Climate change on the North Coast
A few things to consider

Thanks to: Connie Millar, Dave Peterson, Linda Joyce, Andrea Tuttle, Leslie Reid, Sherry Hazelhurst, Brian Staab, Ken Roby, Brian Staab, Nate Mantua, Jim Sedell and others

Michael J. Furniss

Retired Pacific Northwest and Pacific Southwest Research Stations

Resilience: What Can Be Done?

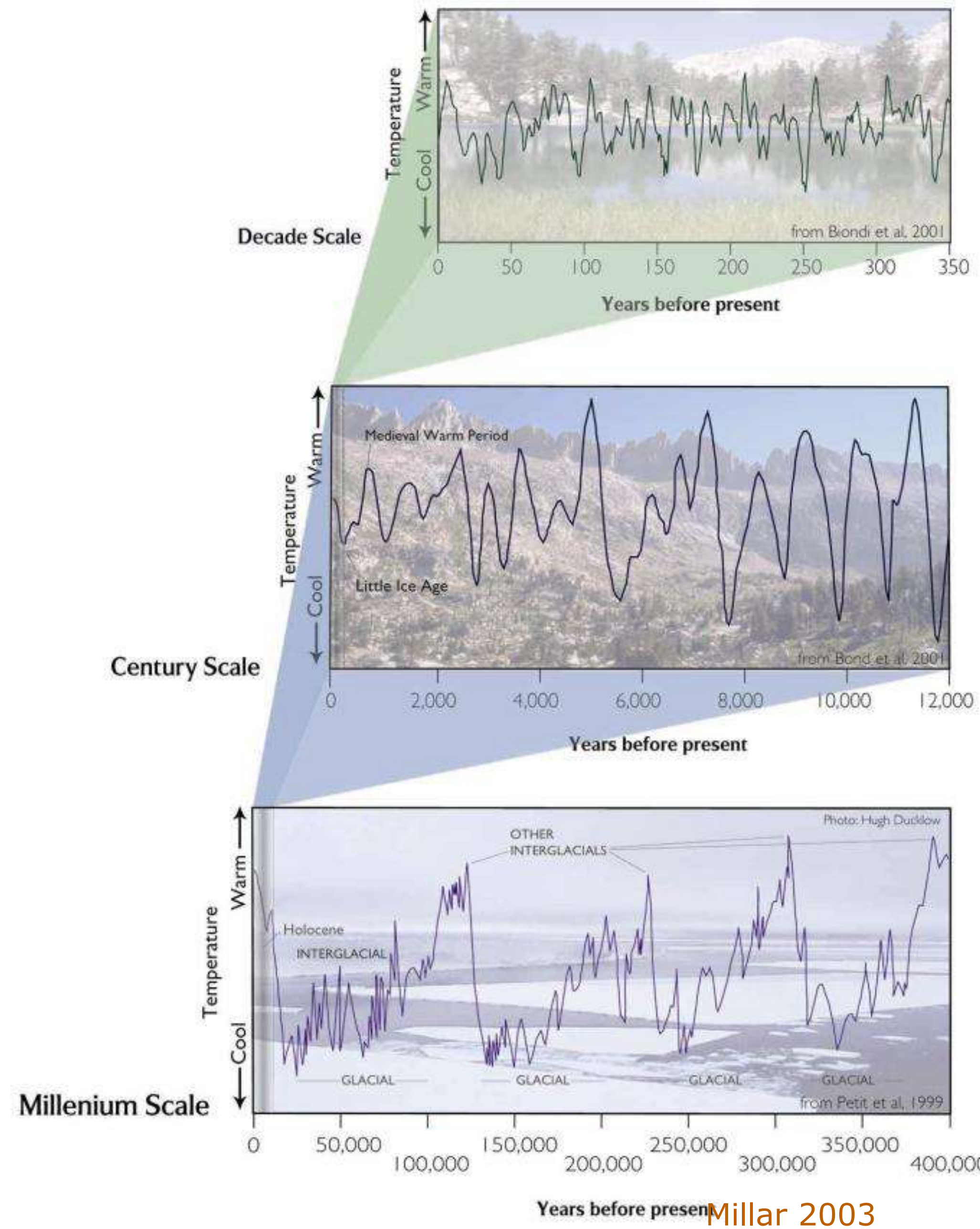
Presilience: What Can Be Done?

- Understand impacts and plan responses
  - **Conduct Vulnerability Assessment**
- Careful, long-term research and monitoring
- Implement and monitor BMPs! Best Practices.
- Focus on consequences & sensitivity, not exposure & probability
- Aggressively and relentlessly reduce carbon emissions of your operations, physical plant, and provisioning

Earth's Natural Climate System

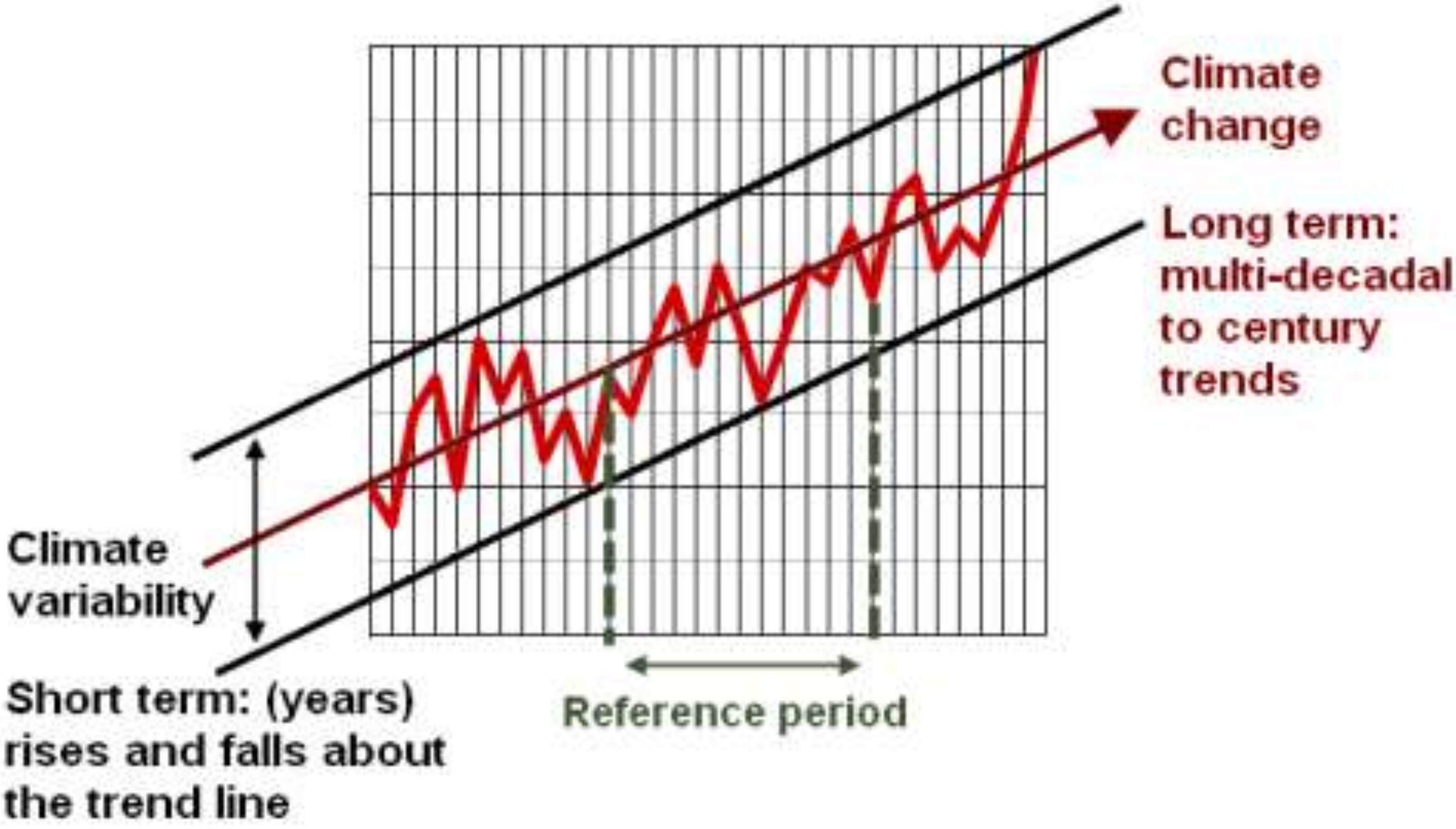
* Continuously Changing; Cyclic
* Nested Cycles: Annual, Decadal, Century & Millennial Scales
* Different Physical Mechanisms
* Changes: Gradual & Directional to Abrupt & 'Chaotic'

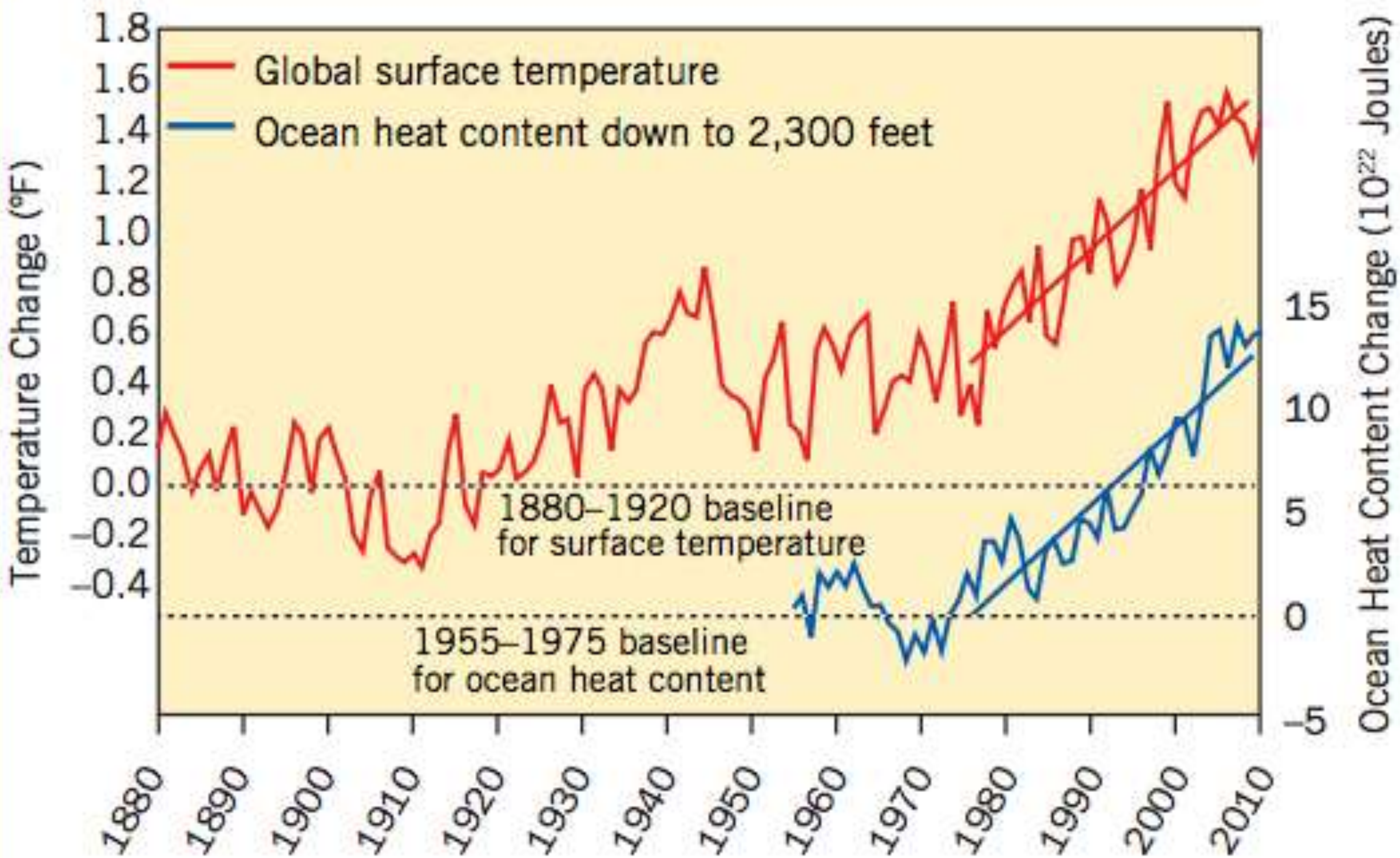
Millar 2007



Millar 2003

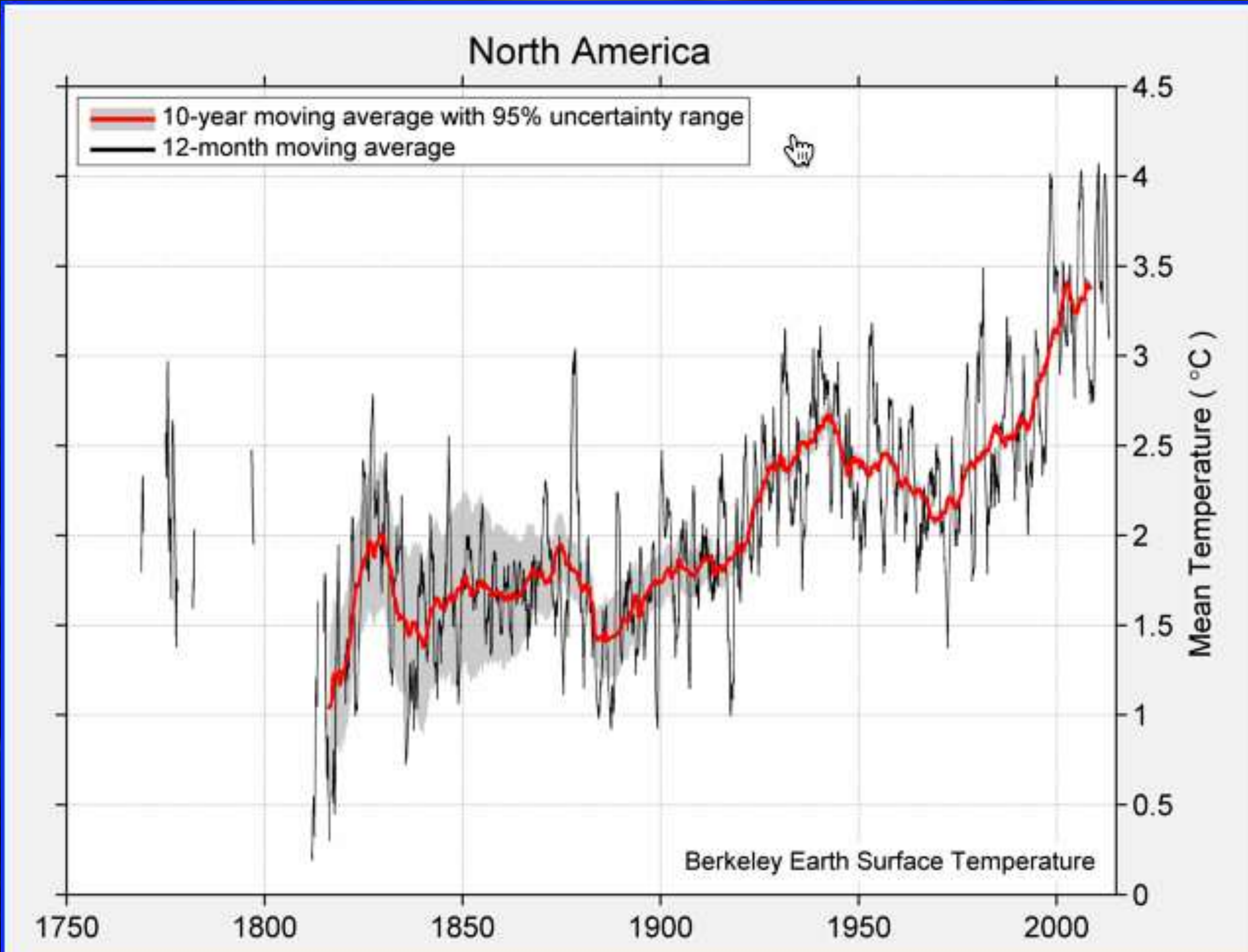
Climate Change & Variability Concepts



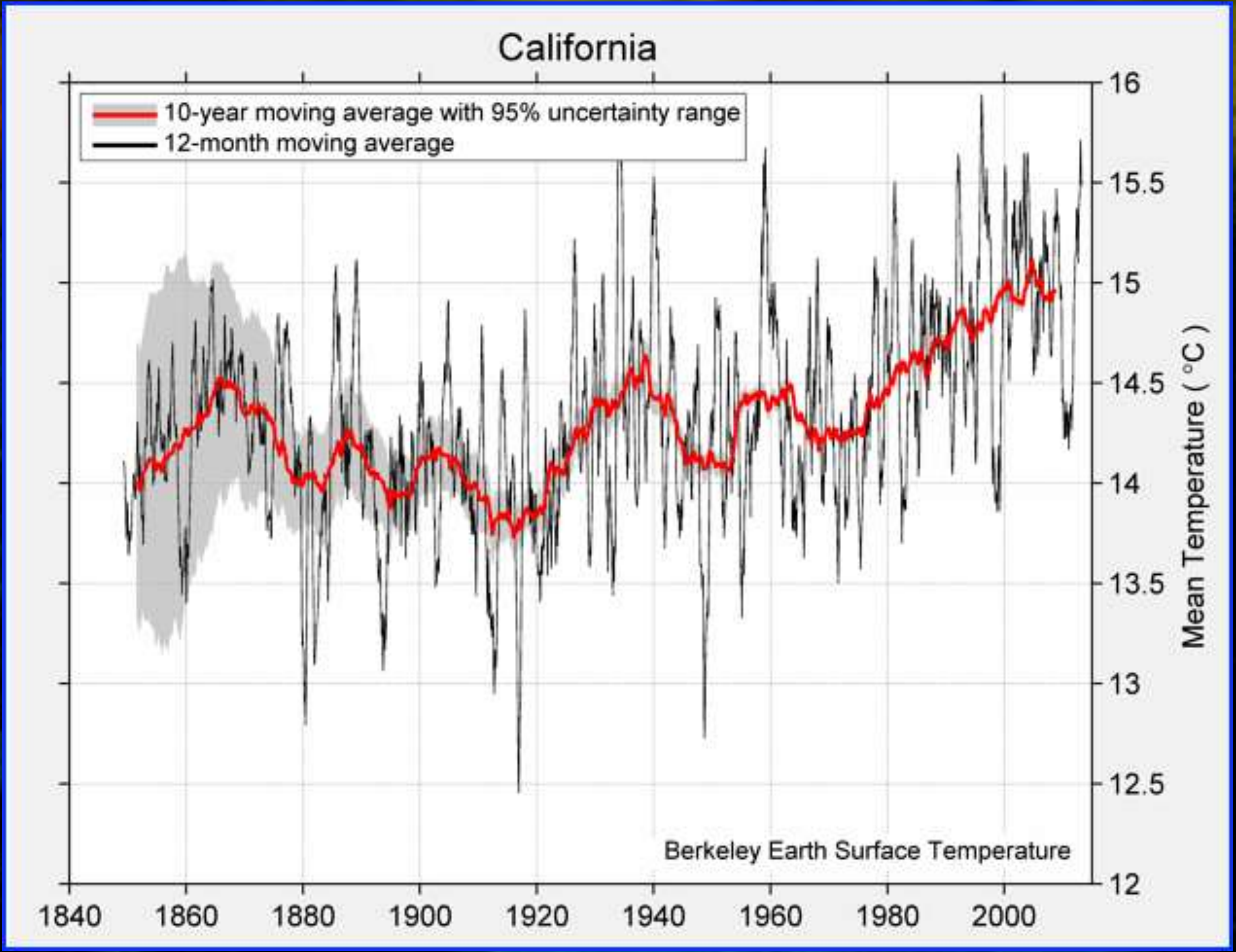


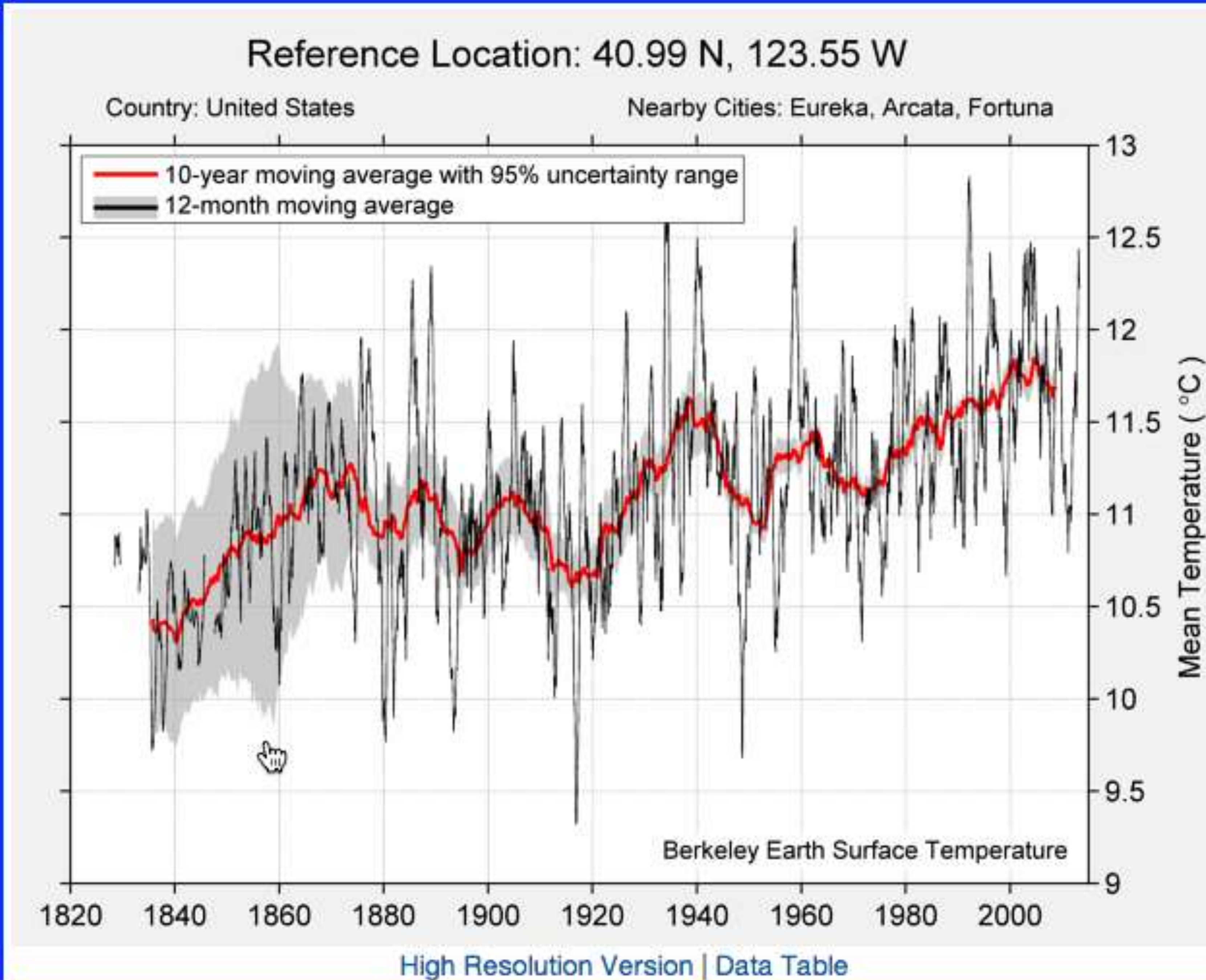
Global surface temperature
Ocean heat content down to 2,300 feet
1880–1920 baseline
for surface temperature
1955–1975 baseline
for ocean heat content
Temperature Change (°F)
Ocean Heat Content Change (10^{22} Joules)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
15
10
5
0
−5
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Coastal Climate Refugia?

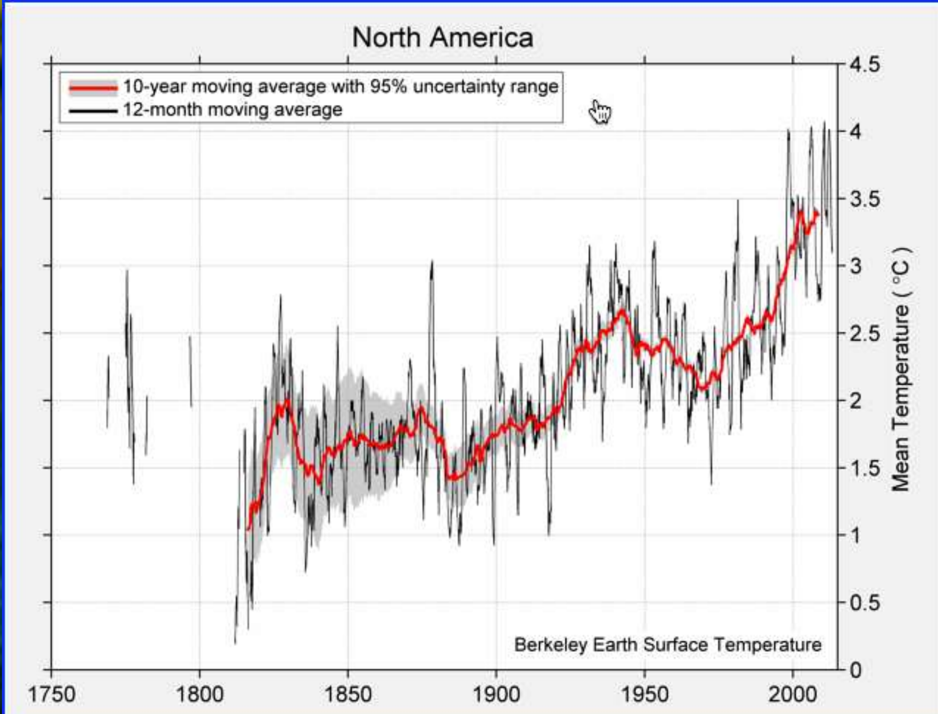


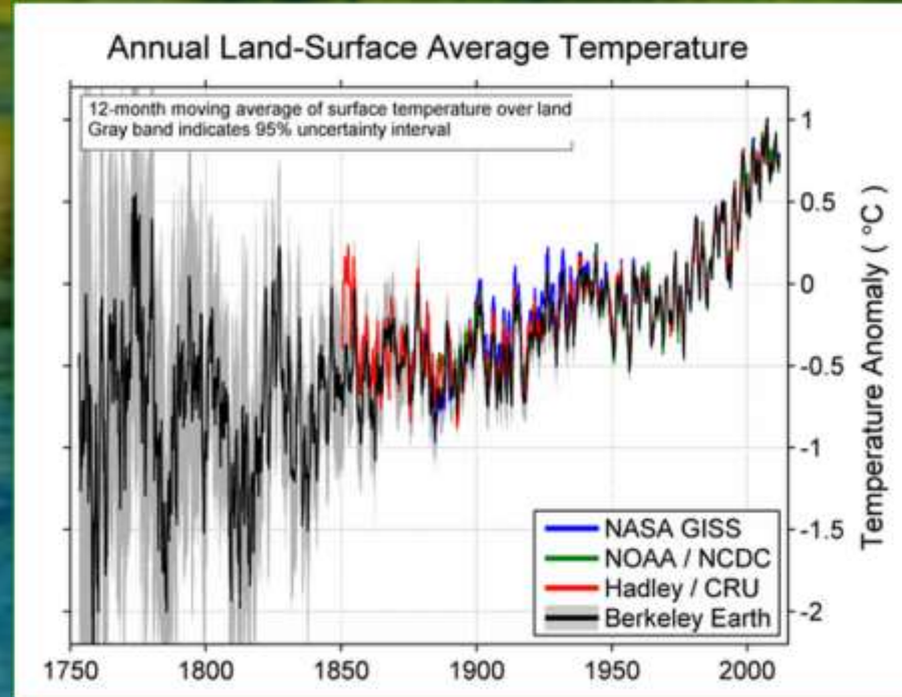
www.berkeleyearth.org

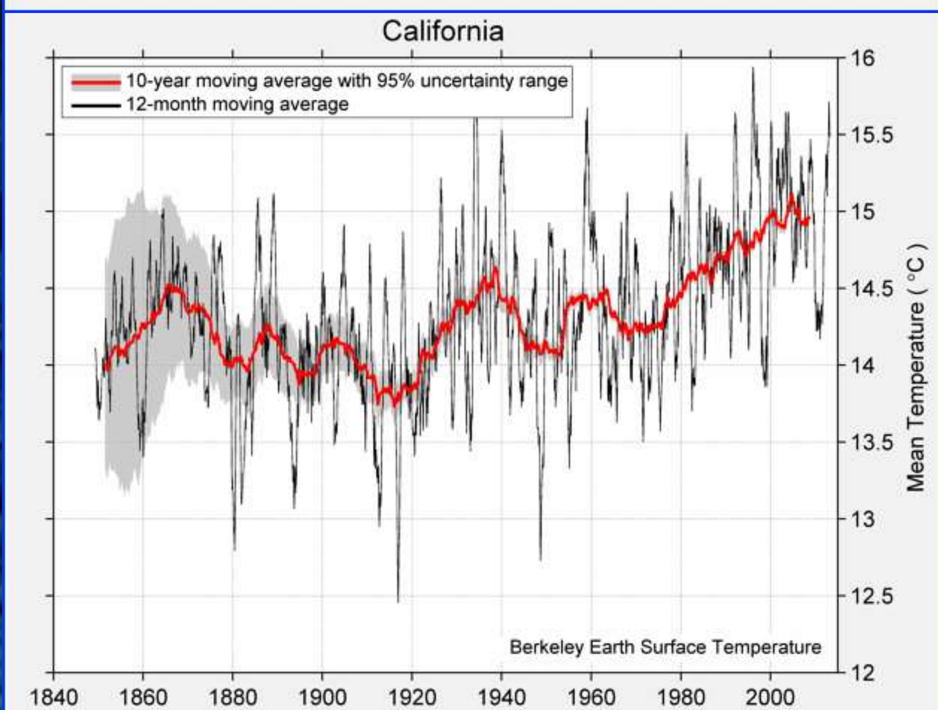

California
10-year moving average with 95% uncertainty range
12-month moving average
Berkeley Earth Surface Temperature
Mean Temperature (°C)
16
15.5
15
14.5
14
13.5
13
12.5
12
1840
1860
1880
1900
1920
1940
1960
1980
2000

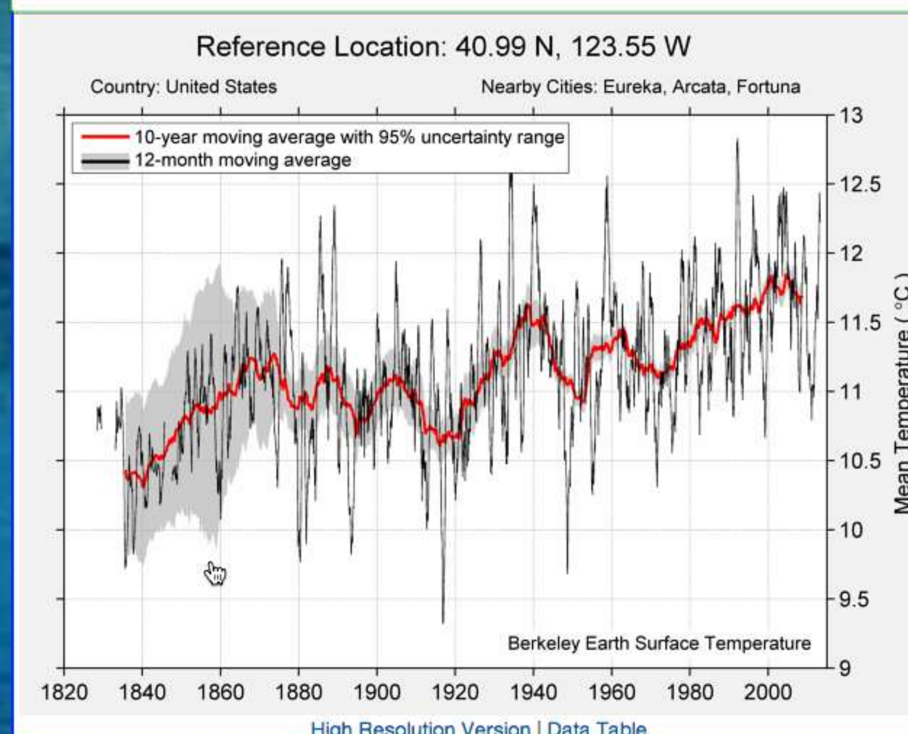


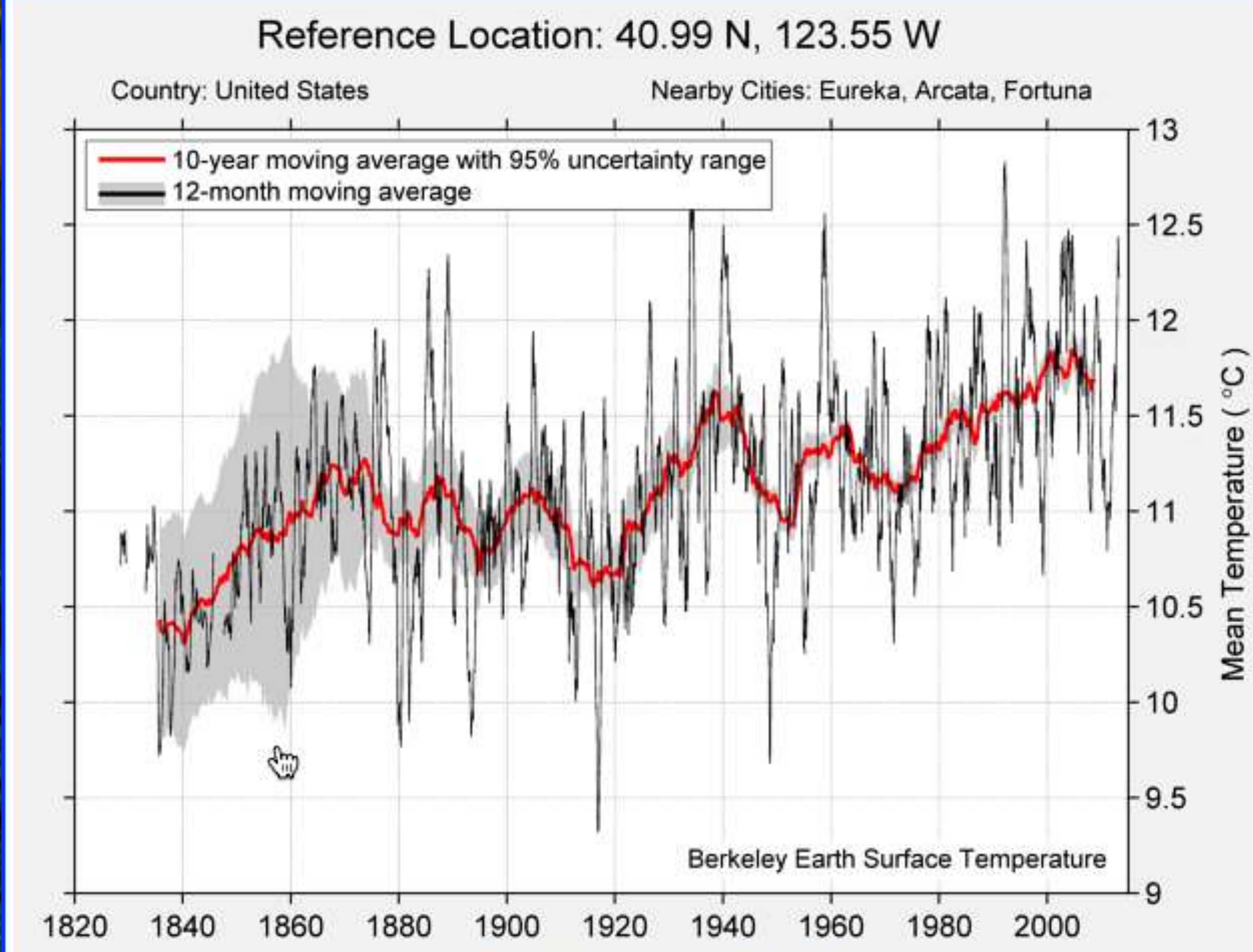
Reference Location: 40.99 N, 123.55 W
Country: United States
Nearby Cities: Eureka, Arcata, Fortuna
10-year moving average with 95% uncertainty range
12-month moving average
Mean Temperature (°C)
13
12.5
12
11.5
11
10.5
10
9.5
9
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000
Berkeley Earth Surface Temperature
High Resolution Version | Data Table


North America
10-year moving average with 95% uncertainty range
12-month moving average
Berkeley Earth Surface Temperature
Mean Temperature (°C)
1750 1800 1850 1900 1950 2000
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5

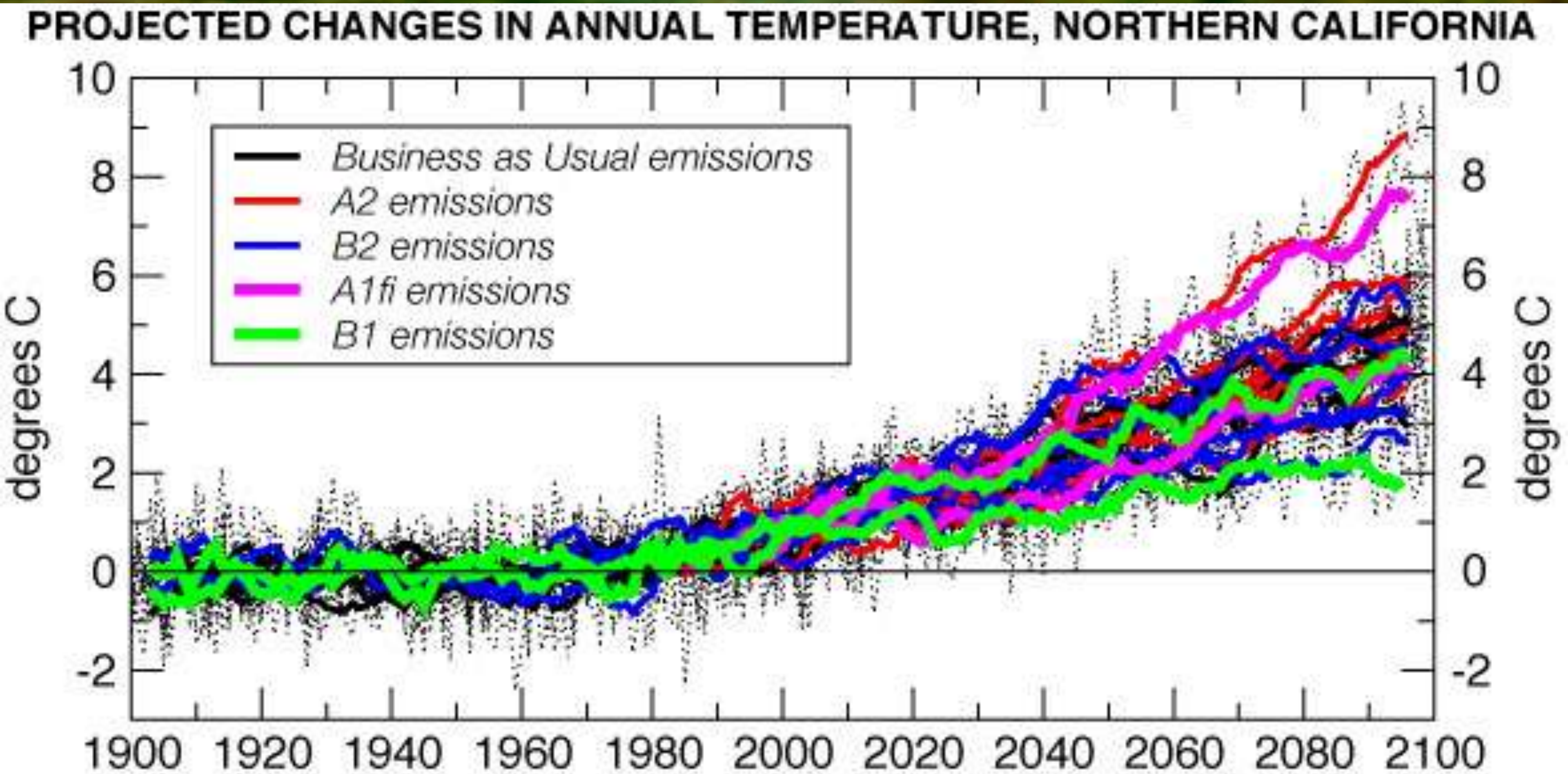

Annual Land-Surface Average Temperature
12-month moving average of surface temperature over land
Gray band indicates 95% uncertainty interval
NASA GISS
NOAA / NCDC
Hadley / CRU
Berkeley Earth
Temperature Anomaly (°C)
1750 1800 1850 1900 1950 2000
1 0.5 0 -0.5 -1 -1.5 -2

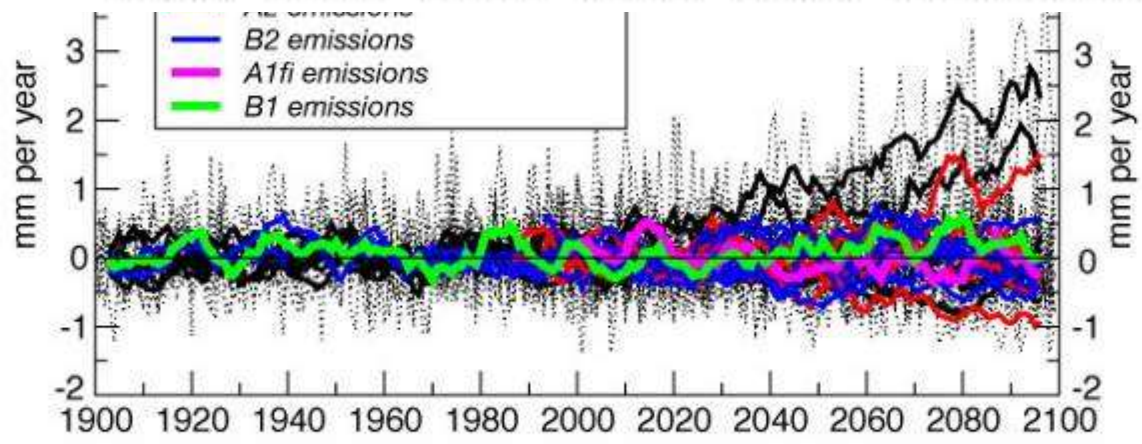

California
10-year moving average with 95% uncertainty range
12-month moving average
Berkeley Earth Surface Temperature
Mean Temperature (°C)
1840 1860 1880 1900 1920 1940 1960 1980 2000
12 12.5 13 13.5 14 14.5 15 15.5 16


Reference Location: 40.99 N, 123.55 W
Country: United States
Nearby Cities: Eureka, Arcata, Fortuna
10-year moving average with 95% uncertainty range
12-month moving average
Berkeley Earth Surface Temperature
Mean Temperature (°C)
1820 1840 1860 1880 1900 1920 1940 1960 1980 2000
9 9.5 10 10.5 11 11.5 12 12.5 13
High Resolution Version | Data Table



High Resolution Version | Data Table





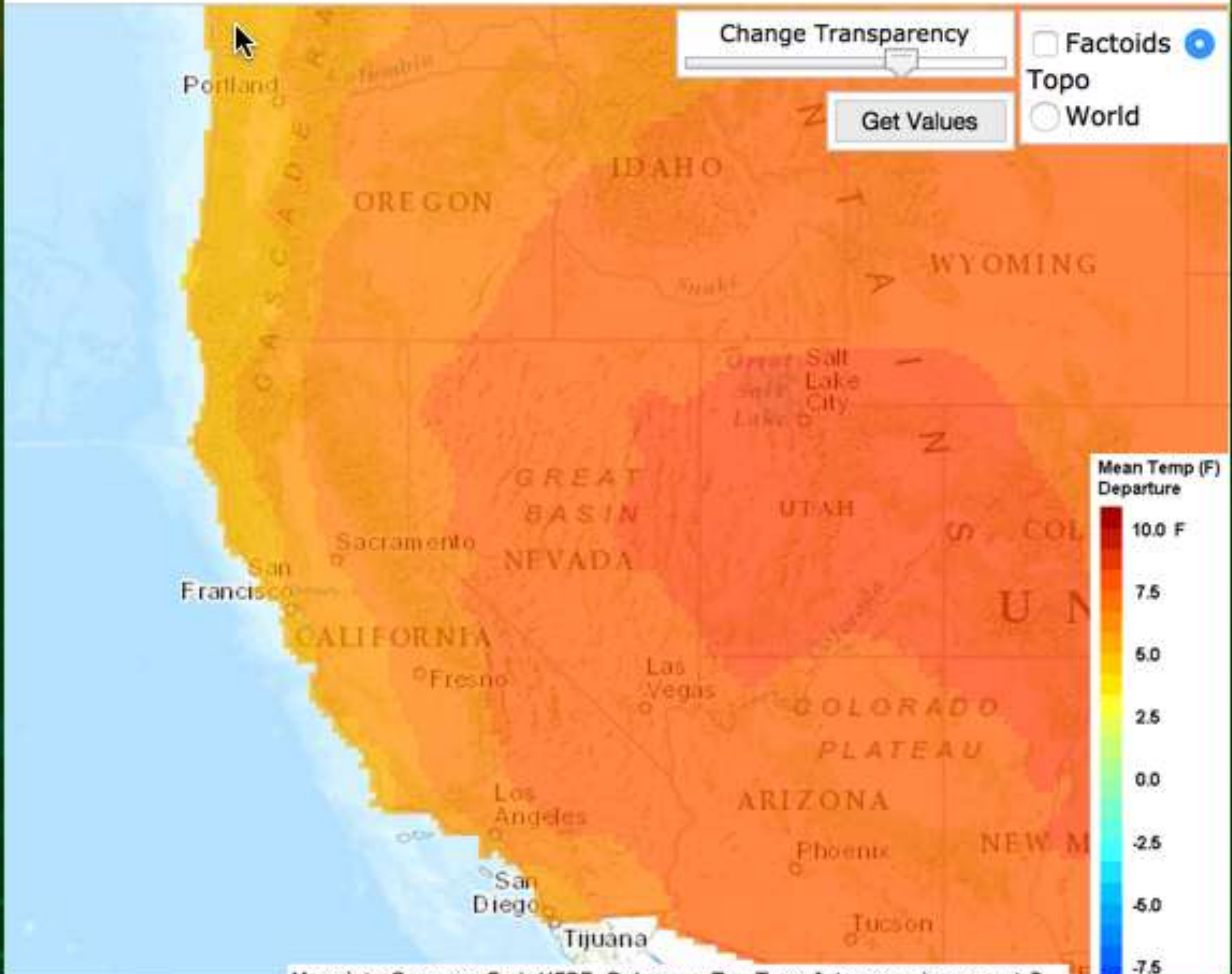
Strong consensus for warming

But large uncertainty with precipitation

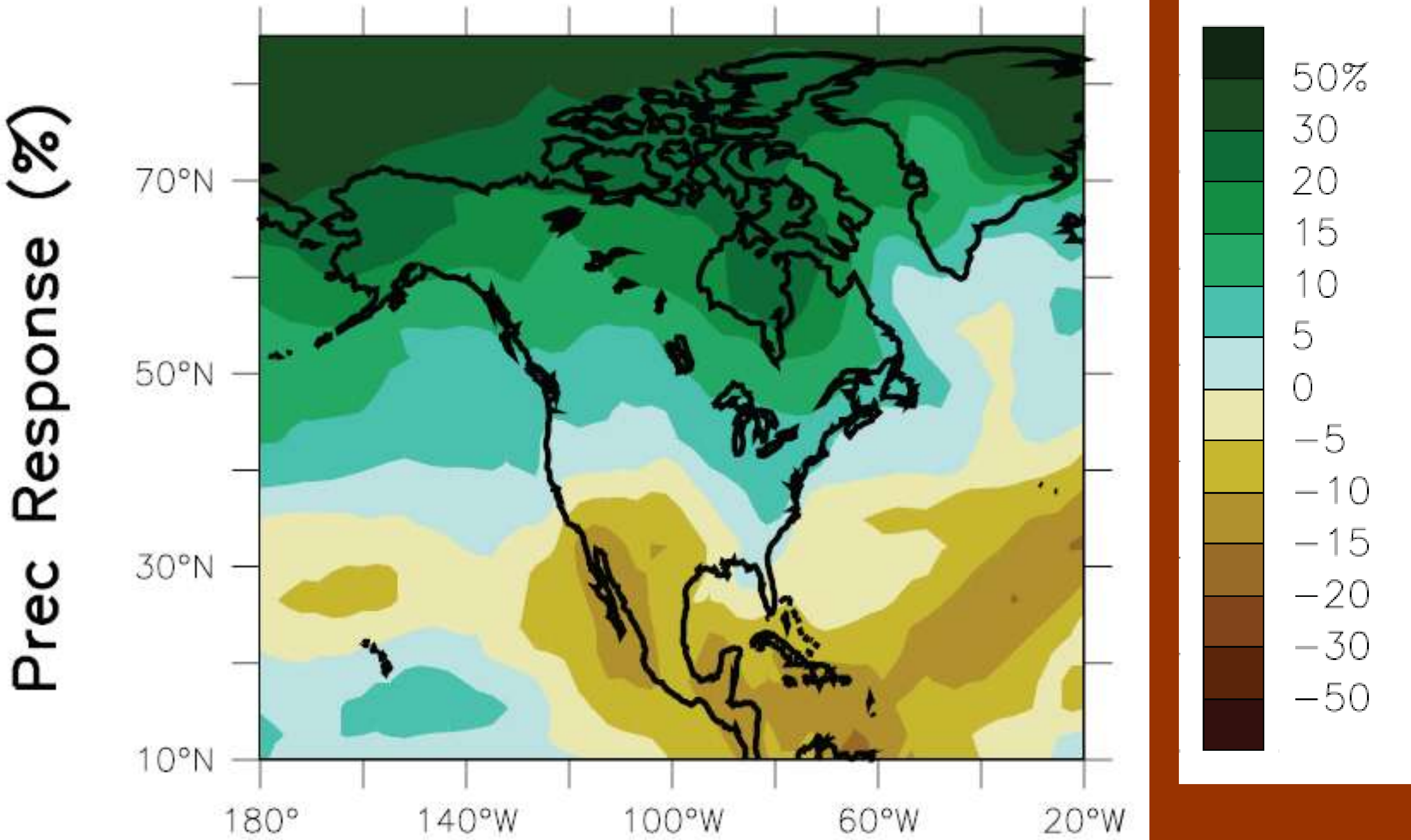
Cayan & Dettinger

Change in Annual Temperature by the 2080s

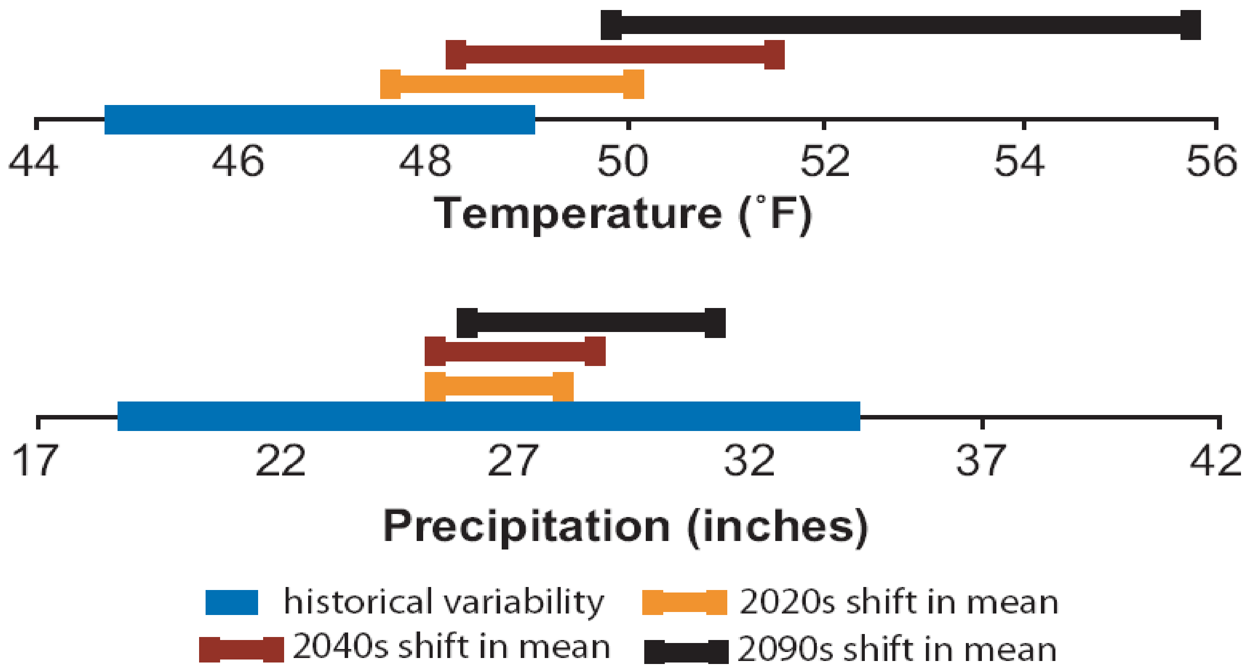
Model: Ensemble Average, SRES emission scenario: A2



Climatewizard.org


Prec Response (%)
70°N
50°N
30°N
10°N
180°
140°W
100°W
60°W
20°W
50%
30
20
15
10
5
0
−5
−10
−15
−20
−30
−50

Projected changes to a "new" climate



Comparison of observed year-to-year variability and projected shifts in temperature and precipitation from climate models

Temperature easy, Precipitation hard

Temperature **easy** and changes **large**

Precipitation **hard** and changes **small** here.

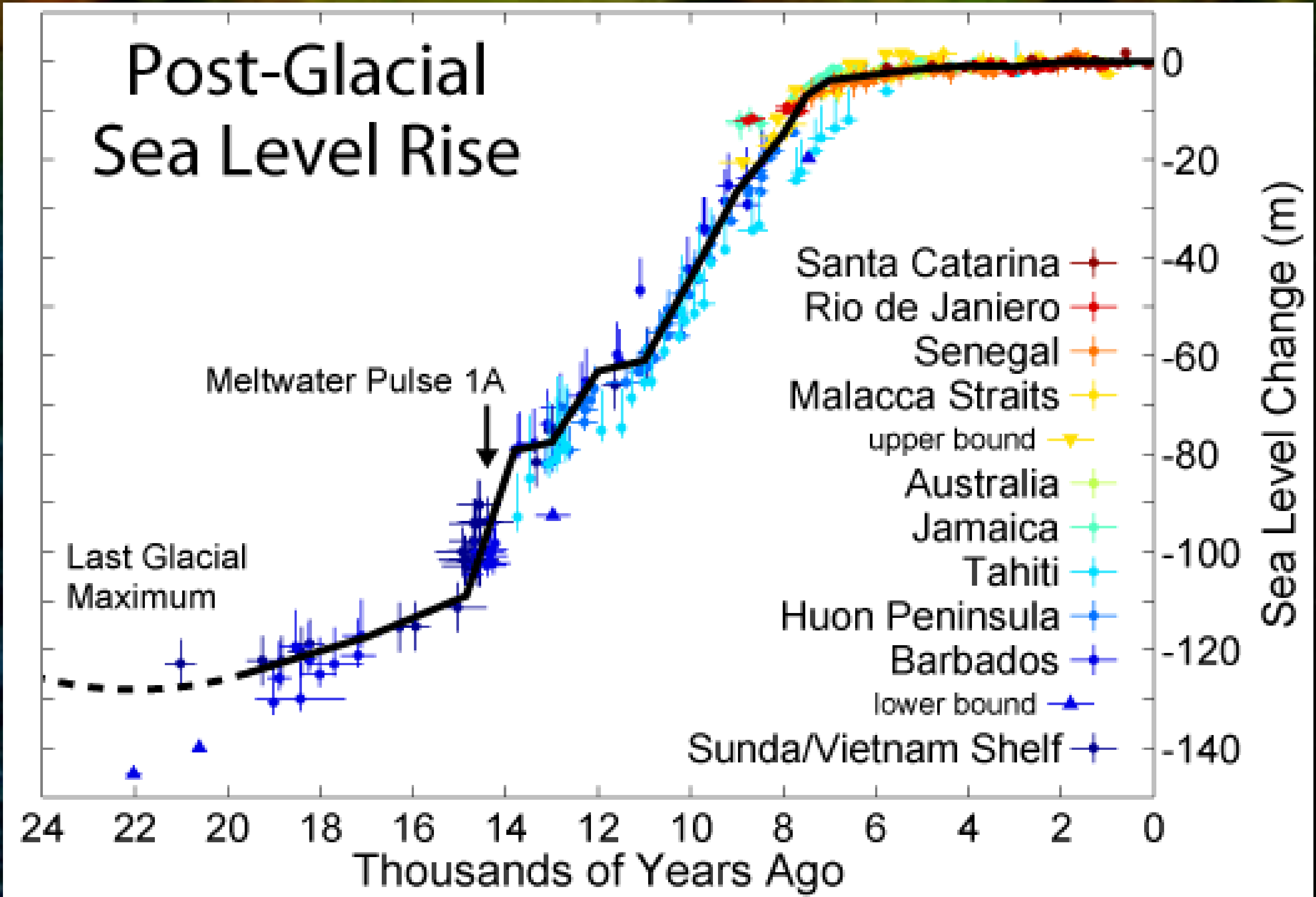
But …. Degree of change in variability **unknown**

But more heat affects water:

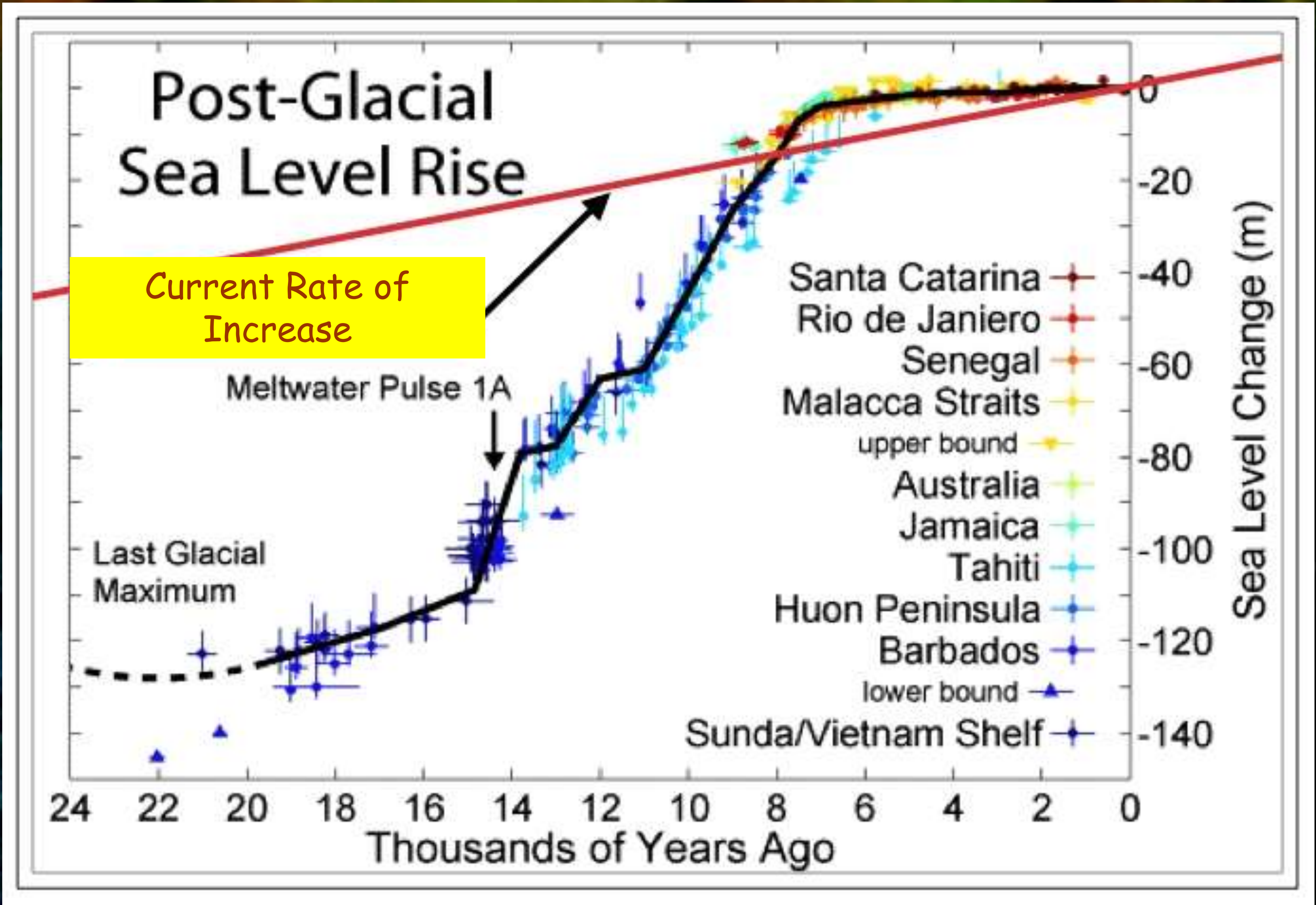
- → More ET, drier soils, and vegetation
- → Less streamflow, streamflow timing Δ
- → Less precip as snow, more as rain
- → Earlier snowmelt
- → More wildfire

Precipitation changes in General

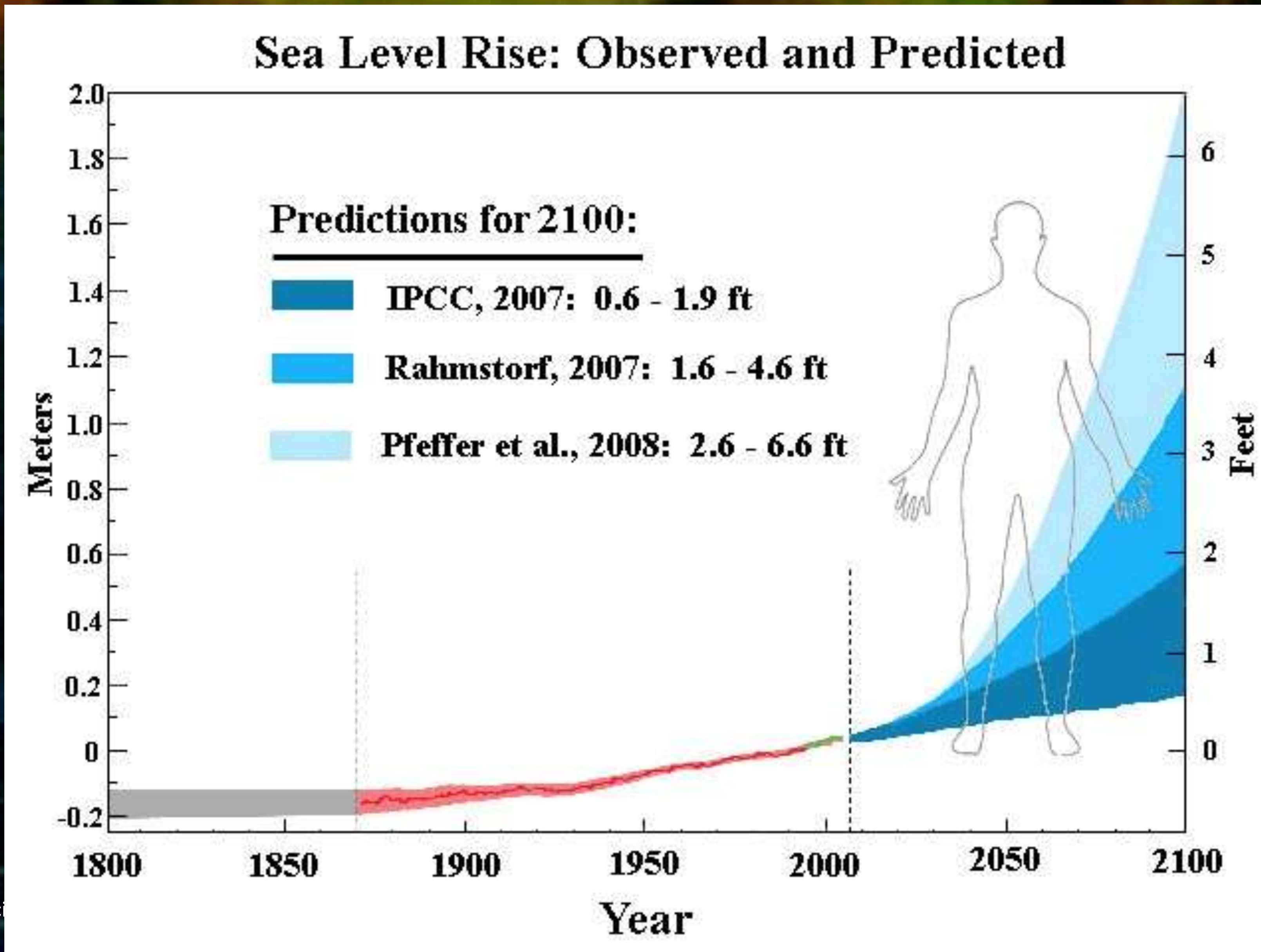
- Wet areas get wetter
- Dry areas get dryer
- Wet season gets wetter
- Dry season gets drier
- Variability goes up
- Less snow



Post-Glacial
Sea Level Rise
Meltwater Pulse 1A
Last Glacial
Maximum
Santa Catarina
Rio de Janiero
Senegal
Malacca Straits
upper bound
Australia
Jamaica
Tahiti
Huon Peninsula
Barbados
lower bound
Sunda/Vietnam Shelf
0
-20
-40
-60
-80
-100
-120
-140
Sea Level Change (m)
24
22
20
18
16
14
12
10
8
6
4
2
0
Thousands of Years Ago



Post-Glacial
Sea Level Rise
Current Rate of
Increase
Meltwater Pulse 1A
Last Glacial
Maximum
Santa Catarina
Rio de Janiero
Senegal
Malacca Straits
upper bound
Australia
Jamaica
Tahiti
Huon Peninsula
Barbados
lower bound
Sunda/Vietnam Shelf
0
-20
-40
-60
-80
-100
-120
-140
Sea Level Change (m)
24 22 20 18 16 14 12 10 8 6 4 2 0
Thousands of Years Ago


Sea Level Rise: Observed and Predicted
Predictions for 2100:
IPCC, 2007: 0.6 - 1.9 ft
Rahmstorf, 2007: 1.6 - 4.6 ft
Pfeffer et al., 2008: 2.6 - 6.6 ft
Meters
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
Feet
6
5
4
3
2
1
0
1800
1850
1900
1950
2000
2050
2100
Year

Paci

Climate change is a risk multiplier

Problems, stresses and risks are multiplied by climate change.

For example:

- Drought
- Flooding
- Population pressures
- Shortage of suitable water supply
- Development and disturbance of watersheds
- And so on

Climate change is a risk multiplier ...

So adapting is

BMPs and Best Practices

that we already know.

We have the know-how to adapt.

More crucial than ever, and more consequential if skipped or inadequate

Modelling climate variability

- We don’t get variability from models
- No extremes or storminess
- But, this is what matters most

Difficulty discerning trends for rare events

Rare event still rare if their probability increases.

Probability of Exceedance

	Design Return Period				
Time in years↓	5	25	50	100	500
5	67	18	10	5	1
20	99	56	33	18	4
50	99	87	64	39	10
100	99	98	87	63	18

Loss of Stationarity Assumption: What it means

Assume that probabilities will worsen...

...Consider that they might worsen a lot.

Loss of Stationarity Assumption: What it means

Use scenarios:

For example:

- The 100-year flood ➔ 10-year flood or 25-year flood
- The 10-year, 7-day low flow ➔ annual low flow, 2-year low flow

www.bit.ly/watervulnerability

Bosques Nacionales Piloto: John Chatel, Caty Clifton, Alan Clingenpeel, Dale Higgins, Ken Hodges, Carol Howe, Laura Jungst, Joan Lui, Christine Mai,, Rory Stienke, Mark Weinhold.
Grupo de dirección: Dan Cenderelli, Mike Furniss, Polly Hays, Kerry Overton, Ken Roby, Brian

Resilience ⟷ **Vulnerability**

To promote resilience you need to know vulnerability

"Two sides of the same coin."

Vulnerability

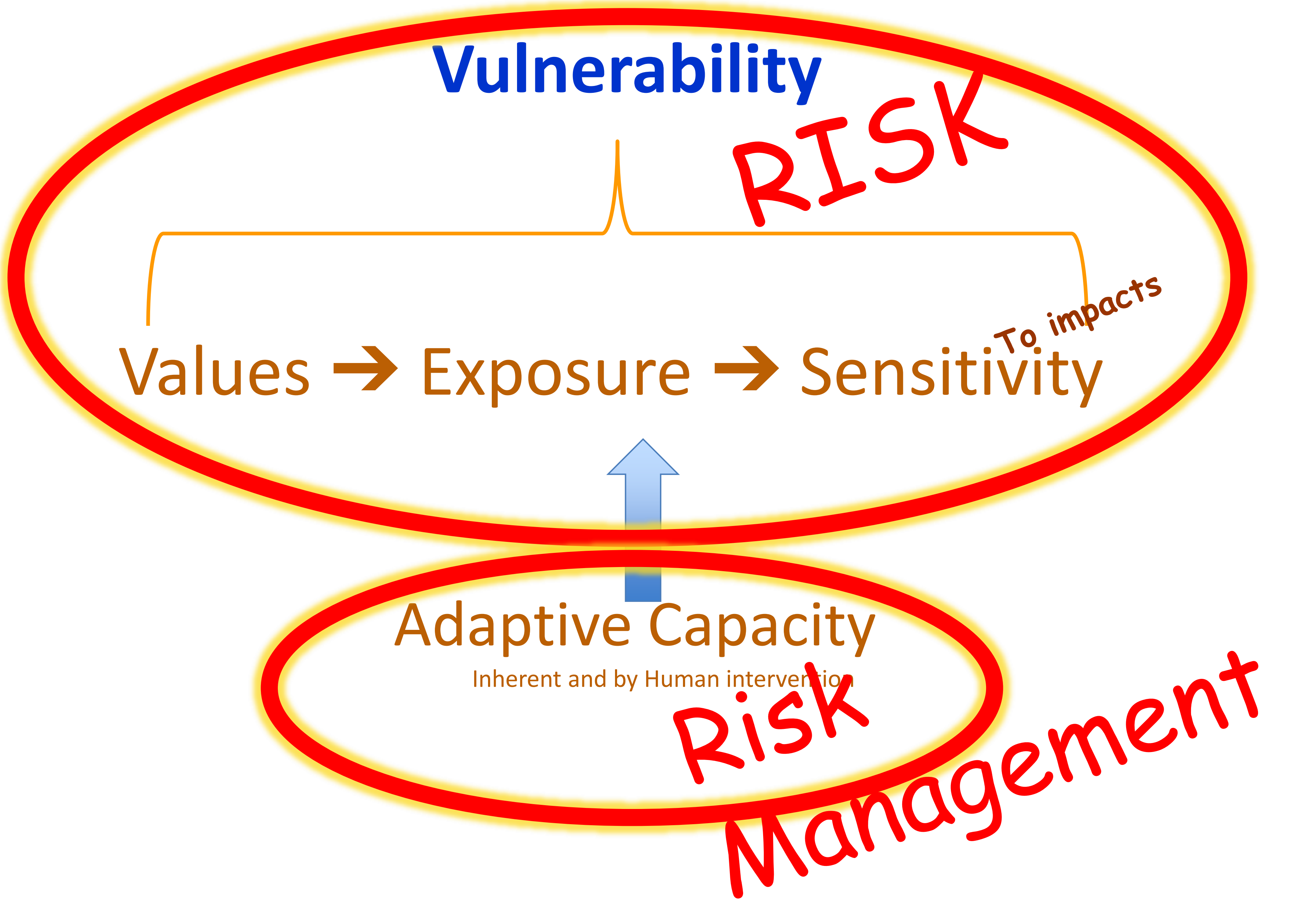
Exposure → Sensitivity → Values

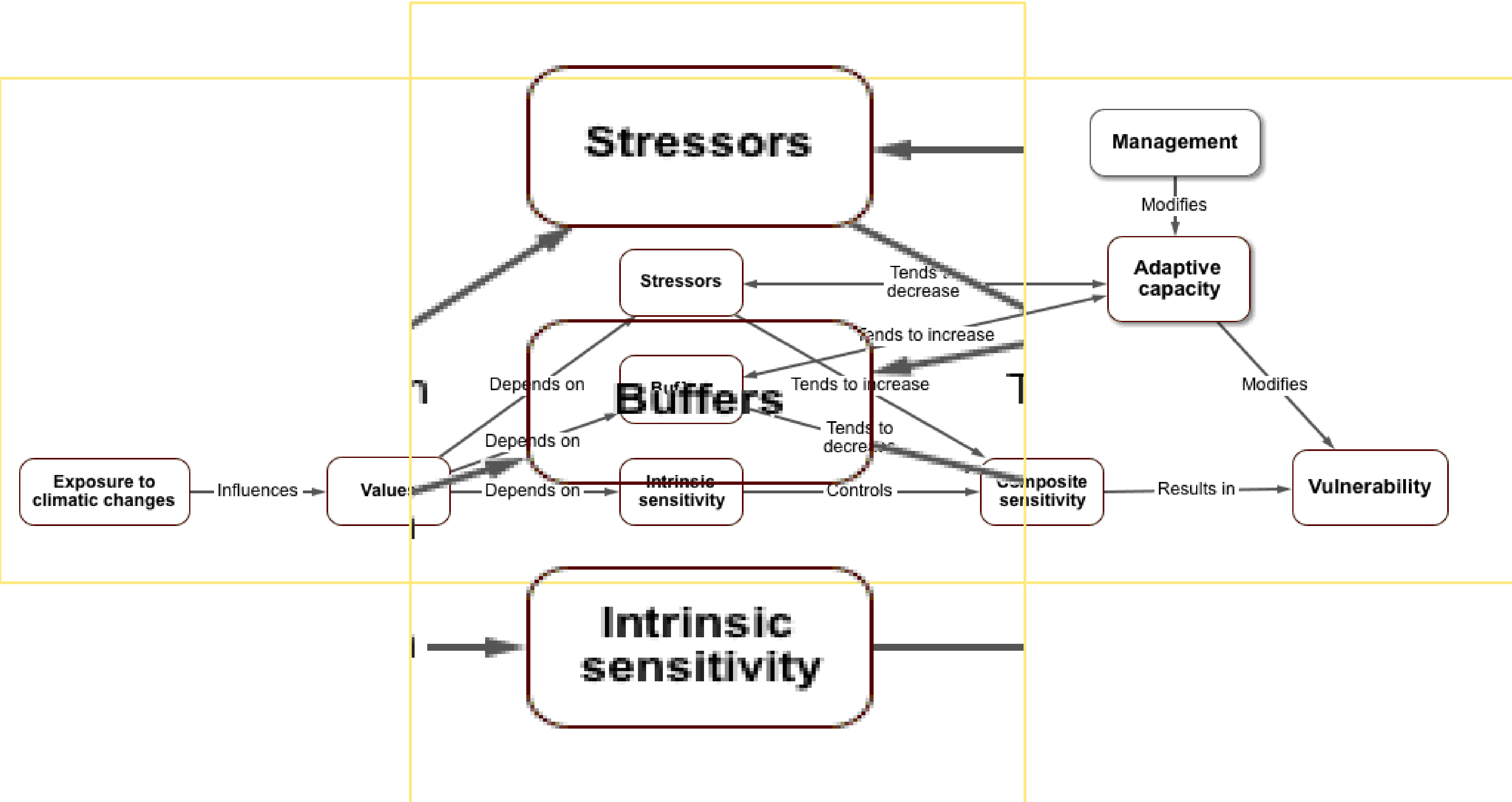
Adaptive Capacity

Inherent and by Human intervention

Fussel 2007

Time scale
Spatial scale
What is valued or domain
Attribute of concern
Hazard


Vulnerability
RISK
To impacts
Values → Exposure → Sensitivity
Adaptive Capacity
Inherent and by Human intervention
Risk
Management



Exposure x Sensitivity ÷ Adaptive Capacity = Vulnerability

Two earthquakes

Loma Prieta (San Francisco USA) 1989	Haiti 2010
Magnitude 6.9	Magnitude 7
62 dead	316,000 dead
4,000 injured	300,000 injured
$6 billion in damages	$14 billion in damages

Fire risk signs. An indicator of vulnerability

Fire risk signs. An indicator of vulnerability

USAID
FROM THE AMERICAN PEOPLE

= Vulnerability to Wildfire

We can adapt with:

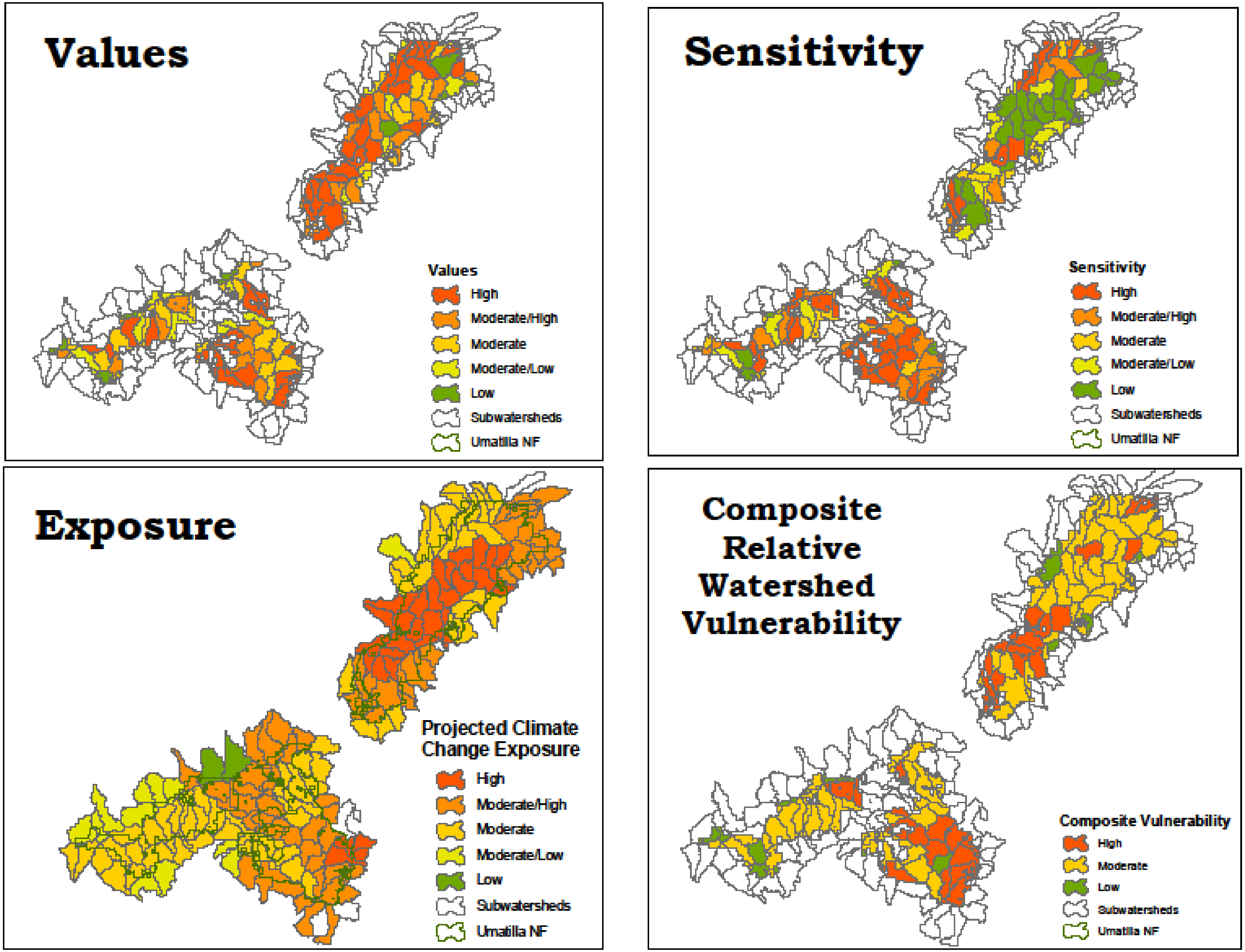
- Maintaining fire suppression resources,
- Doing fuels treatments,
- Remote fire detection, and so on.

Exposure

- Weather
- Wind
- Temperature
- Humidity

Sensitivity

- Fuel
- Topography
- Suppression
- Resources


Values
Values
High
Moderate/High
Moderate
Moderate/Low
Low
Subwatersheds
Umatilla NF
Sensitivity
Sensitivity
High
Moderate/High
Moderate
Moderate/Low
Low
Subwatersheds
Umatilla NF
Exposure
Projected Climate Change Exposure
High
Moderate/High
Moderate
Moderate/Low
Low
Subwatersheds
Umatilla NF
Composite Relative Watershed Vulnerability
Composite Vulnerability
High
Moderate
Low
Subwatersheds
Umatilla NF

Generalizations about ecosystem vulnerability

- Vulnerability will be greater in low diversity ecosystems
- Vulnerability will be greatest in areas of high stressors, cumulative effects, and population pressure
- Vulnerability will be greatest in areas of over-allocated and inadequate water supplies
- Vulnerability will tend to be greater in boundary ecosystems and at the limits of species current ranges.
- Vulnerability will be greater in areas where soils are thin, droughty, or highly erodible.
- Vulnerability will tend to be greater in areas with extensive invasive species
- Greater problems for species already in decline
- Vulnerability will be greater in fragmented ecosystems
- Ecosystem changes will have significant effects on wildlife and aquatic biota

at the

Arcata Theater Lounge
December 21st 2014

The '64 Flood

50th Anniversary Gathering

Festive

Fun

Interactive

Food and drink
Films old and new

A 1964 Immersion

Variety show
Brief presentations

Doors open at 6 pm
Events begin at 7 pm

Tickets **$10**
available at Ticket Outlets or at www.arcatatheater.com

SPONSORS:

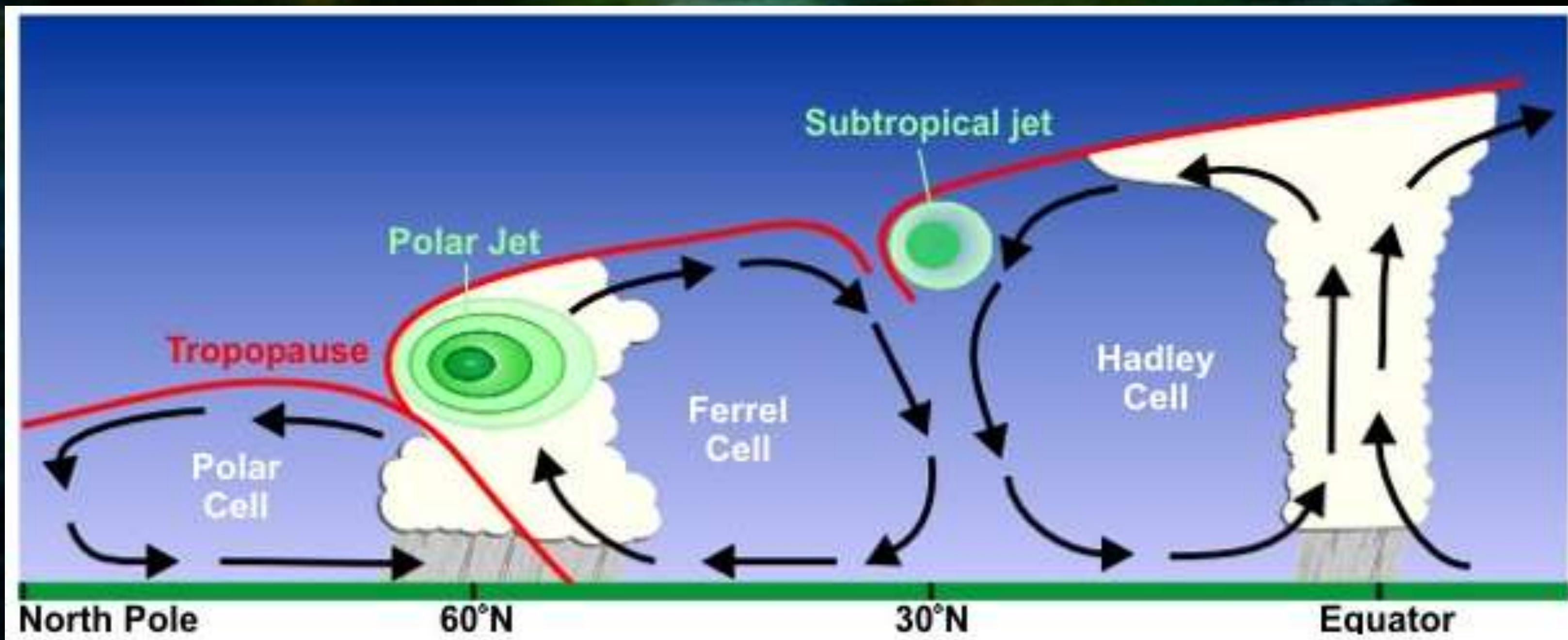
Smith River Alliance

Cascadia GeoSciences

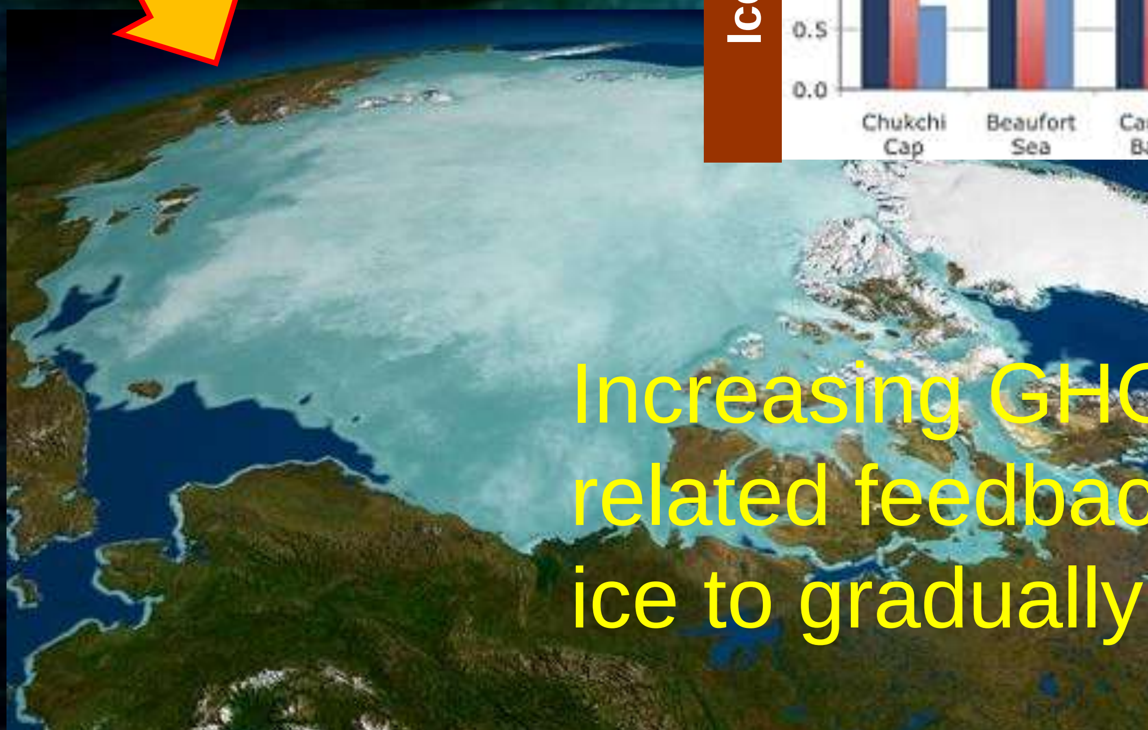
Mad River Union

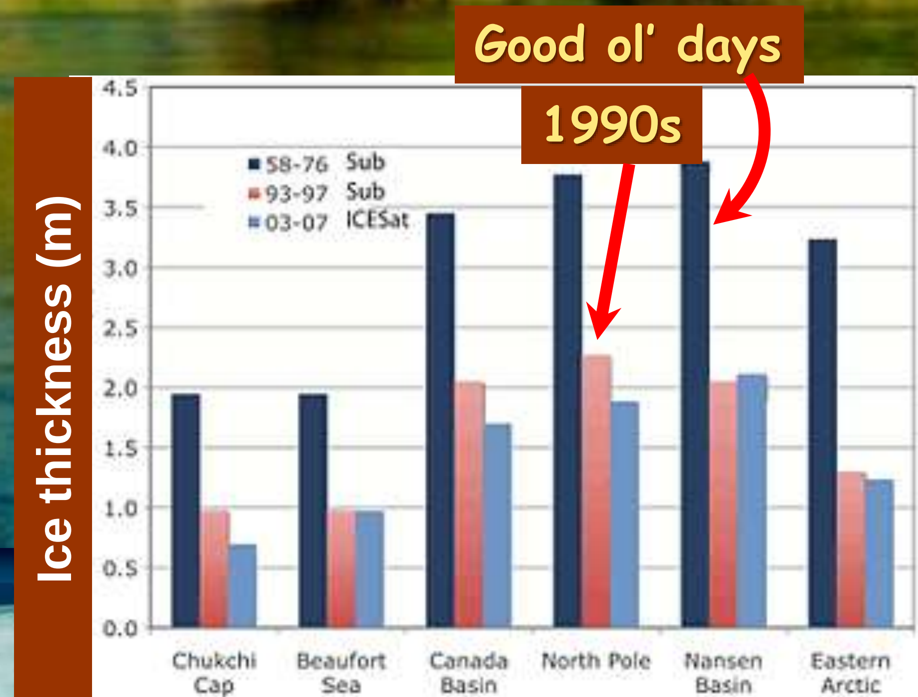
Wild Earth Press

facebook.com/1964flood


Subtropical jet
Polar Jet
Tropopause
Hadley
Cell
Ferrel
Cell
Polar
Cell
North Pole
60°N
30°N
Equator

GHGs





Rothrock and Kwok, 2009

Increasing GHGs and related feedbacks caused ice to gradually thin.

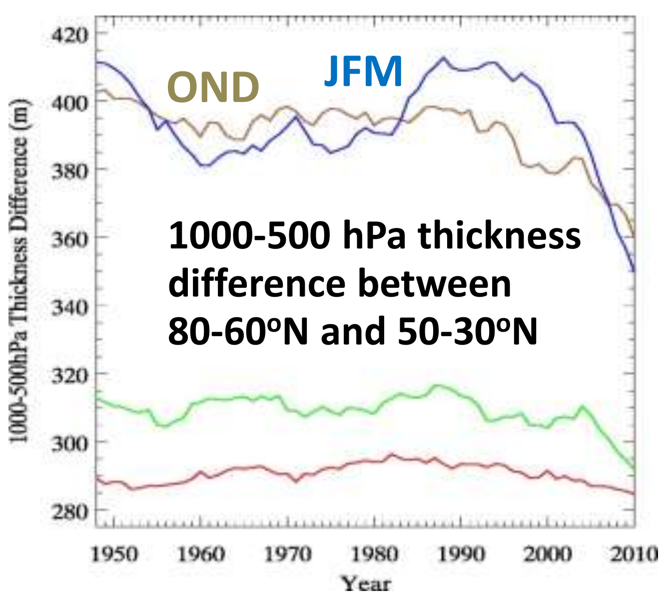
Connecting the dots (focus on fall and winter):

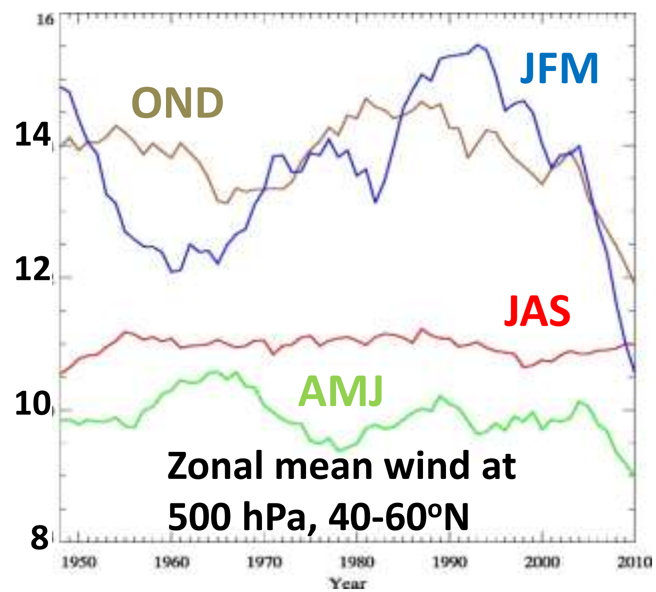
Thickness increases are larger in high latitudes than in mid-latitudes **=> expect 2 main effects:**

First effect: Weaker poleward temperature gradient

=> weaker zonal wind speeds.

N. America and N. Atlantic

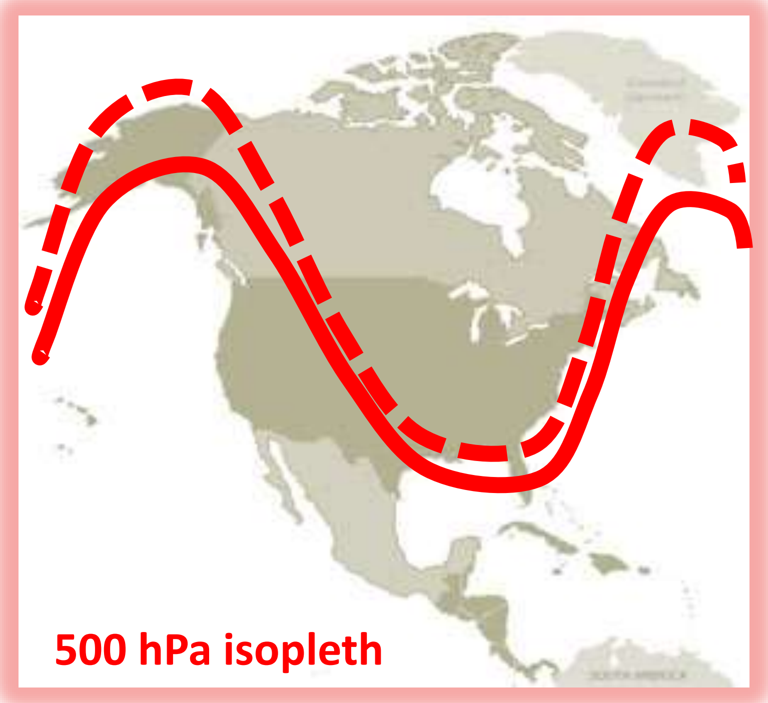




~ 20% less

Second effect:

Larger warming at high latitudes causes peaks of ridges of the Jet Stream to elongate



Wave amplitude increases

Higher-amplitude waves progress more slowly

More persistent weather patterns

Summary

Arctic Amplification

High latitudes warming more than mid-latitudes

=> Poleward thickness gradient weakening

Weaker upper-level, zonal-mean flow, reduced phase speed

Peaks of upper-level ridges elongate northward, wave amplitude increases

- **Rossby waves progress more slowly**
- **Weather conditions more persistent**
- ***Increased probability of extremes: cold spells, heat waves, flooding, prolonged snowfall, and drought***

Presilience: What Can Be Done?

- Understand impacts and plan responses
  - **Conduct Vulnerability Assessment**
- Careful, long-term research and monitoring
- Implement and monitor BMPs! Best Practices.
- Scenario planning & risk assessment
- Focus on consequences, not probability
- Aggressively and relentlessly reduce carbon emissions of your operations, physical plant, and provisioning