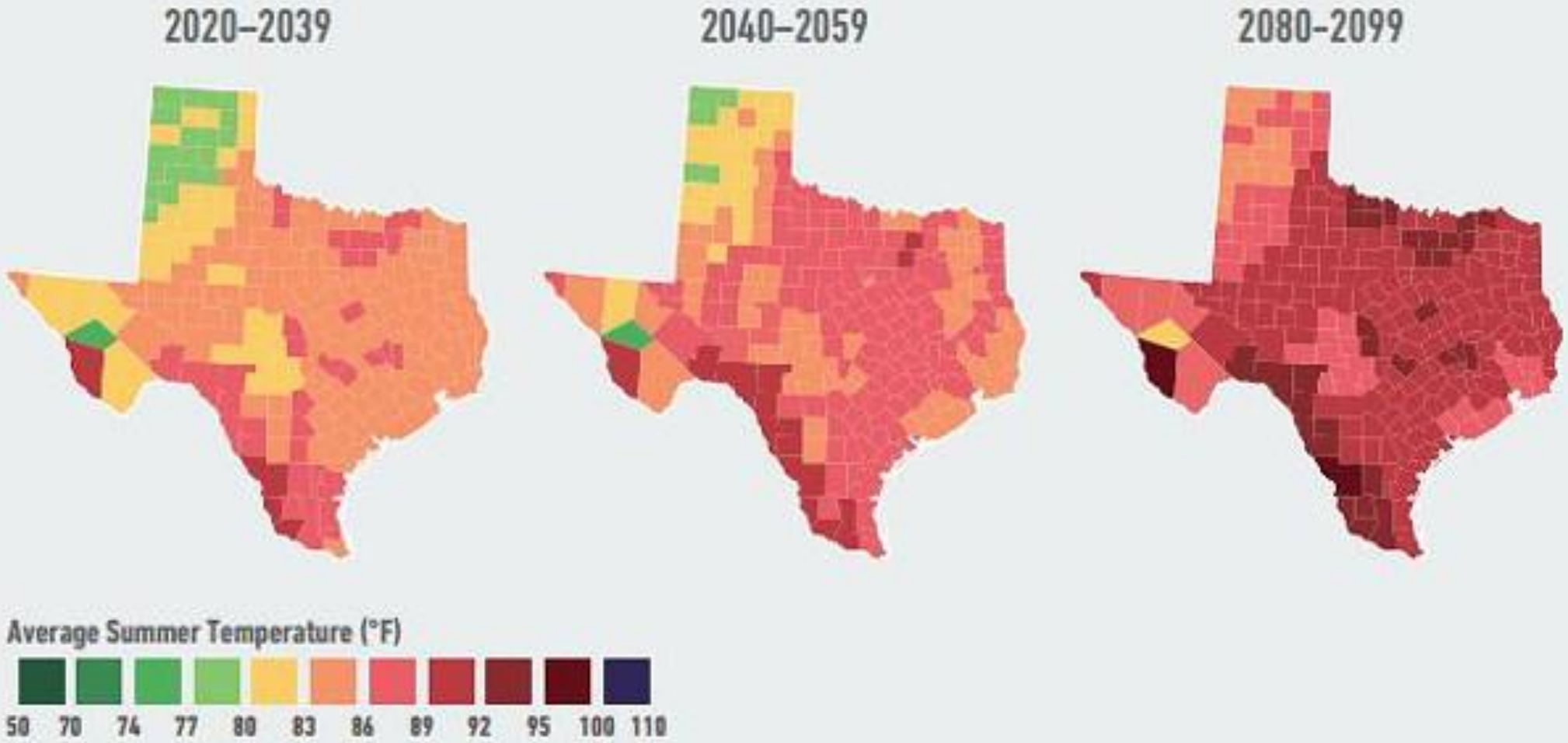
In the recent past Houston averaged less than 20 days per year over 100° F.

In 2080-2090, using a lower emissions scenario, models predict 20-30 days over 100° F

In 2080-2090, using a higher emissions scenario, models predict 100-120 days over 100° F

U.S. Global Change Research Program, 2009 Report

TEXAS: AVERAGE SUMMER TEMPERATURE



Source: American Climate Prospectus

Climate Change – John Nielsen-Gammon Texas State Climatologist

- Texas temperatures have been increasing for the past 40 years.
- The rate of change (so far, about a degree to a degree and a half Fahrenheit) is similar to what would be expected given the global trends.
- So it appears to be largely anthropogenic and should be expected to continue.

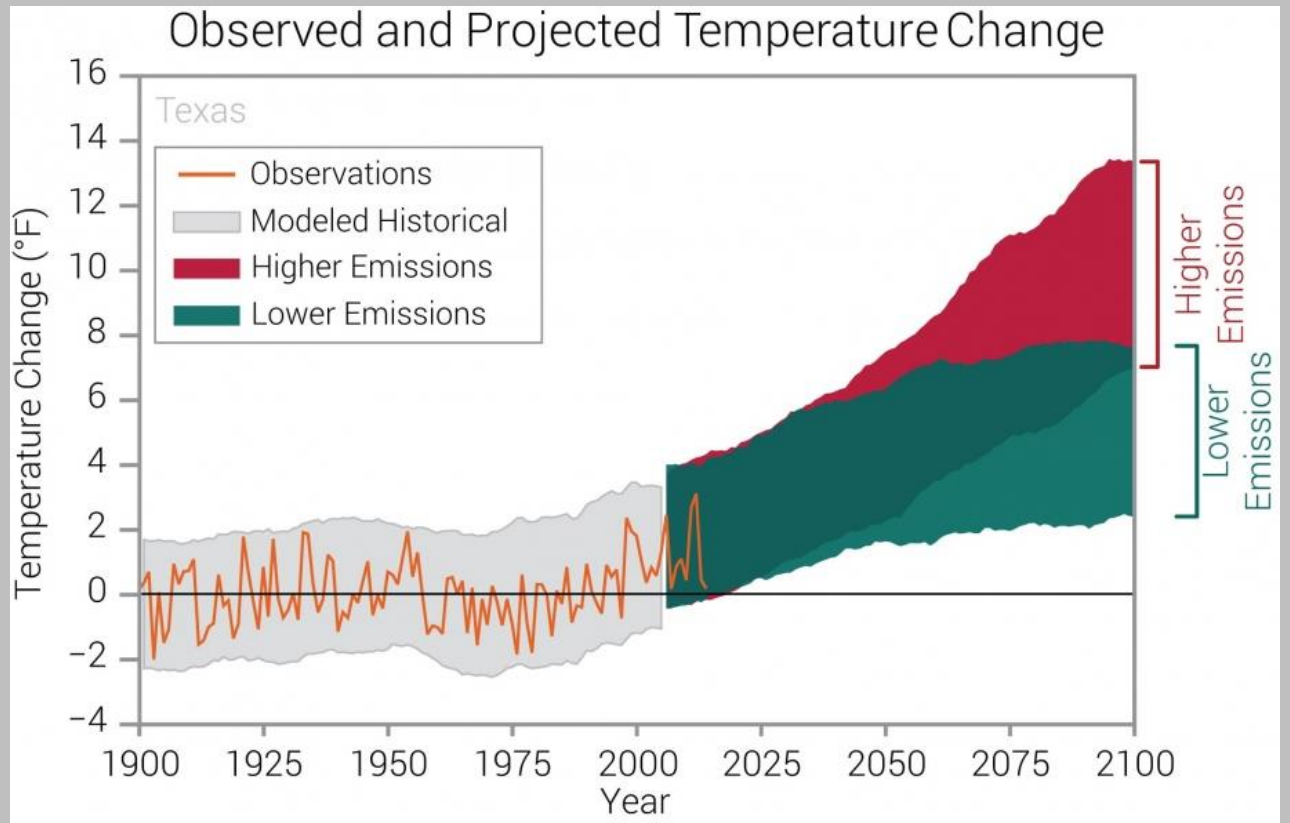
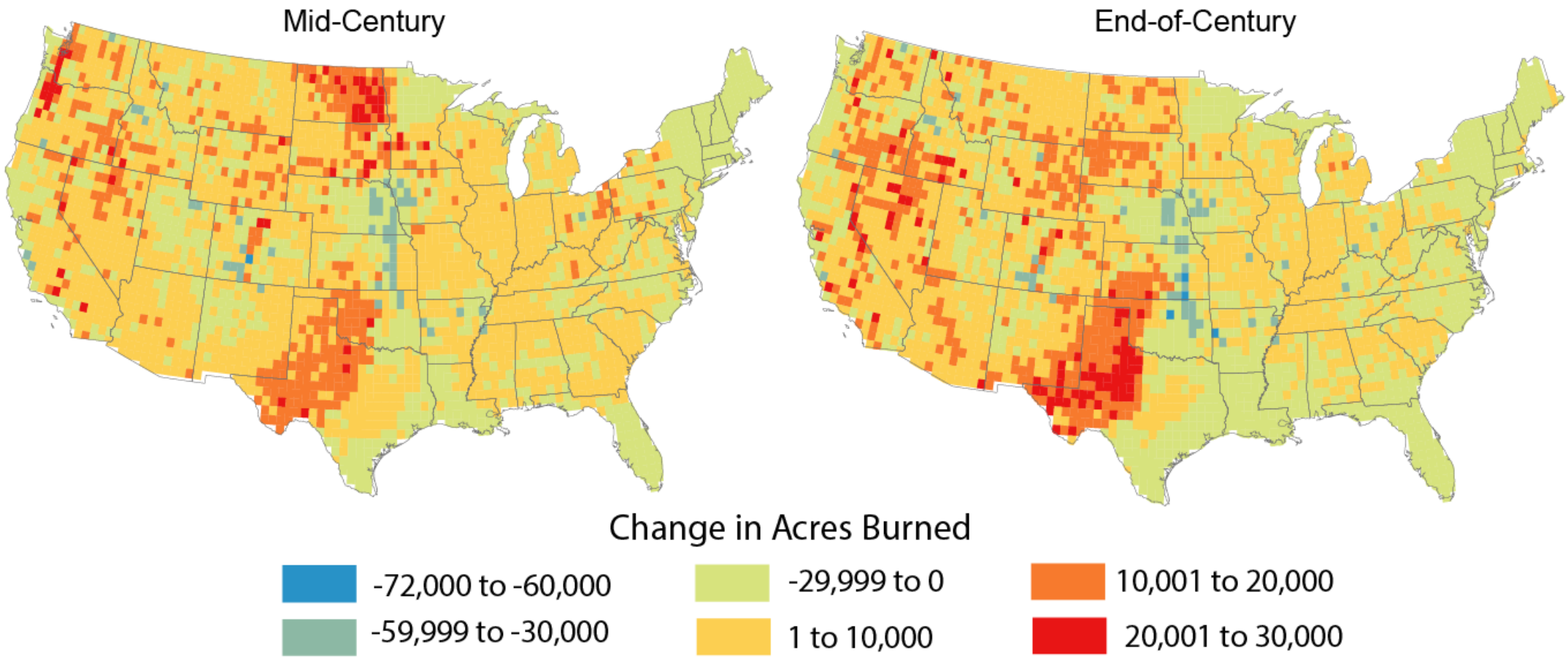


Figure 1. Projected Impact of Unmitigated Climate Change on Wildfire Activity

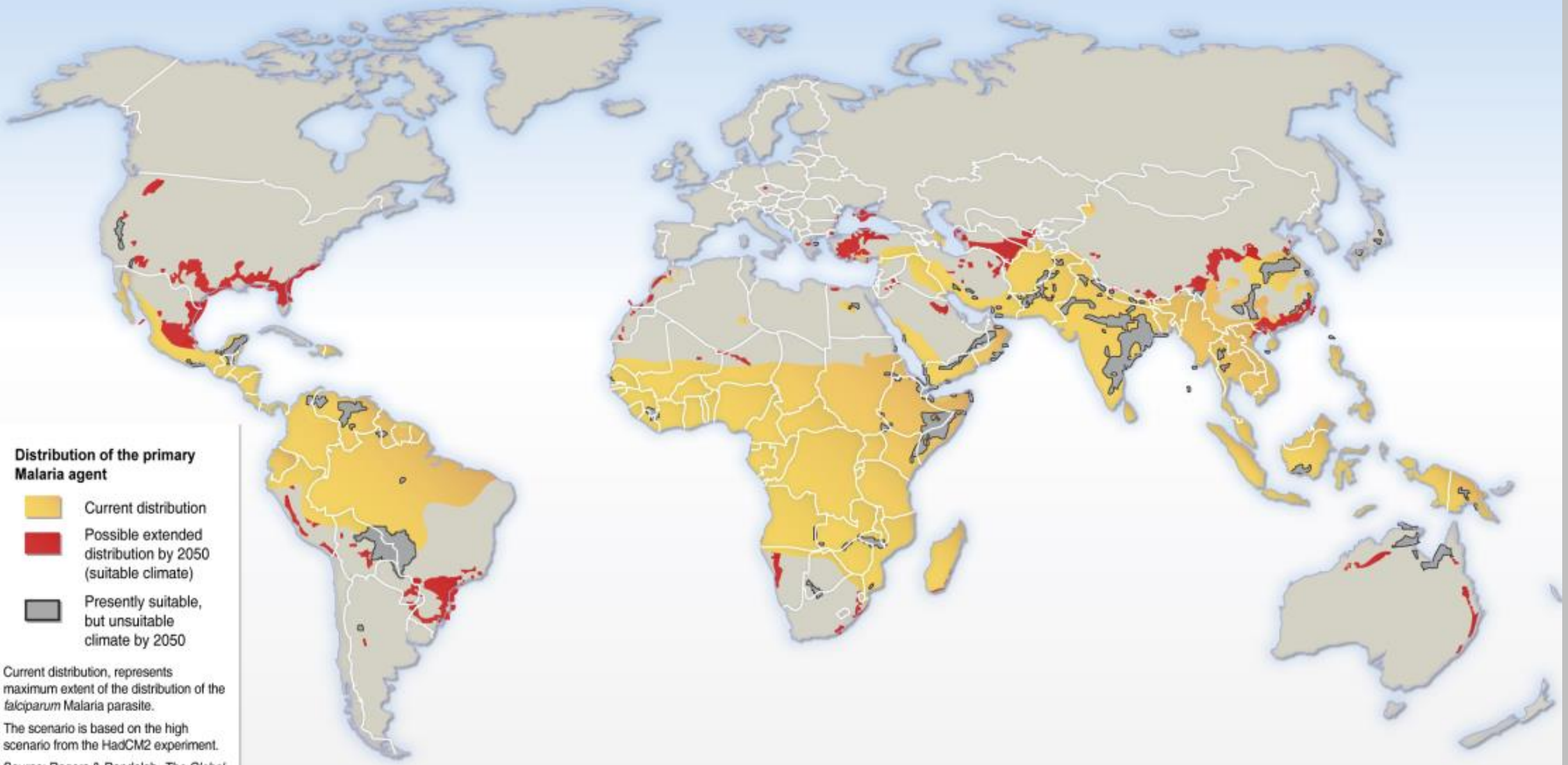
Change in average annual acres burned under the Reference scenario by mid-century (2035-2064) and end of century (2085-2114) compared to the historic baseline (2000-2009) using the IGSM-CAM climate model. Acres burned include all vegetation types and are calculated at a cell resolution of 0.5° x 0.5°.

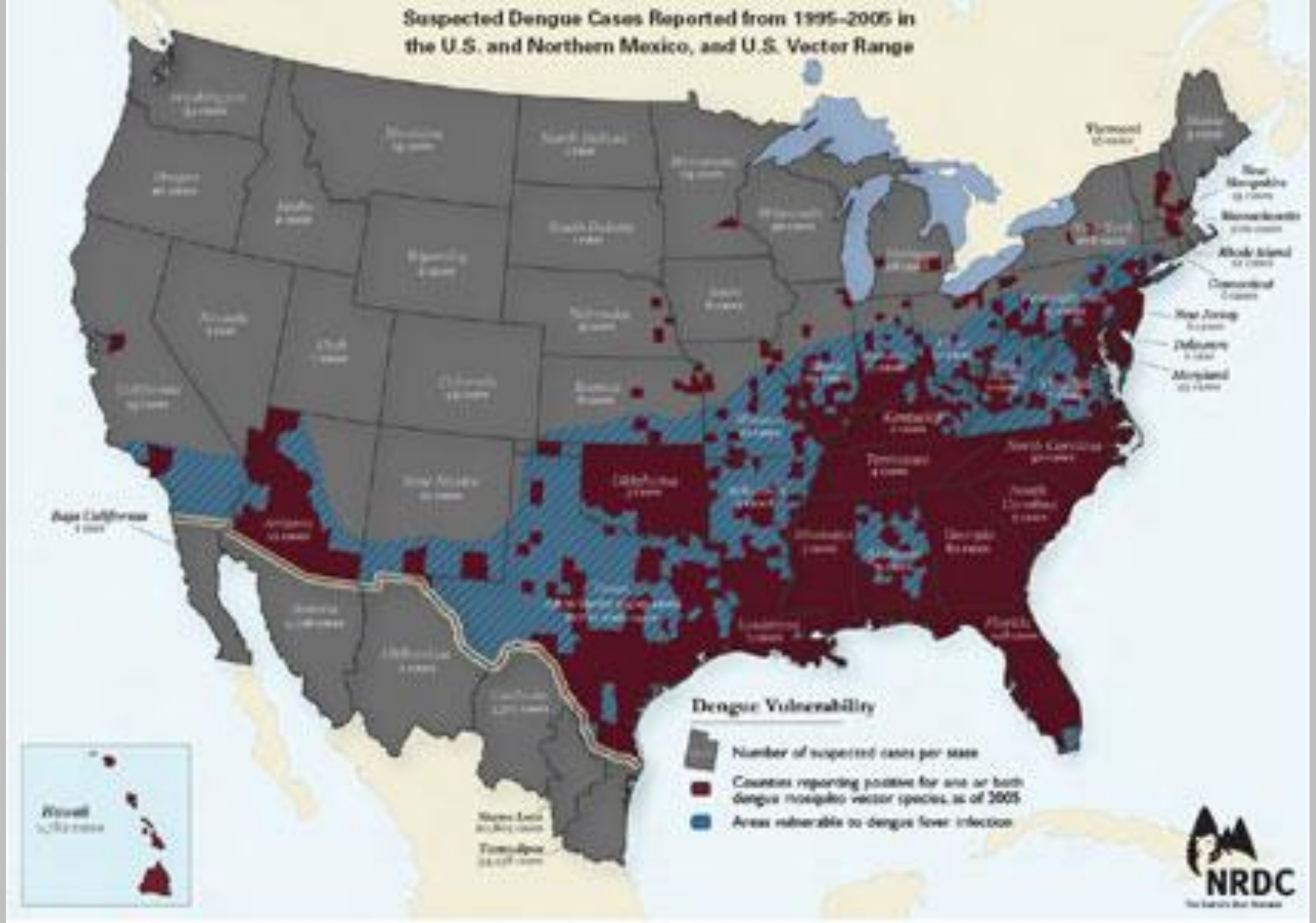


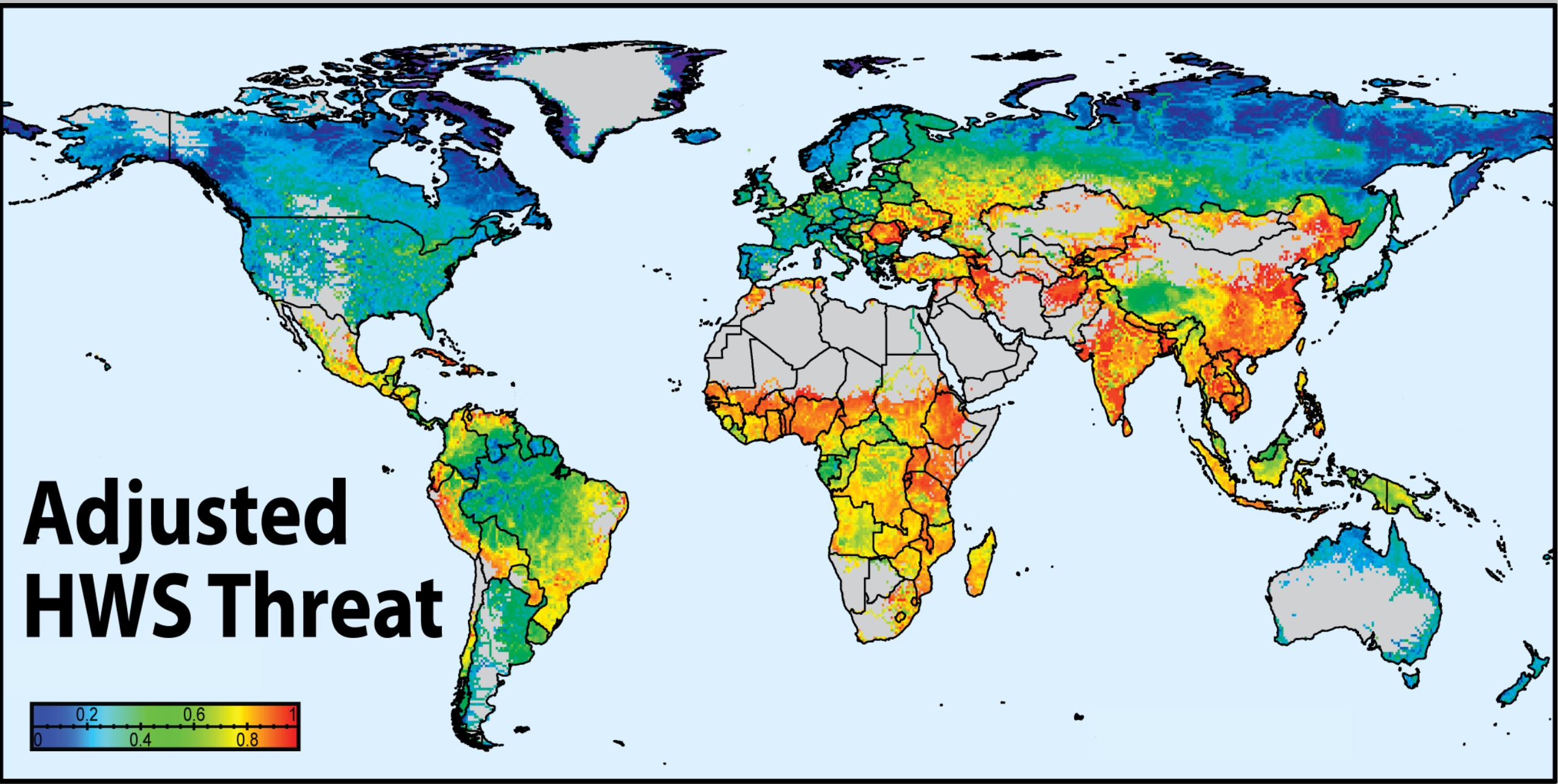
For more information, visit EPA's "Climate Change in the United States: Benefits of Global Action" at www.epa.gov/cira.

Heat-Related Deaths Increase to 2100

Climate Change and Malaria

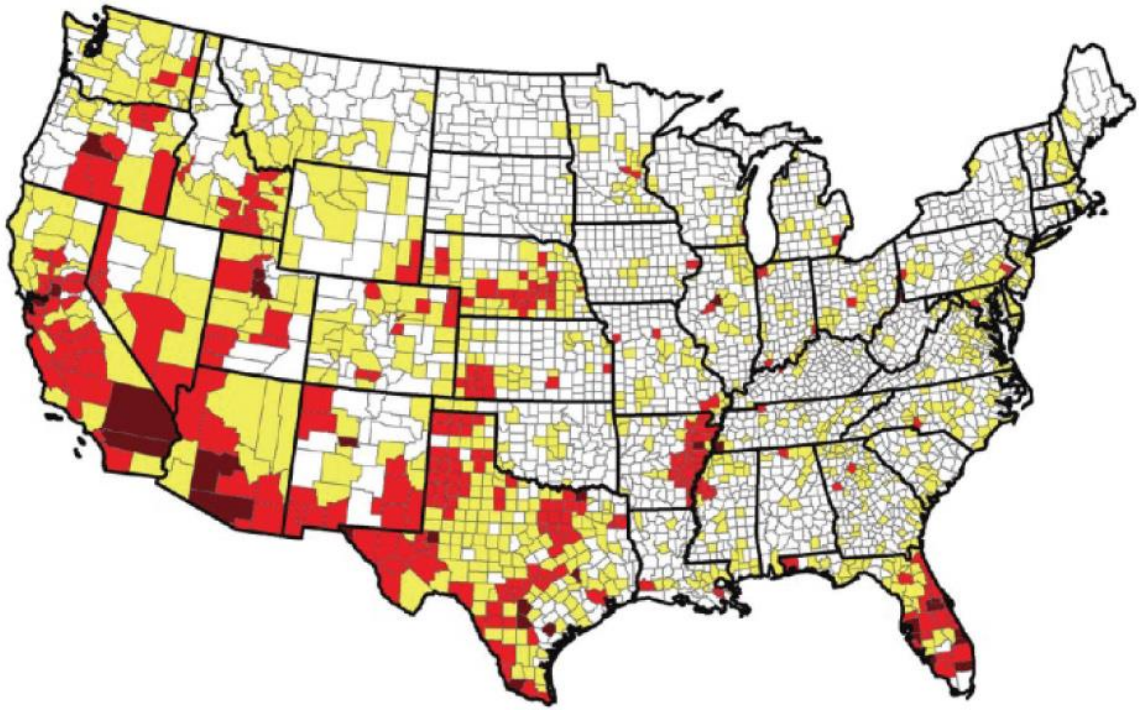



Suspected Dengue Cases Reported from 1995–2005 in the U.S. and Northern Mexico, and U.S. Vector Range
Dengue Vulnerability
Number of suspected cases per state
Counties reporting positive for one or both dengue mosquito vector species as of 2005
Areas vulnerable to dengue fever infection
NRDC


Adjusted
HWS Threat
0
0.2
0.4
0.6
0.8
1

Water Supplies Projected to Decline

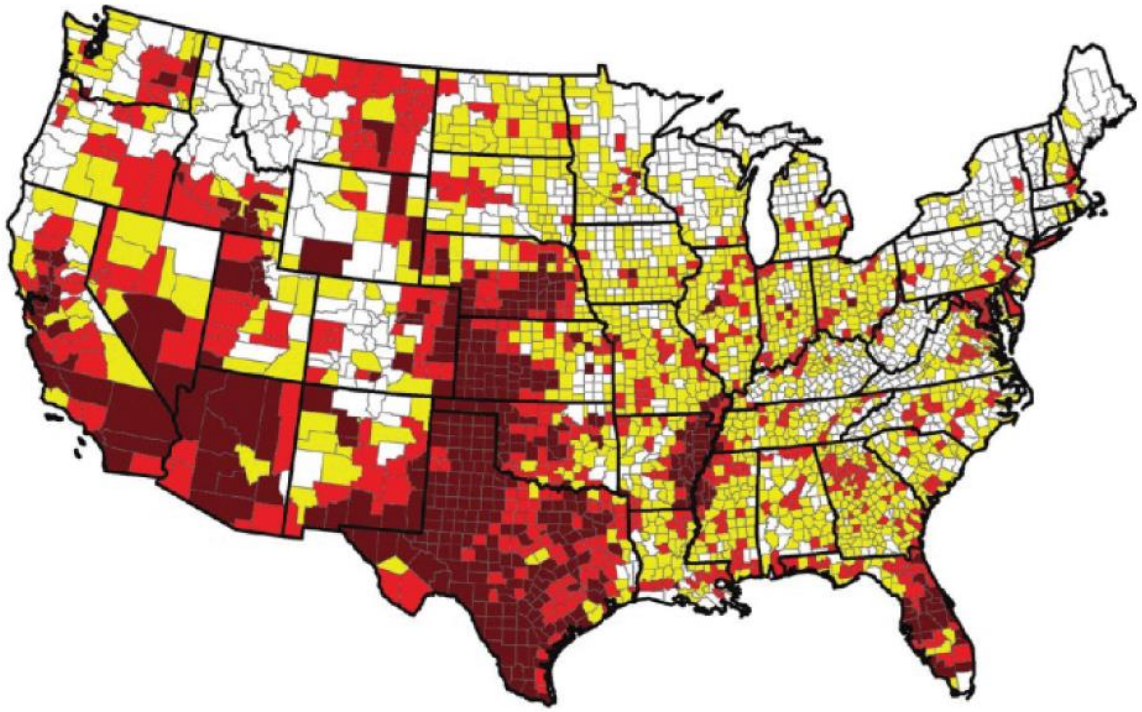
No Climate Change Effects



Water Supply Sustainability Risk Index (2050)

- Extreme (29)
- High (271)
- Moderate (821)
- Low (2020)

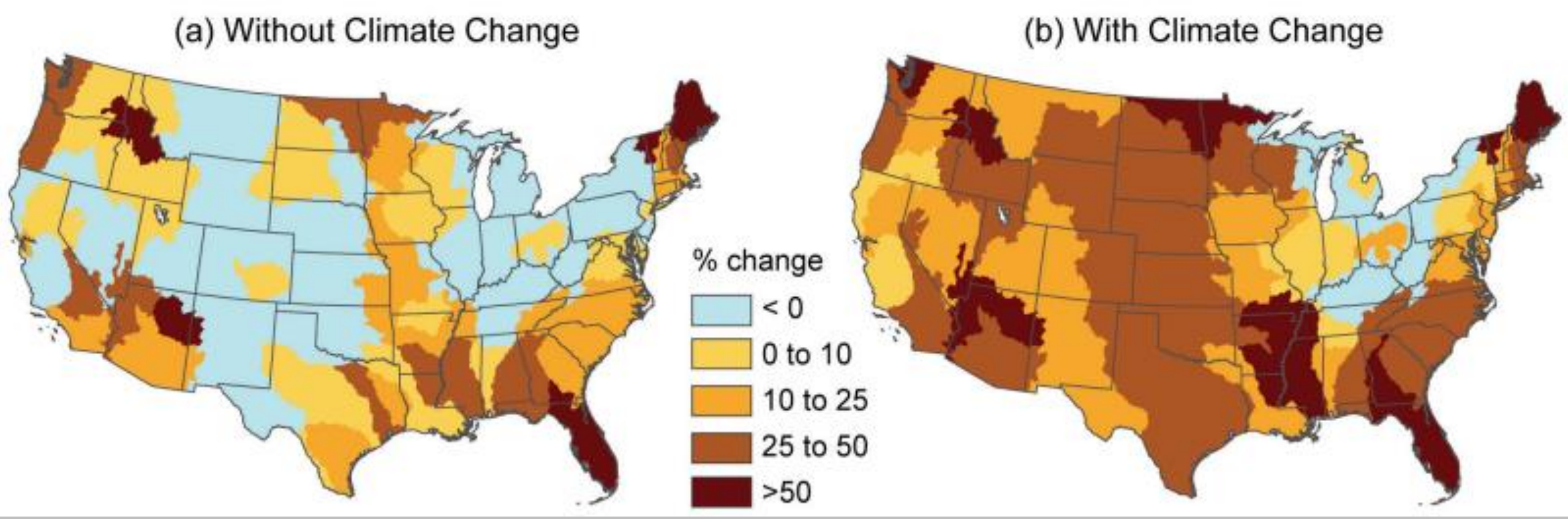
Climate Change Effects

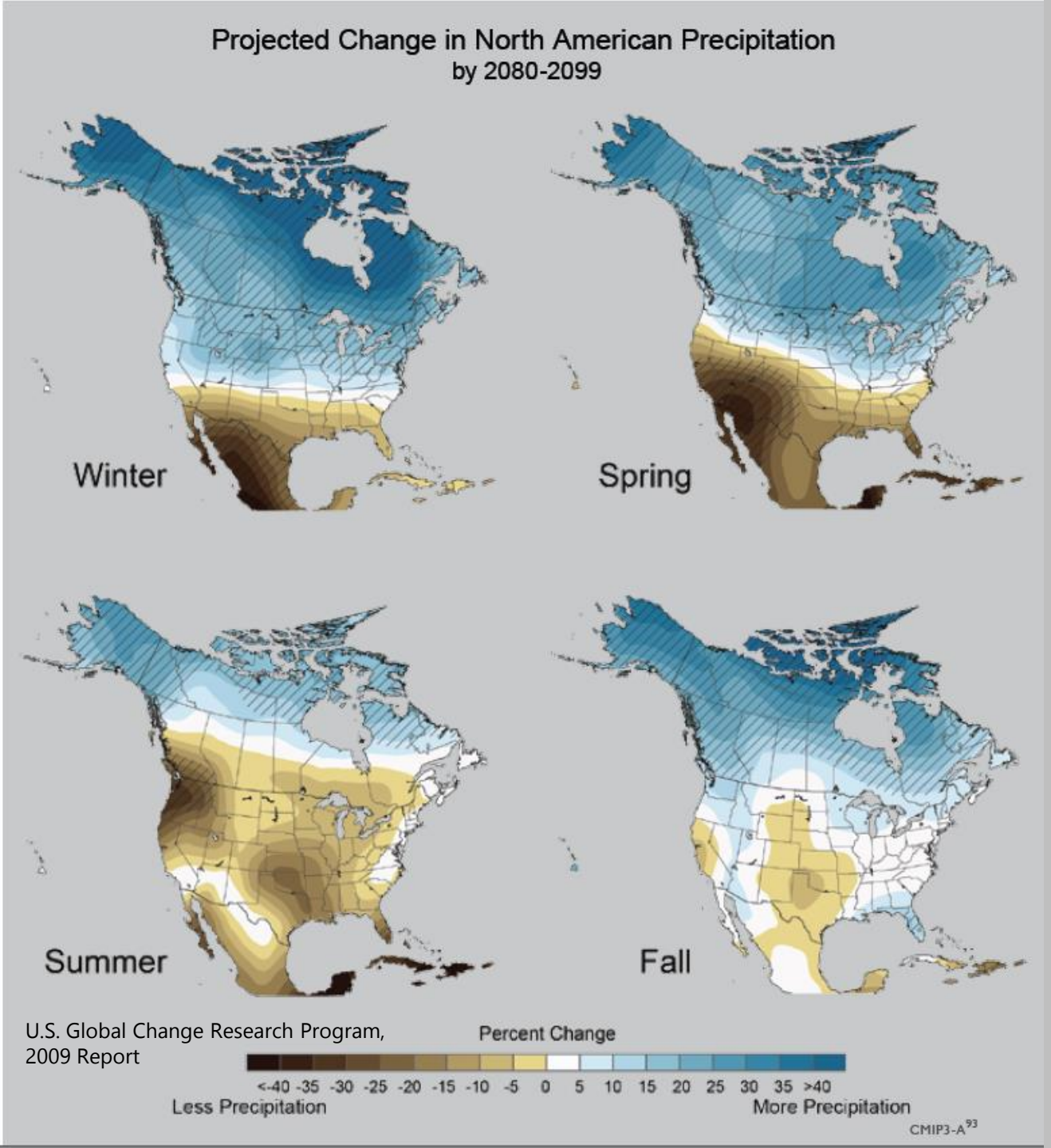


Water Supply Sustainability Risk Index (2050)

- Extreme (412)
- High (608)
- Moderate (1192)
- Low (929)

Change in Future Water Demand With and Without Climate Change

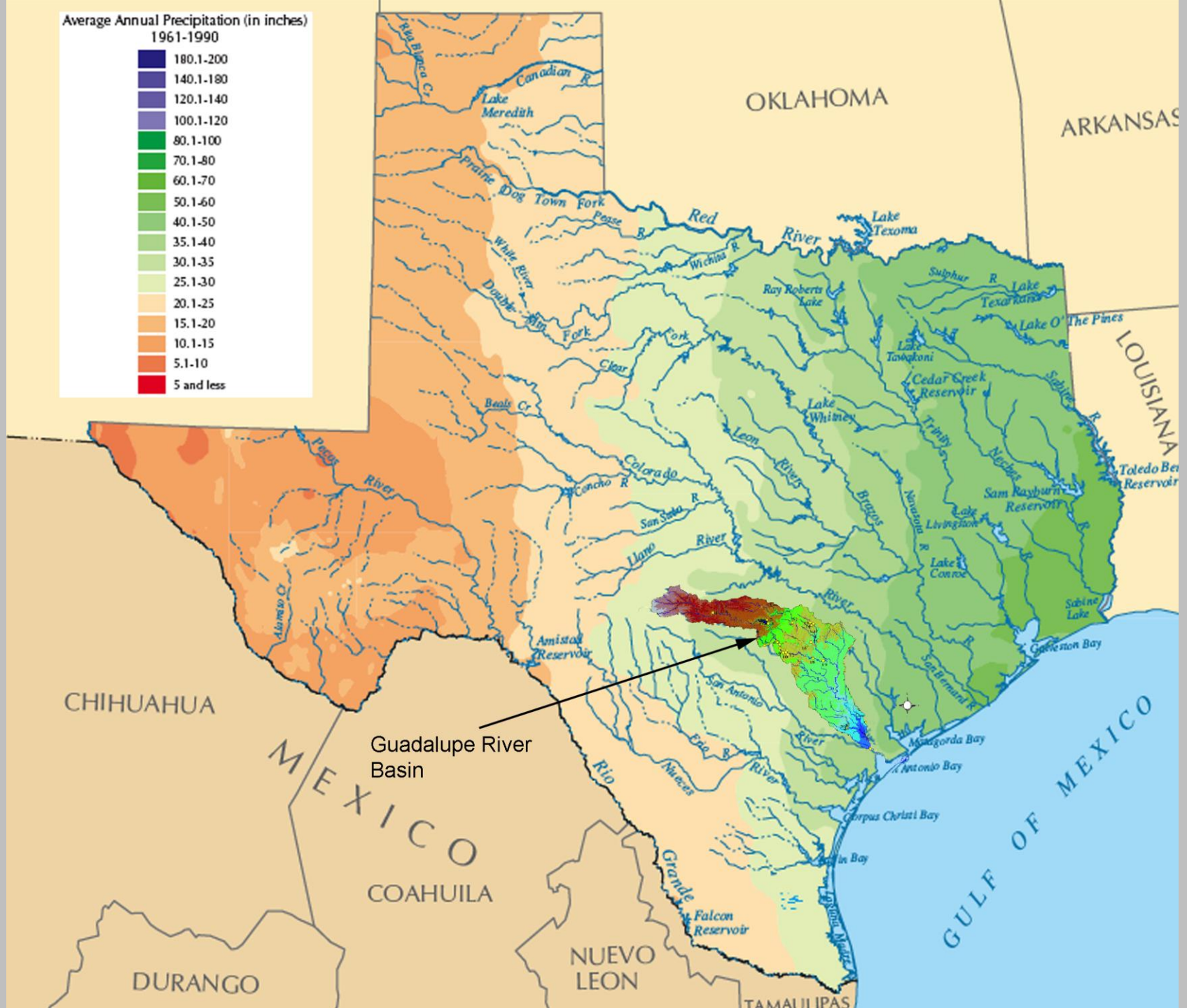




Climate Change - John Nielsen-Gammon
Texas State Climatologist

Texas overall rainfall has increased by about 5-8% over the past century, except for West Texas, which has seen little change.

Climate projections from models are inconsistent and tend to favor a decrease, so the future for Texas precipitation is unclear (though large changes are unlikely).


Average Annual Precipitation (in inches)
1961-1990
180.1-200
140.1-180
120.1-140
100.1-120
80.1-100
70.1-80
60.1-70
50.1-60
40.1-50
35.1-40
30.1-35
25.1-30
20.1-25
15.1-20
10.1-15
5.1-10
5 and less
OKLAHOMA
ARKANSAS
LOUISIANA
CHIHUAHUA
COAHUILA
NUEVO LEON
TAMAULIPAS
DURANGO
MEXICO
GULF OF MEXICO
Guadalupe River Basin
Lake Meredith
Lake Texoma
Ray Roberts Lake
Lake Tawakoni
Cedar Creek Reservoir
Lake Whitney
Sam Rayburn Reservoir
Lake Livingston
Lake Conroe
Amistad Reservoir
Falcon Reservoir
Canadian R.
Red River
Pecos River
Colorado
Brazos
Trinity
Neches
Sabine Lake
Galveston Bay
Matagorda Bay
Corpus Christi Bay
San Antonio River
Nueces
Rio Grande

Conclusions (for the year 2100)

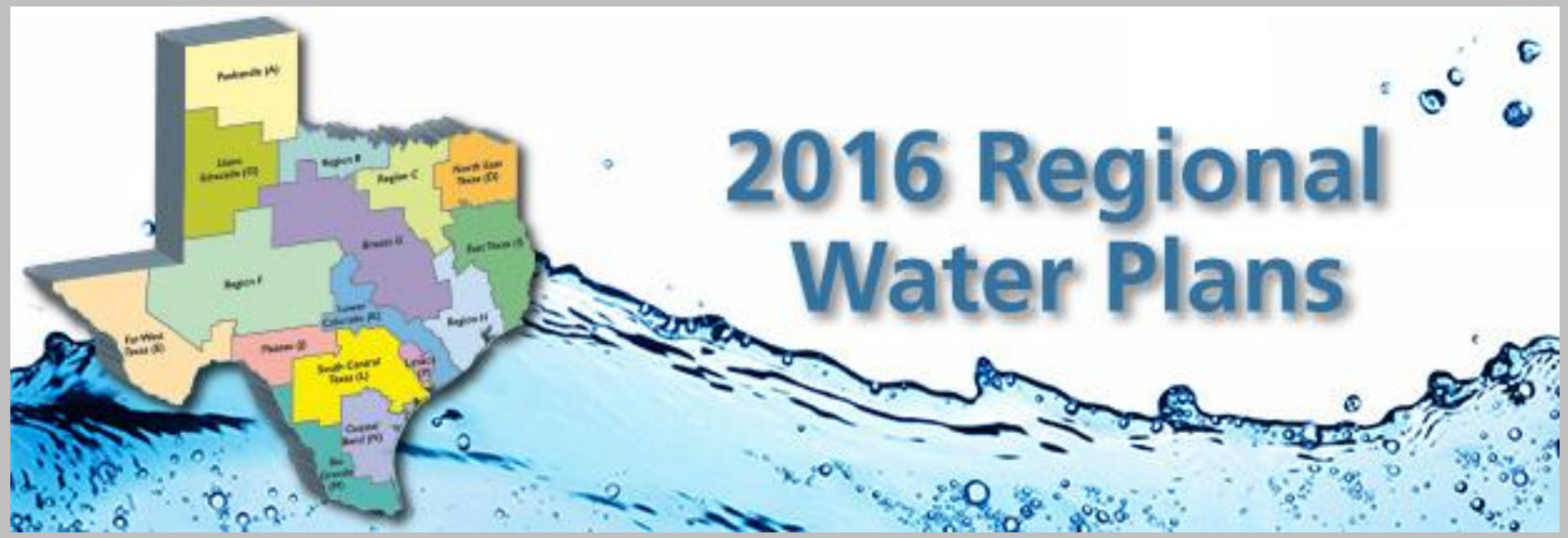
Climate Change Cause

1.River basin temperature changes by >3.5˚ C (6.3˚ F)
2.Inland Precipitation decreases by 15%
3.Coastal temperature changes by 3.0 – 3.5˚ C (5.4-6.3˚ F)

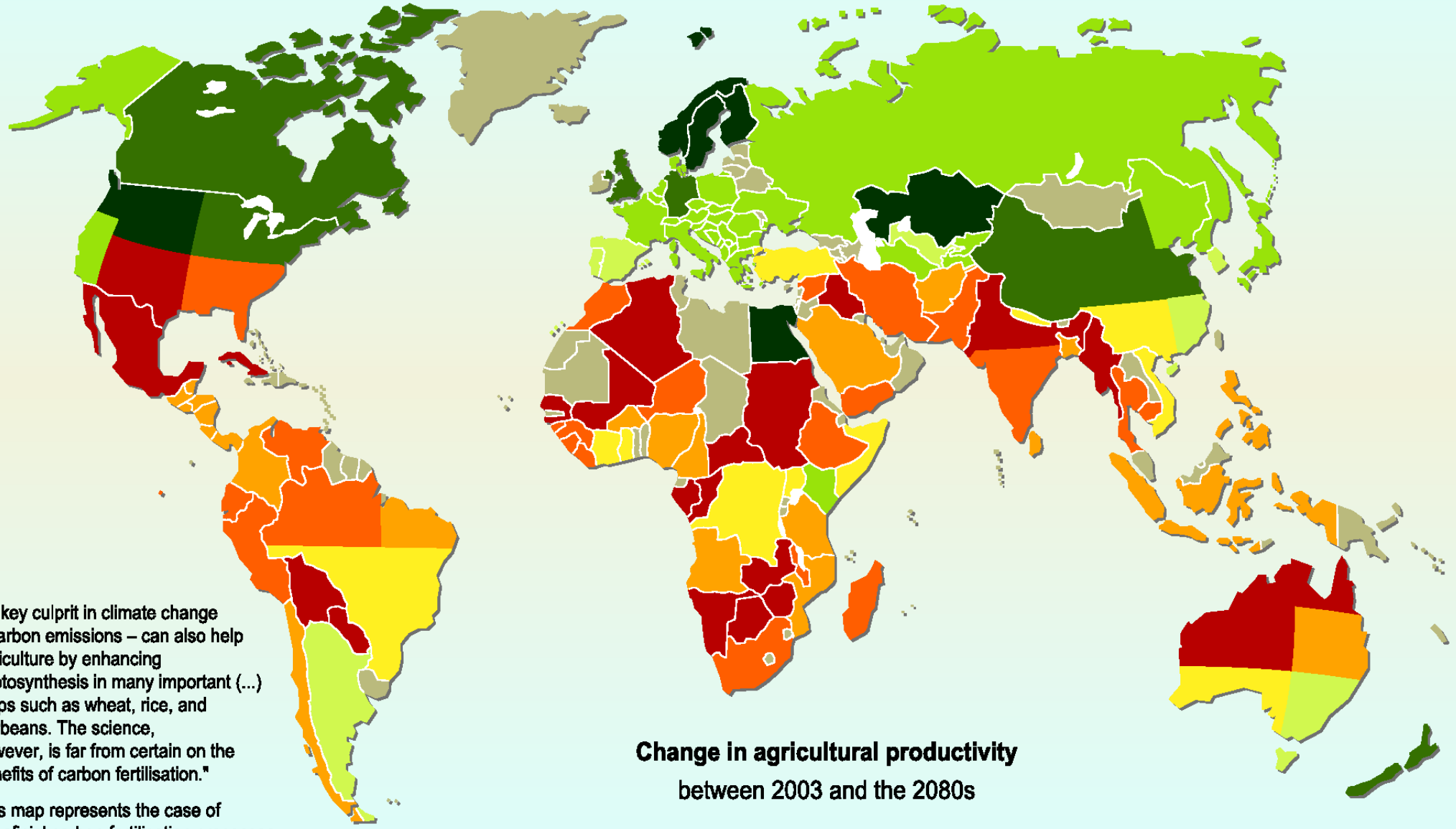
River-Bay System Effect

1.Annual river basin runoff decreases by 7.5%
2.Frequency of years with annual flow less than 1,000 cu ft/sec increases by 35%
3.Average River flow decreases by 120,200 ac ft/yr for the Guadalupe and 42,000 ac ft/yr for the San Antonio River. (Total loss of fresh water to San Antonio Bay is 162,200 ac ft/yr.)
4.Concomitantly, evaporation from San Antonio Bay increases by 108,000 acre ft/yr, resulting in a total fresh water deficit of 270,200 ac ft/yr with respect to current climate conditions.
5.These effects will be near linear in time from the present to the year 2100.

No Serious Consideration of Climate Change



Projected impact of climate change on agricultural yields



" A key culprit in climate change – carbon emissions – can also help agriculture by enhancing photosynthesis in many important (...) crops such as wheat, rice, and soybeans. The science, however, is far from certain on the benefits of carbon fertilisation."

This map represents the case of beneficial carbon fertilisation processes.

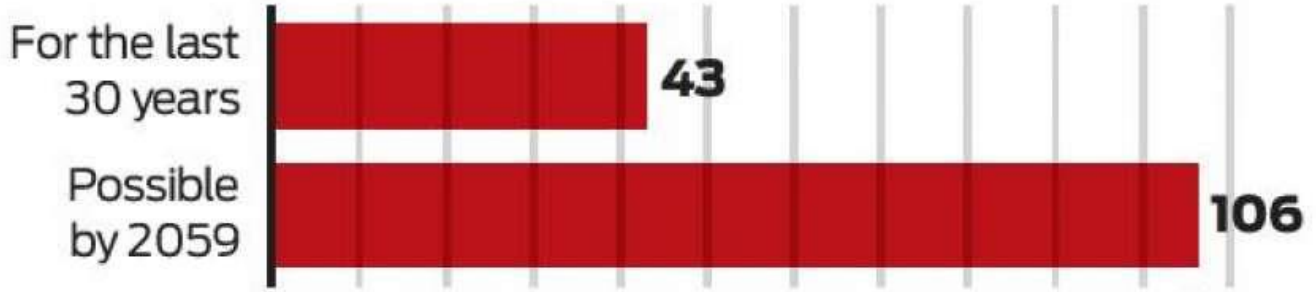
Source: Cline W., 2007, *Global Warming and Agriculture*.

Climate-related troubles in Texas

A report released by the Risky Business Project states that:

- By 2020-2039, extreme heat driven by climate change likely will claim more than 2,570 additional lives each year in Texas — the highest total number of heat-related deaths for any state.

- Days per year of temperatures above 95° F. in Texas



- By midcentury, heat-related labor productivity will decline, likely costing the economy up to $12.5 billion statewide each year.

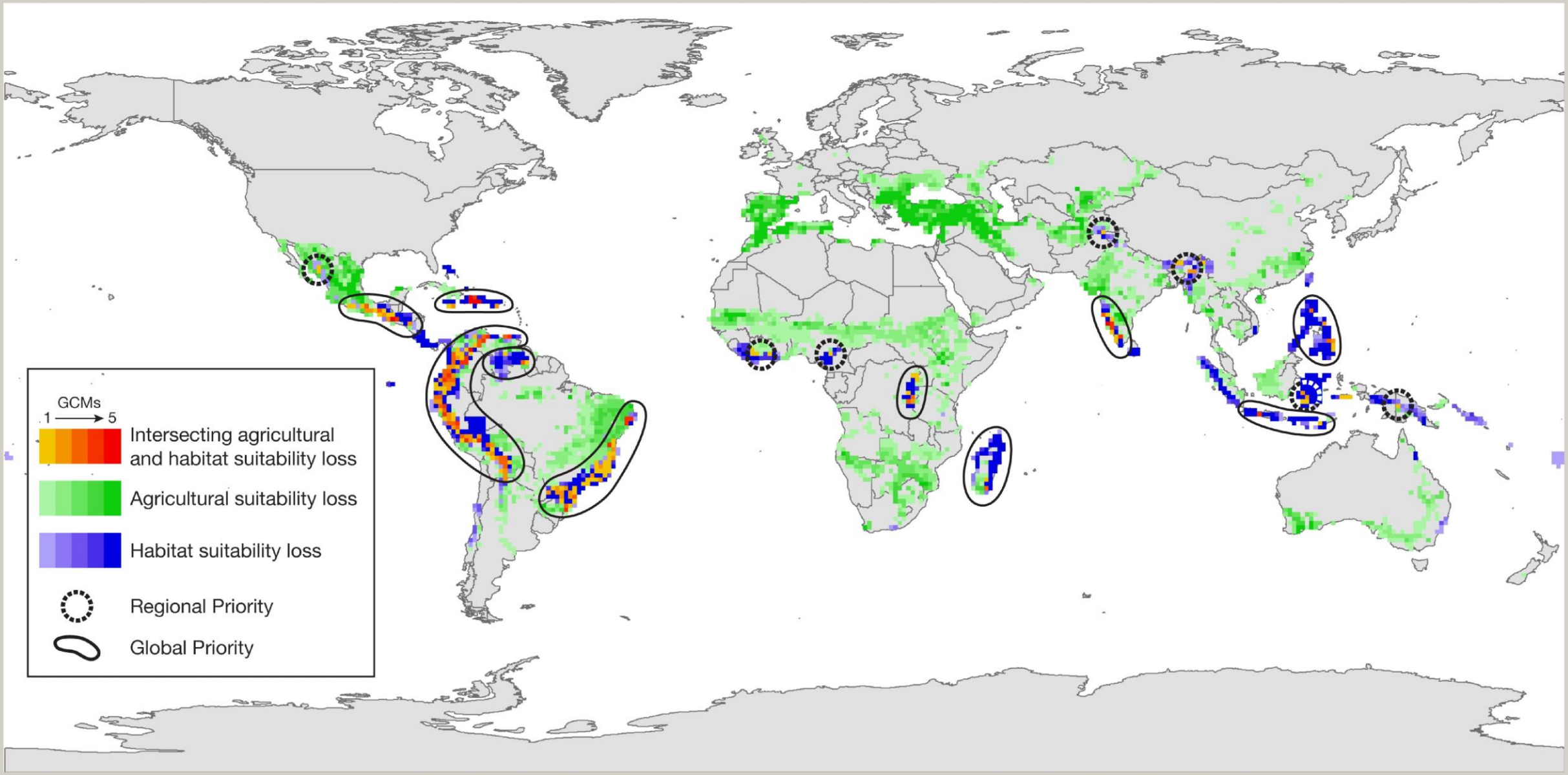
- Without significant agricultural adaptation, corn yields likely will decrease by as much as 22% by 2020-2039.

22% corn yield decrease

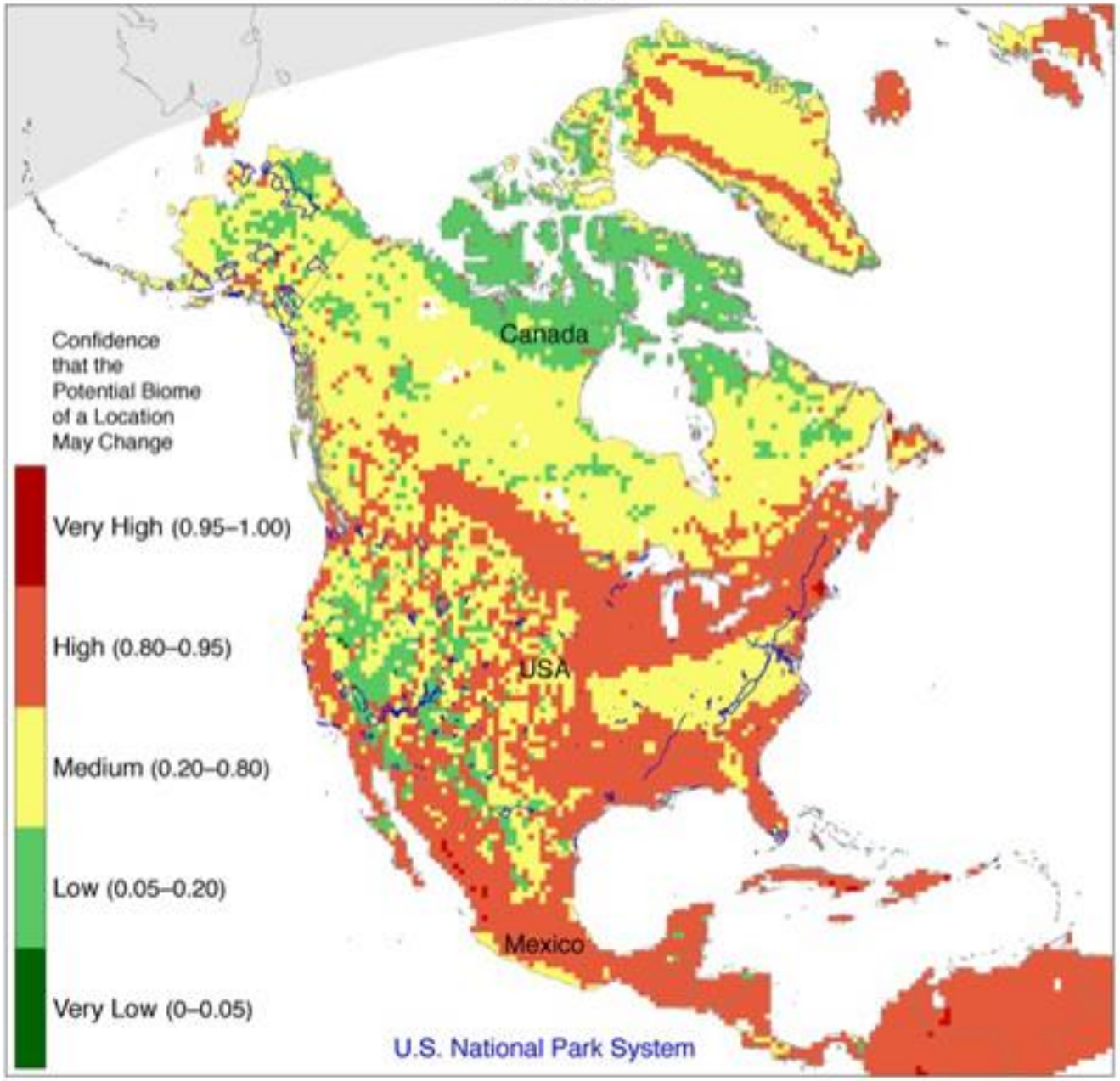
- Workers in agriculture, construction and manufacturing are among the most vulnerable to higher temperatures and declining productivity.

Source: Risky Business Project

San Antonio Express-News

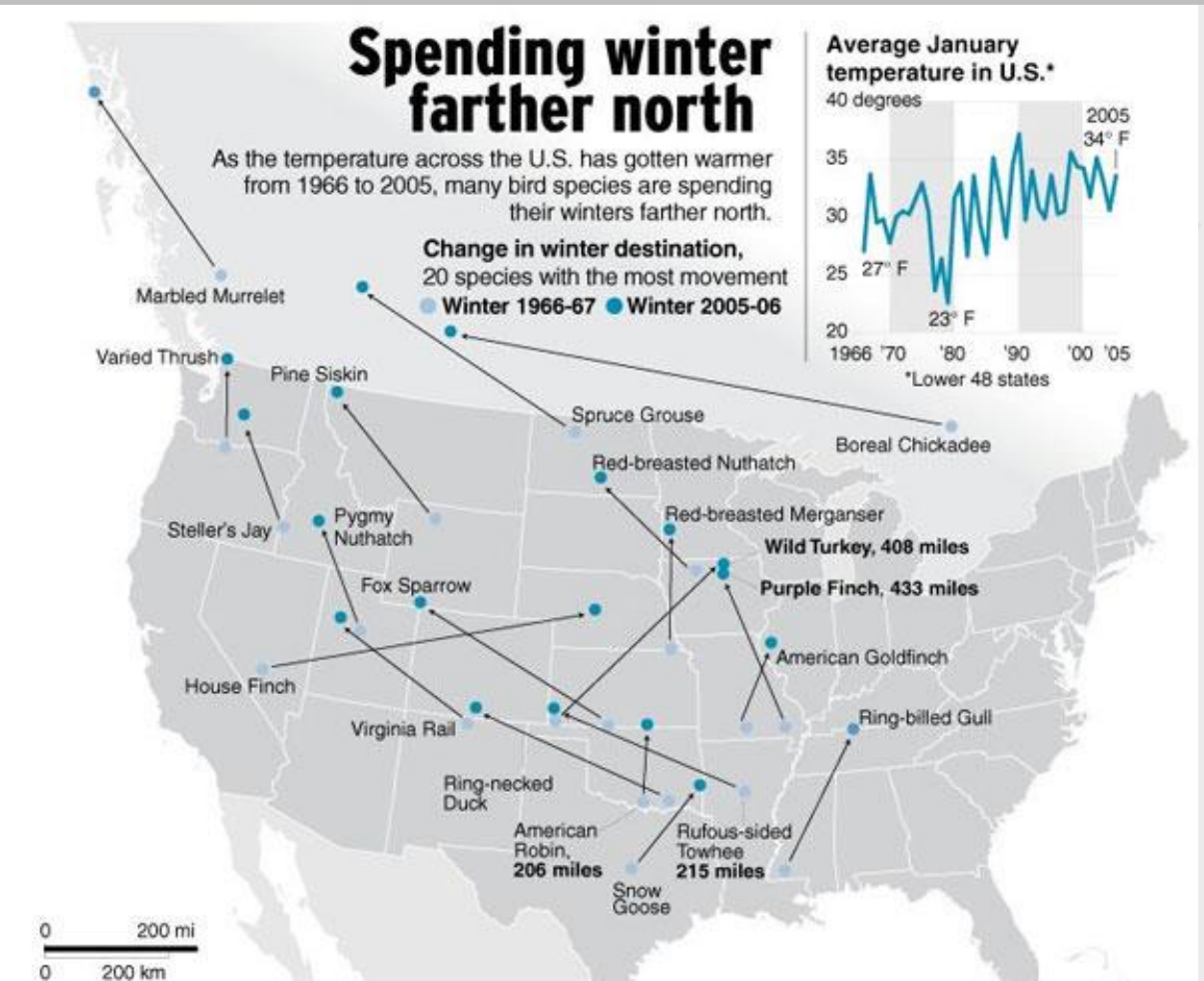

GCMs
1
5
Intersecting agricultural and habitat suitability loss
Agricultural suitability loss
Habitat suitability loss
Regional Priority
Global Priority

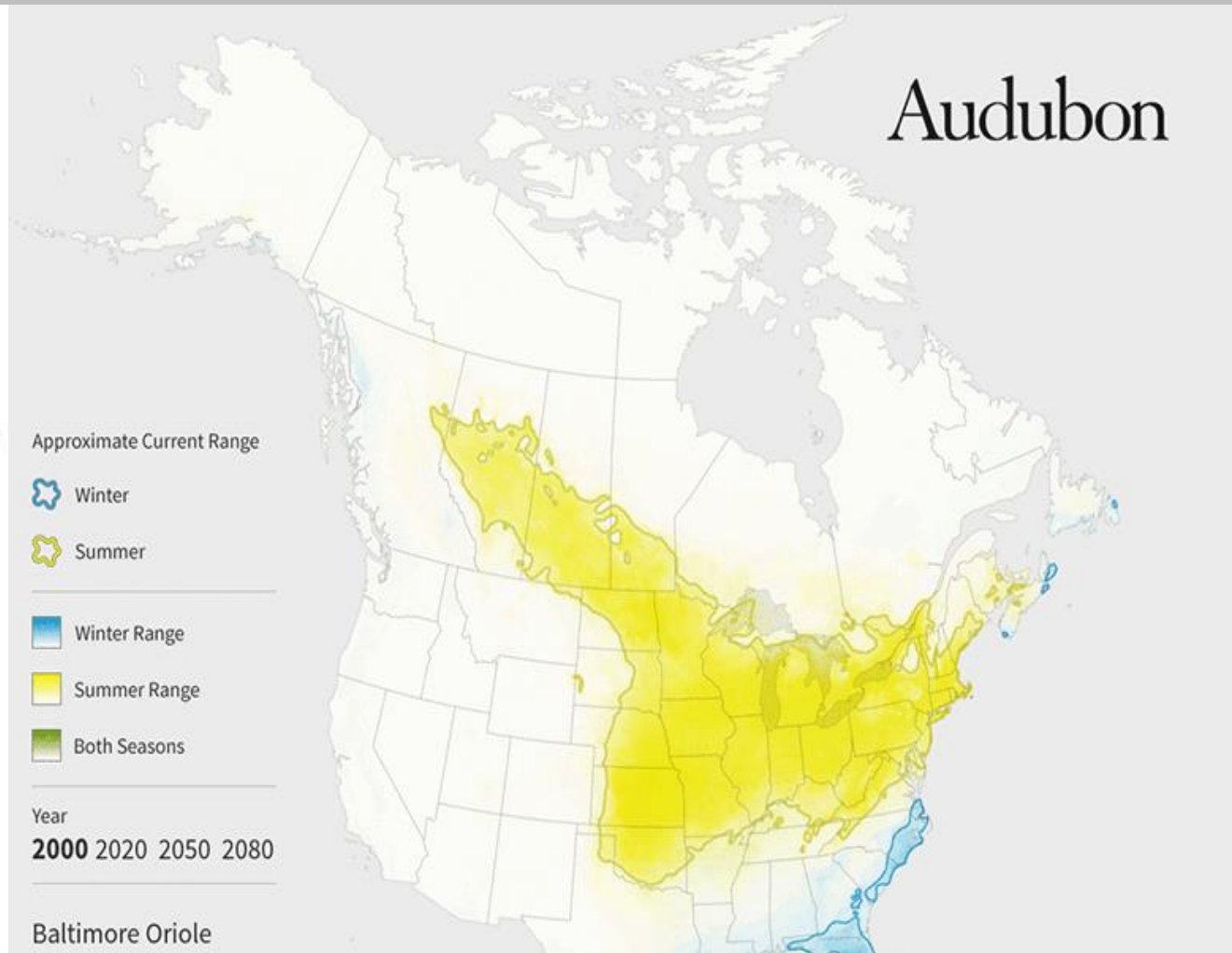
Vulnerability to Biome Shifts due to Climate Change, as Mediated by Habitat Intactness
1990-2100

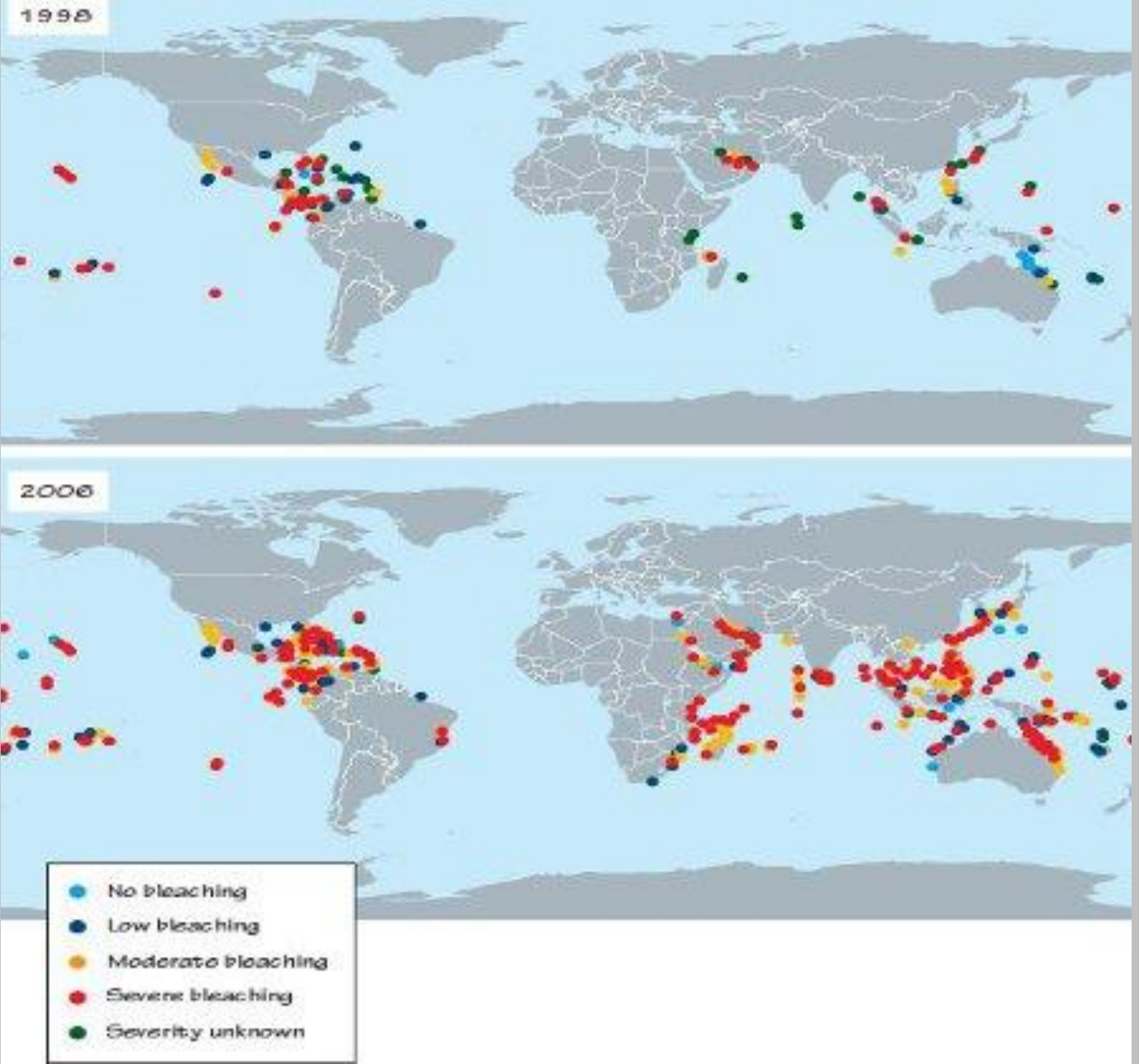


Eigenbrod, F., P. Gonzalez, J. Dash, and I. Steyl. 2014. Vulnerability of ecosystems to climate change moderated by habitat intactness. Global Change Biology. doi: 10.1111/gcb.12669.

Bird Migration Affected By Climate Change



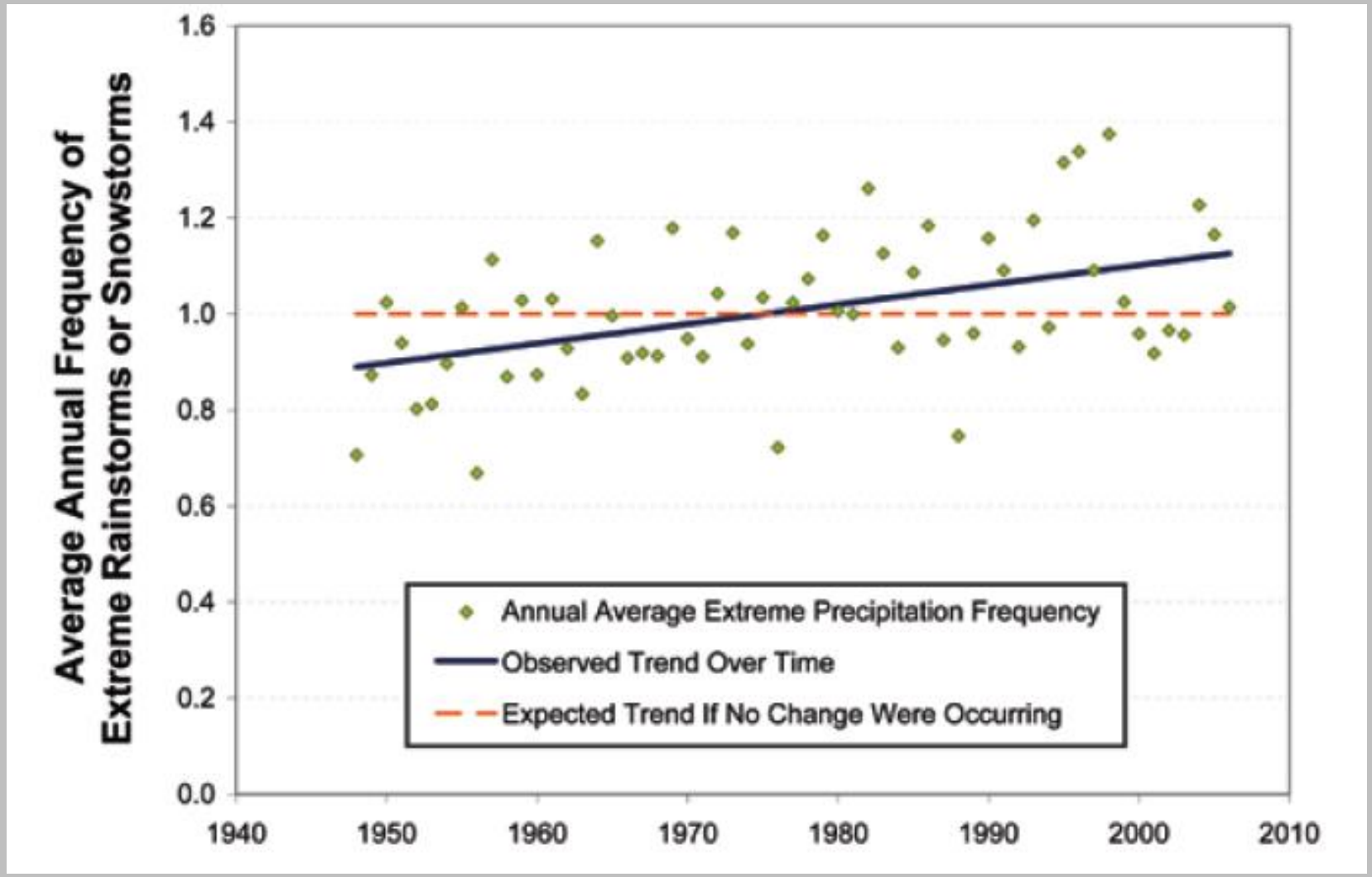




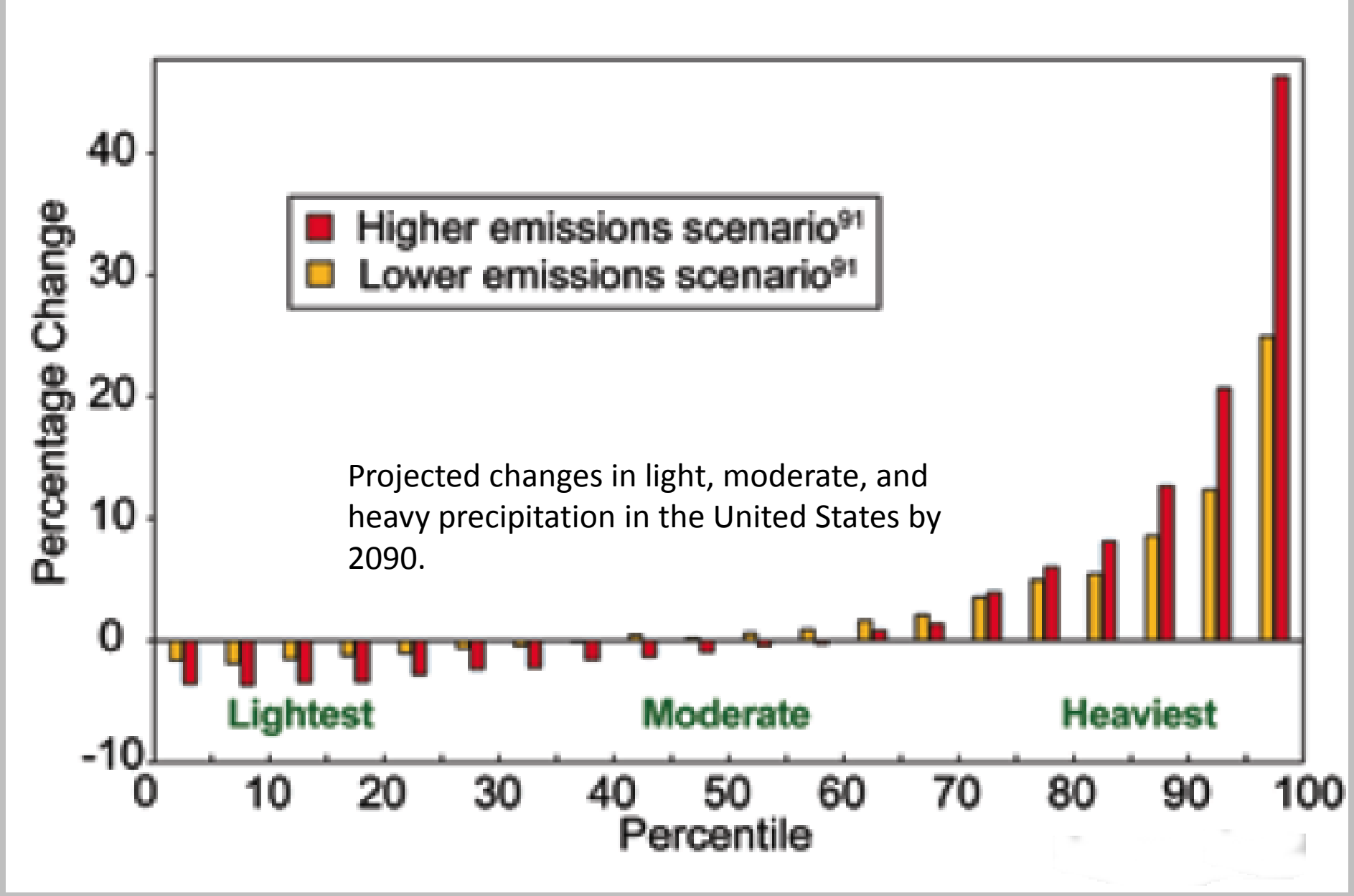
Status Report on Coral Bleaching Around the World 1998, 2006

Climate Change - John Nielsen-Gammon Texas State Climatologist

- Texas frequency of extreme daily rainfall has increased by about 20% over the past century.
- Extreme rainfall is more robustly connected to global climate change than is total rainfall, and that trend should be expected to continue also.

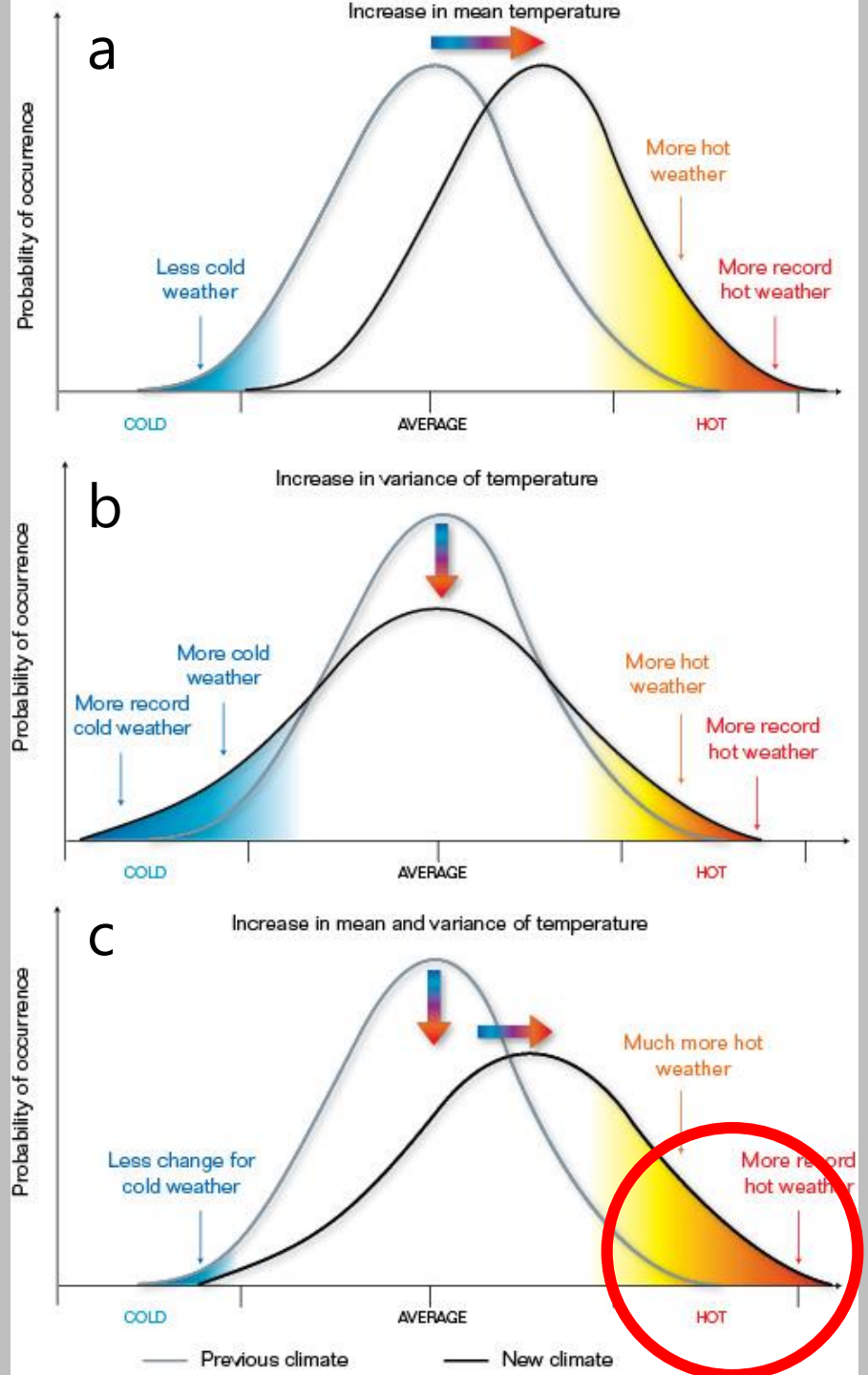


Annual average frequency of storms with extreme precipitation in the United States from 1948–2006. Analysis of the slope of this graph shows that storms with extreme levels of precipitation have increased in frequency by 24 percent across the continental United States over this time period. With 95 percent confidence from the t-test, the average increase in extreme precipitation frequency lies between 22 and 26%



Projected changes in light, moderate, and heavy precipitation in the United States by 2090.

Projected changes in light, moderate, and heavy precipitation in the United States by 2090.



How will climate change manifest itself?

Consider a weather event with a temperature probability given by the left hand curve in a. Notice the low probability of a hot event.

Consider that climate change has shifted the entire curve to the right because of increased amounts of energy in the atmosphere. Now notice the increased probability of a hot event.

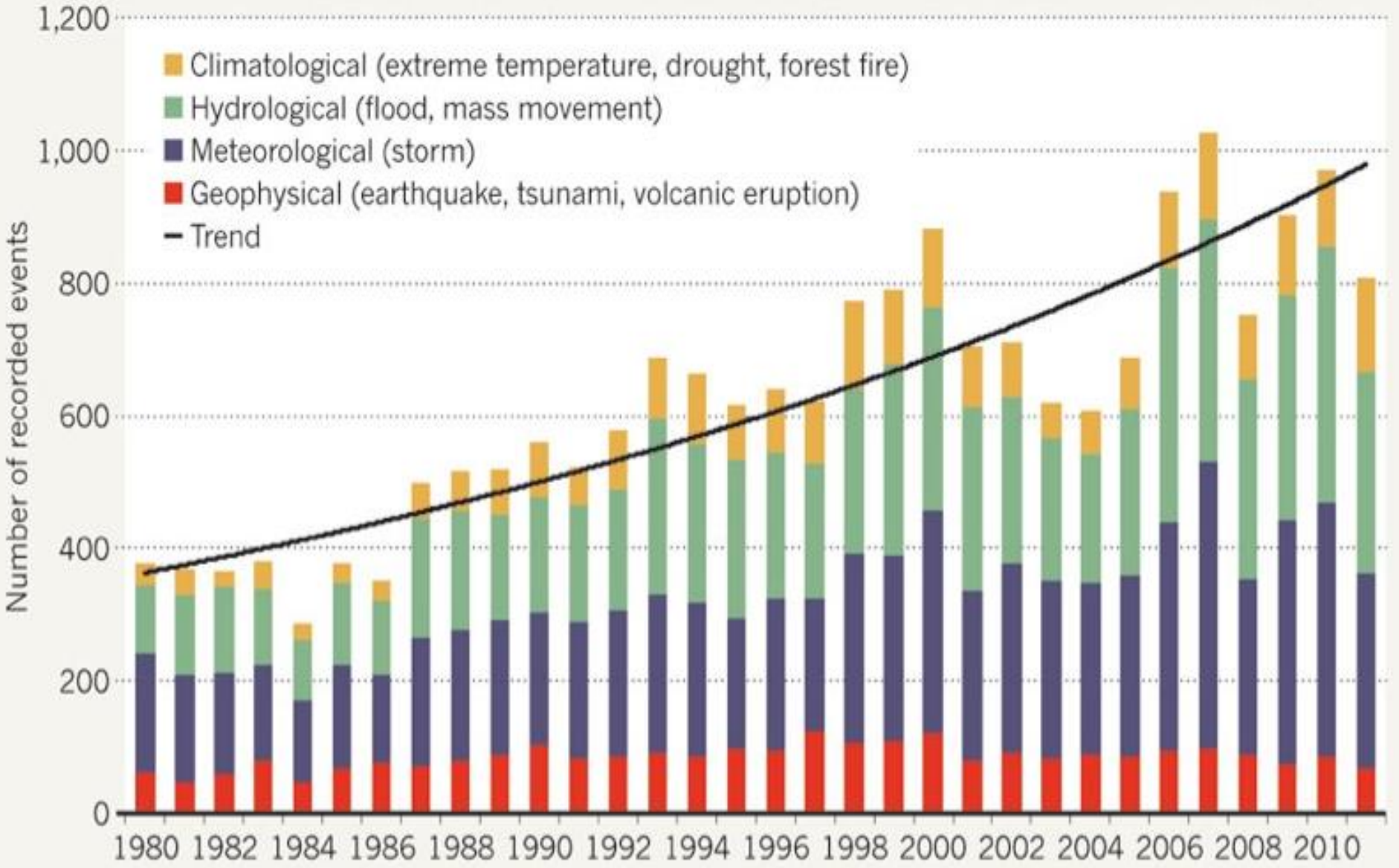
Climate change may change the probability distribution in other ways as shown in b and c.

Regardless, the probability of a hot event becomes greater.

CATASTROPHE COUNT

Munich Re

An increase in severe storms is helping to drive up the number of recorded disasters, but this cannot be conclusively attributed to climate change.



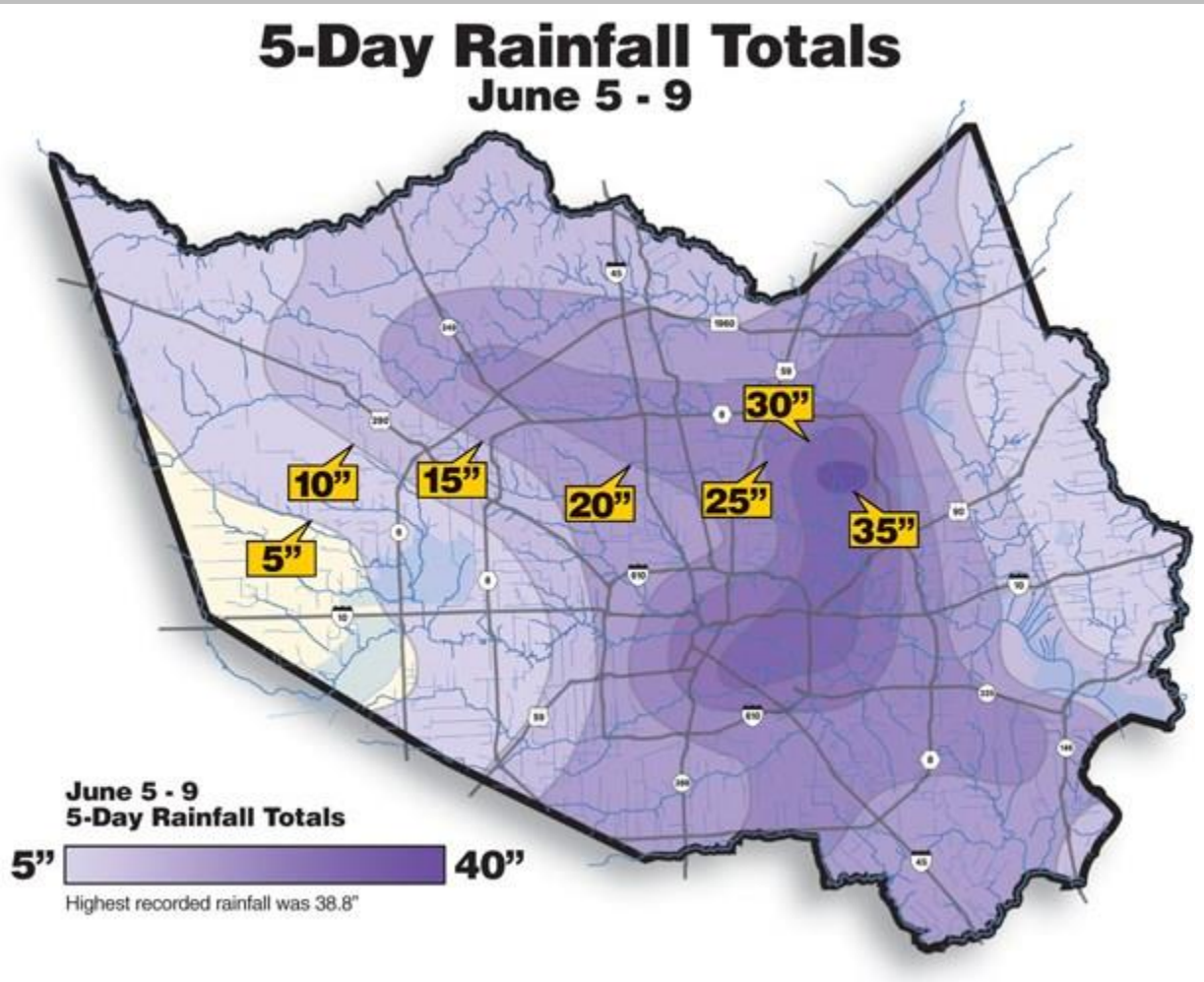
OFF THE CHARTS

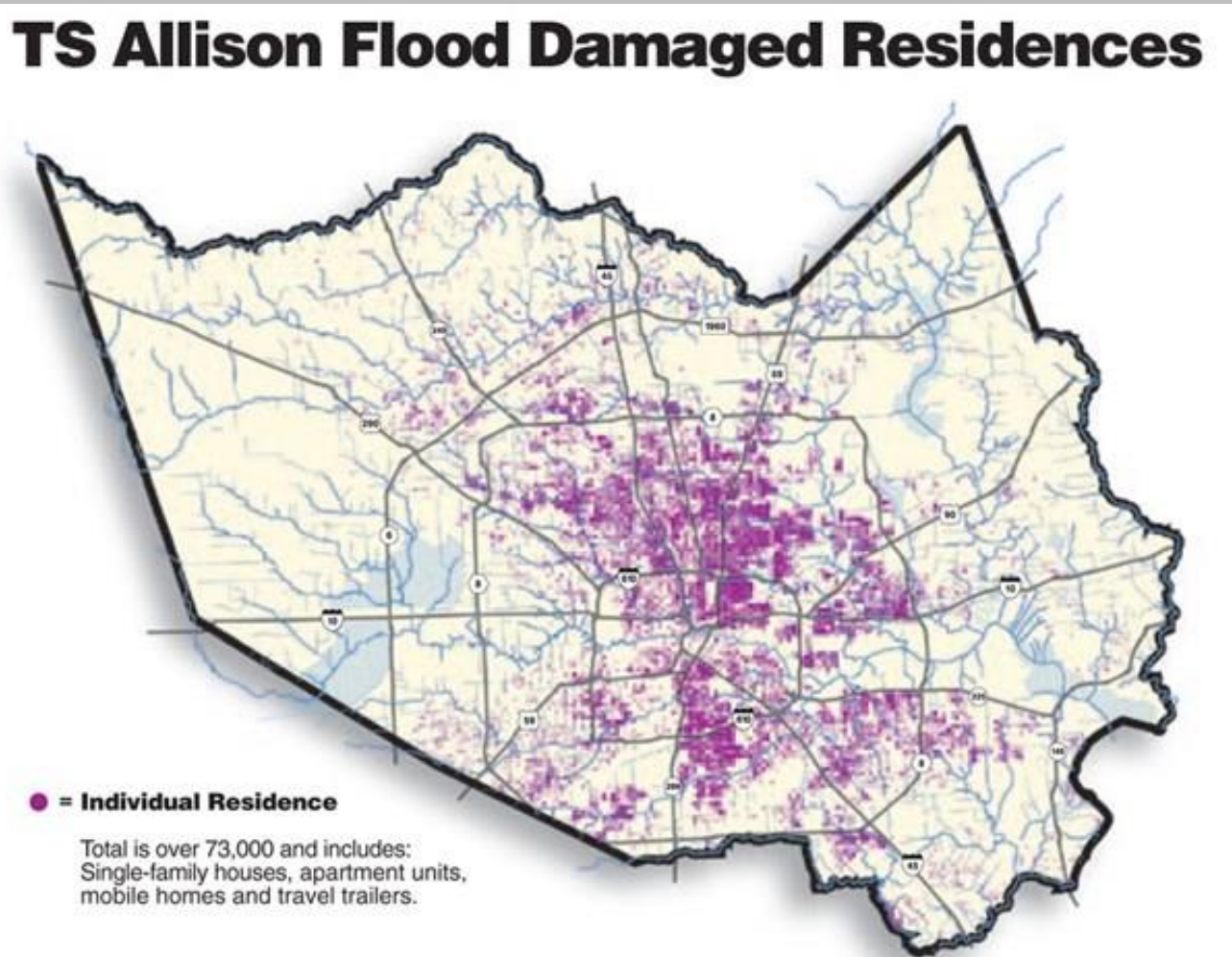
TROPICAL STORM ALLISON PUBLIC REPORT

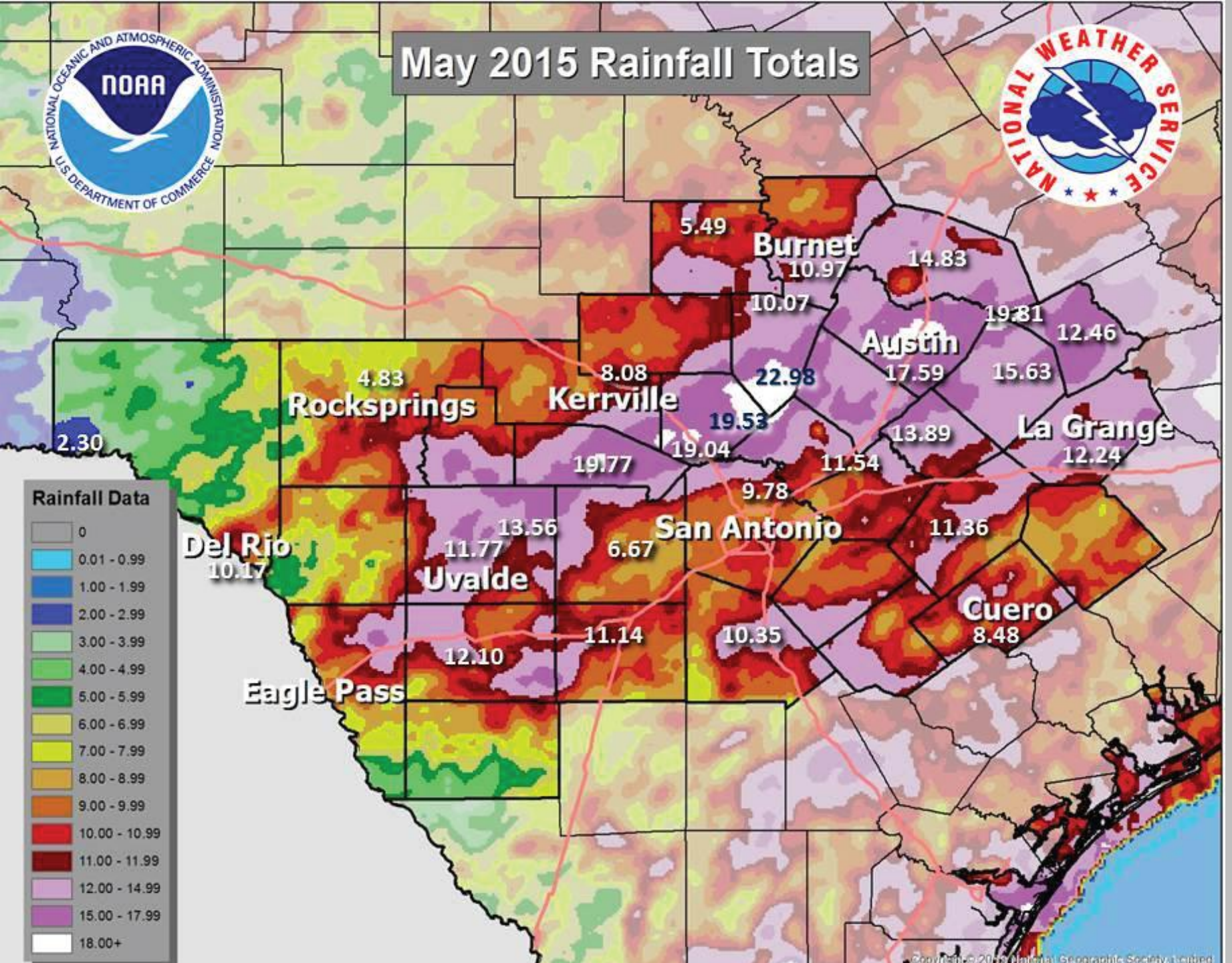
UNPRECEDENTED DAMAGE
UNPRECEDENTED RELIEF
UNPRECEDENTED RECOVERY

Harris County Flood Control District

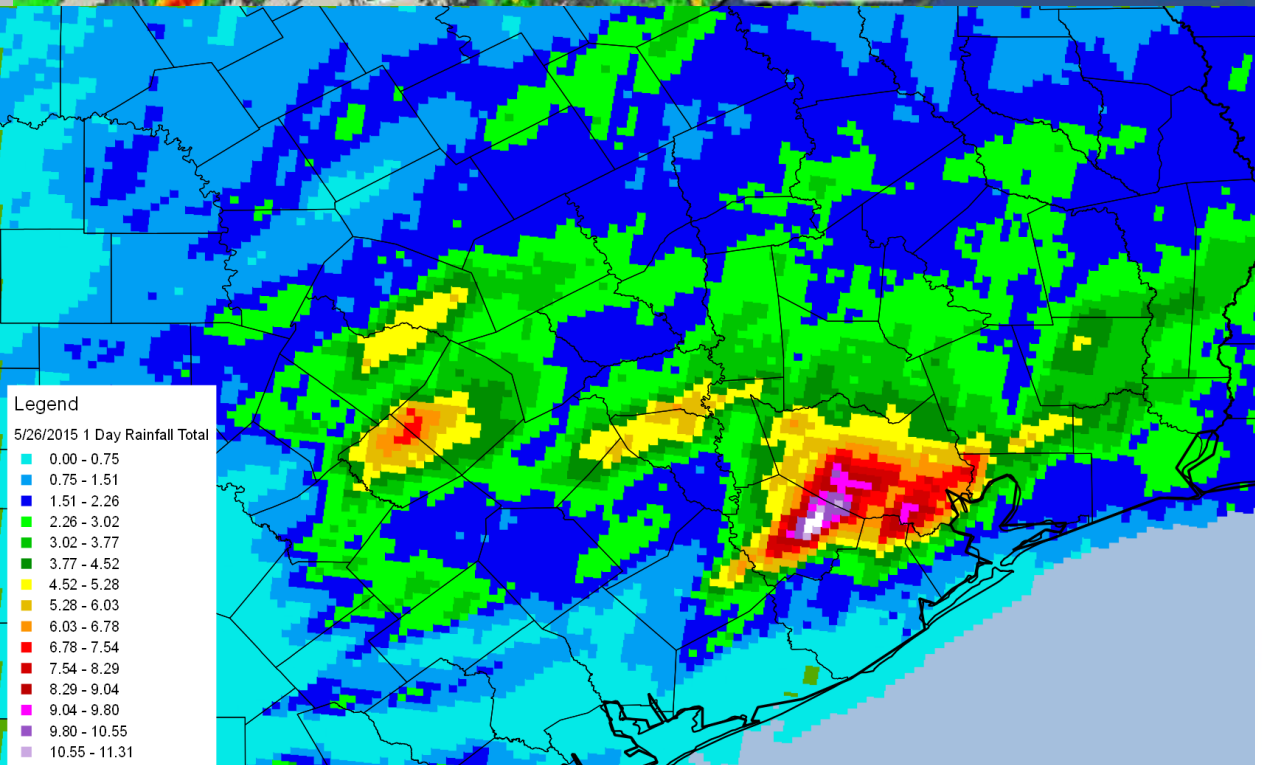
Tropical Storm Allison

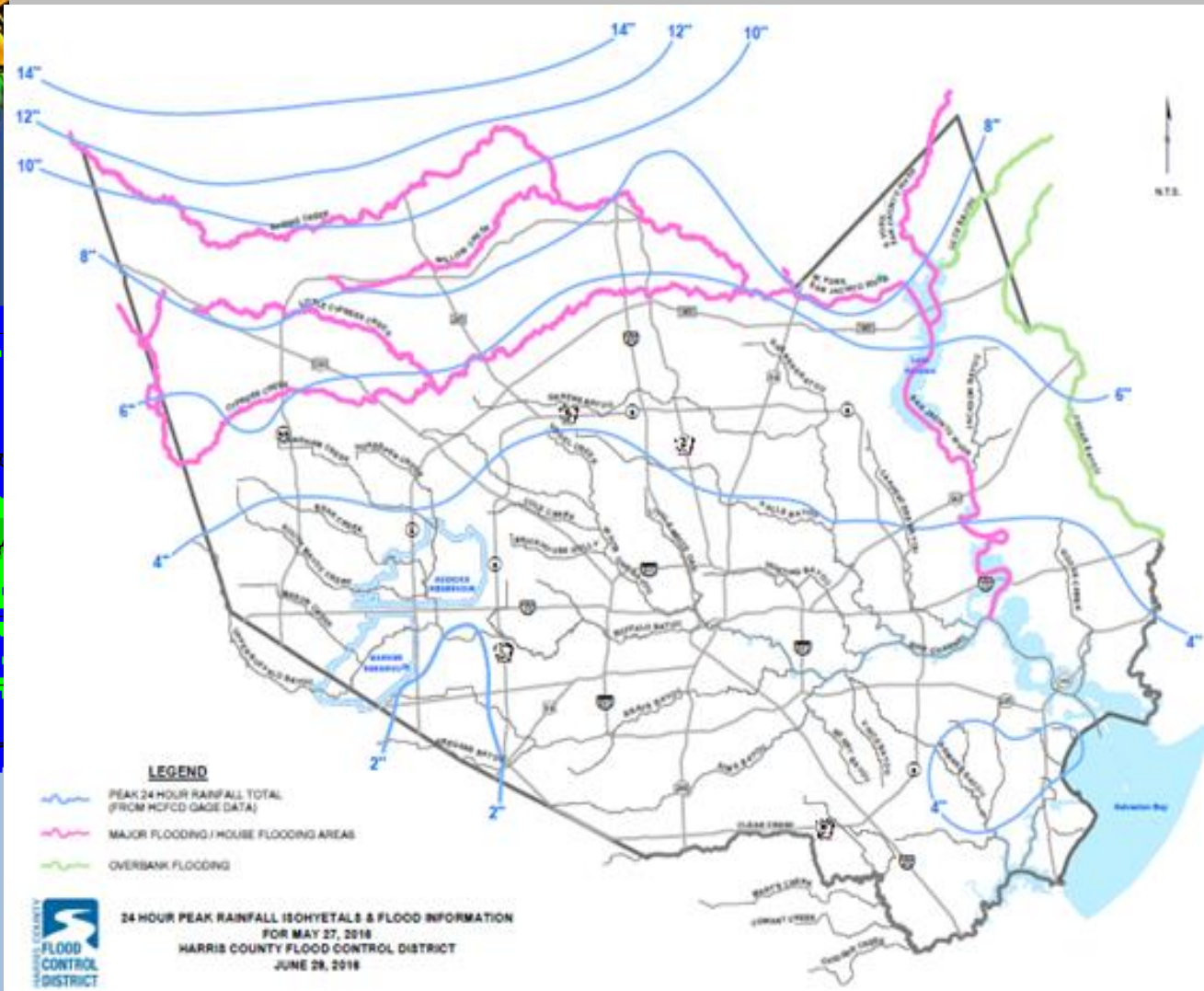





May 2015 Rainfall Totals
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
NATIONAL WEATHER SERVICE
Rainfall Data
0
0.01 - 0.99
1.00 - 1.99
2.00 - 2.99
3.00 - 3.99
4.00 - 4.99
5.00 - 5.99
6.00 - 6.99
7.00 - 7.99
8.00 - 8.99
9.00 - 9.99
10.00 - 10.99
11.00 - 11.99
12.00 - 14.99
15.00 - 17.99
18.00+
5.49
Burnet
10.97
14.83
10.07
19.81
12.46
Austin
17.59
15.63
4.83
Rocksprings
8.08
Kerrville
22.98
19.53
19.04
13.89
La Grange
12.24
2.30
19.77
11.54
9.78
San Antonio
13.56
11.36
Del Rio
10.17
11.77
6.67
Uvalde
Cuero
8.48
11.14
10.35
12.10
Eagle Pass

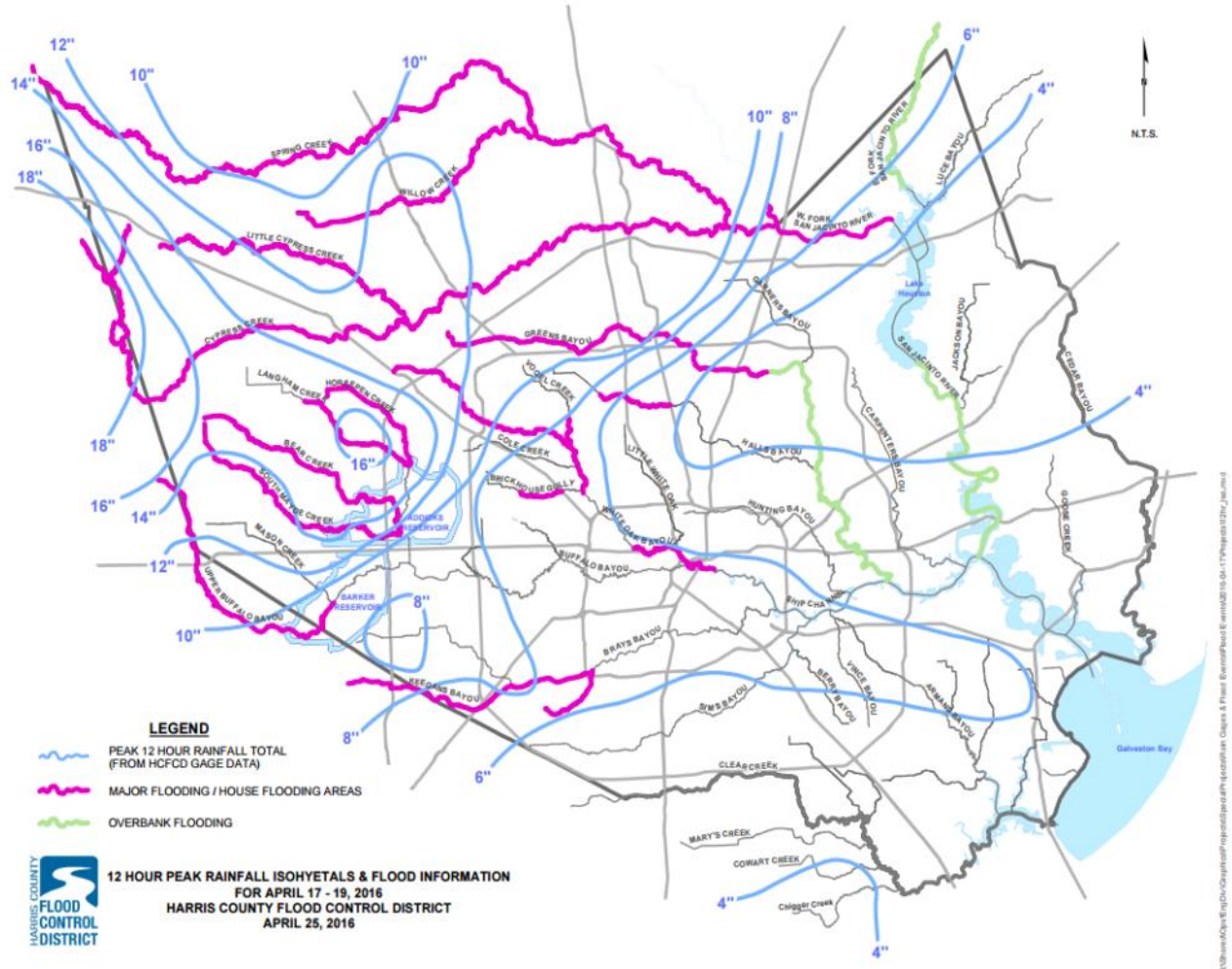
Memorial Day Flood 2015





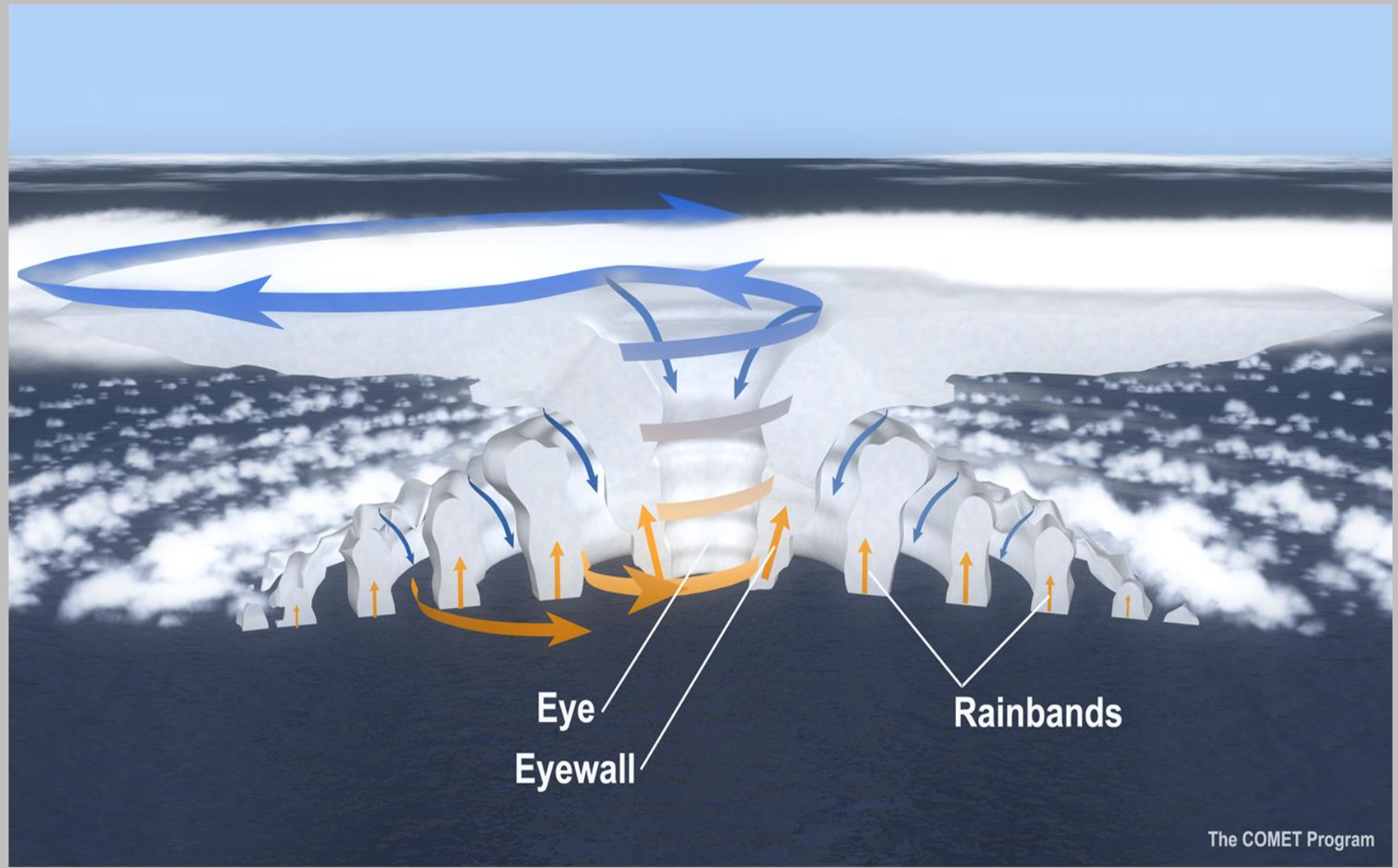
Tax Day Flood
April 2016

Location	Rainfall	Duration	Extrapolated Return Frequency
Pattison (Waller County)	23.50 in	14.5-hr	~ 10,000 yr (0.01%)
Pattison (Waller County)	21.93 in	24-hr	~ 2,000 yr (0.05%)
Monaville (Waller County)	19.30 in	10-hr	~ 2,500 yr (0.04%)
Mound Creek at Mathis	16.70 in	12-hr	~ 1,000 yr (0.1%)
Langham Creek at W Little York	16.60 in	12-hr	~ 900-yr (0.11%
Cypress Creek at Sharp Rd	16.10 in	12-hr	~ 900-yr (0.11%
Langham Creek at Longenbaugh	15.70 in	12-hr	~ 700-yr (0.14%)
Cypress Creek at Katy Hockley	15.10 in	12-hr	~ 600-yr (0.17%)

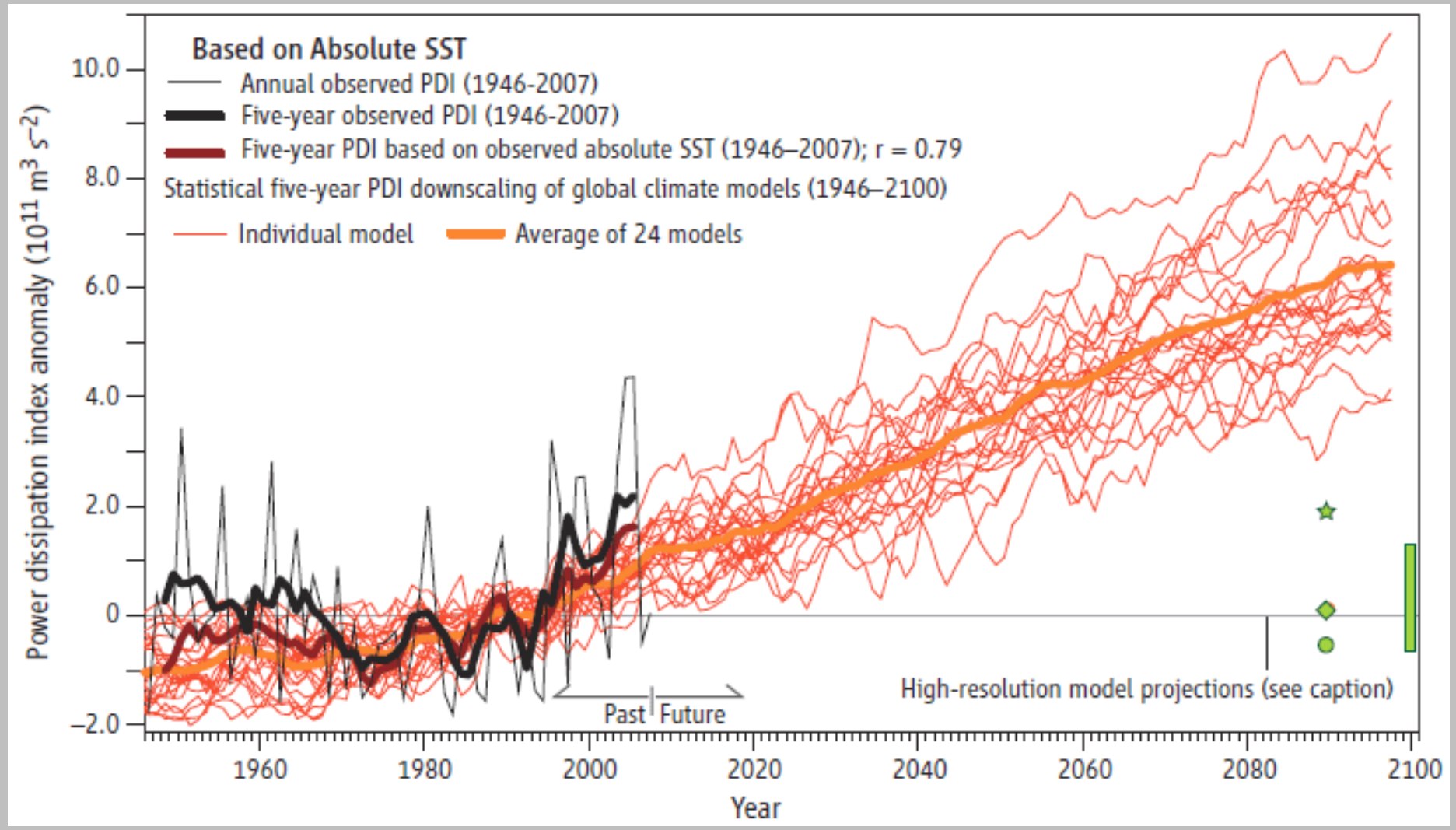


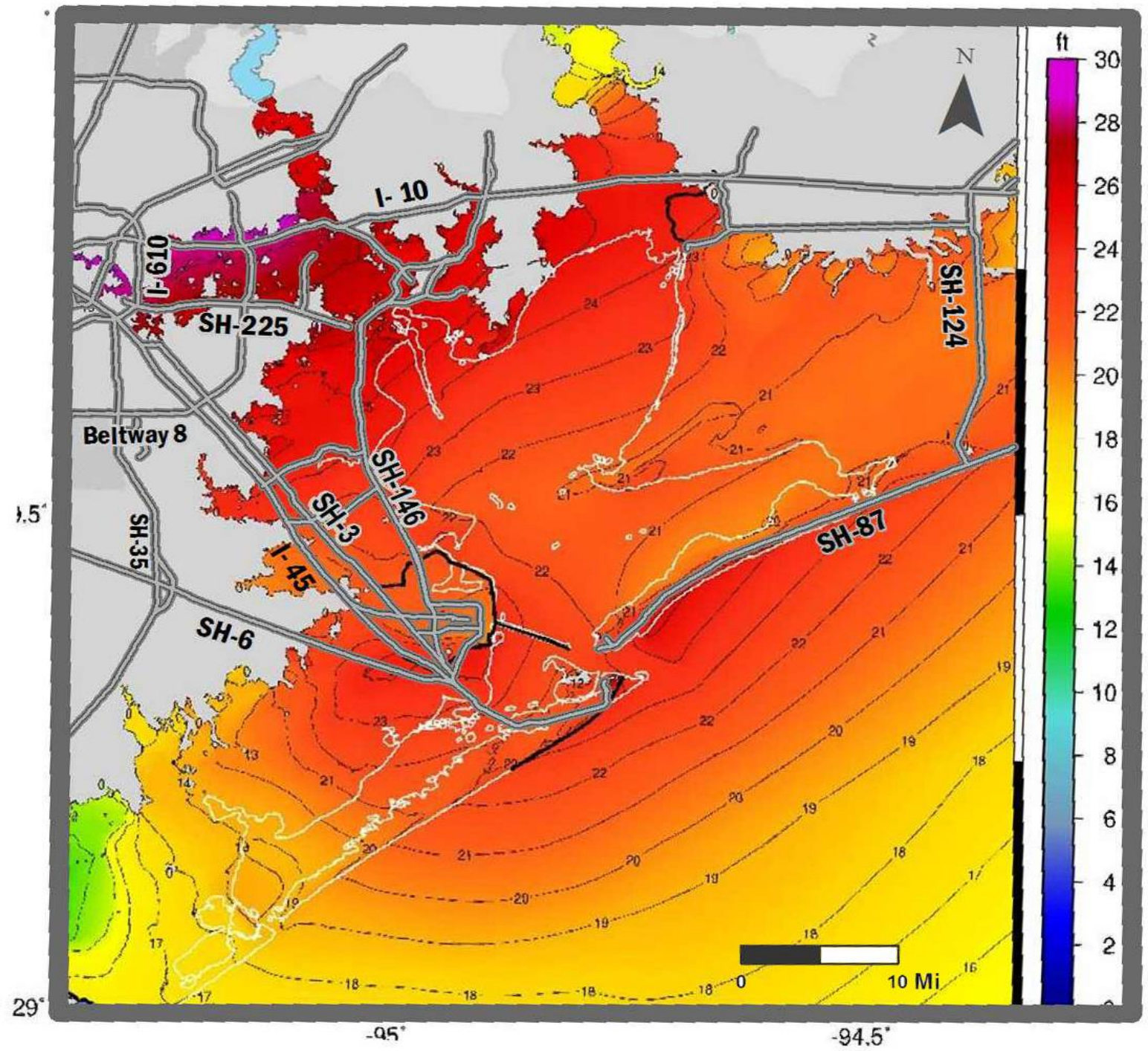
Watershed	Bridge	Gage Elevation	Flood Frequency	Previous Record	Previous Record Date
Cypress Creek	Huffmeister	132.79	~0.2%(500-yr)	131.63	Oct. 1998
Cypress Creek	Eldridge	128.71	~0.2%(500-yr)	126.10	Oct. 1994
Cypress Creek	Grant	127.52	~0.2%(500-yr	125.40	Oct. 1994
Cypress Creek	SH 249	120.51	~1%(100-yr)	120.50	June 2001
Cypress Creek	Stuebner-Airline	110.02	~1%(100-yr)	109.70	June 2001
Cypress Creek	Kuykendahl	101.35	~2%(50-yr)	101.30	May 1989
Langham Creek	W Little York	112.84	~0.2%(500-yr)	110.70	April 2009
Lt Cypress Creek	Becker	197.62	~1%(100-yr)	197.20	July 2012
Lt Cypress Creek	Cypress Rosehill	161.62	~0.2%(500-yr)	160.40	July 2012
Lt Cypress Creek	Kluge	136.84	~0.2%(500-yr)	136.30	Oct. 1994
S Mayde Creek	Peek	141.36	~10%(10-yr)	142.90	Oct. 1998
S Mayde Creek	Morton	123.74	~2%(50-yr)	118.62	Sept. 2008
Bear Creek	Clay	114.86	~0.2%(500-yr)	114.40	April 2009
Horsepen Creek	Trailside	118.50	~1%(100-yr)	112.80	Oct. 2009
Cane Island	Hwy 90	137.88	~1%(100-yr)	134.30	April 2009
Mason Creek	Prince Creek	106.30	~1%(100-yr)	106.10	April 2009

Hurricane Heat Pump



Sea surface temperature and PDI - Power Dissipation Index



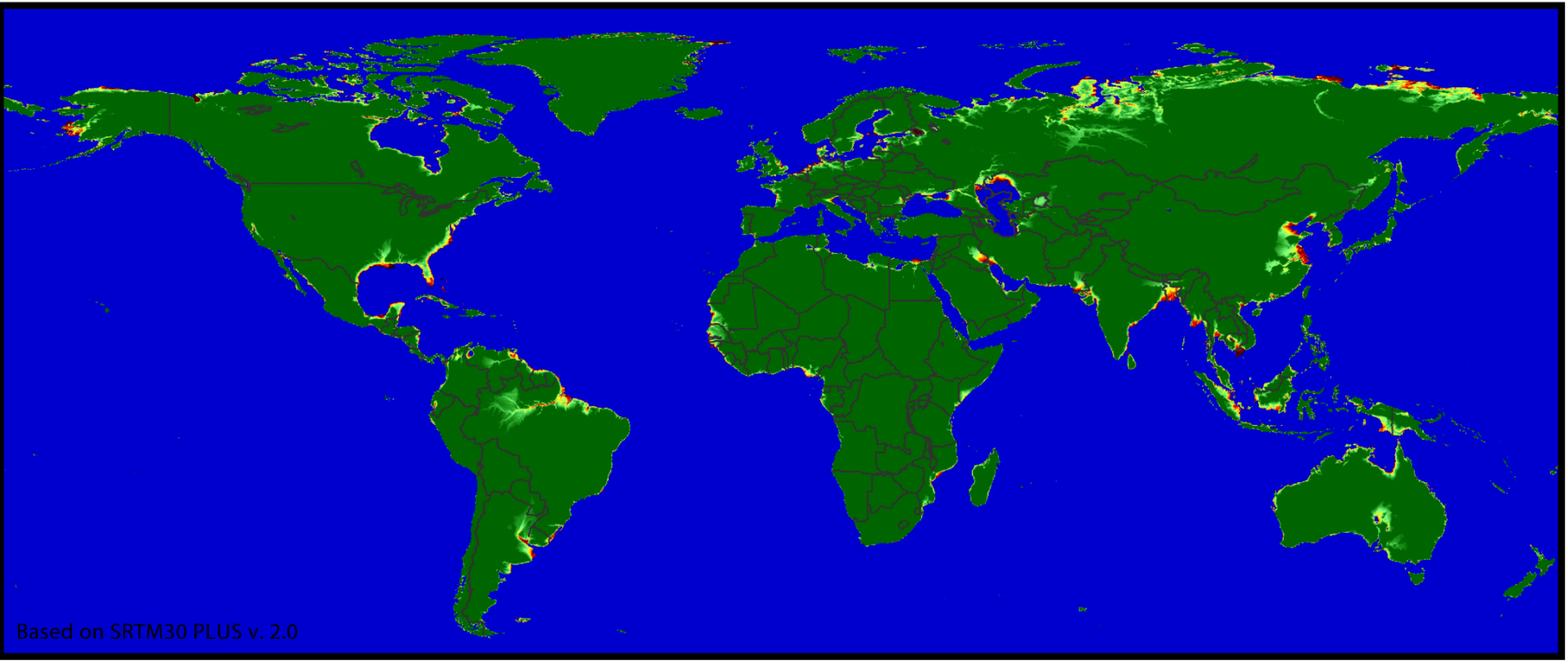


FEMA Storm #36

250 Year Storm Event

Sea Level Rise to 2085

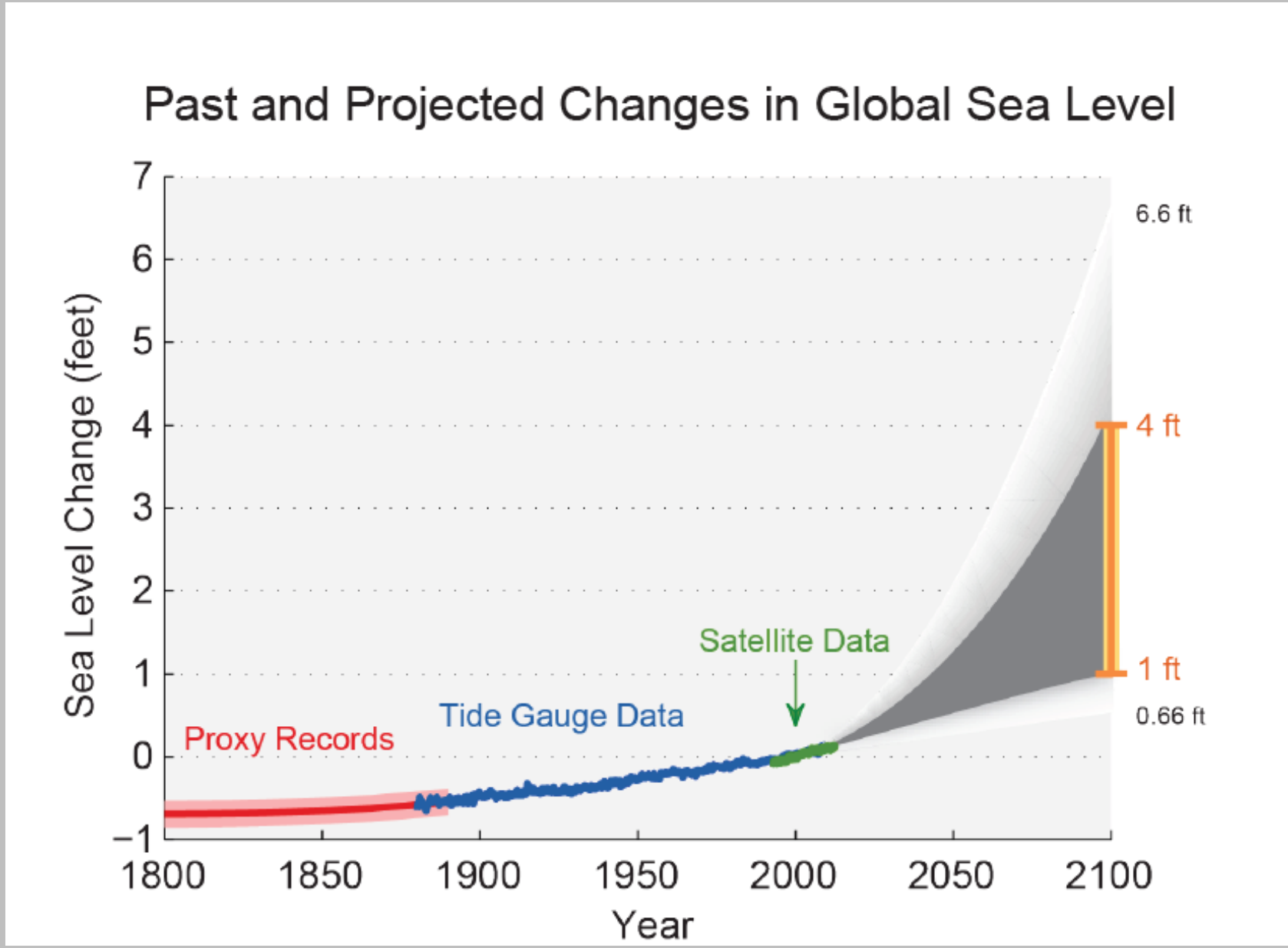
Regions Vulnerable to Sea Level Rise

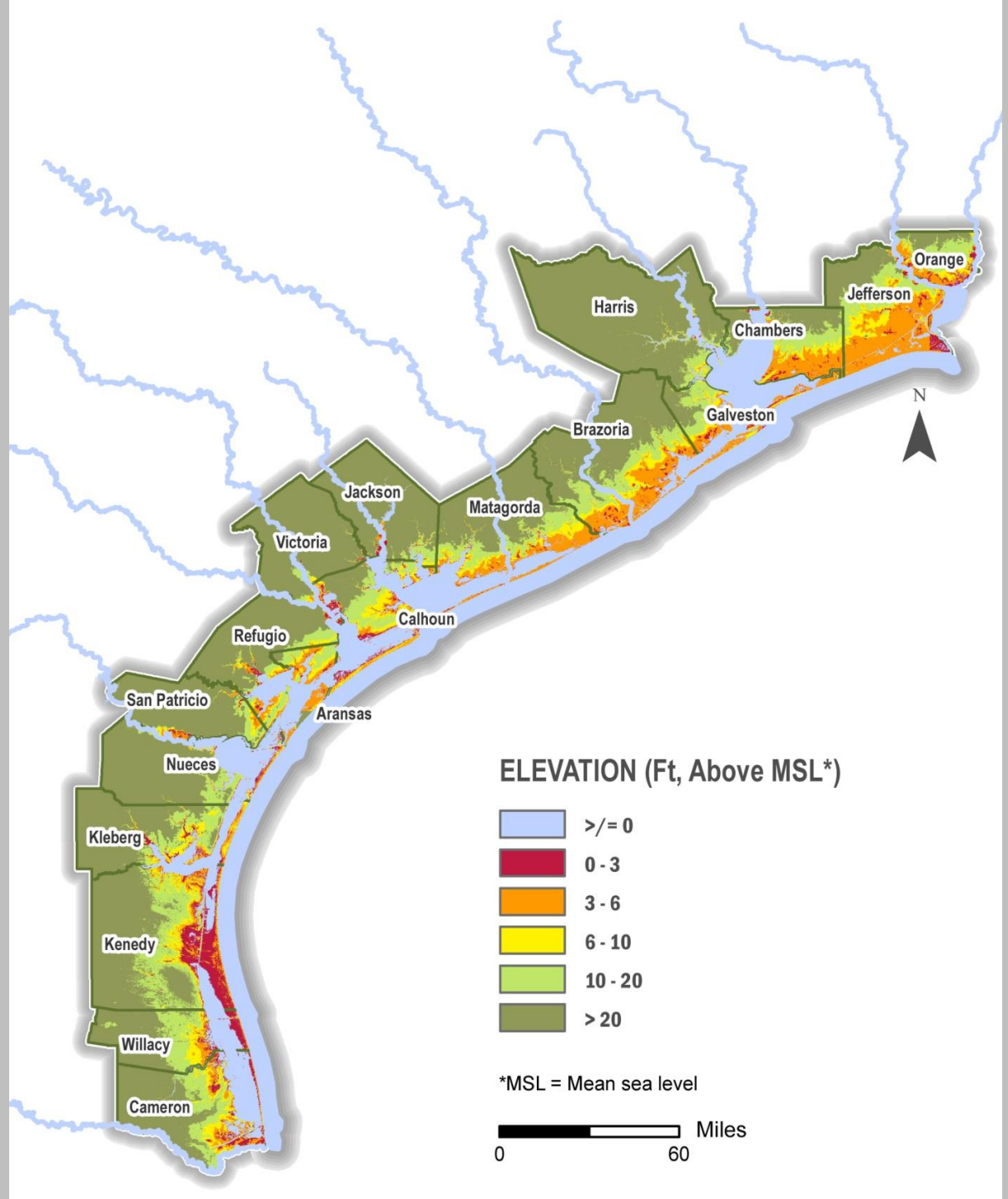


Height Above Sea Level (m)

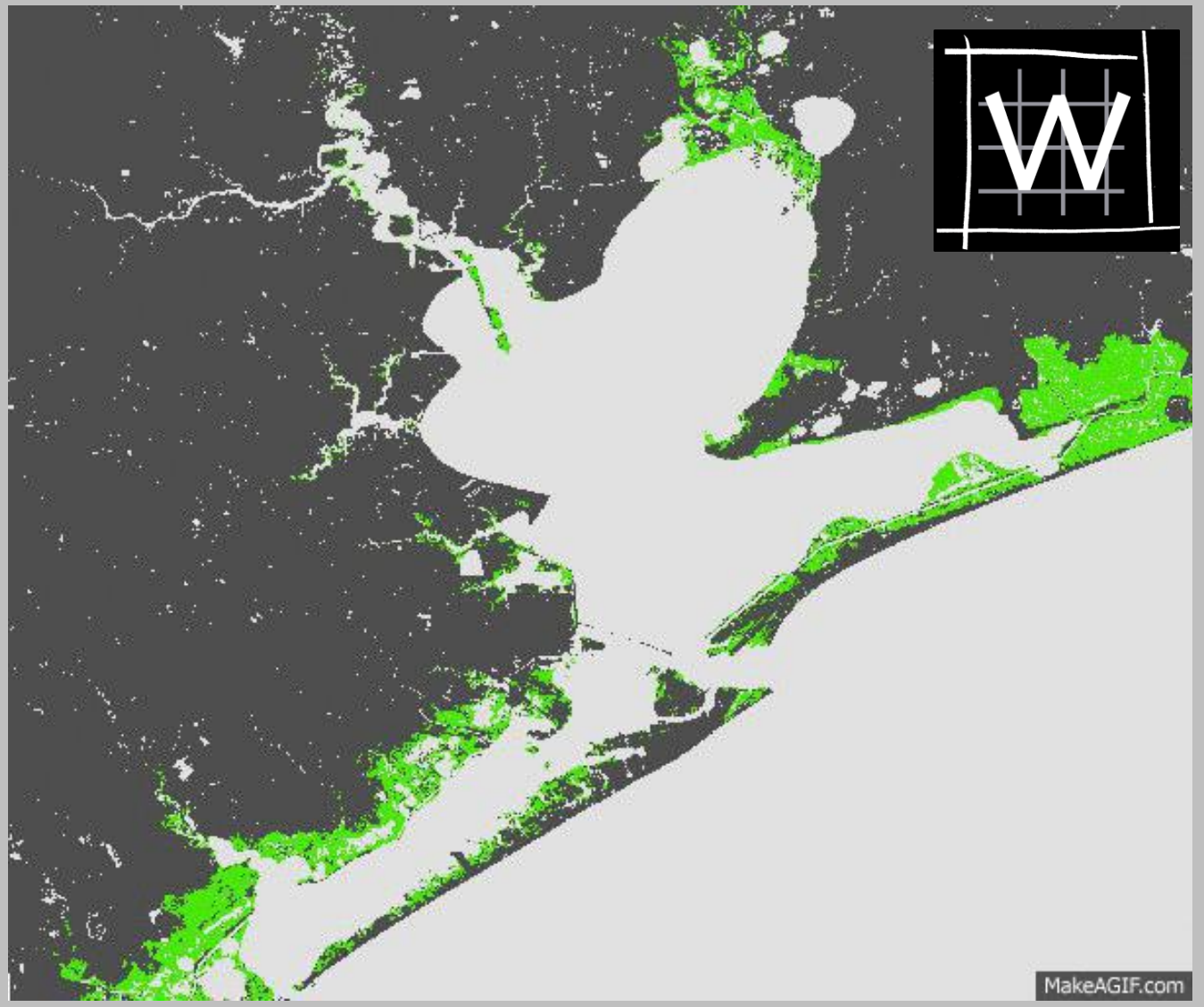
0 1 2 3 5 8 12 20 35 60 80

Climate Change – Sea Level Rise

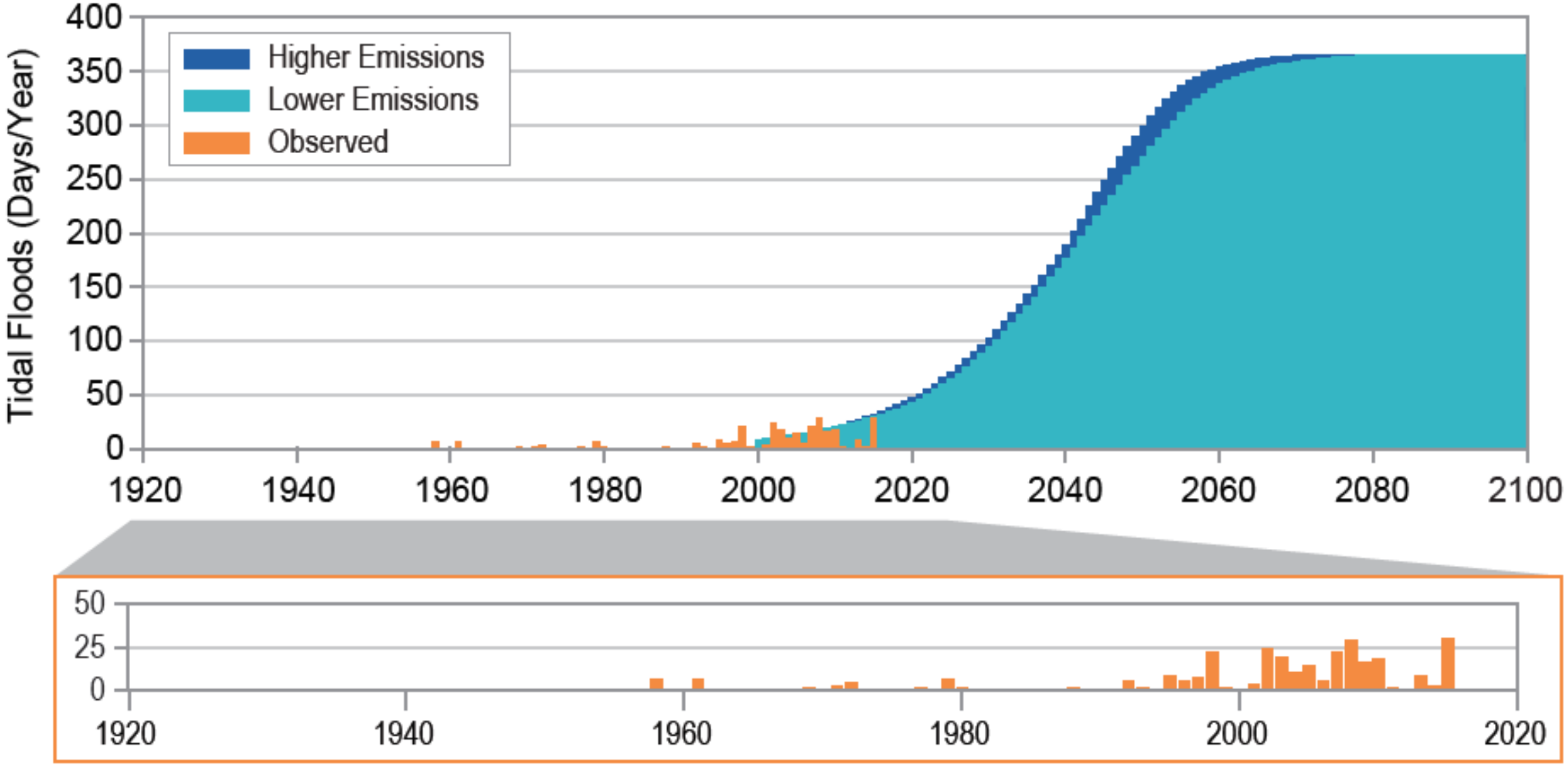



Orange
Jefferson
Harris
Chambers
Galveston
Brazoria
N
Jackson
Matagorda
Victoria
Calhoun
Refugio
San Patricio
Aransas
Nueces
Kleberg
Kenedy
Willacy
Cameron
ELEVATION (Ft, Above MSL*)
>/= 0
0 - 3
3 - 6
6 - 10
10 - 20
> 20
*MSL = Mean sea level
Miles
0
60

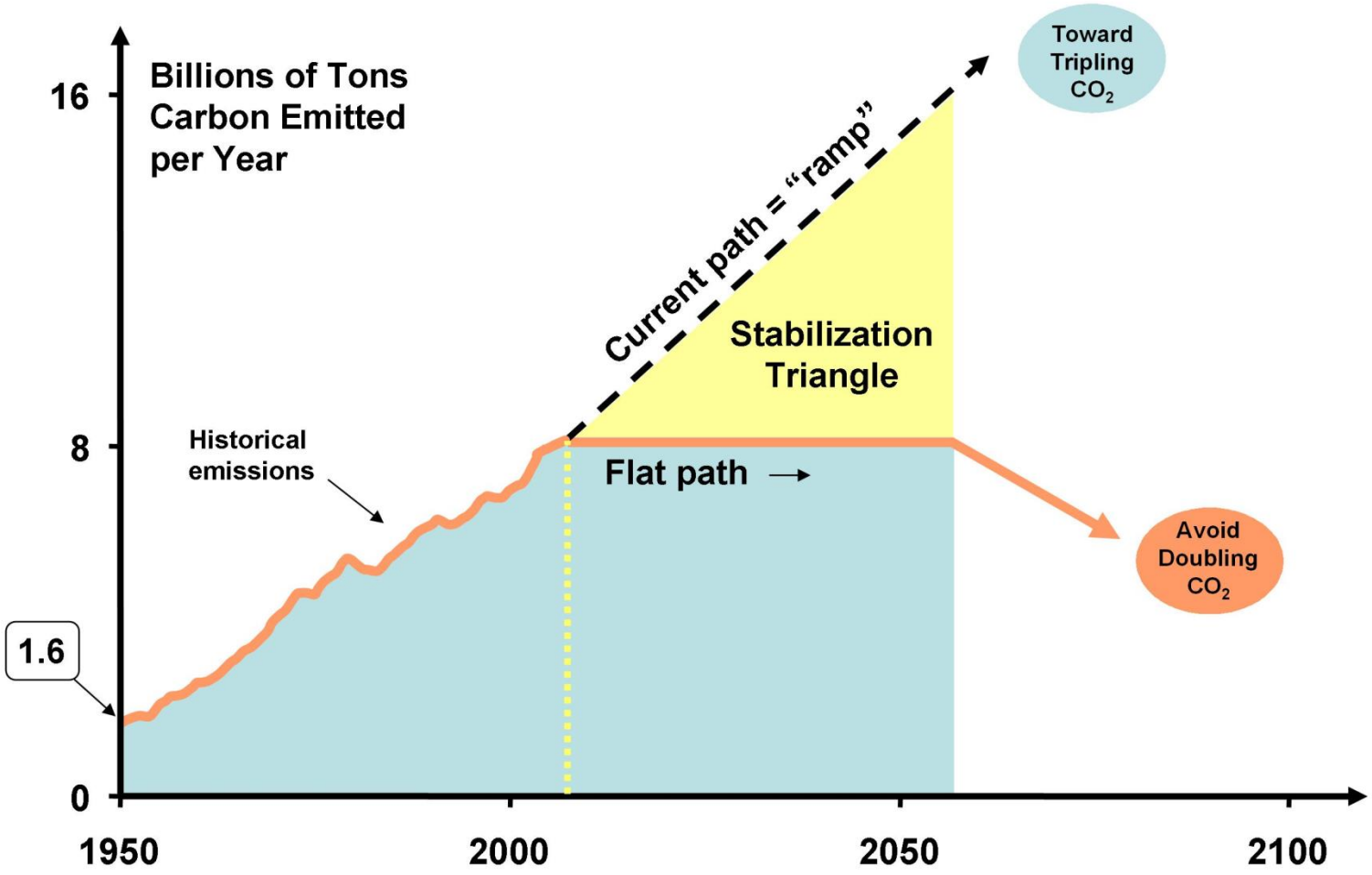
Marsh Migration Necessity



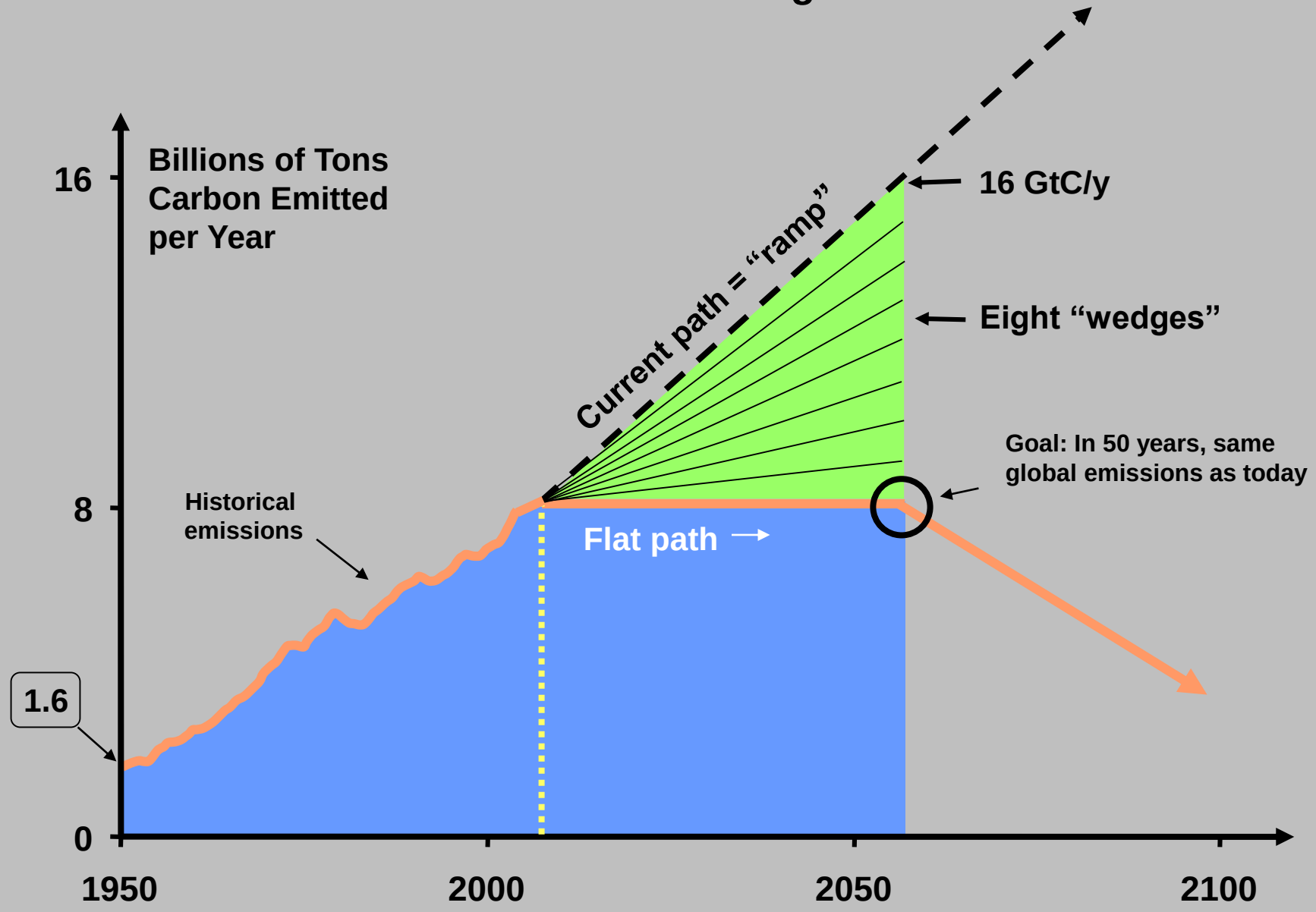
Observed and Projected Annual Number of Tidal Floods for Port Isabel, TX



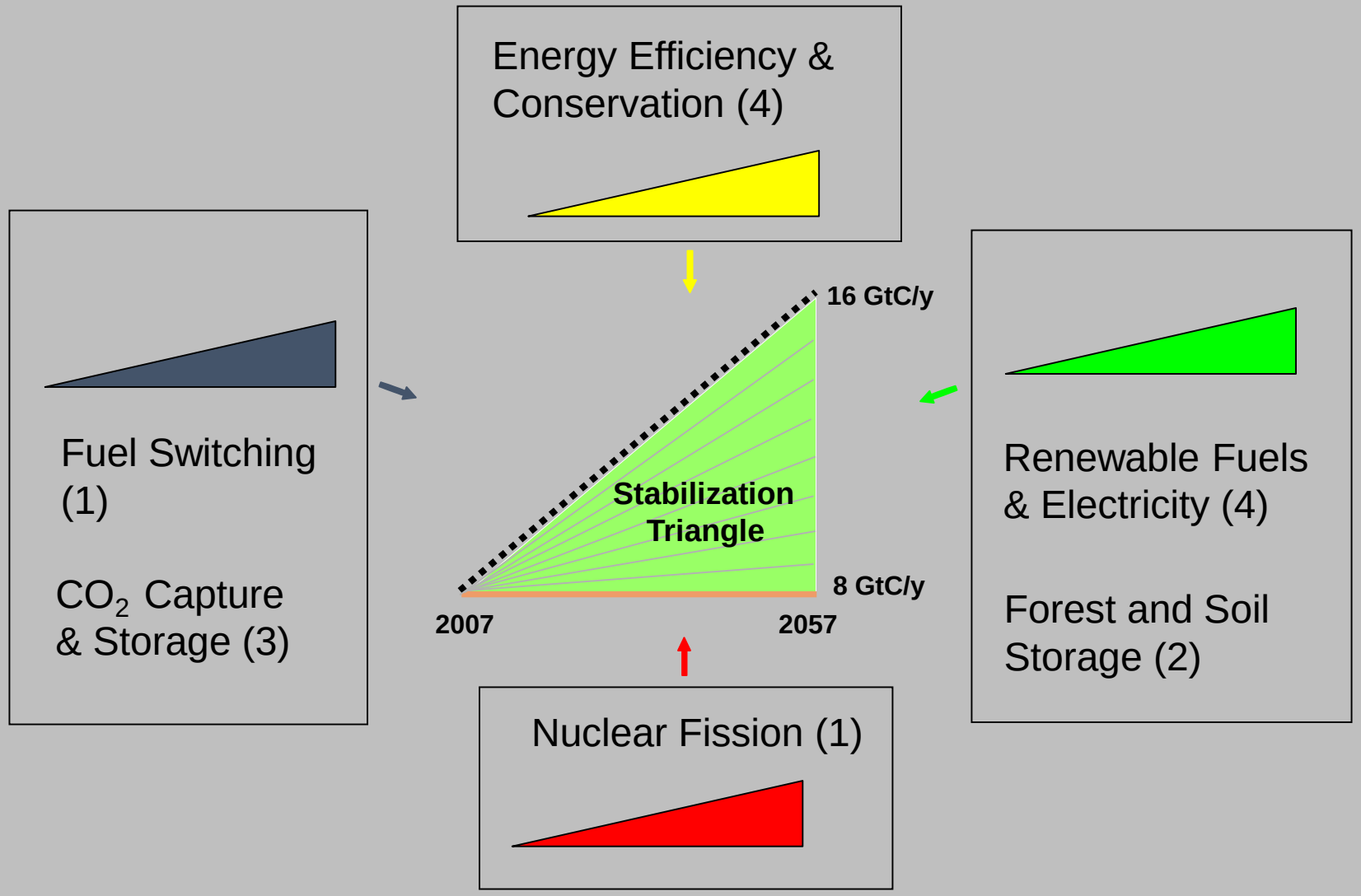
Carbon Stabilization



Stabilization Wedges



15 Wedge Strategies in 4 Categories

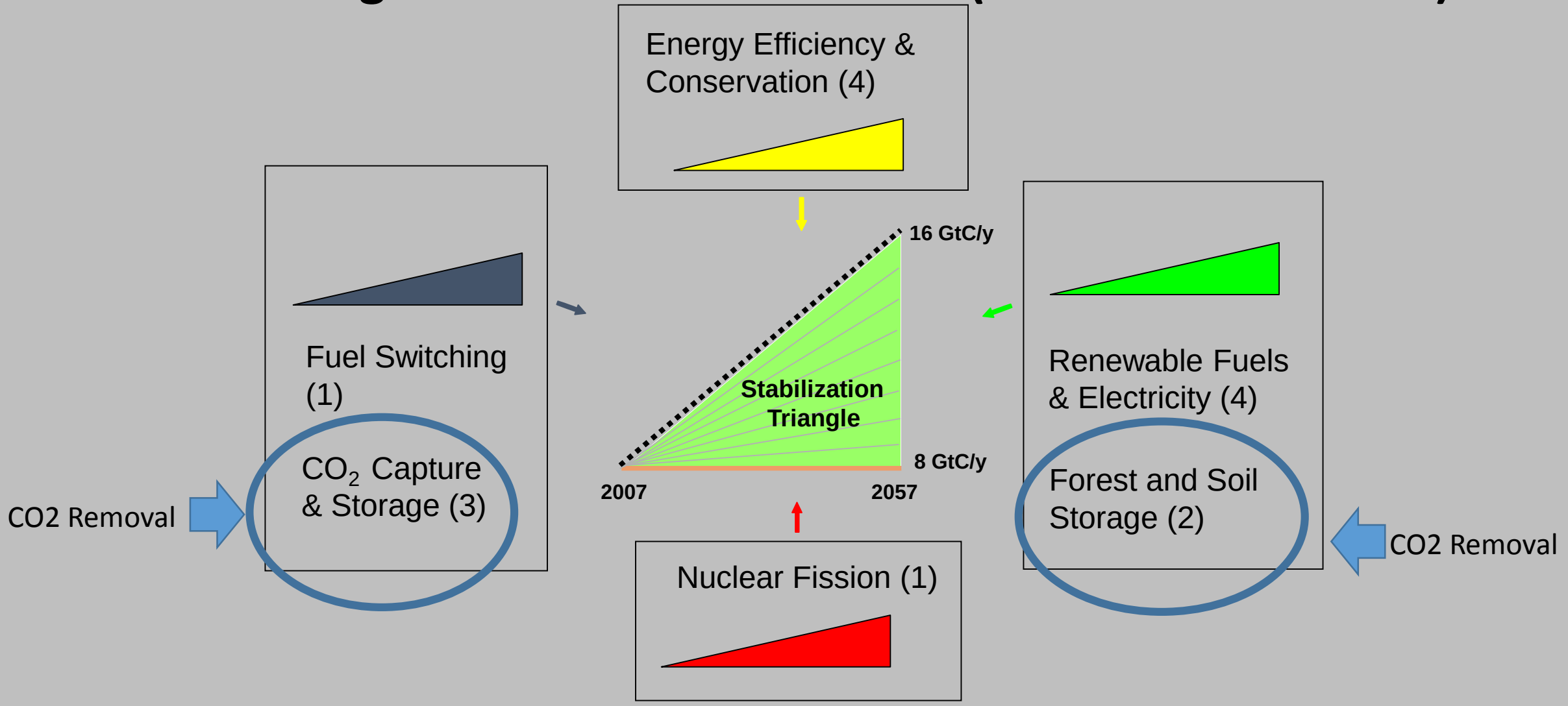


Concepts For Addressing Climate Change Implicit in Wedges Approach

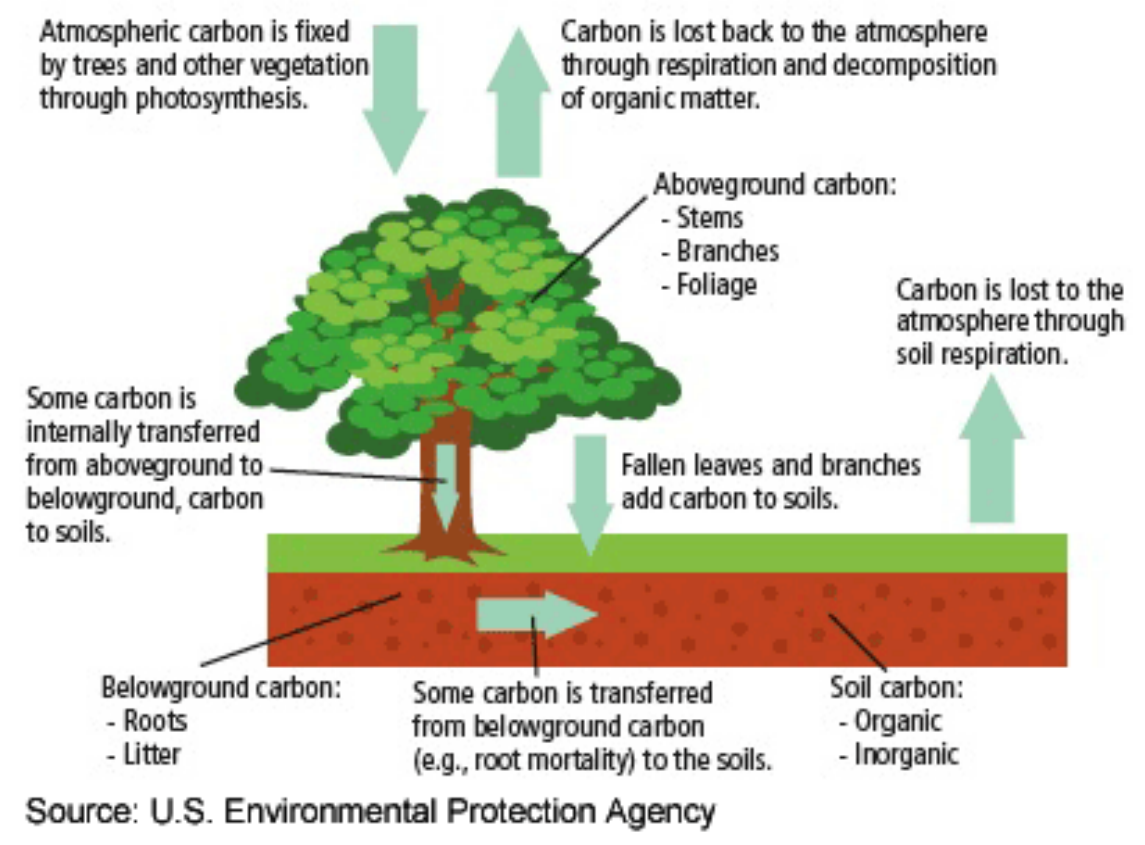
- Avoid hydrocarbon usage –
  - Renewables, Nuclear
- Minimize hydrocarbon usage –
  - Efficiency
- Mitigate/Offset hydrocarbon usage –
  - Carbon Sequestion

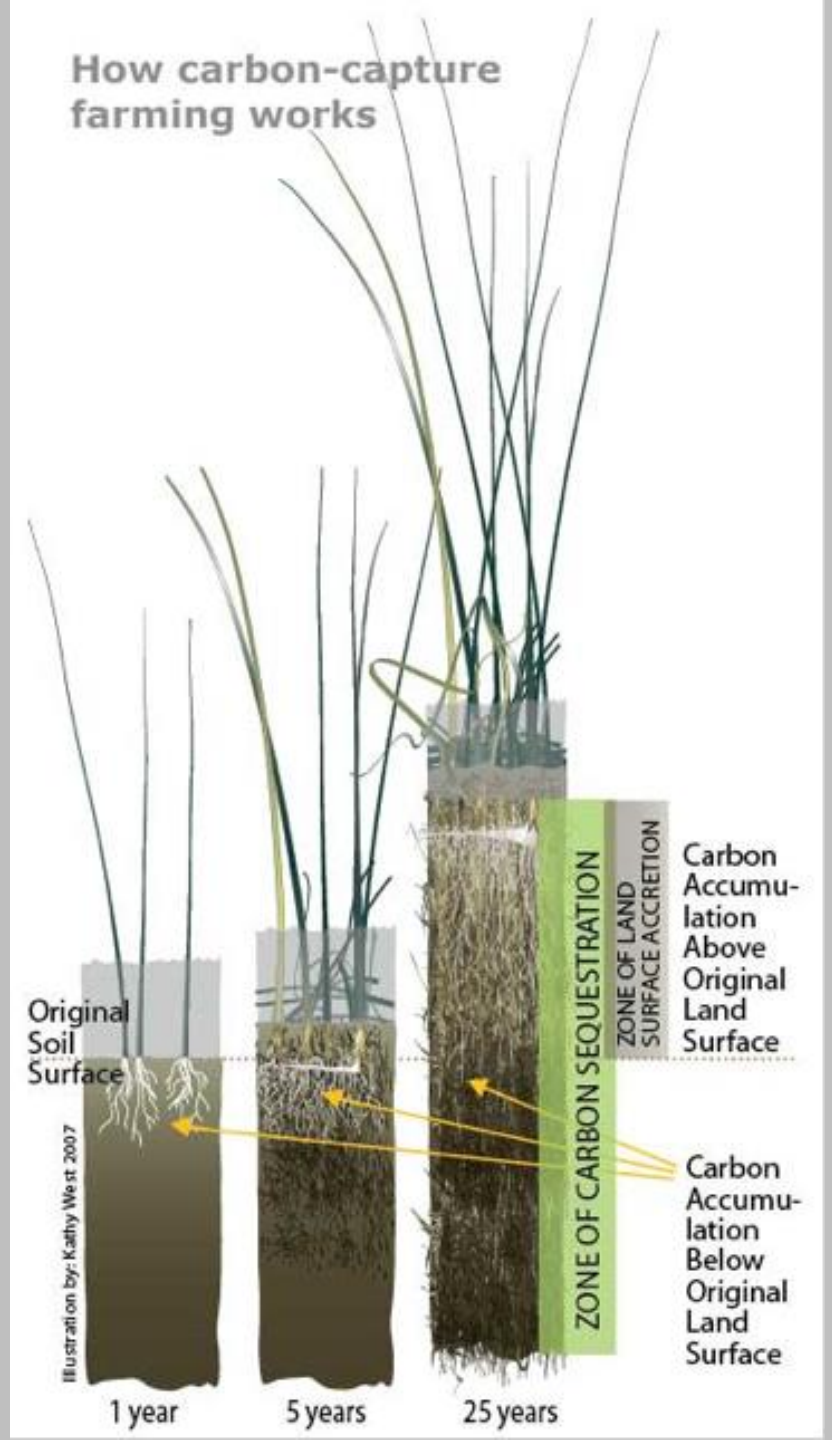
15 Wedge Strategies in 4 Categories

Each Wedge Is 1 Billion Tons Carbon (About 3.6 Tons CO2)



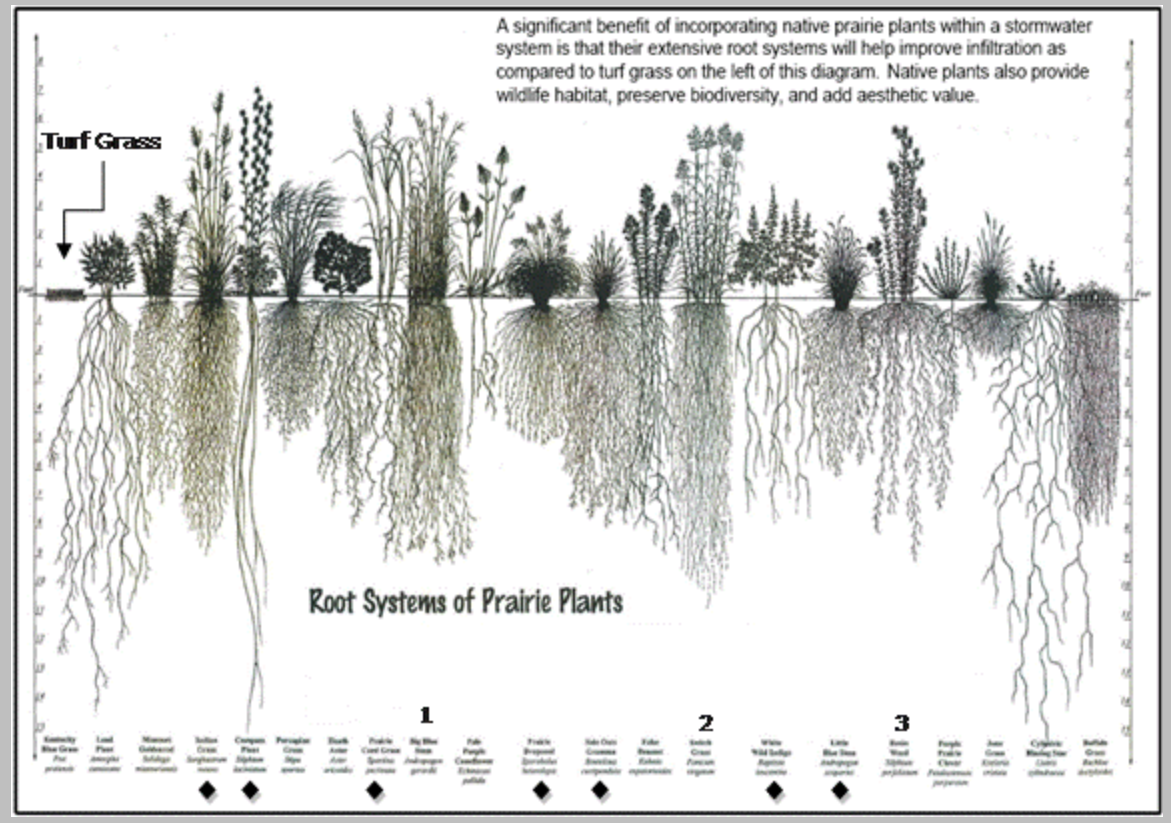
Carbon Sequestration Forest





Carbon Sequestration Marsh

Prairie Grass Root System



United States Land Area 2.4 billion acres
Carbon Footprint 3 billion tons
Land Needed at 3 tons/acre = 1 billion acres

What Should Oil and Gas Industry Do Now?

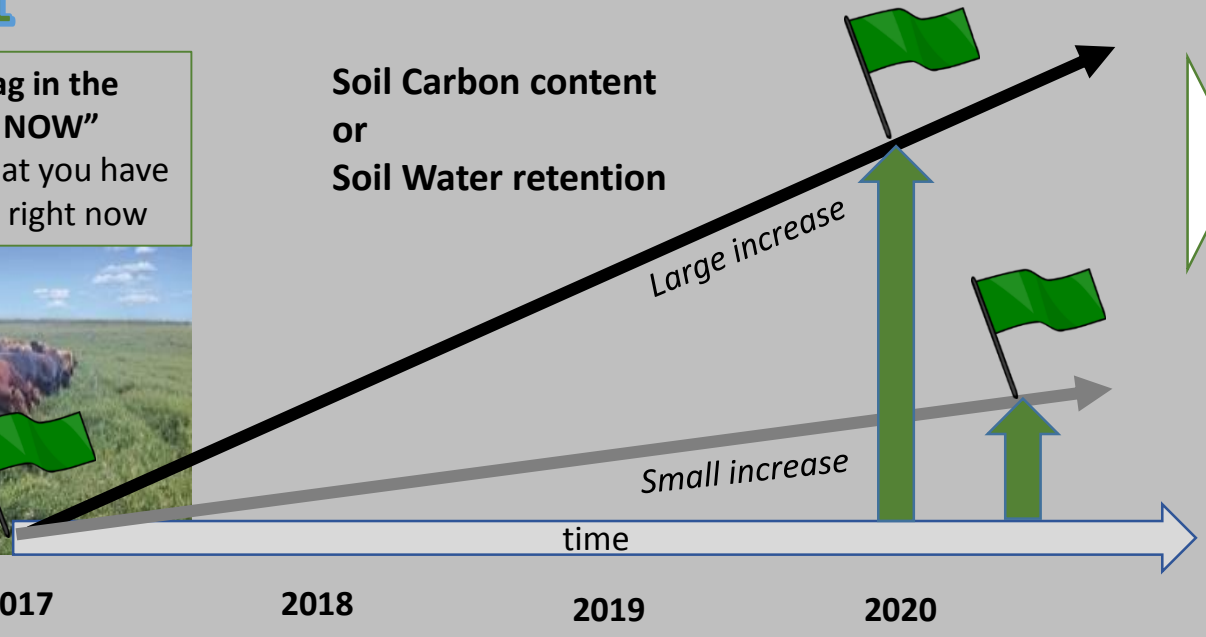
1

"Put a flag in the ground NOW"
Measure what you have in your soil right now

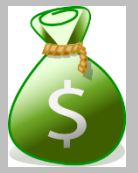
2

To measure the increase in your soils 3-5 years from now

Soil Carbon content
or
Soil Water retention



The increase in eco-benefits : Carbon Content and Water absorption, can potentially be traded and turned into additional landowner income

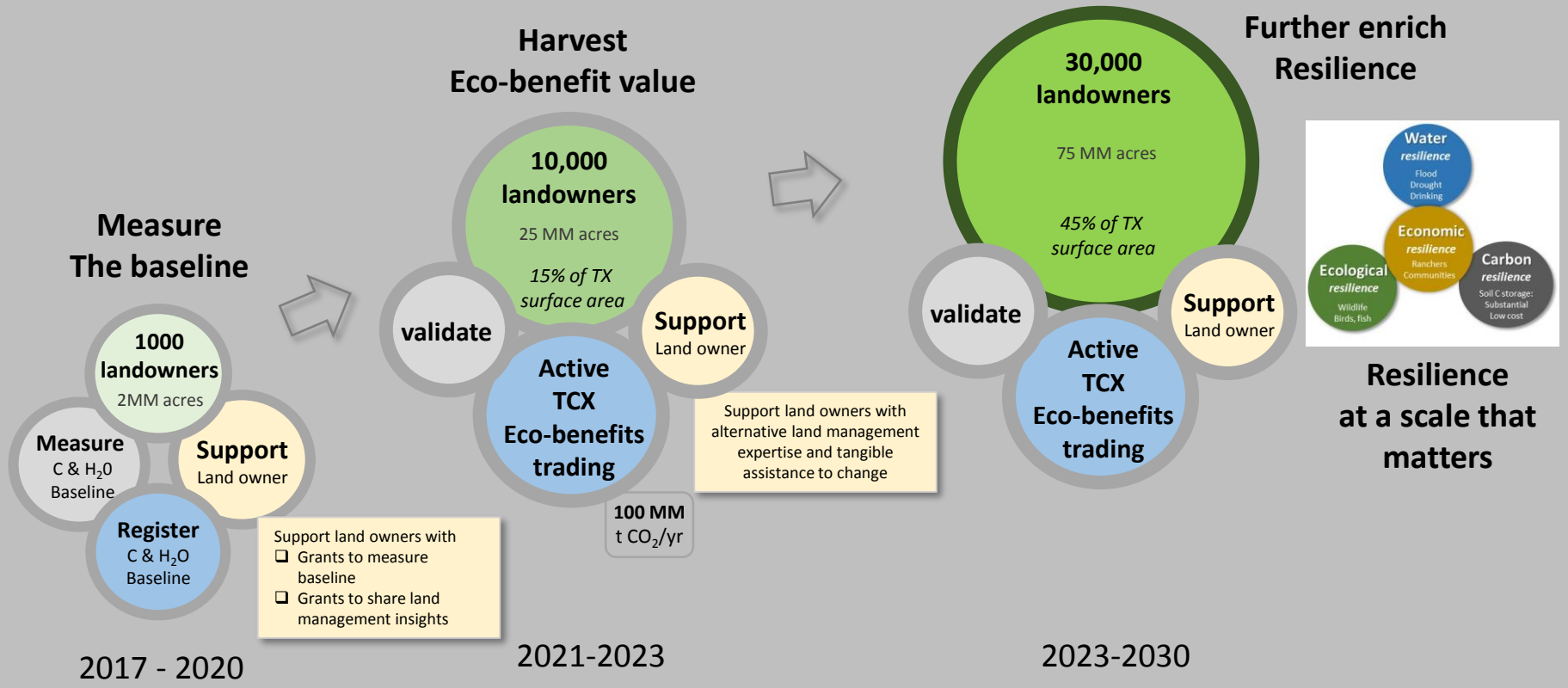


Buy carbon dioxide storage rights

TCX *Fast Track*

Roadmap to a Scale that Matters

Measure now..... to develop key landowner support mechanisms.... to support fast and responsible growth to a scale that matters.



Carbon Musical Chairs (With Many Less Chairs)
7 to 14 Billion Tons For Sequestration Globally
3 billion Tons Required by U.S. Oil and Gas
32 billion Tons Needed Globally

Do You Have Yours?