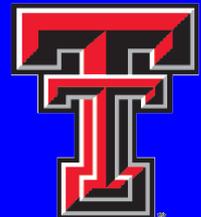


What's Happening?
**Projected Climate Change Impacts To
California and the San Francisco Bay Region**
2C or Not 2C ? - that is the CHALLENGE...

CDFG Climate College Webinar
November 5, 2012

Tom Suchanek, Ph.D.
Lead Scientist / Climate Change Coordinator
Western Ecological Research Center
U.S. Geological Survey
Sacramento, CA

Thanks to:



- Dan Cayan (USGS)
- Mike Dettinger (USGS)
- John Takekawa (USGS)
- Josh Ackerman (USGS)
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- Nate Stephenson (USGS)
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- Patrick Barnard (USGS)
- Jeff Burgett (USFWS)
- Mendel Stewart (USFWS)
- Richard Feeley (NOAA)
- Michelle Orr (Phil Williams & Assoc.)
- Josh Collins (San Francisco Estuary Institute)
- Ellie Cohen (PRBO-Conservation Science)
- Katharine Hayhoe (Texas Tech Univ)
- Healy Hamilton (Cal Acad Sci)

- 
- **Background/Update on Global Climate Change**
 - **Global Emissions: by country and per capita**
 - **Projections: Temperature, Precipitation, Snowpak, etc.**
 - **Potential Impacts: Physical, Chemical, Biological/Ecological**
 - **Ongoing Climate Change Research in California and Region**
 - **Where Do We Go From Here?**

What's Happening?

Projected Climate Change Impacts To
California and the San Francisco Bay Region

2C or Not 2C ? - that is the CHALLENGE...

Variability Is The Key

Expect Extreme Weather Events

Super Storm SANDY



The New Normal ??

FACTORS INFLUENCING SANDY'S IMPACTS:

Confluence of:

- Long-term Ongoing Sea Level Rise
- Full Moon (Spring Tides = highest tides of month)
- Lowest Barometric Pressure Ever for Northeast (raises sea level)
- Extreme Storm Wave Heights
- Storm Wave Surge (14 ft - exceeded predictions of 11.5 ft)
- Peak of Wave Surge Occurred at Peak High Tide
- Gulf Stream Temperature 5° F Above Normal
- Very High Storm Winds
- SANDY Combined With Another Storm



Fourth Synthesis Report
CLIMATE CHANGE 2007

SYNTHESIS REPORT



Fifth Synthesis Report due 2014

IPCC



A Report of the Intergovernmental Panel on Climate Change



Tools/Data used to investigate climate change:

MODERN EVIDENCE:

- Global temperature records over the past 150 yrs
- Tidal gauge records over the past 150 yrs
- Atmospheric CO₂ concentrations since 1958
- Altered phenologies: (Life Cycle timing)
 - > first bud and flowering times
 - > bird nesting and migration data

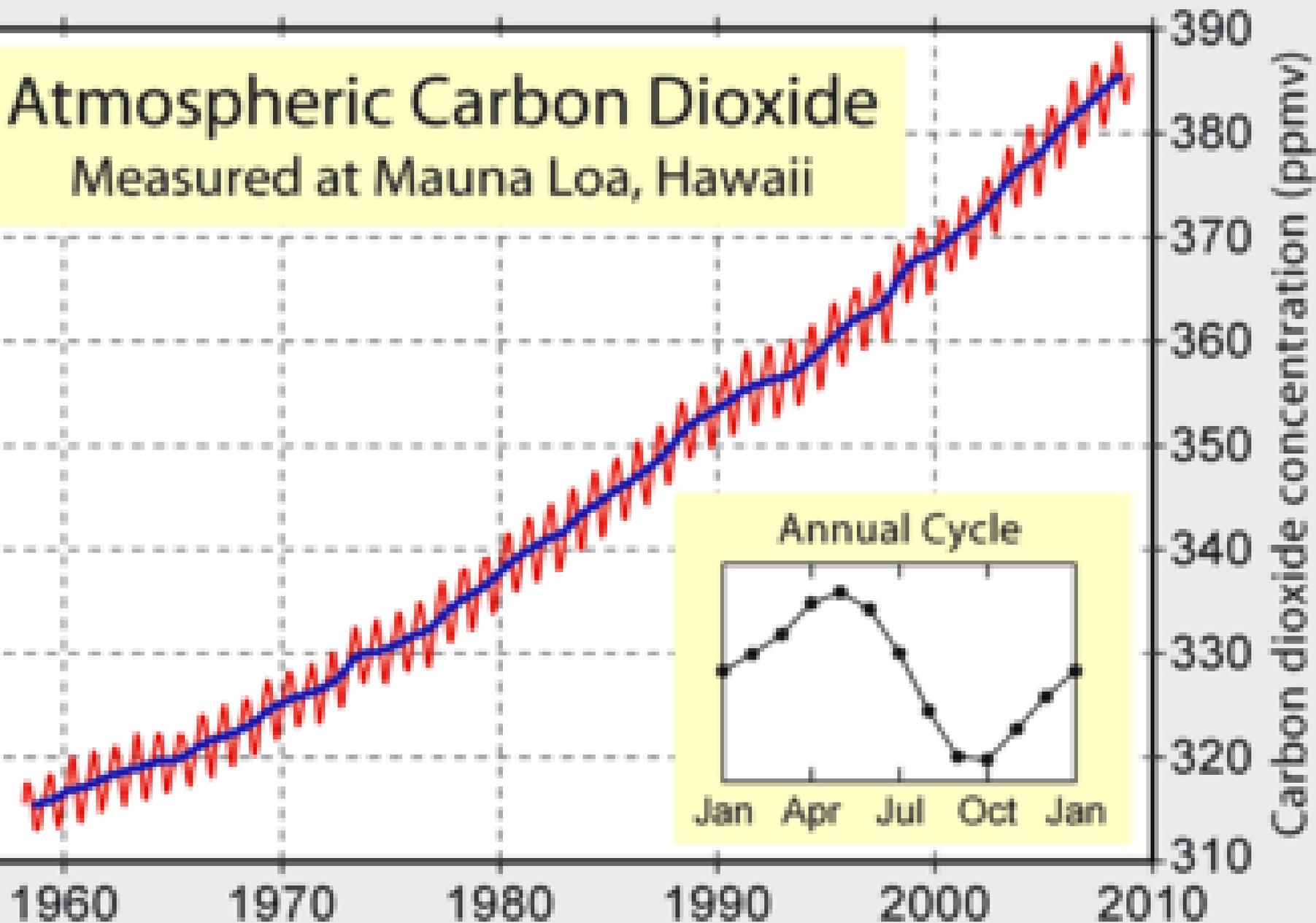
HISTORICAL EVIDENCE: Proxies

- Oxygen isotopes in marine and freshwater animal shells
- Tree-ring data
- Sediment core data
- Ice core data

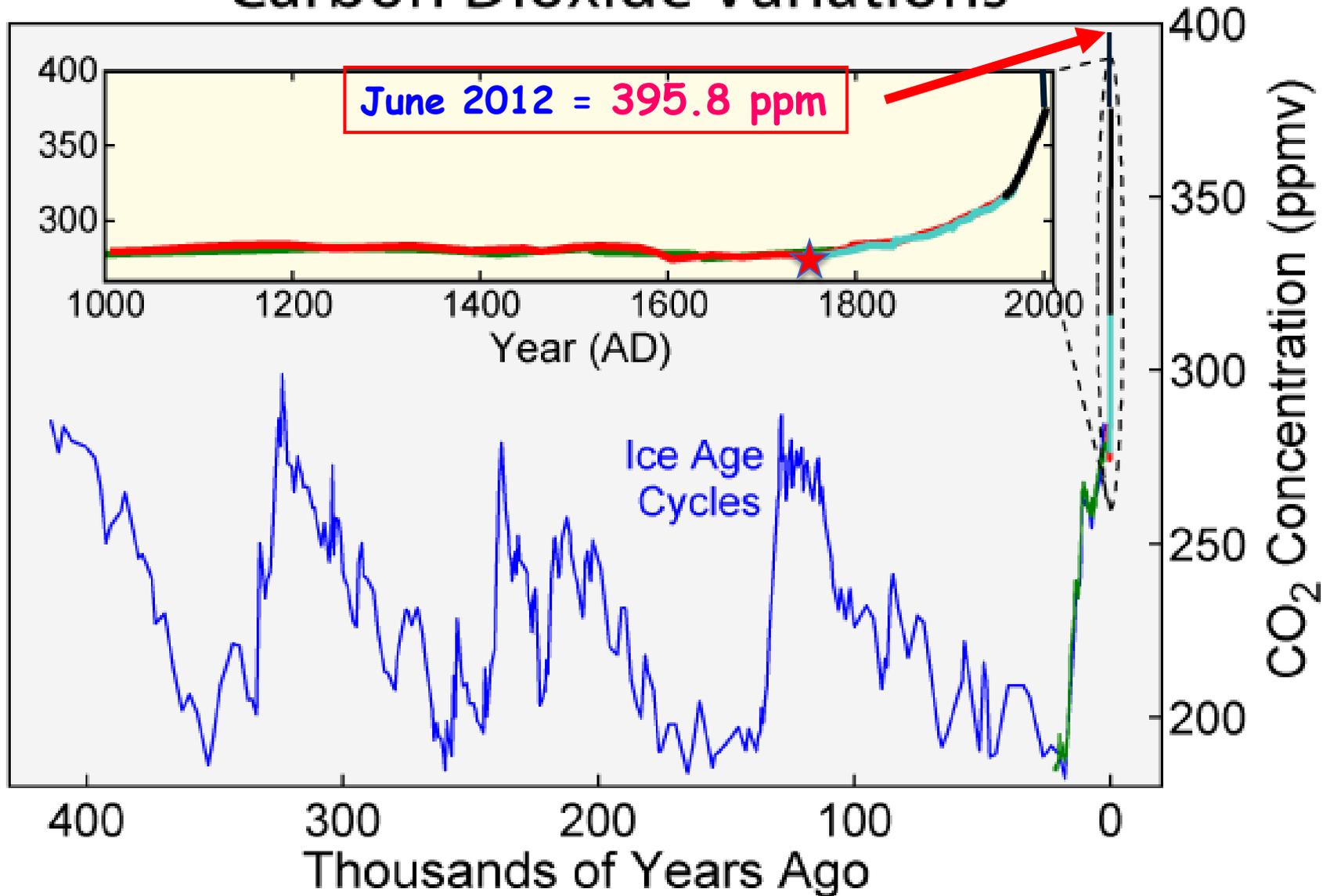
The Keeling Curve

400

Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii

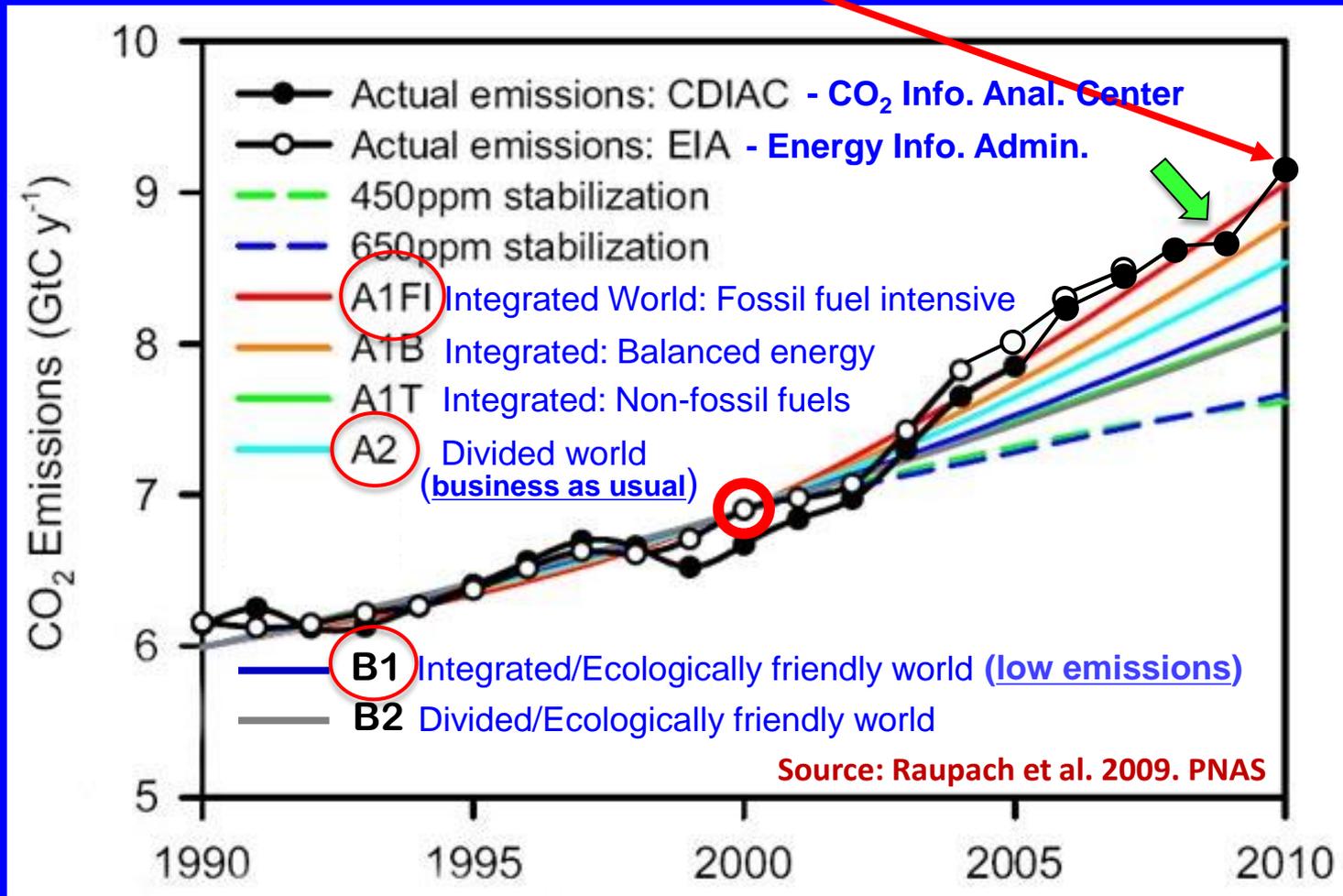


Carbon Dioxide Variations



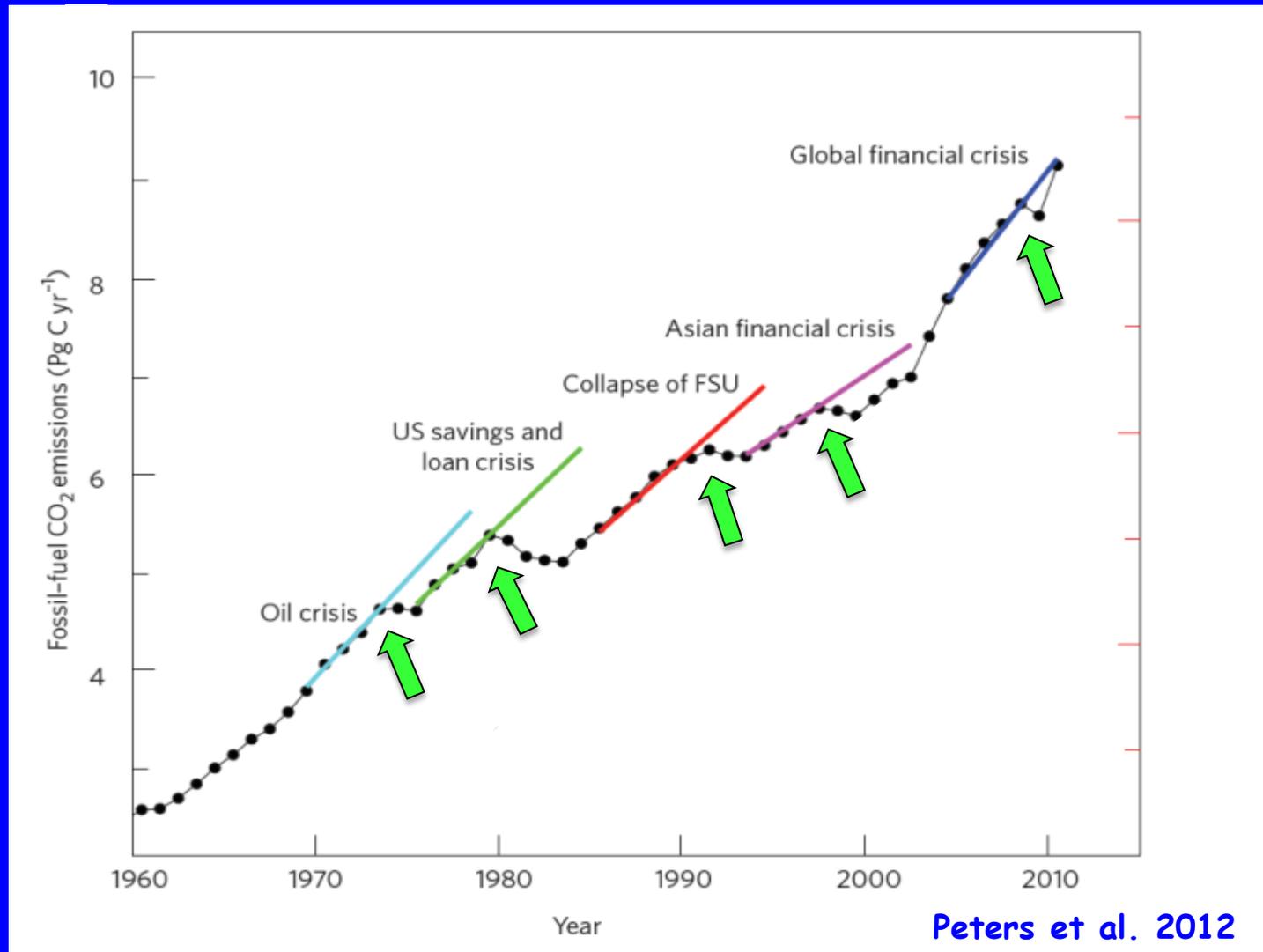
Global Carbon Emissions

Measured emissions have exceeded most IPCC scenario estimates.



1 GigaTon = 10⁹ Tons = 1 Billion Tons

Global Carbon Emissions



1 Petagram (= 1 Gigaton) = 10^{15} g = 1 Quadrillion g

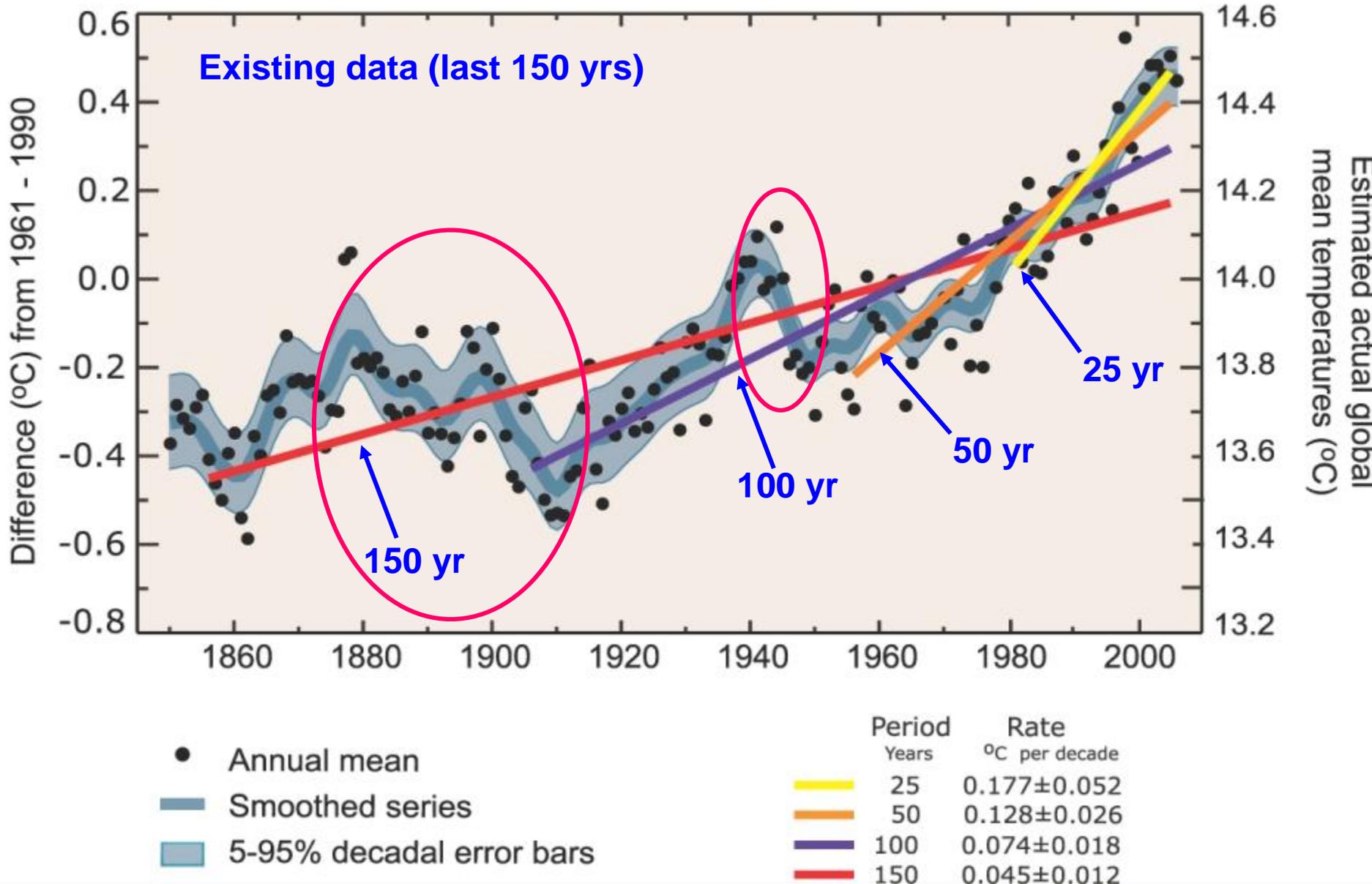
Top 5 CO₂ emitters: 2010

C vs CO₂

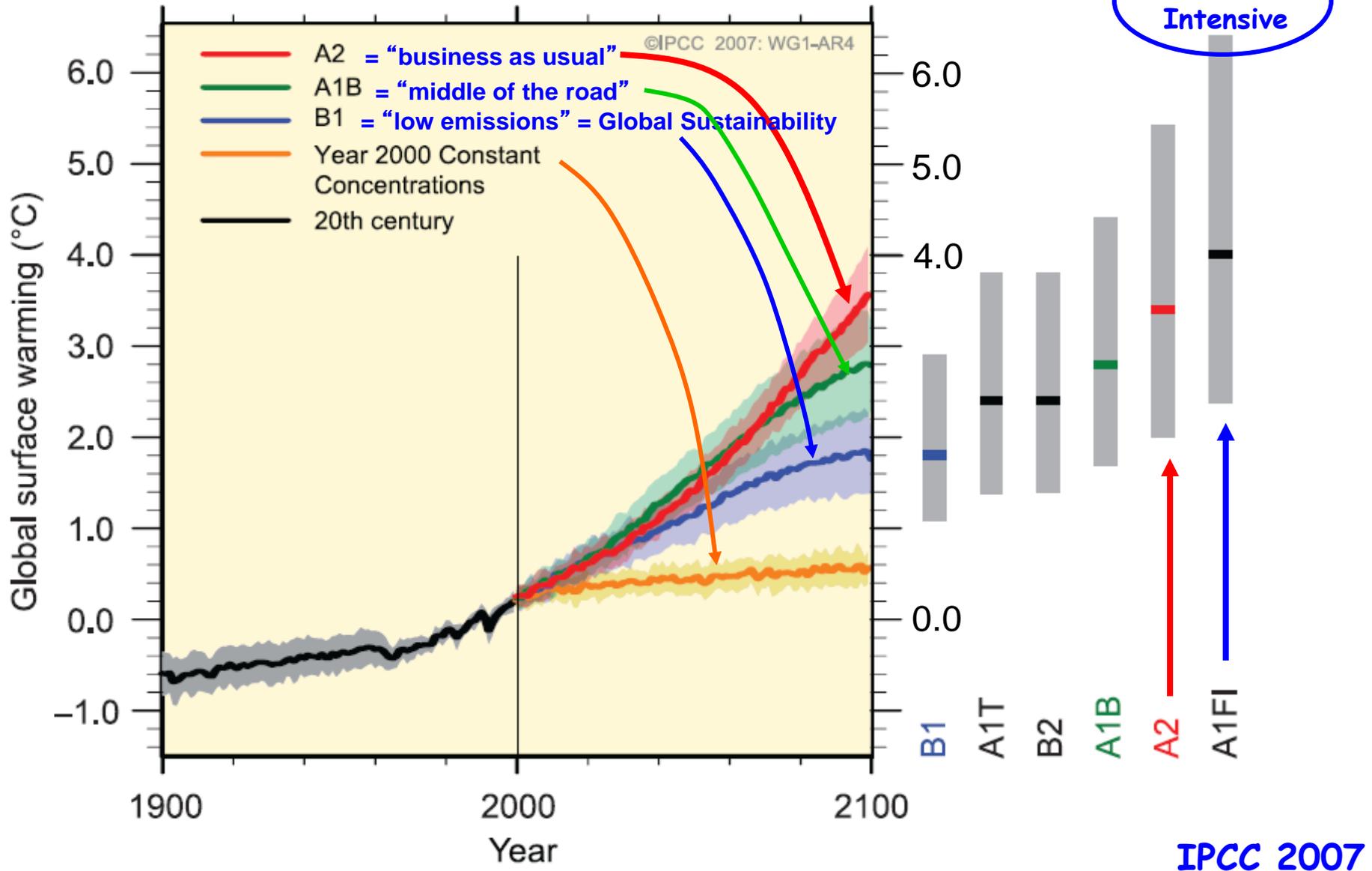
1 ton Carbon = 3.67 tons CO₂

	GigaTons of CO ₂	% of Total	2009 Tons Per Capita CO ₂ emissions	1999-2009 % Change In CO ₂ emissions
1  <u>China</u>	7.7	25.4 %	5.1	+ 161 %
2  <u>United States</u>	5.4	17.8 %	16.2	- 13 %
3  <u>India</u>	1.6	5.3 %	1.4	+ 100 %
4  <u>Russia</u>	1.6	5.2 %	10.8	- 27 %
5  <u>Japan</u>	1.5	3.6 %	8.6	- 0.3 %
<u>Qatar</u>			40.1	+ 33 %

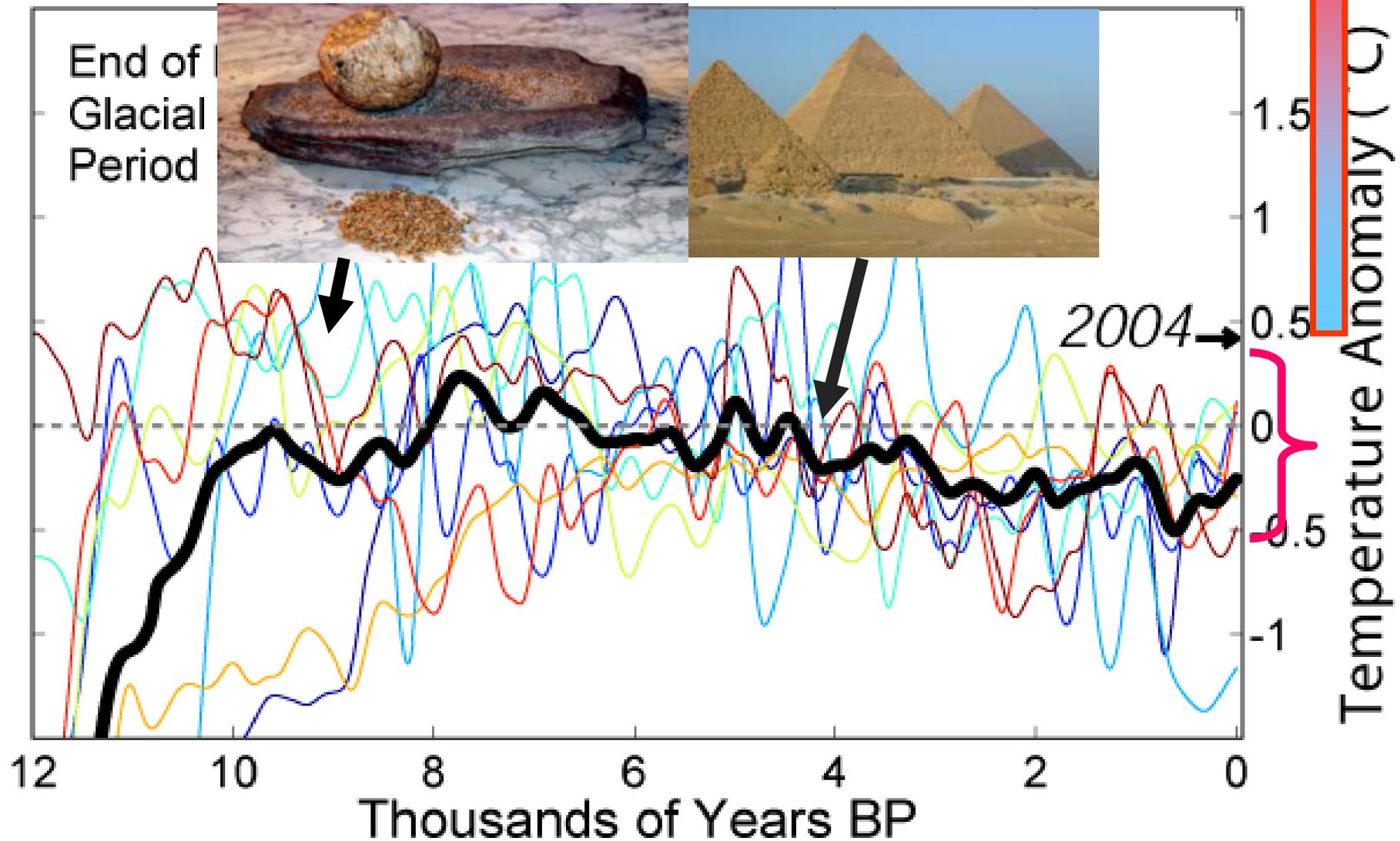
Rate of temperature change is increasing



MULTI-MODEL AVERAGES AND ASSESSED RANGES FOR SURFACE WARMING



Holocene Temperature Variations



Global Temperatures from 1881 → 2006

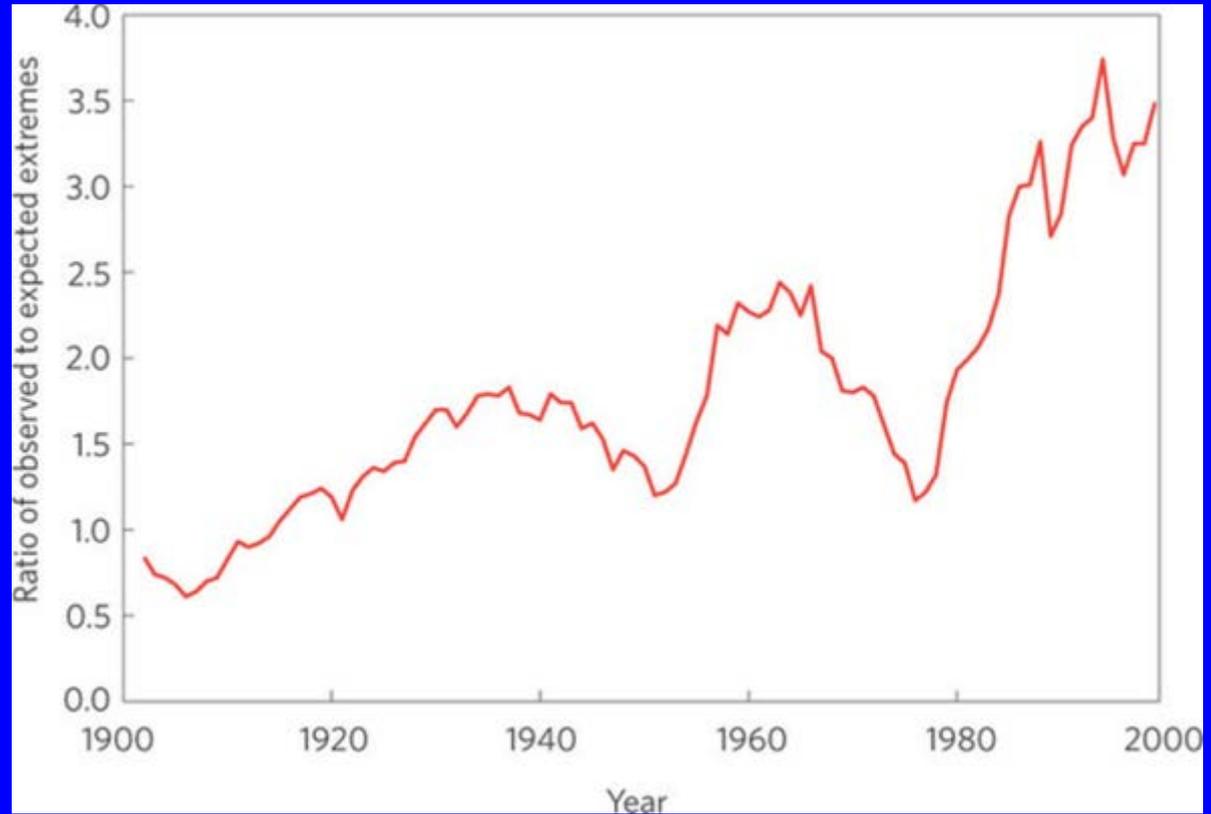




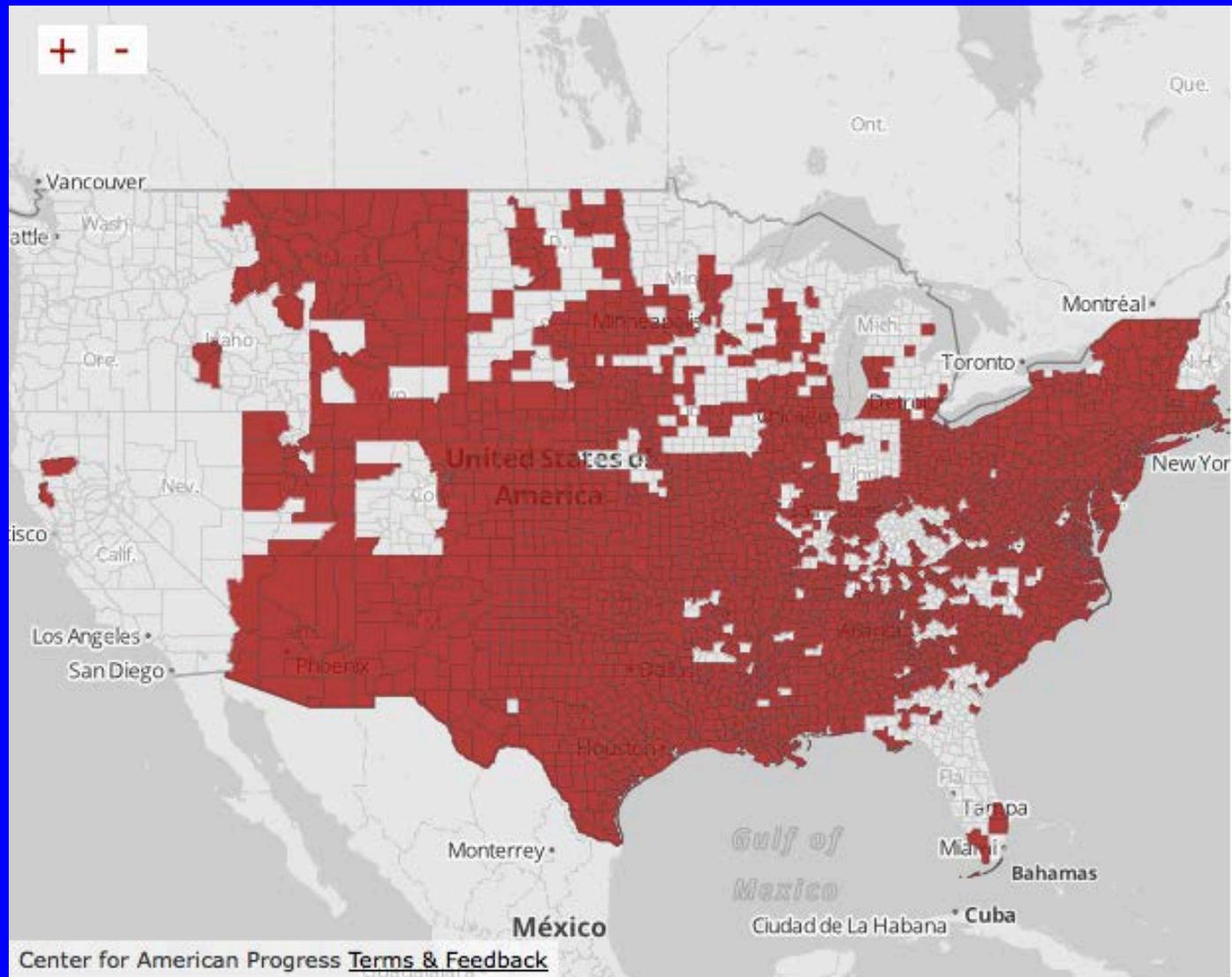
March 2012: 15,272 heat records broken in the US - includes every state

July 2012 was the hottest month on record for the contiguous U.S. since record keeping began in 1895.

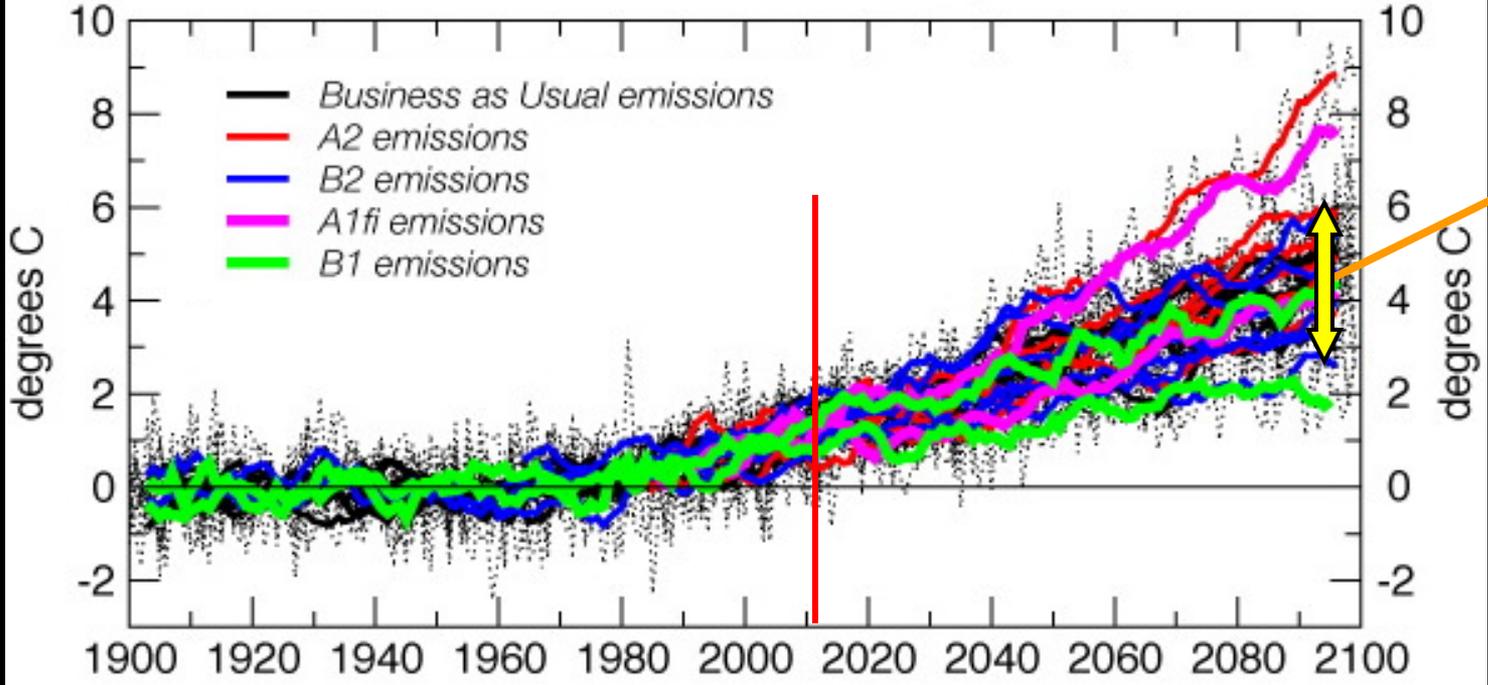
Century increase in the number of monthly heat records broken



Counties affected by at least one extreme weather event, causing over \$1 Billion in damage in 2010-2011.



PROJECTED CHANGES IN ANNUAL TEMPERATURE, NORTHERN CALIFORNIA



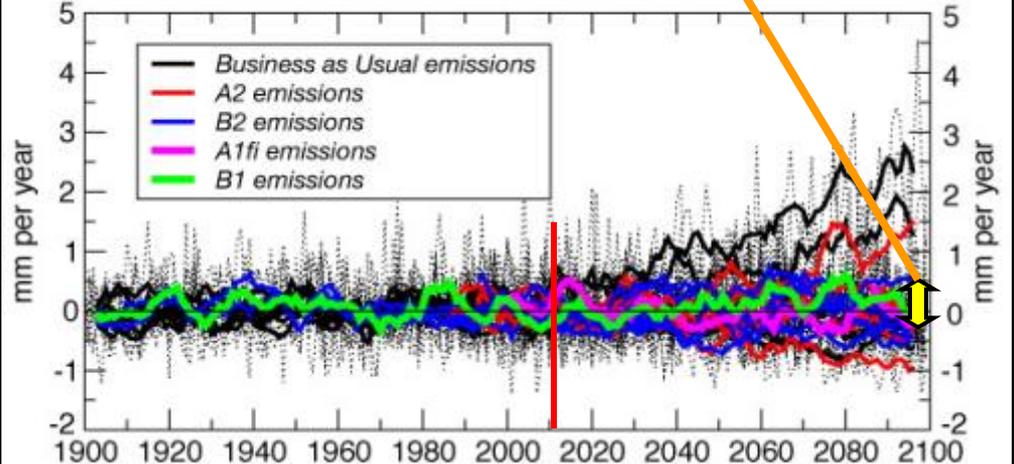
20 of 23
in this
range

19 of 23
in this
range

Strong consensus
for warming

Large uncertainty
with precipitation

PROJECTED CHANGES IN ANNUAL PRECIPITATION, NORTHERN CALIFORNIA



Dettinger, 2005; Hidalgo et al, 2008

Atmospheric Rivers

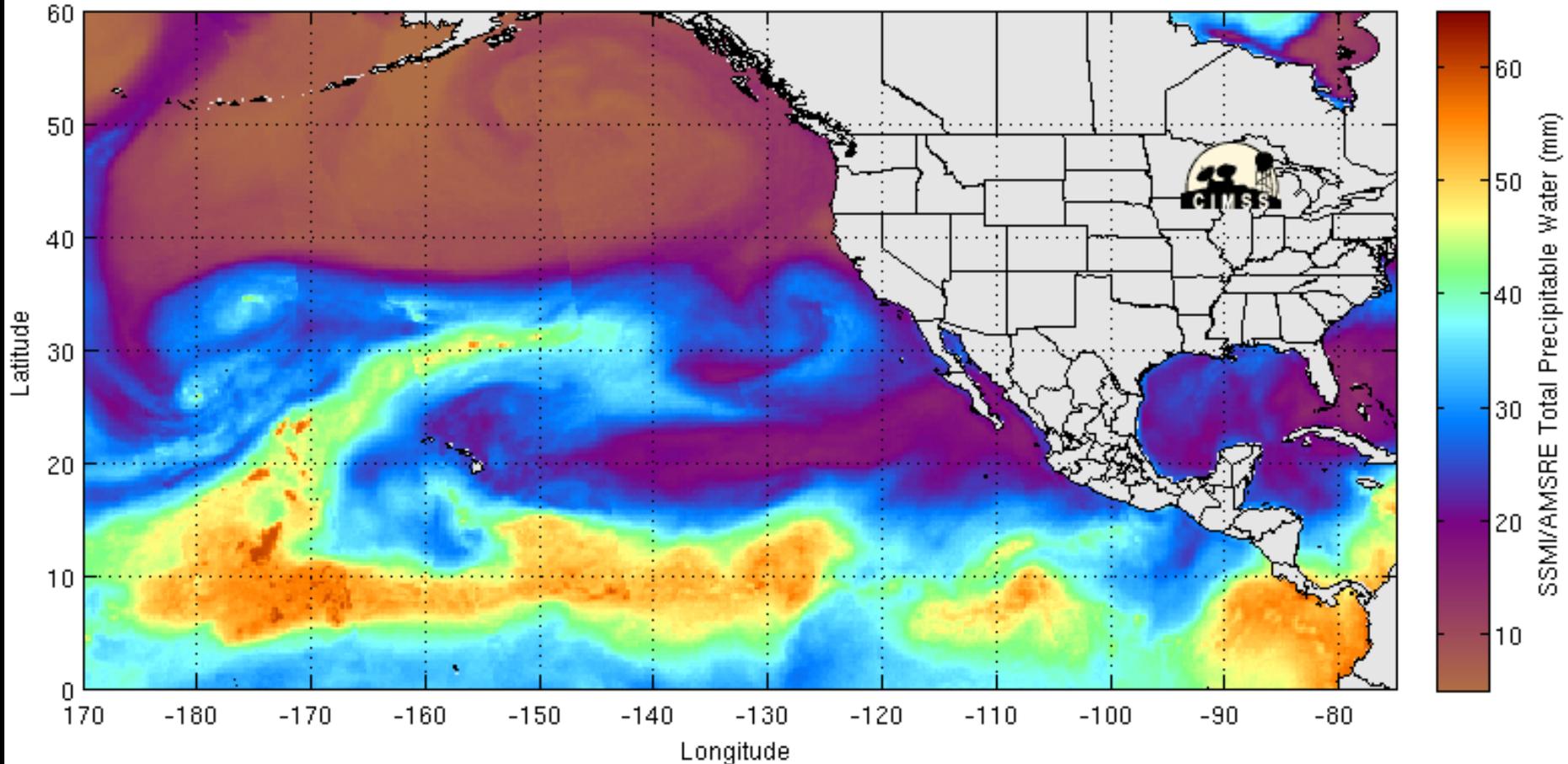
SUPER STORM

26 inches of rain in coastal CA

December 17-22, 2010

17 feet of snow in the Sierra

Morphed composite: 2010-12-17 00:00:00 UTC



Statistical Downscaling for the State of California

Mike Dettinger & Dan Cayan
US Geological Survey, La Jolla, CA

*CDFG/USGS/USFWS Downscaling Workshop,
CSU Sacramento, Nov 3, 2010*



Scripps Institution of Oceanography

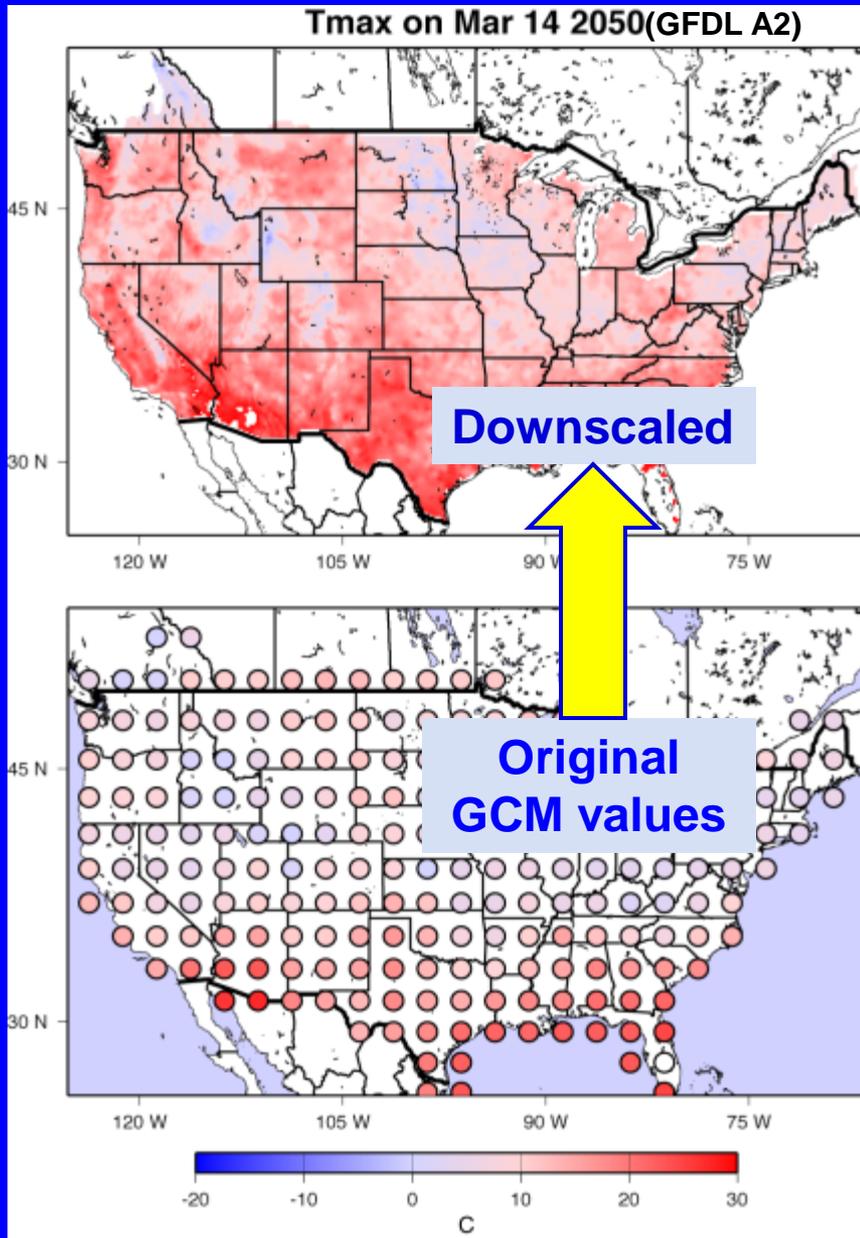
CEC's
California Climate
Change Center



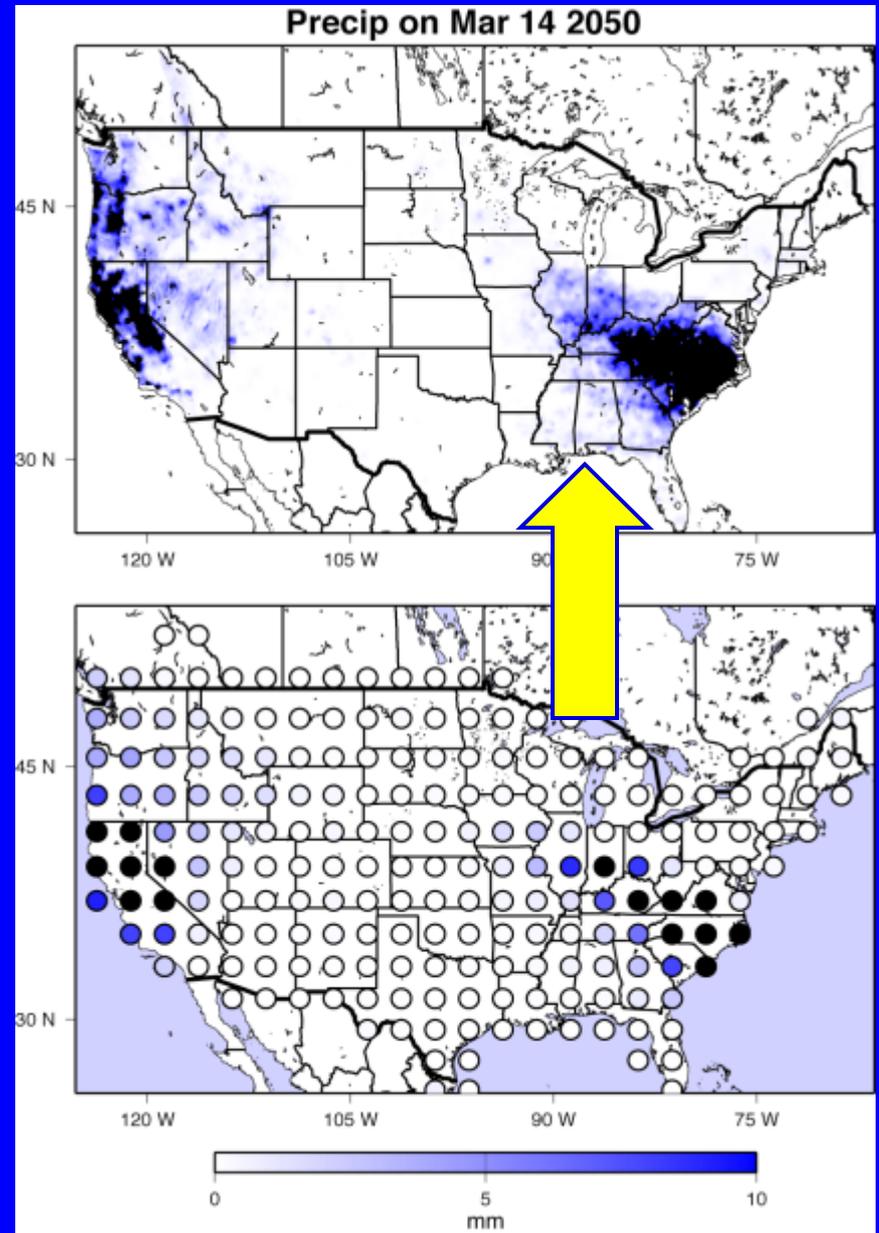
NOAA OGP's
California
Applications
Program



THE DOWNSCALING PROCESS:



One day in the 21st Century...



Approaches for Downscaling Climate Change Projections: Implications of Multiple Scales

2.5° = 275 km

1° = 110 km

1/8° = 12 km

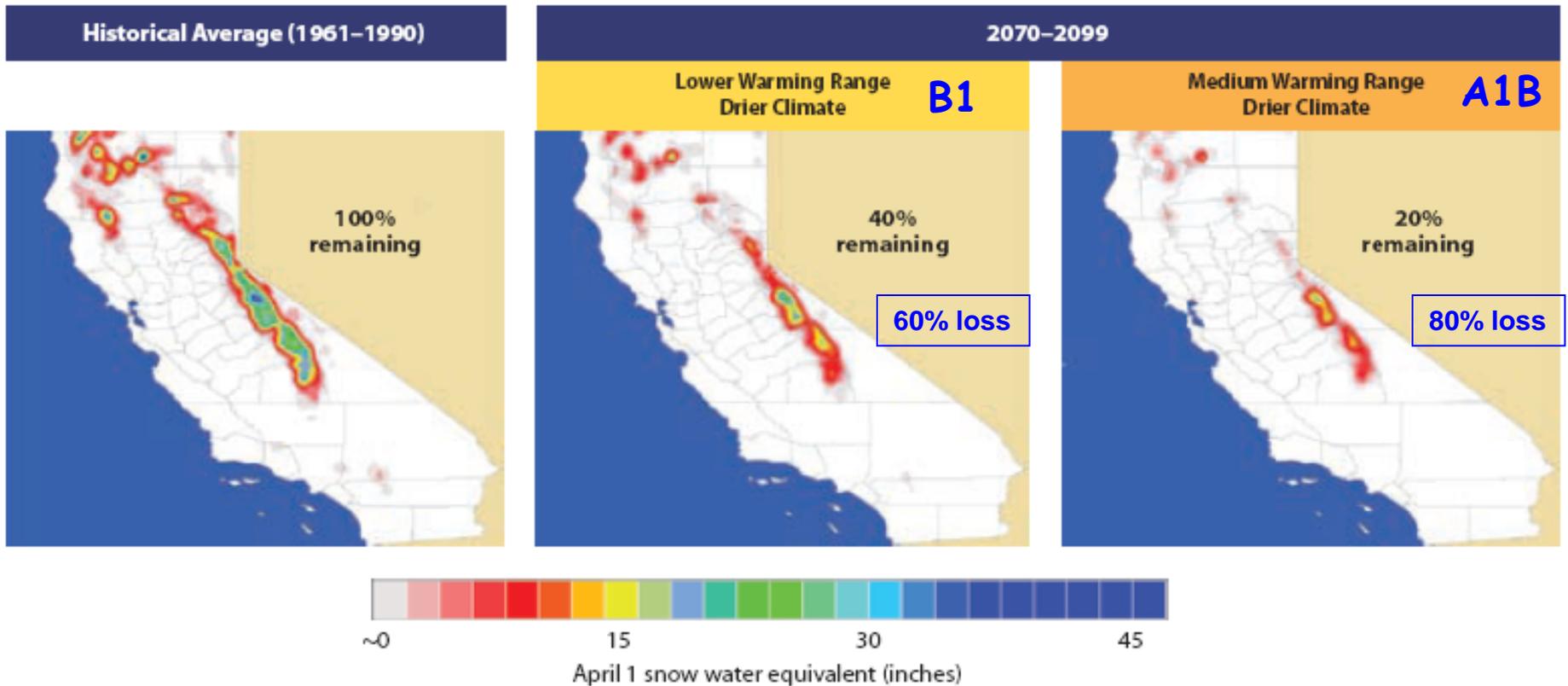
270m

90m

Lorraine E. Flint and Alan L. Flint
U.S. Geological Survey
Sacramento, CA

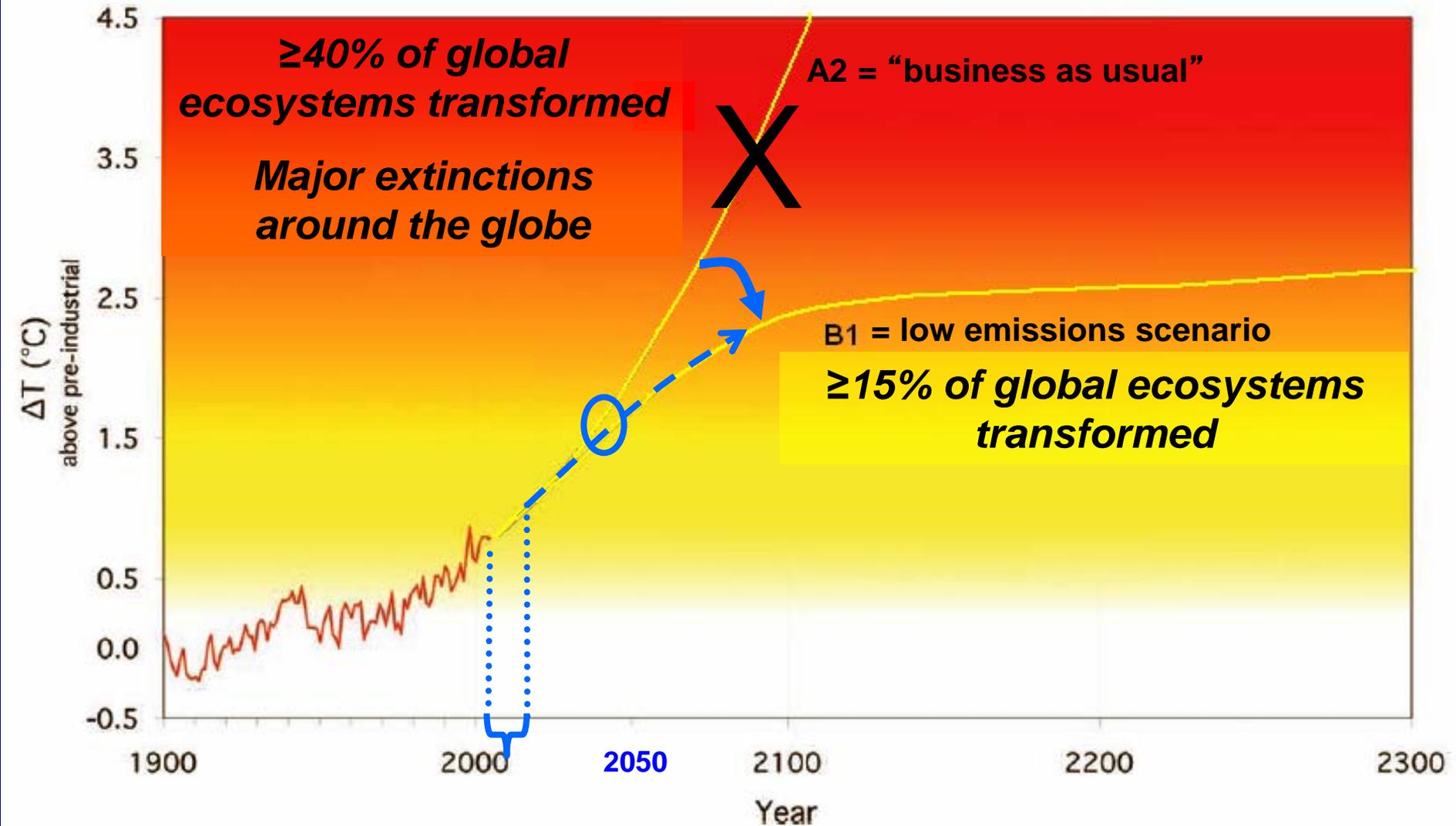
Impacts on Snowpack

Decreasing California Snowpack

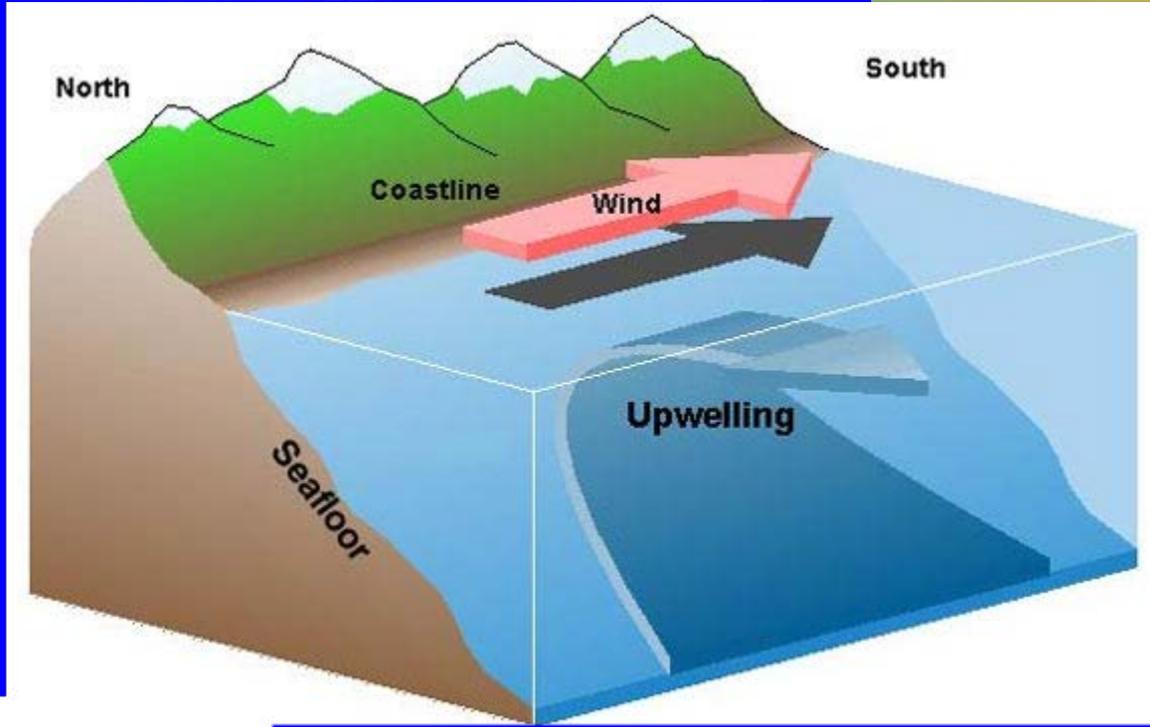
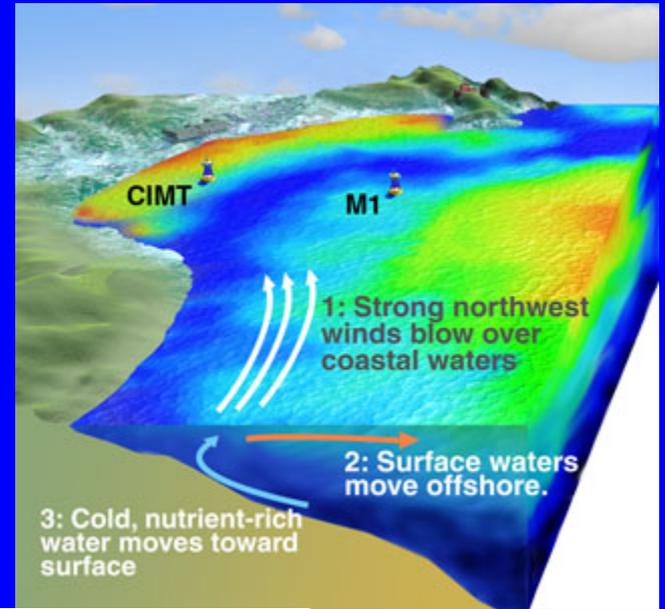
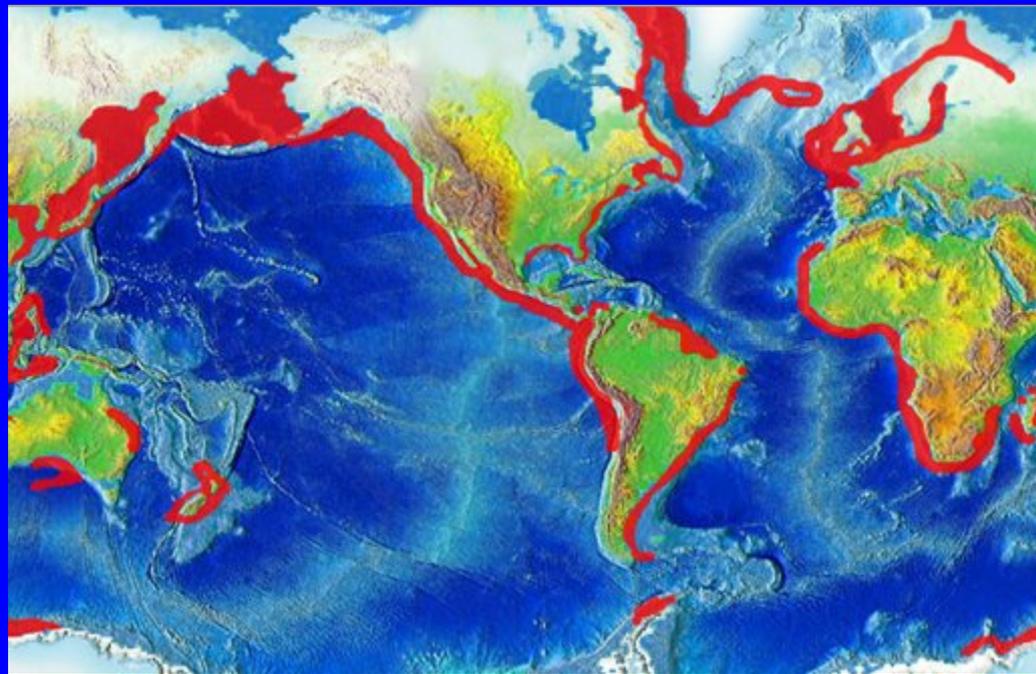


from: Luers et al. 2006 (CEC)

Biological/Ecological Impacts ?

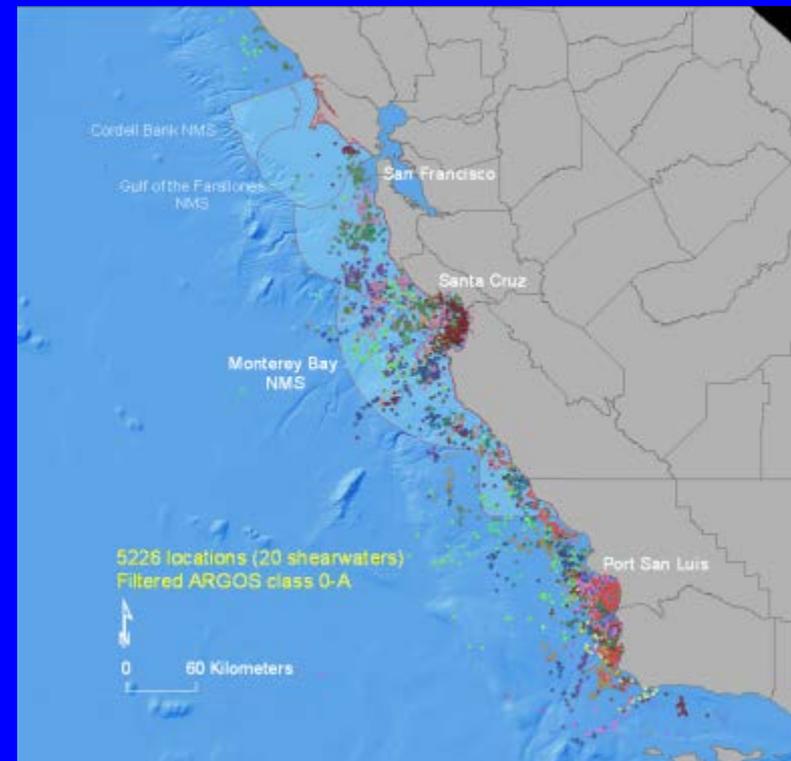
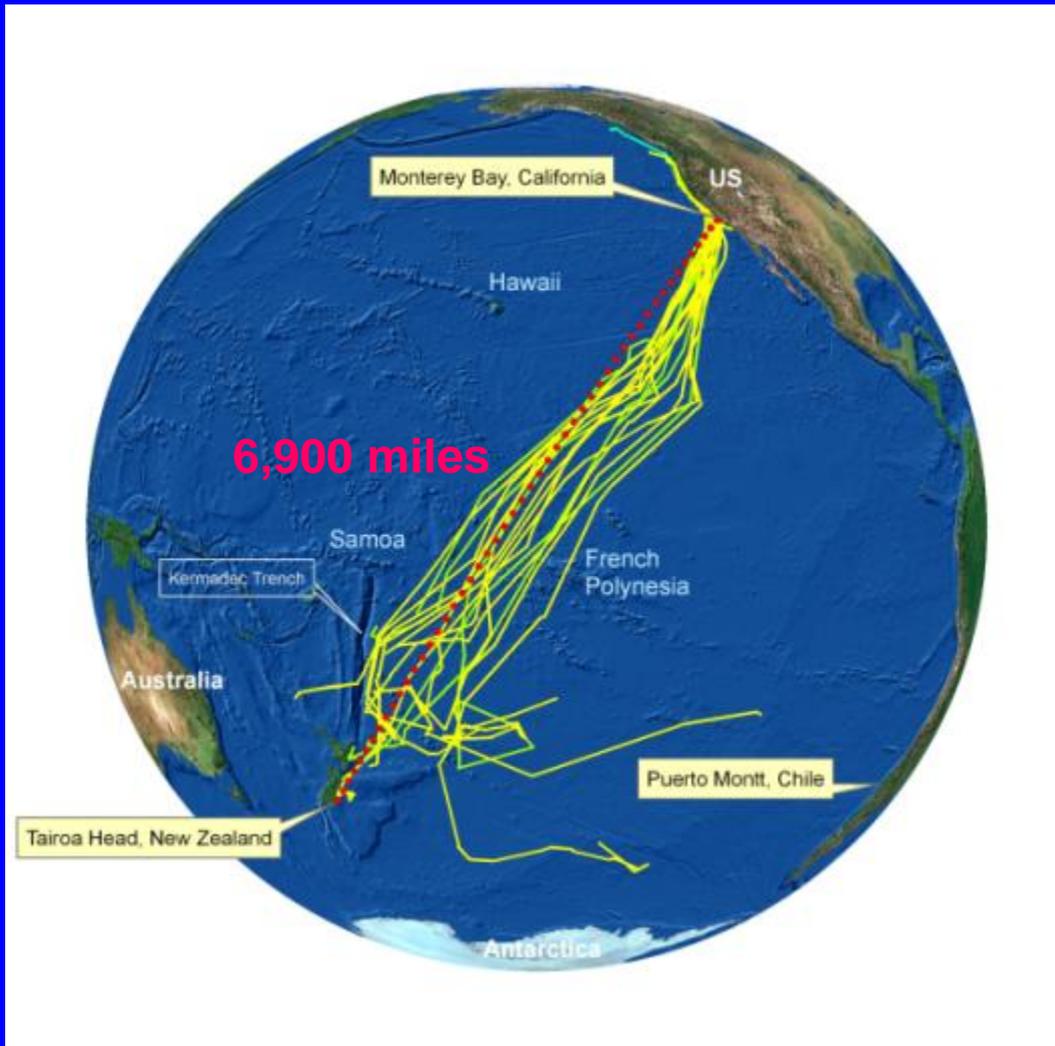


UPWELLING & EL NIÑO



El Niño
slows winds
& upwelling

Movements and trans-Pacific migration of the Sooty Shearwater (*Puffinus griseus*)



Upwelling, Fog & El Niño

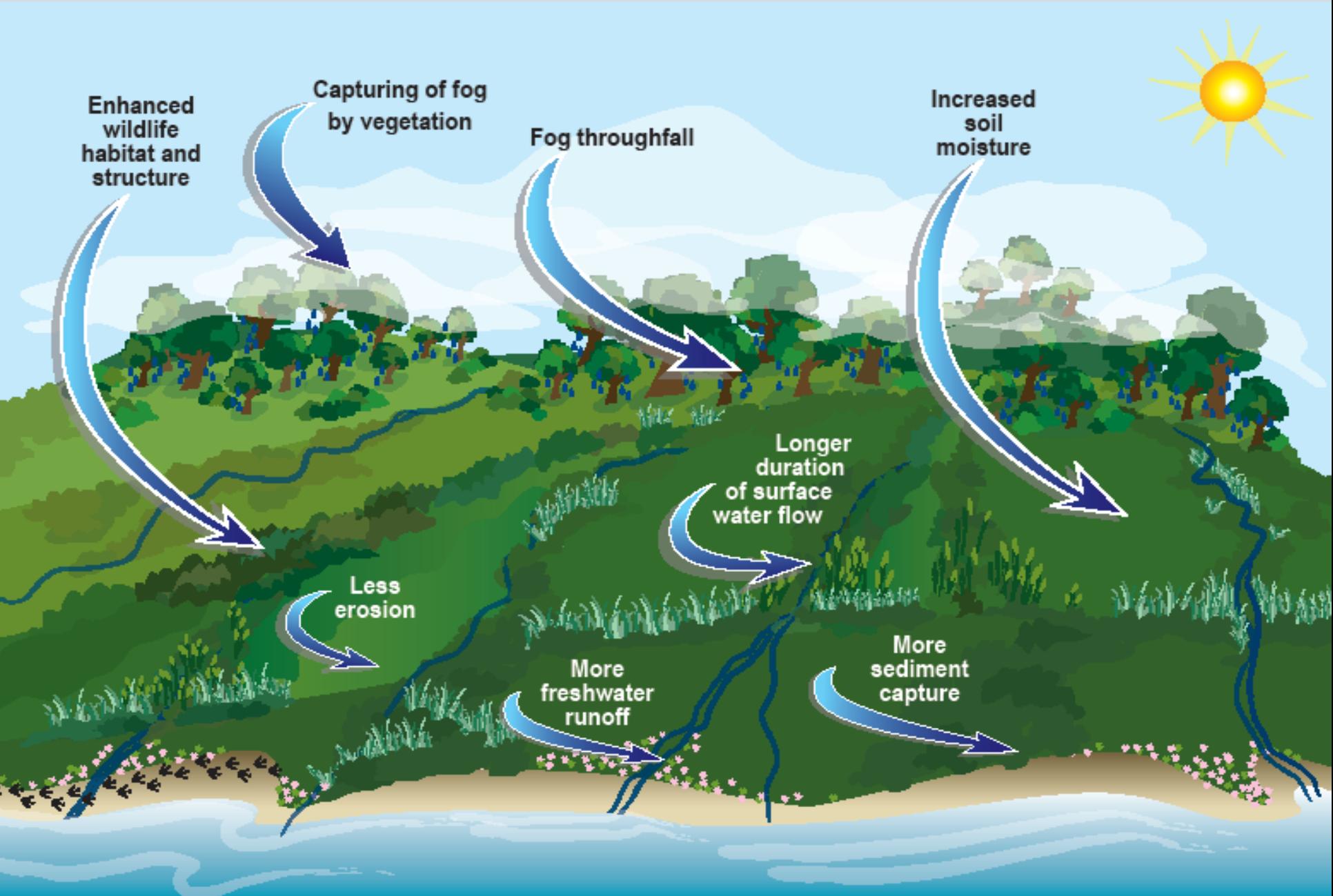


"The coldest winter I ever saw was the summer I spent in San Francisco."

Mark Twain







FOG CAPTURE (McEachern)



Fog drip sampler mounted at Santa Rosa Island weather station

Artificial fog collector on Santa Rosa Island





Altered Phenologies



USA National Phenology Network

<http://www.usanpn.org/>



89 of 100
flowering plants
in DC area
blooming 4.5 days
earlier in 2000
vs. 1970.

Egg laying date of
NA tree swallows
~ 9 days earlier
(1959 to 1991)
(Dunn & Winkler
1999)



Earlier arrival
of migrants
(Root et al.
2004)

Maine lobsters
molted 15-30 days
earlier in 2012.
(Moretto 2012)



© Gary Braasch Photography

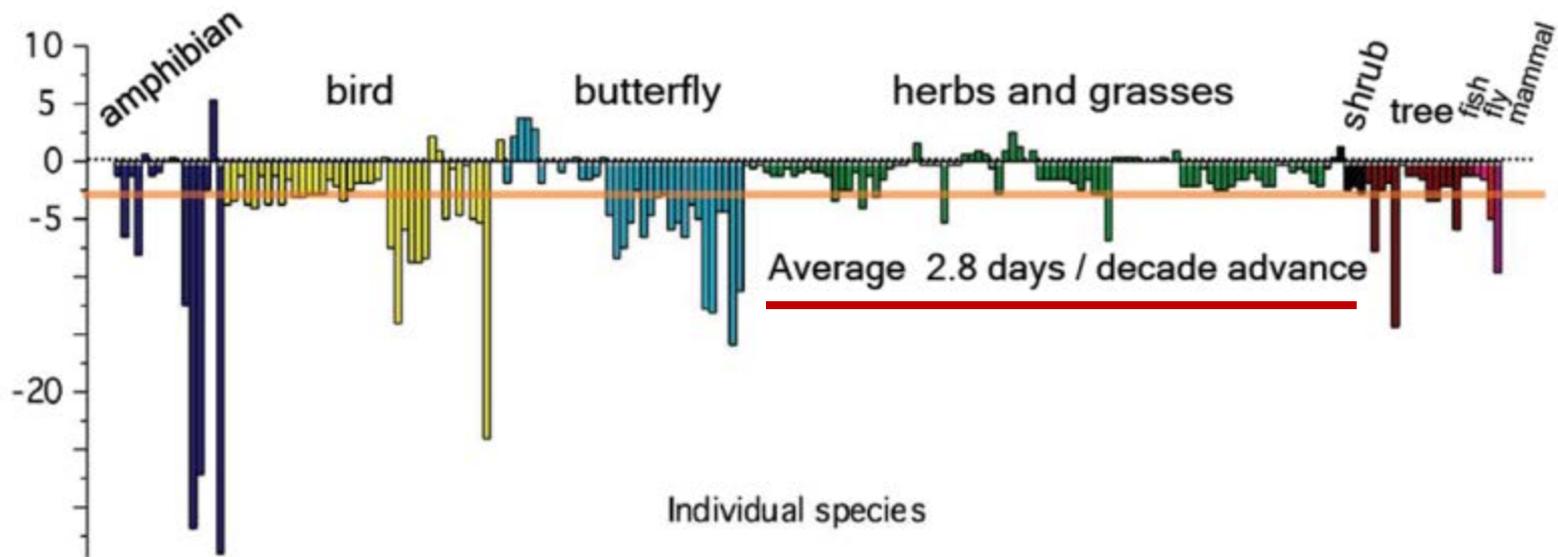
ALTERED PHENOLOGIES

Trends in timing of spring events Among northern temperate species

DAYS

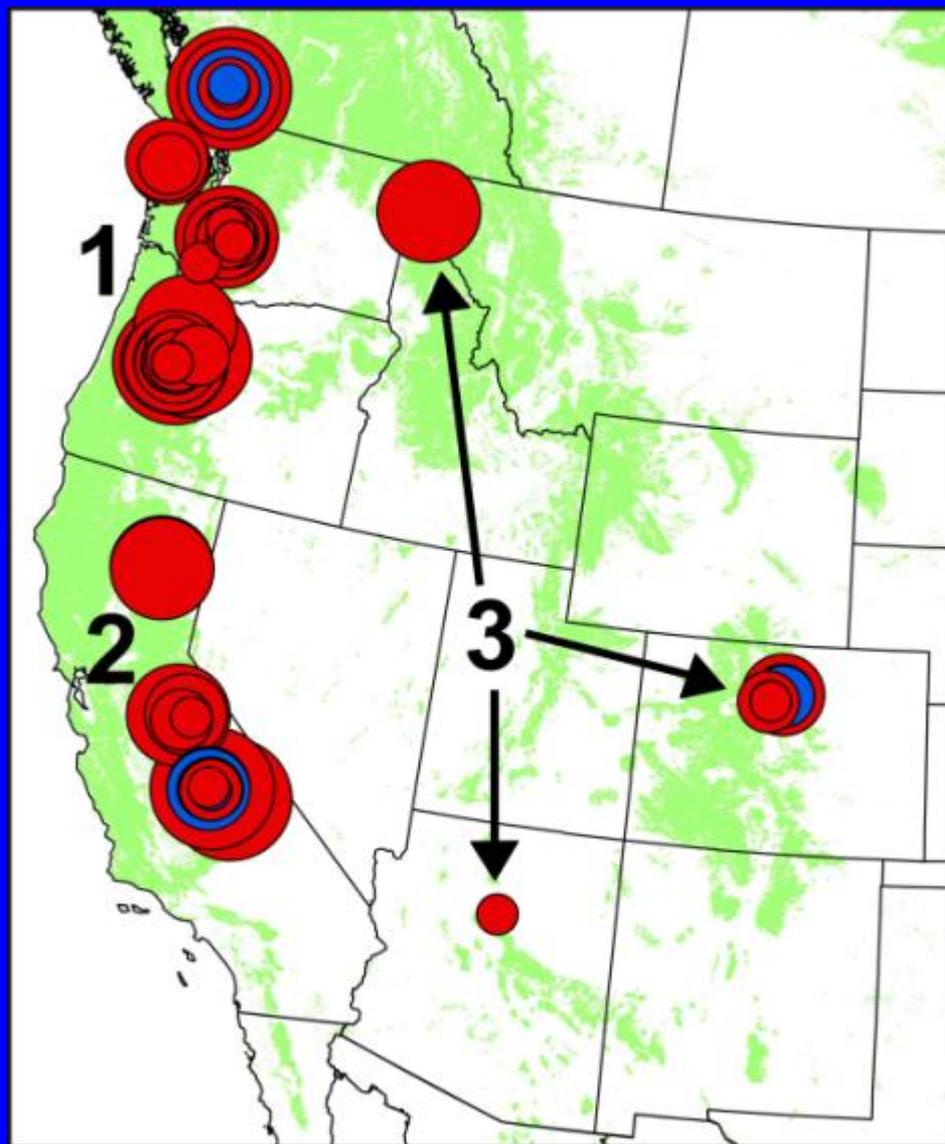
↑ later

↓ earlier



n = 203 Time span = 17 to 99 years

Tree mortality rates are increasing in the western US



Widespread

- Mortality rates increased across three biogeographic regions

	<u>P</u>	<u>Doubling</u>
1) Pac. NW	0.001	17 yr
2) California	0.005	25 yr
3) Interior	0.032	29 yr

Pine bark beetle infestations correlated with drought stress...



The Red Hand of Death
Fraser Experimental Forest
Colorado - 2006

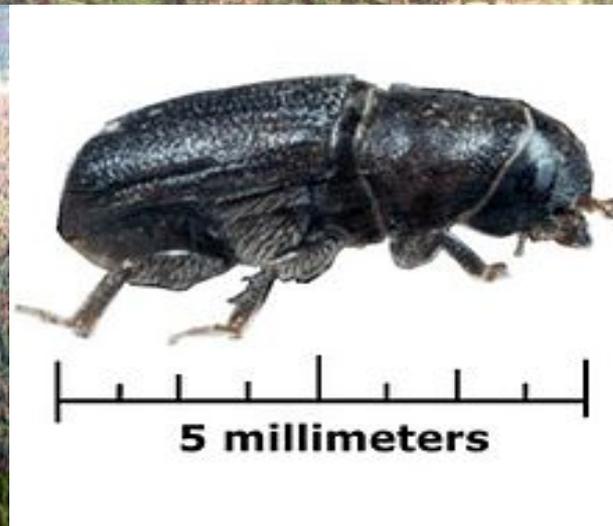
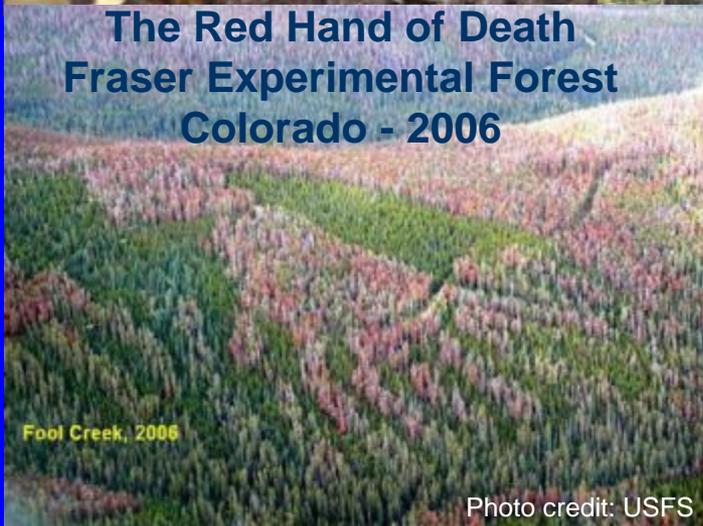


Photo credit: USFS

Climate Change and Fire

- Warmer and drier spring conditions =
 - early snowmelt
 - lower summer soil and fuel moisture
 - longer fire seasons
 - increased fire frequency and extent
- Fire intensity and severity may also increase



Since 1985 the number of large wildfires in the western U.S. has increased by 4X.



HOT OFF THE PRESSES....

**Sea-Level Rise for the Coasts of California, Oregon, and Washington:
Past, Present, and Future**

Committee on Sea Level Rise in California, Oregon, and Washington

*Board on Earth Sciences and Resources and Ocean Studies Board
Division on Earth and Life Studies*

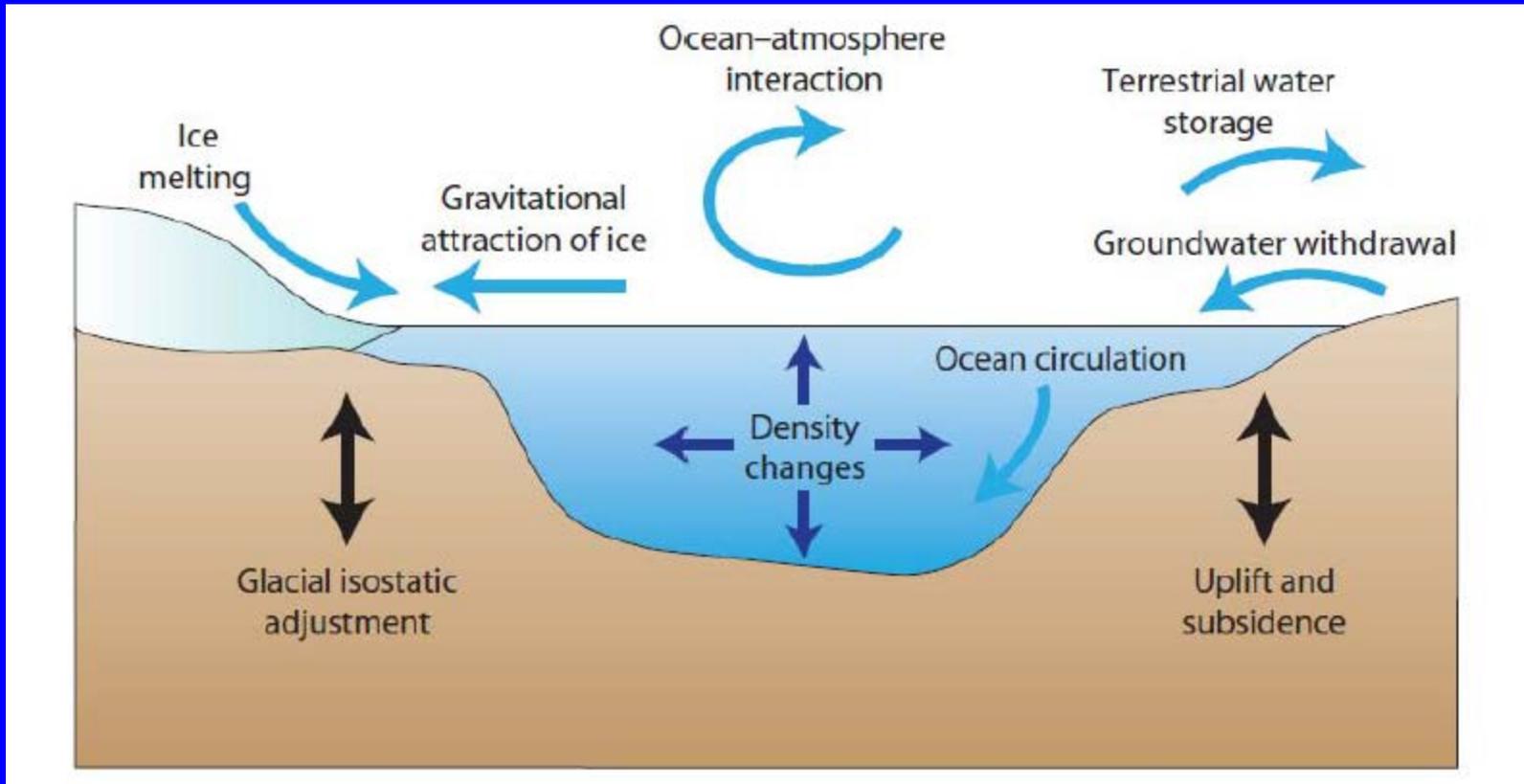
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

**Prepublication
2012**

<http://dels.nas.edu/Report/Level-Rise-Coasts/13389>

SEA LEVEL RISE

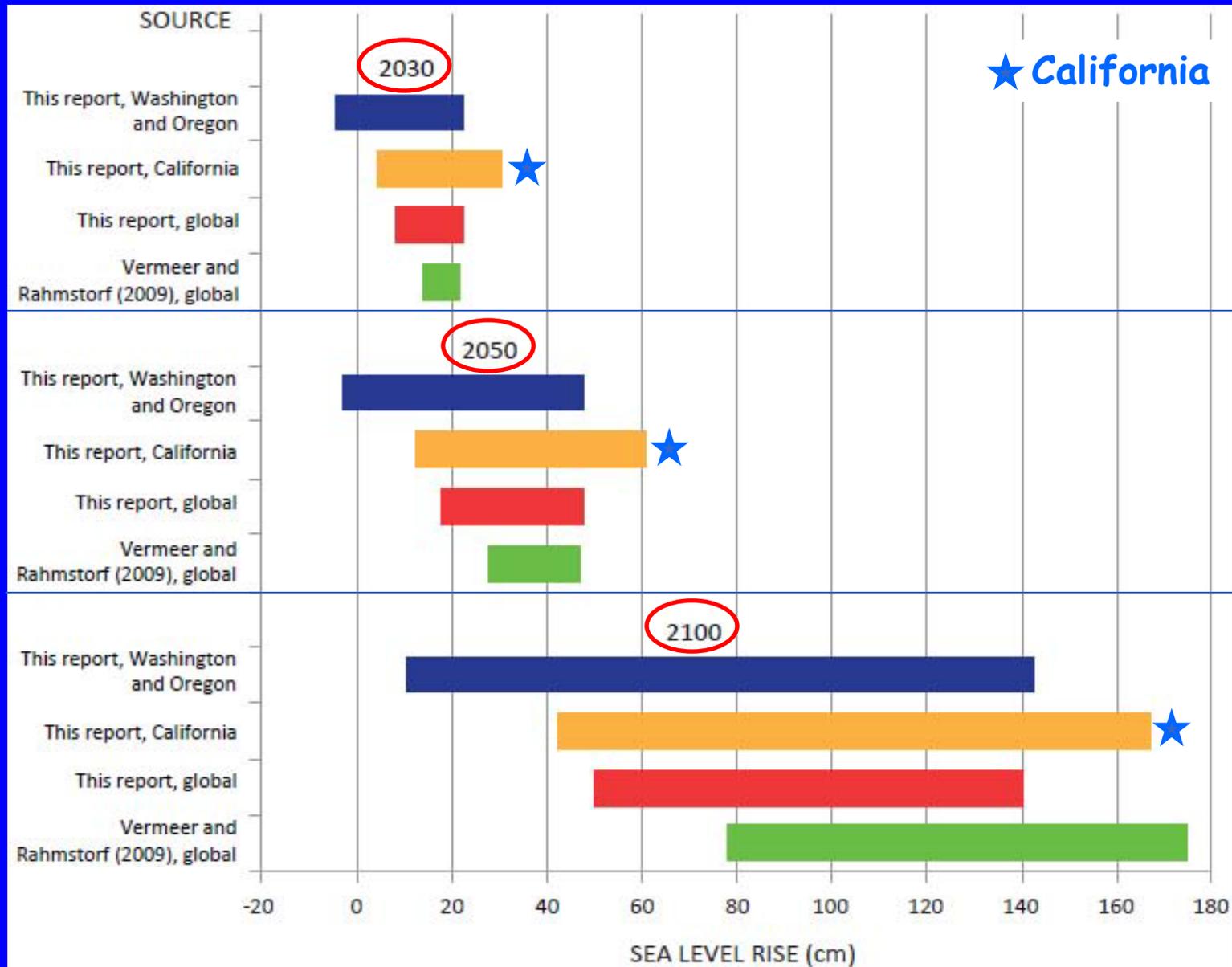


About 50% from expansion...

About 50% from melting of glaciers & ice caps ...

NRC: 2012

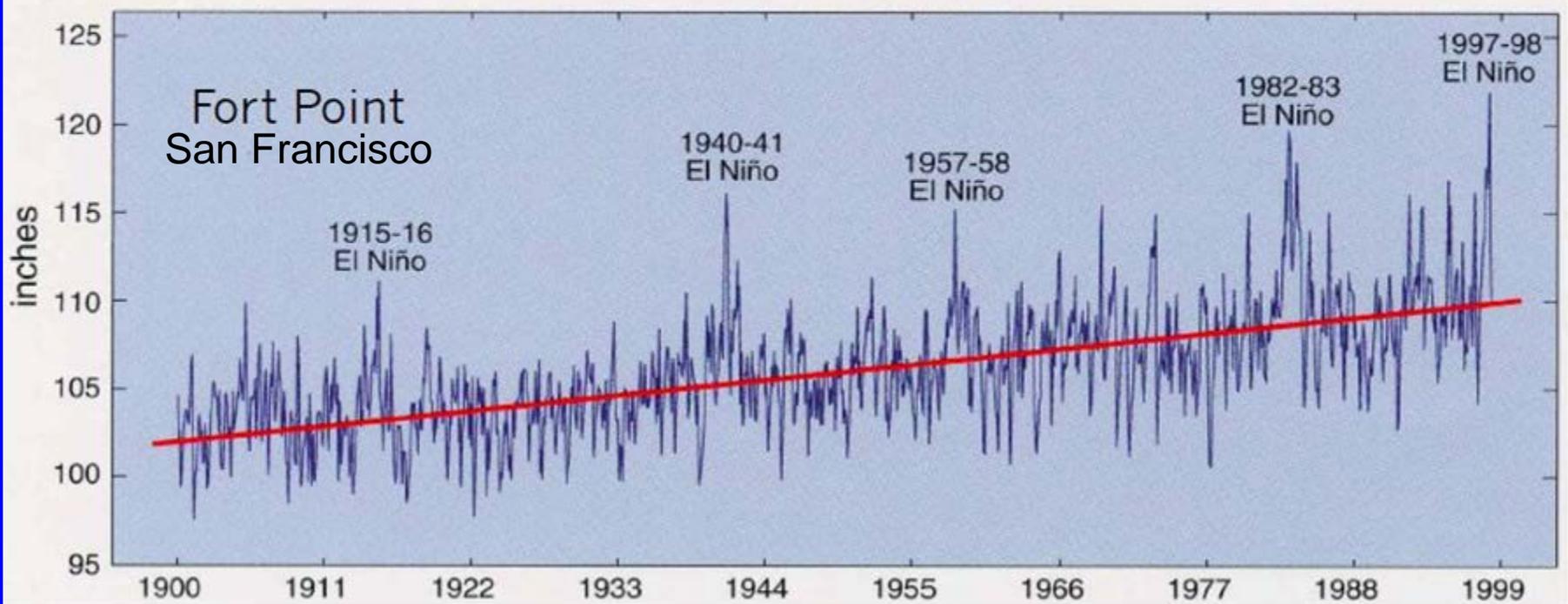
Estimates of future Sea Level Rise



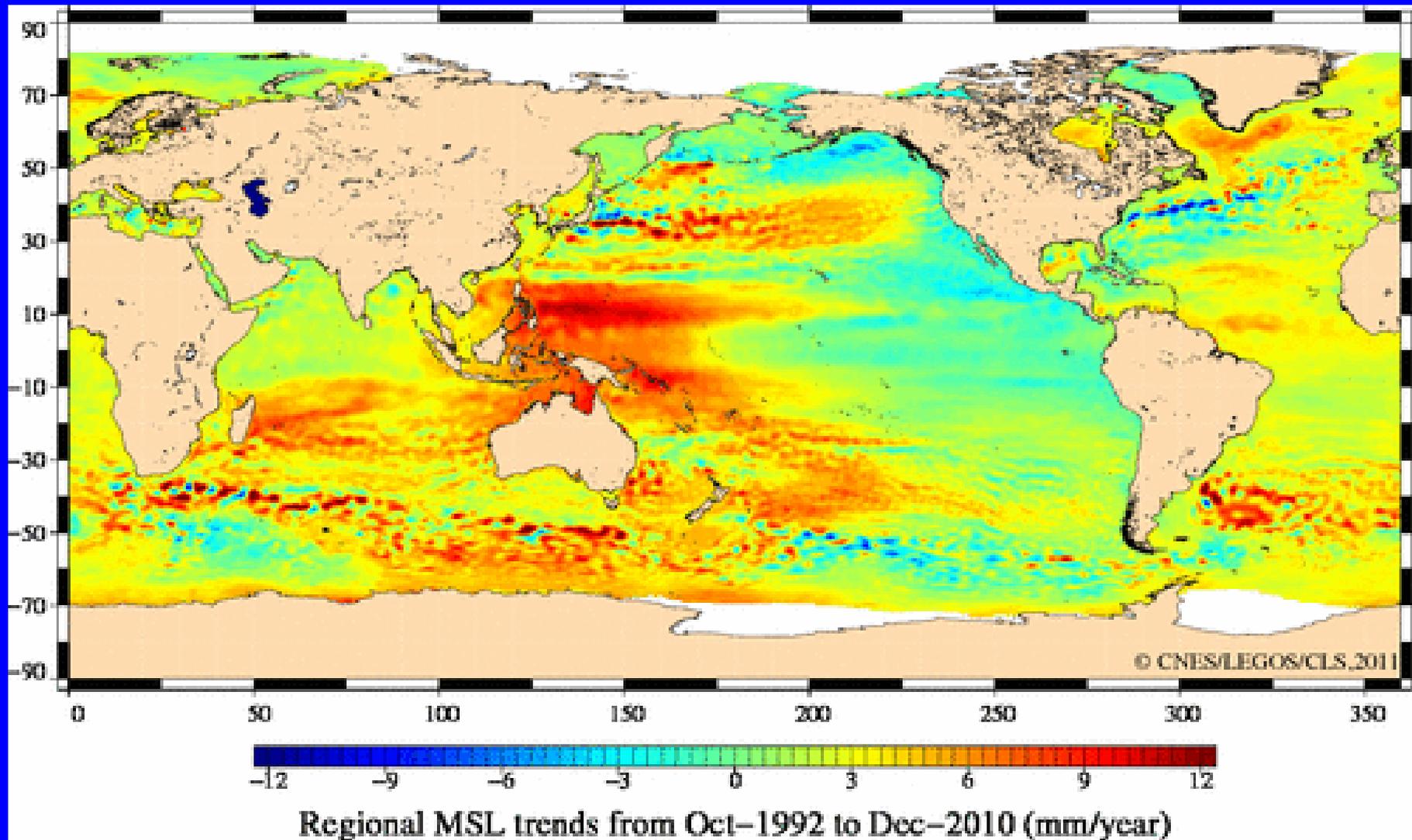
El Niño Events Affect Sea Level

Local sea level rises during warm climate phases like El Niño, and falls during cool climate phases like La Niña

~ 10 inches higher than average



Sea Level Rise



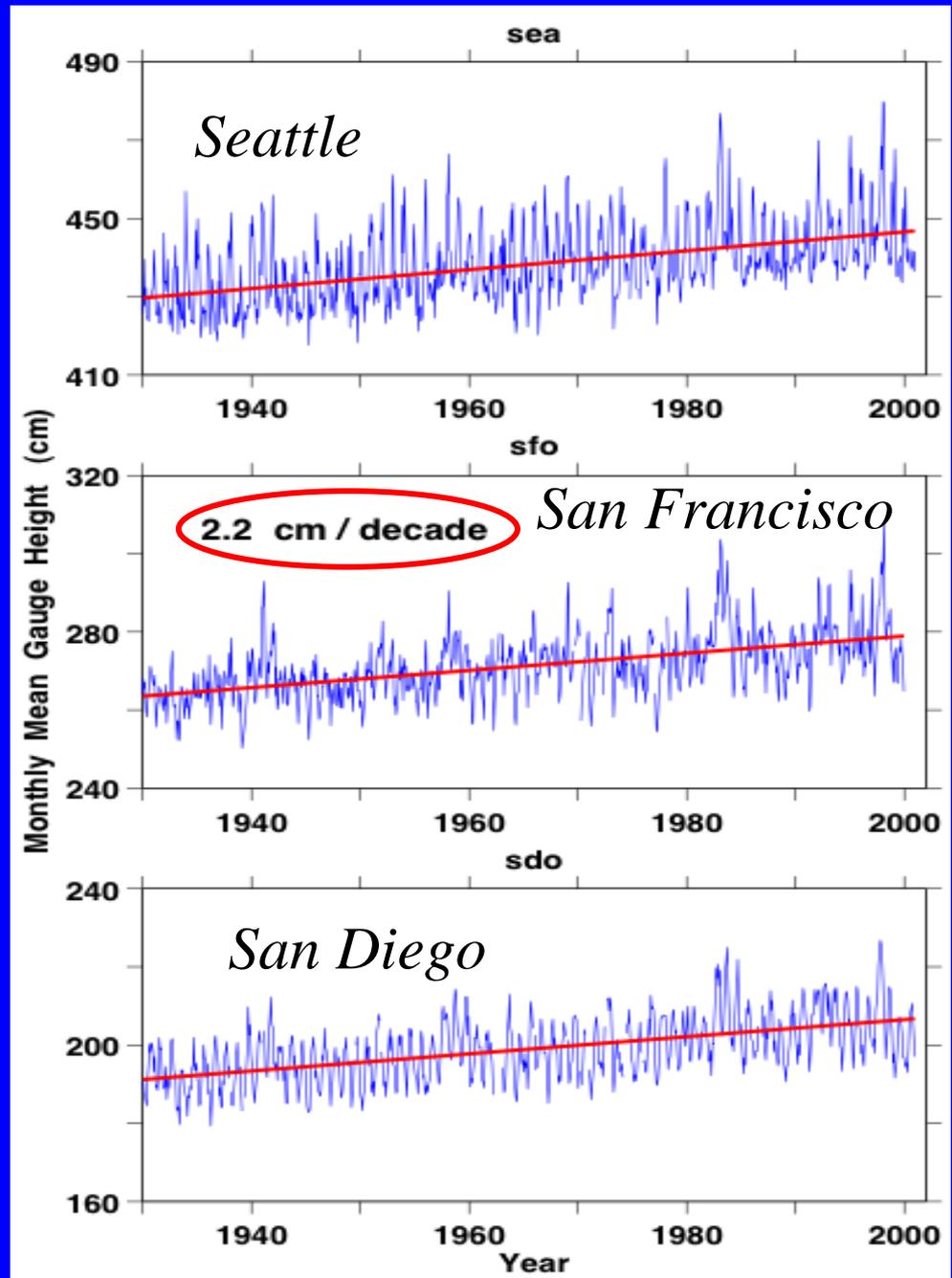
Sea Level Rise: West Coast



West Coast sea level:
consistent upward trends
from Seattle to San Diego

This is consistent with estimates
of global sea level rise.

75 yrs



West Coast Trends

- Global sea level rise up to 1.6m (or 1.9m?) by 2100
- Winter wave height increasing ~1-3 cm/yr
- Extreme wave height increasing ~10 cm/yr
- Wave surge increasing, especially in the north...
- Increase in magnitude and frequency of storms



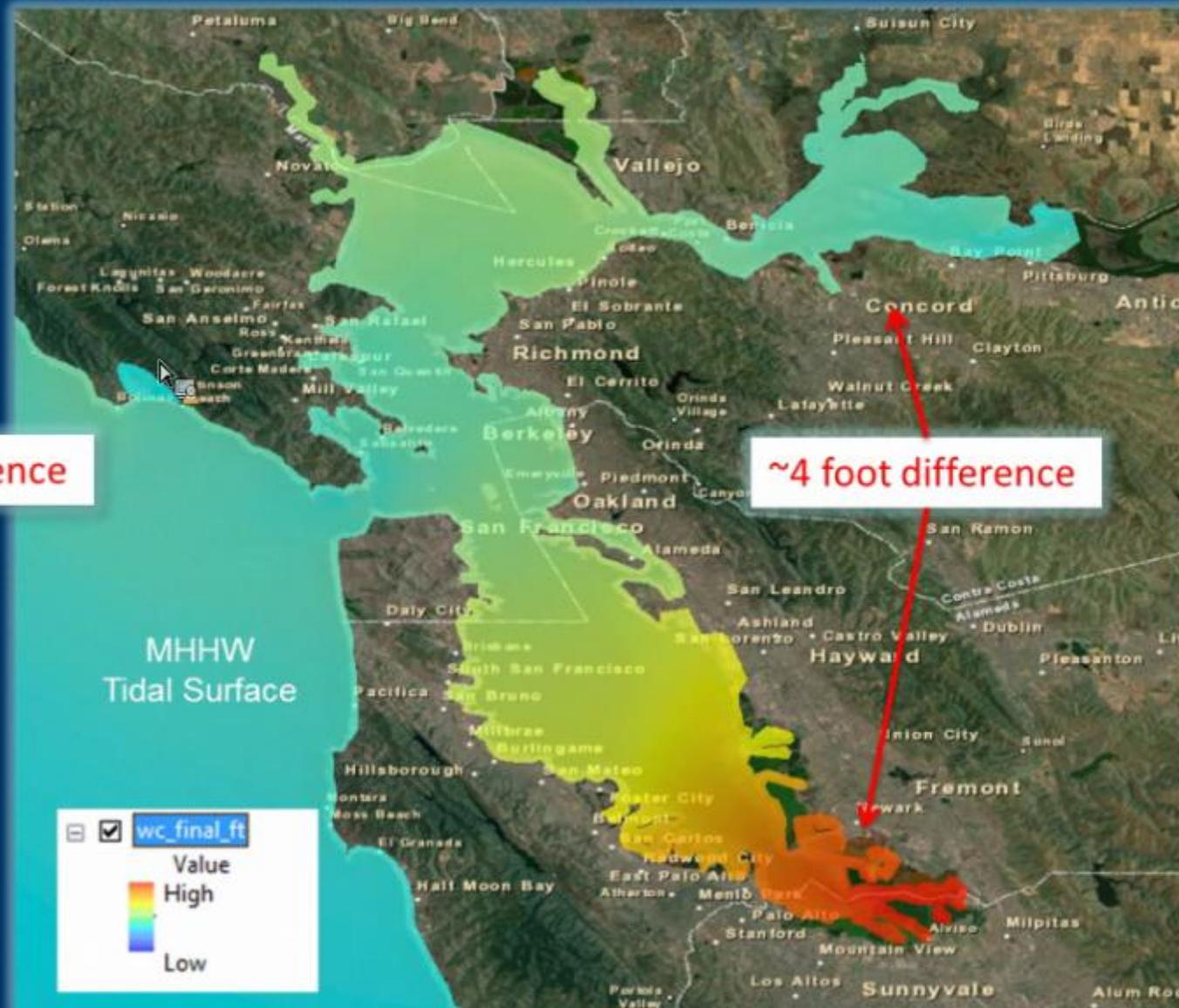
- Sources: IPCC (2007)
- Allan and Komar (2006, Journ of Coastal Res),
- Climate Progress – June 2009
- NRC 2012

The Ocean Is Not a Flat Surface

(especially in bays and estuaries)



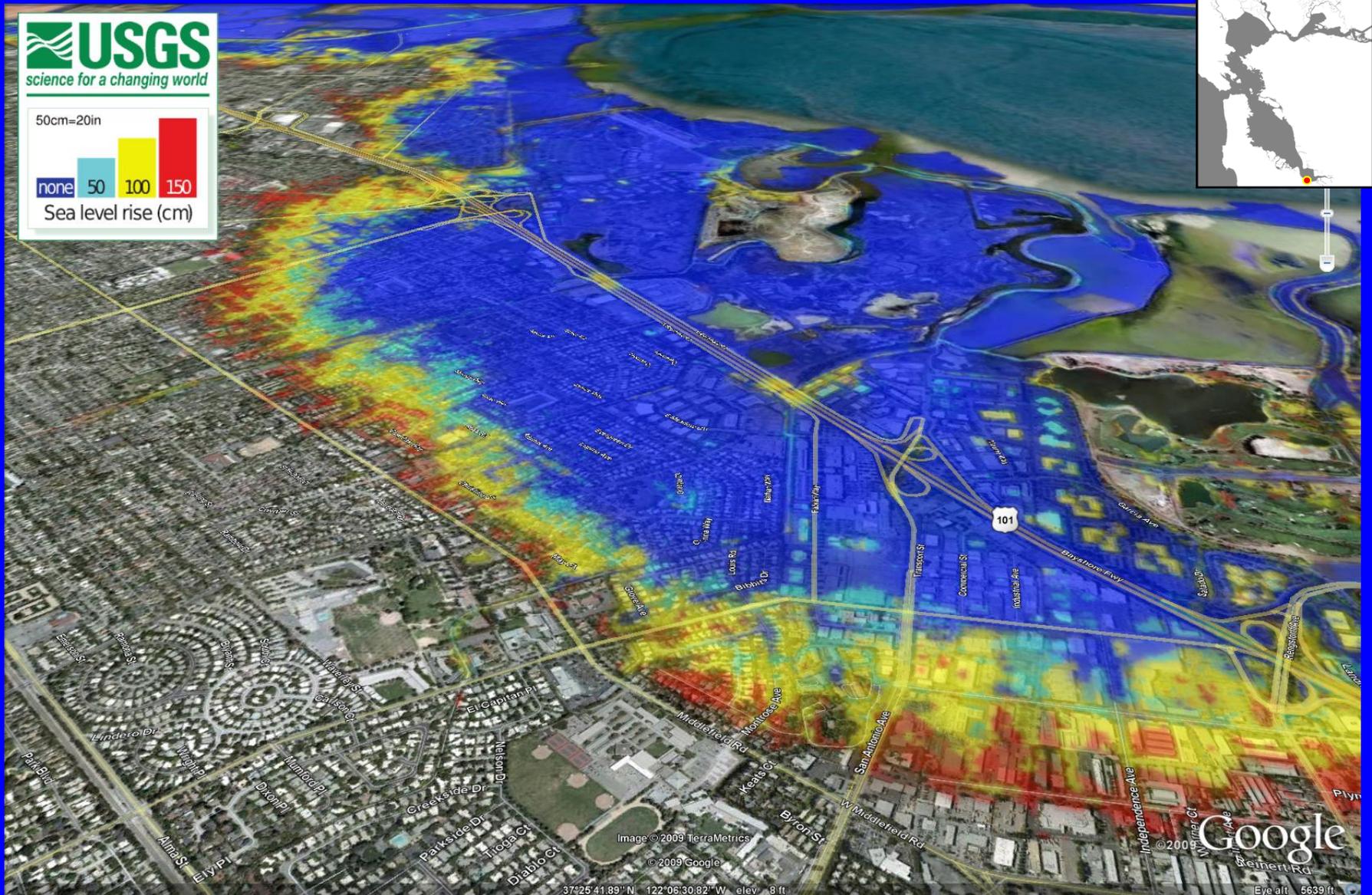
~8 foot difference



~4 foot difference

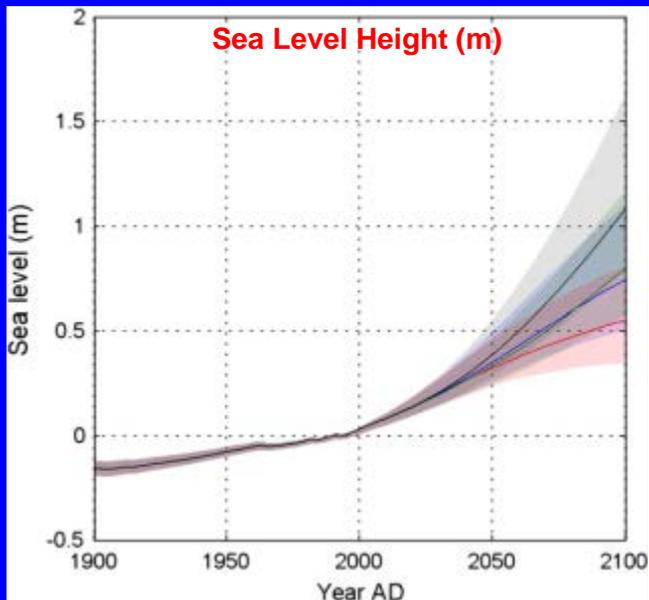
South Bay: Projections

100 yr Storm Surge +



Representative Concentration Pathways (RCP) - W/m²

Sea level projections through 2100 with RCP scenarios.

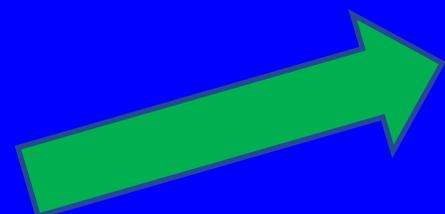


■ RCP8.5
(~ A1FI)

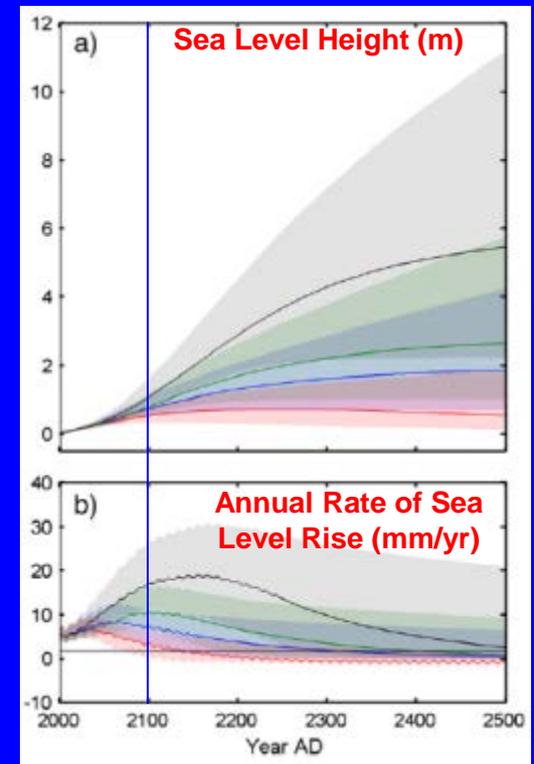
■ RCP6

■ RCP4.5

■ RCP3PD



Sea level projections through 2500 with RCP scenarios.



Think about it....



Sea level rise will inundate low elevation areas unprotected by levees and erode existing levees.



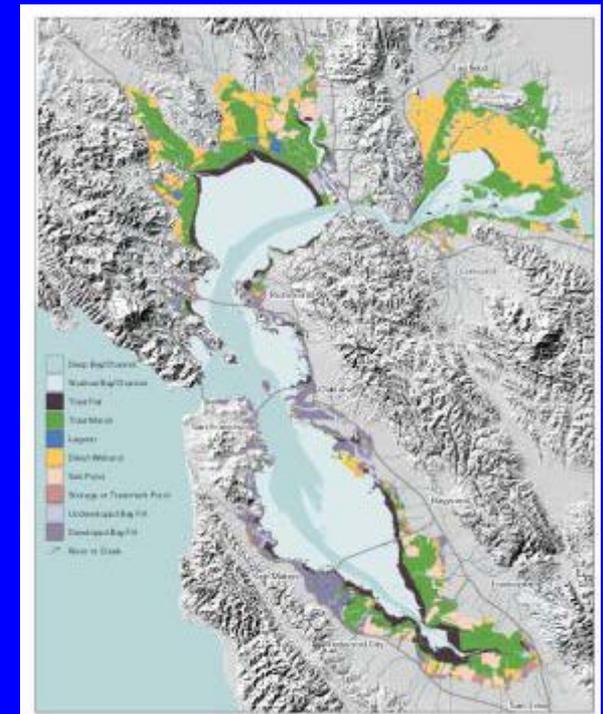
Past
1849

Present

With levee construction
and development

2100

Will the Future Be This ??



Relative positions of three marsh-dependent species.

Black Rail
Fed Sp of Concern
St Threatened



Salt Marsh Harvest Mouse
Fed Endangered



California Clapper Rail
Fed Endangered



Mixed species

Sarcocornia pacifica

Spartina foliosa

HHW

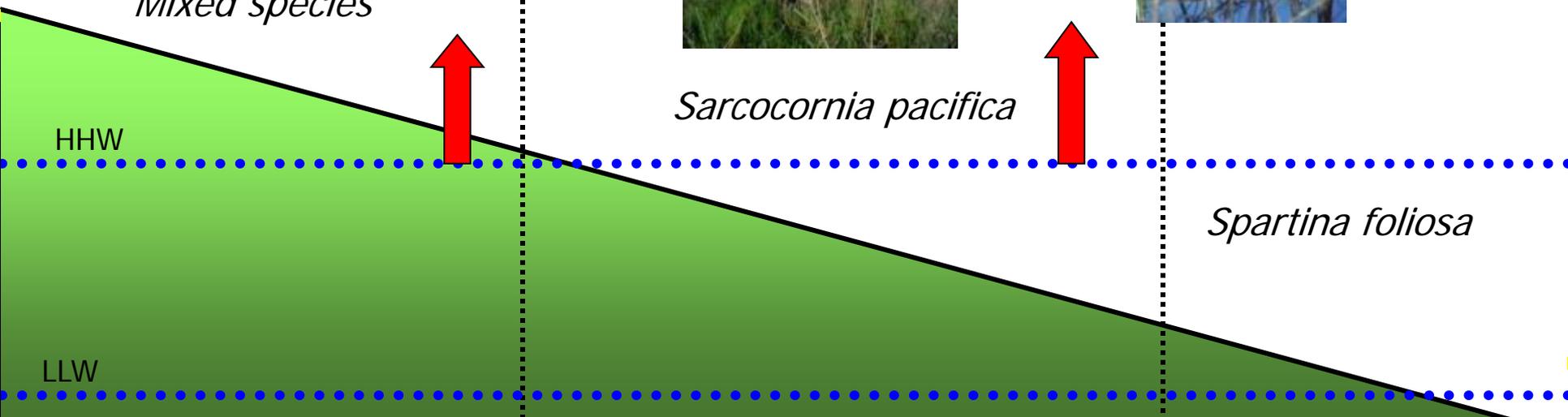
LLW

High marsh

Low marsh

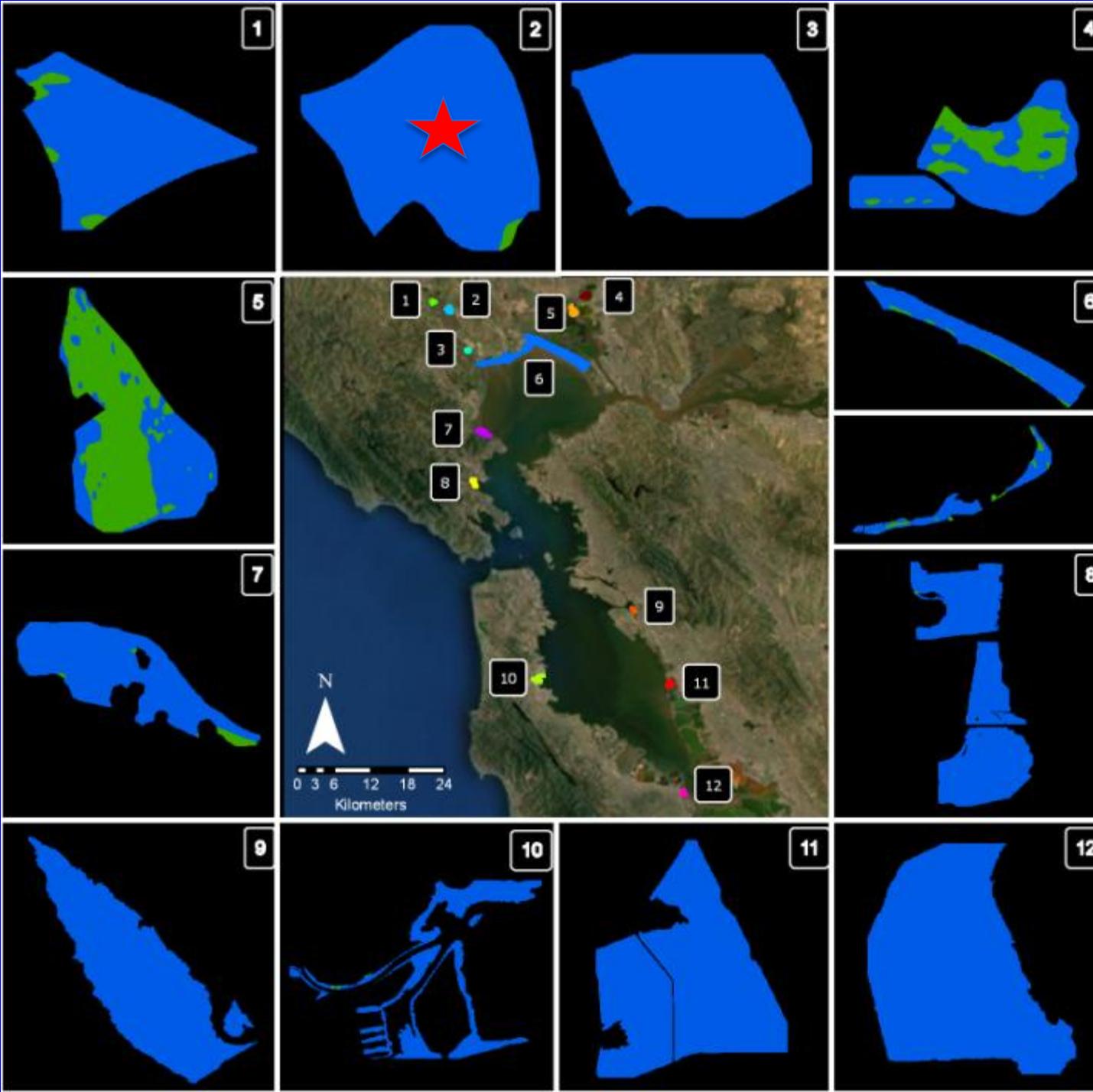
Tidal mud flat

Salt Marsh Elevation Gradient



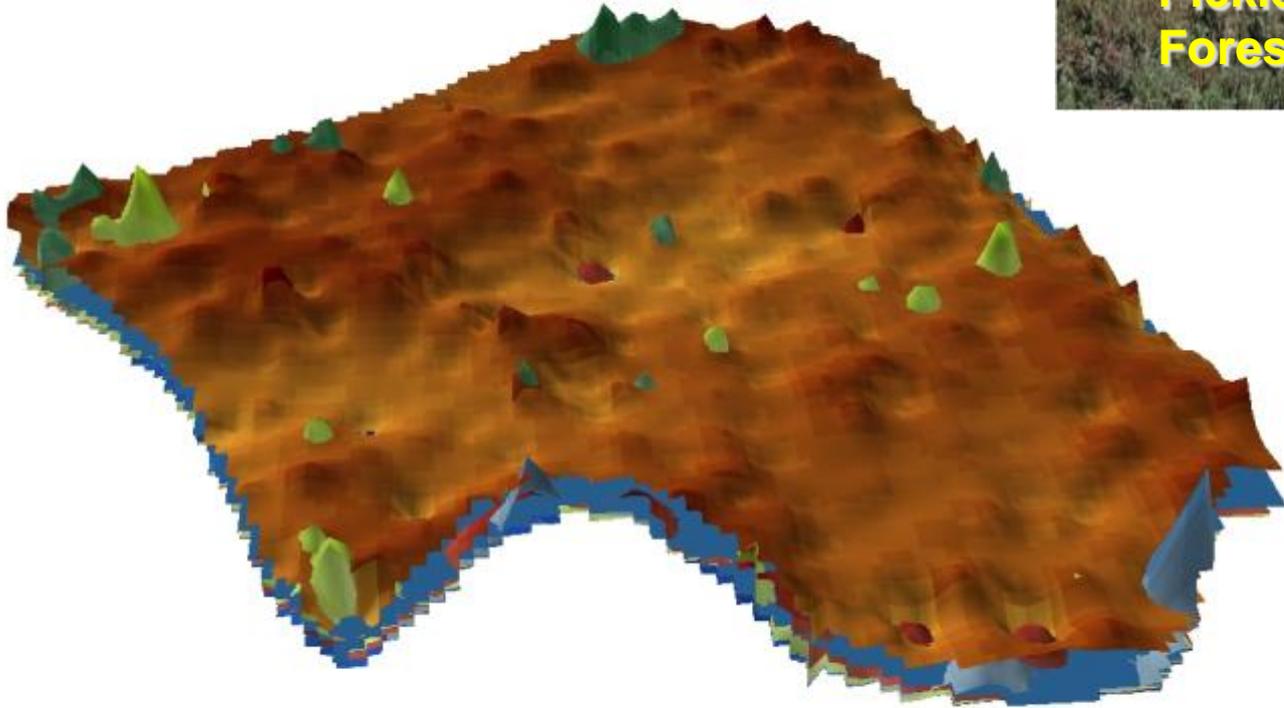
San Francisco Bay Area Salt Marshes

Inundation at Mean Higher High Water

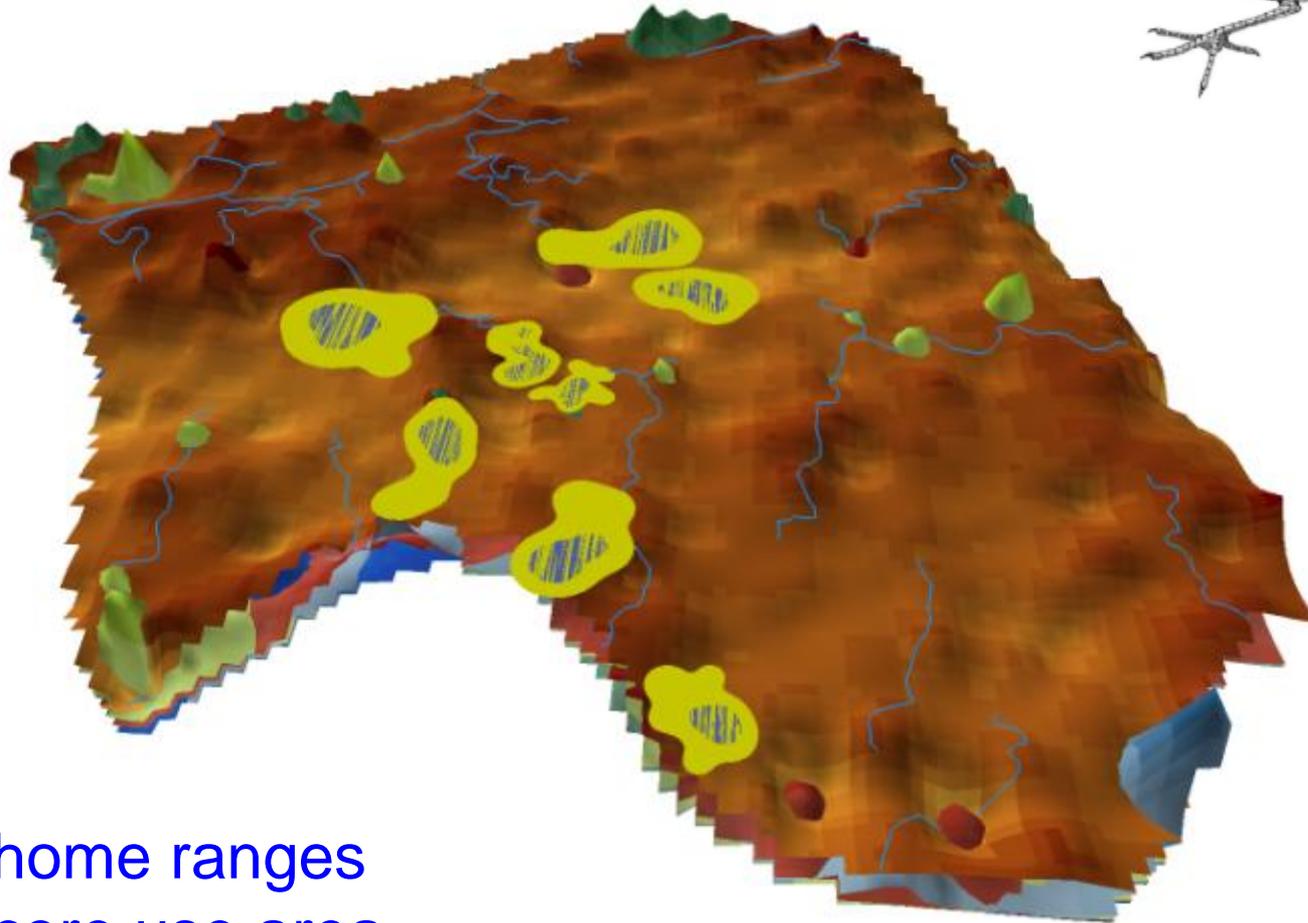
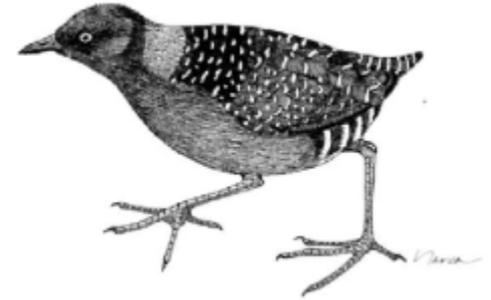


1	Gambonini	95.7%
2	Petaluma	99.1%
3	Black John	100%
4	Fagan	70%
5	Coon Island	38%
6	SPB NWR	93%
7	China Camp	97%
8	Corte Madera	99.8%
9	Arrowhead	100%
10	Colma	99.5%
11	Cogswell	100%
12	Laumeister	100%

Petaluma Tidal Marsh
water level = 2.0 m
<1% inundated



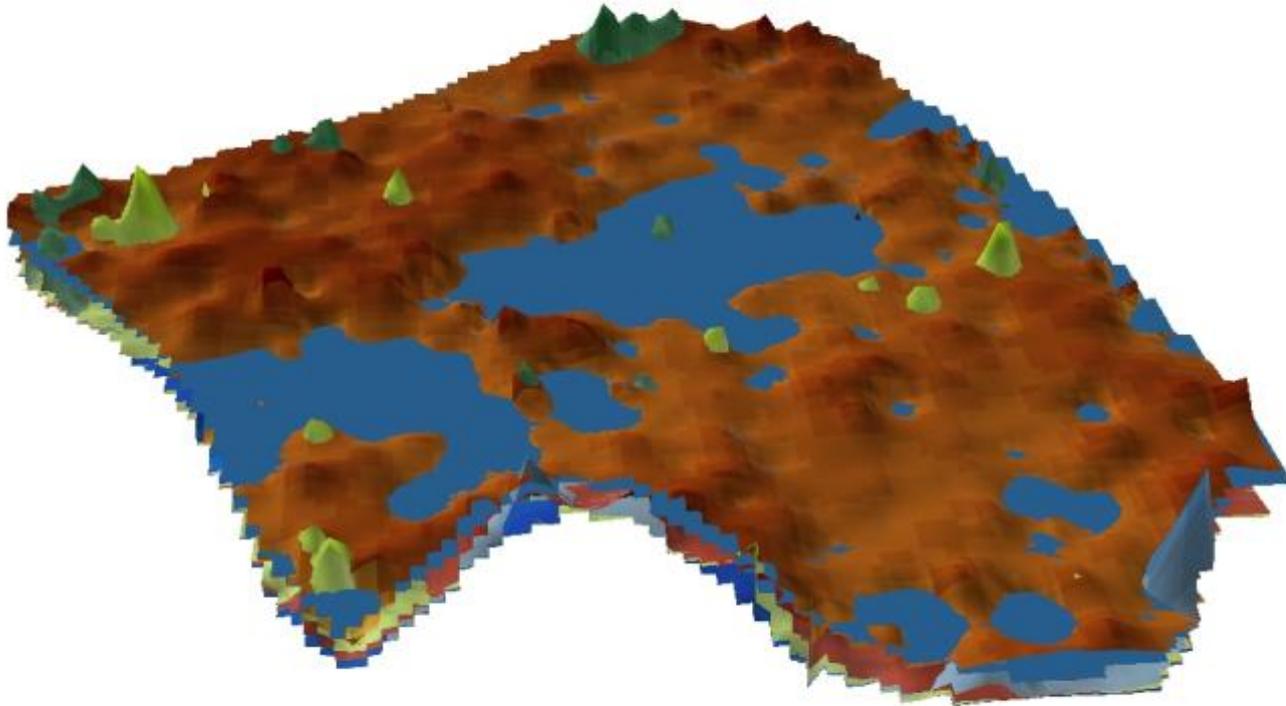
Petaluma Tidal Marsh California Black Rail



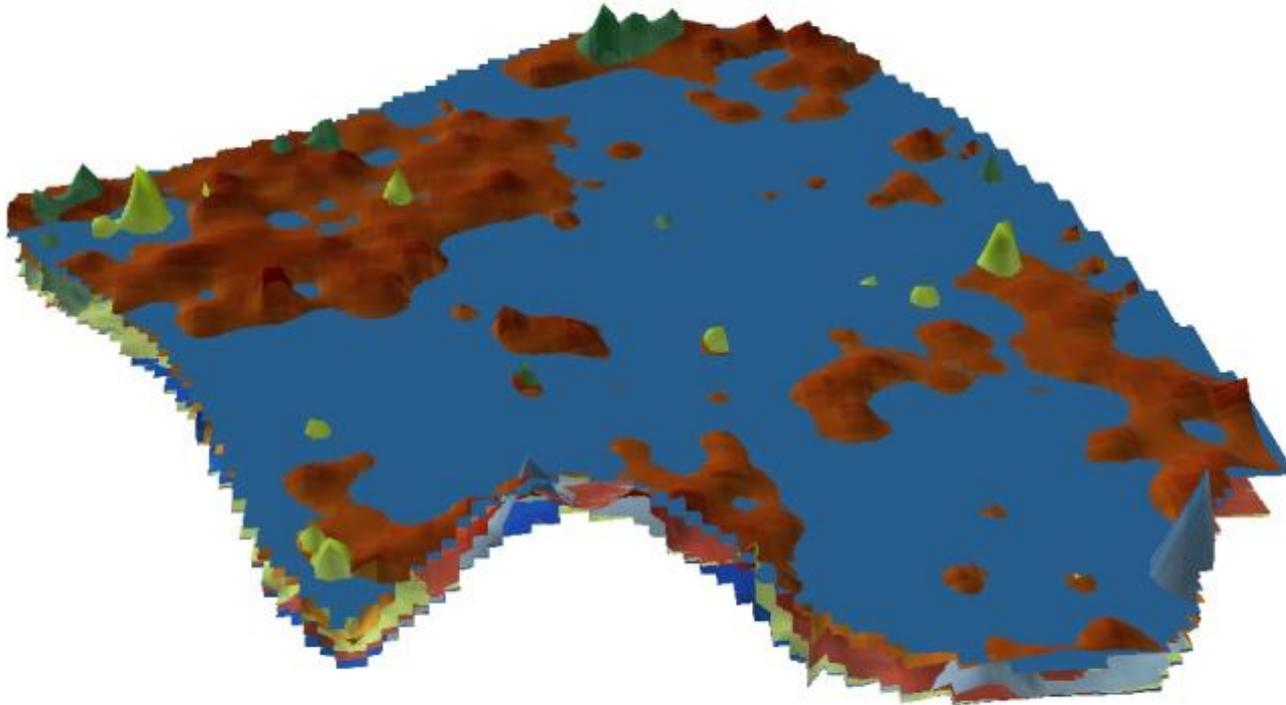
0.59 ha home ranges
0.14 ha core use area

(Tsao et al. 2009, Condor 111:599-610)

Petaluma Tidal Marsh
water level = 2.25 m
35% inundated

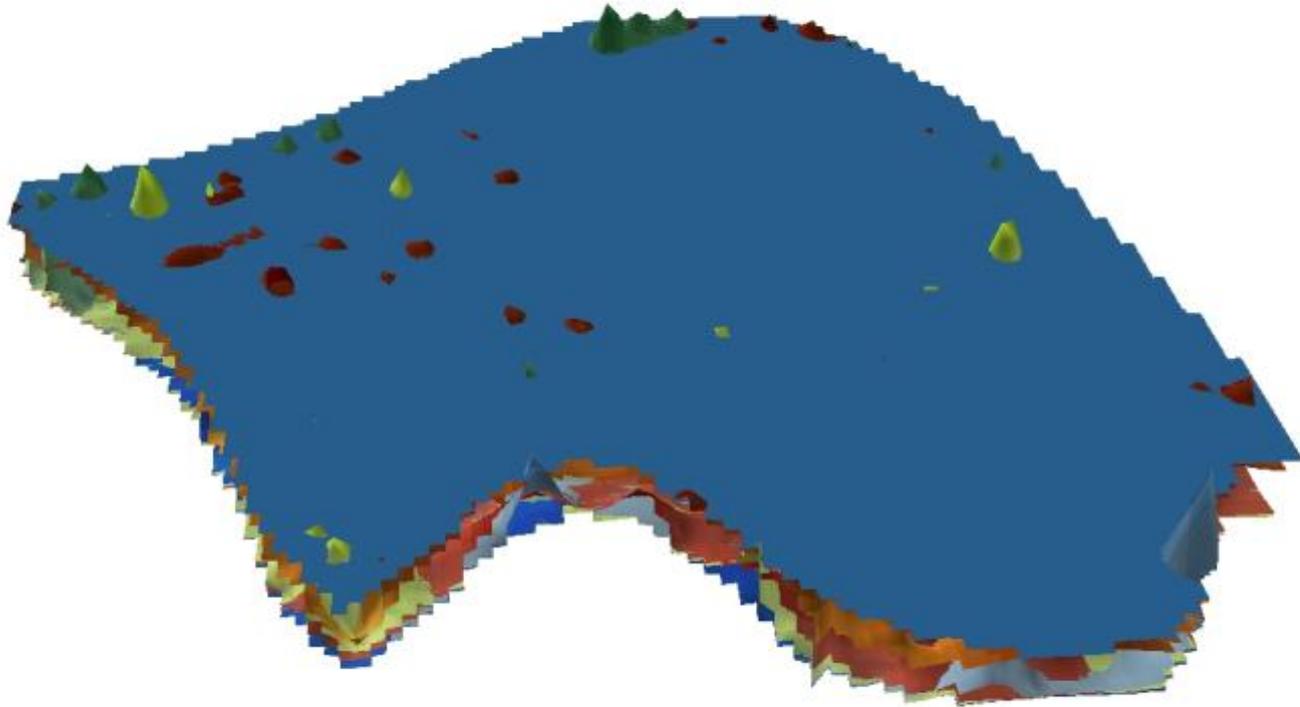


Petaluma Tidal Marsh
water level = 2.35 m
90% inundated



Petaluma Tidal Marsh
water level = 2.5 m
>99% inundated

**What will happen
with Sea Level Rise?**

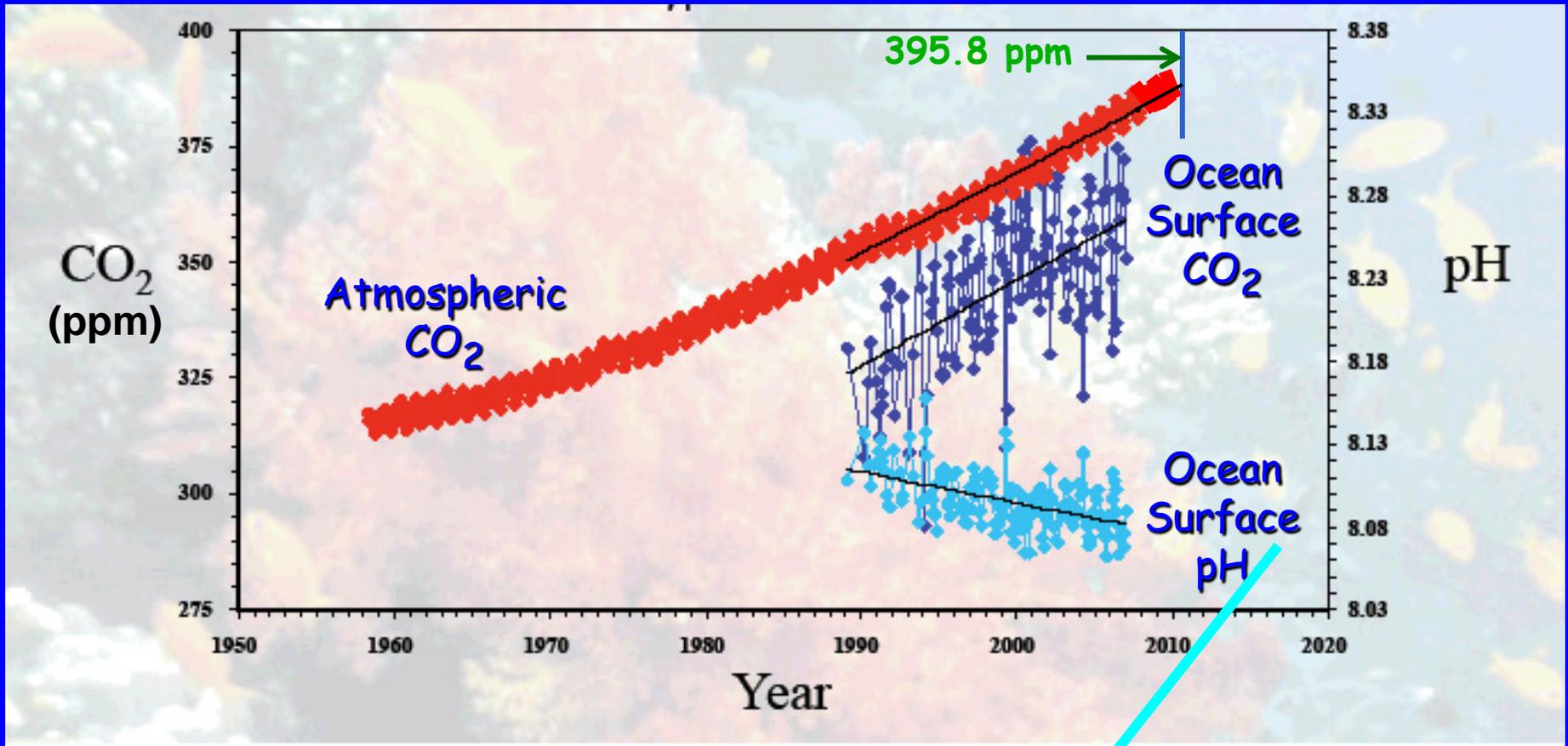




Ocean Acidification:

The ocean absorbs $\sim\frac{1}{4}$ of global C emissions.

Inverse relationship between Atmospheric CO_2 and Ocean pH.



Decreased pH lowers the saturation of CaCO_3 in seawater.

OCEAN ACIDIFICATION

HOW WILL CHANGES IN OCEAN CHEMISTRY AFFECT MARINE LIFE?

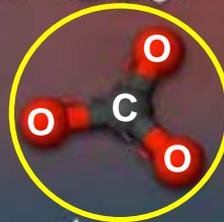
CO₂ absorbed from the atmosphere



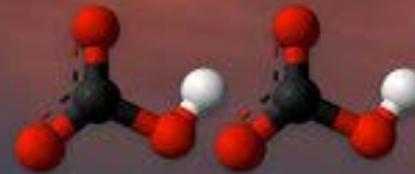
carbon dioxide



water



carbonate ion



2 bicarbonate ions

consumption of carbonate ions impedes calcification

Since ~ 1850, the pH of the oceans has decreased by ~ 0.1 pH units (= 30% increase in acidity).

By the end of this century, it is predicted that the ocean surface will be more acidic than it has been in 400 M yrs.



Climate Change will happen in the face of
and in concert with all of the other
stressors that already exist in the
Bay-Delta... including:

Contaminants: Mercury, Selenium, Pesticides, PCBs,
PBDEs, Pharmaceuticals, other emerging contaminants

Invasive Species: New species ~ every 14 weeks

Land Use Change/Development:

So.....

WHERE DO WE GO FROM HERE ??????

Many ongoing studies.....

Computational
Assessments of
Scenarios of
Change in the
a
Delta
Ecosystem

<http://cascade.wr.usgs.gov/index.shtm>

Global
Climate
Models



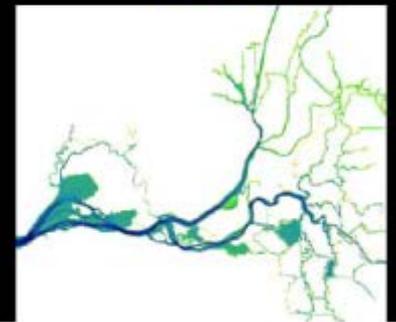
Downscaled
To Region



Watershed
Model



Delta
Model



CASCaDE I

New downscaled scenarios: A product of
SF Bay PES & CASCaDE projects:



Computational
Assessments of
Scenarios of
Change in the
Delta
Ecosystem

CASCaDE II



Now What ?

Durban, South Africa: COP17 United Nations Framework Convention

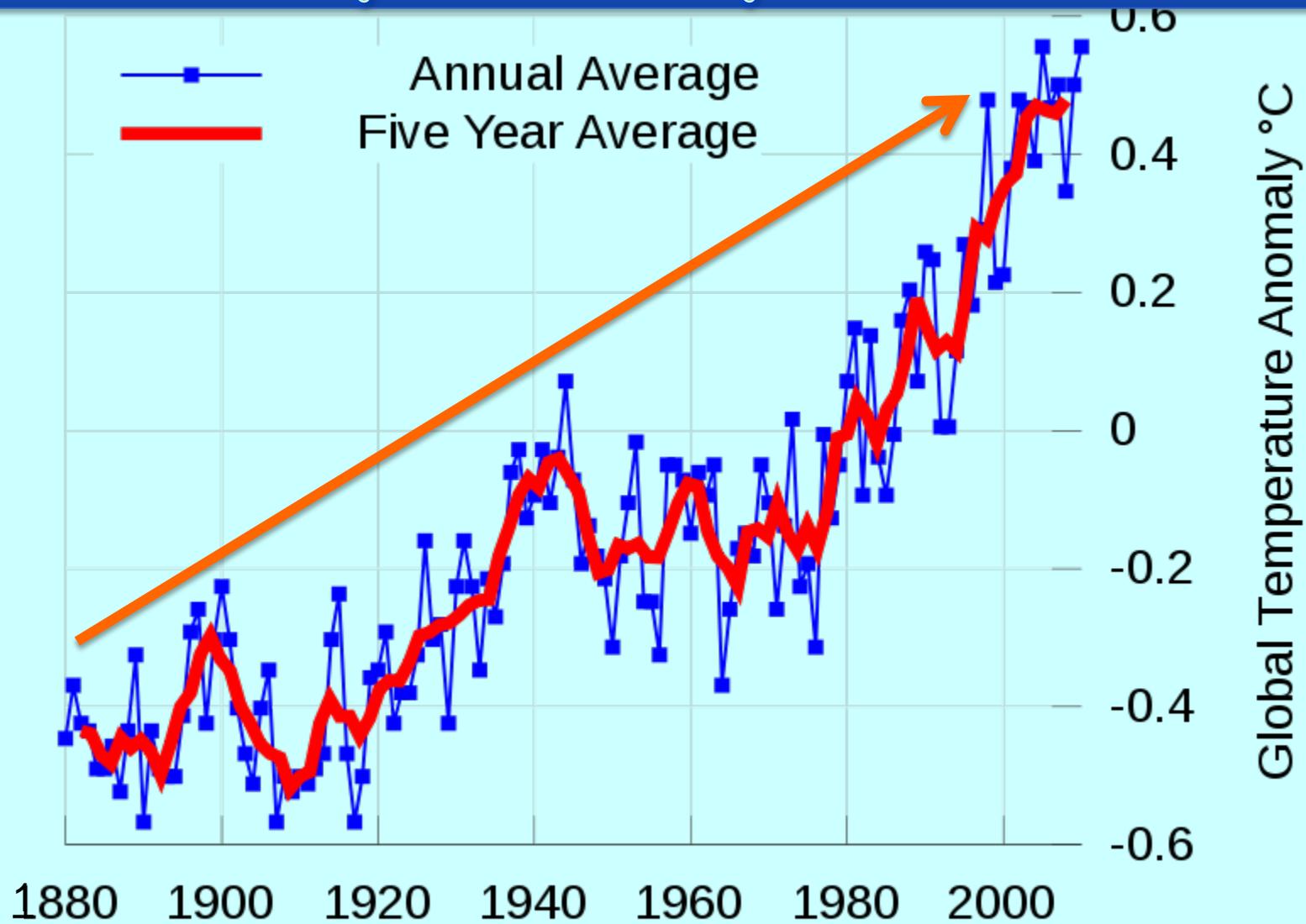
Conference Of the Parties - to the United Nations
Framework Convention on Climate Change

Climate Conference in Durban
Nov 28-Dec 9, 2011

- 194 countries participated

Goal: To develop an agreement whereby the international community would work together to keep global warming at or below a 2°C increase [=3.6°F increase] from pre-industrial levels (~ 1750).

We're nearly half-way there... $+0.9^{\circ}\text{C}$



Results: “Durban Platform” For Enhanced Action

- A negotiated agreement was passed on Dec 11, 2011.
- Kyoto Protocol was renewed for 5 more years: to 2017
- Delegates agreed to start negotiations for a NEW legally binding treaty to be decided by 2015 and to come into force by 2020.
- Many countries will not sign agreement unless the U.S. and developing China & India agree to legally binding resolutions.
- Many political battles can / will still be waged....
- Note: For the U.S. to sign on to a climate treaty, it must be passed & ratified by both houses of Congress.

This year's COP18 will be held in Qatar (Nov 26-Dec 7).

Global Warming Skeptics ?

Definitive Scientific Research...

The Bottom Line.....

Positive proof of global warming.



**18th
Century**

1900

1950

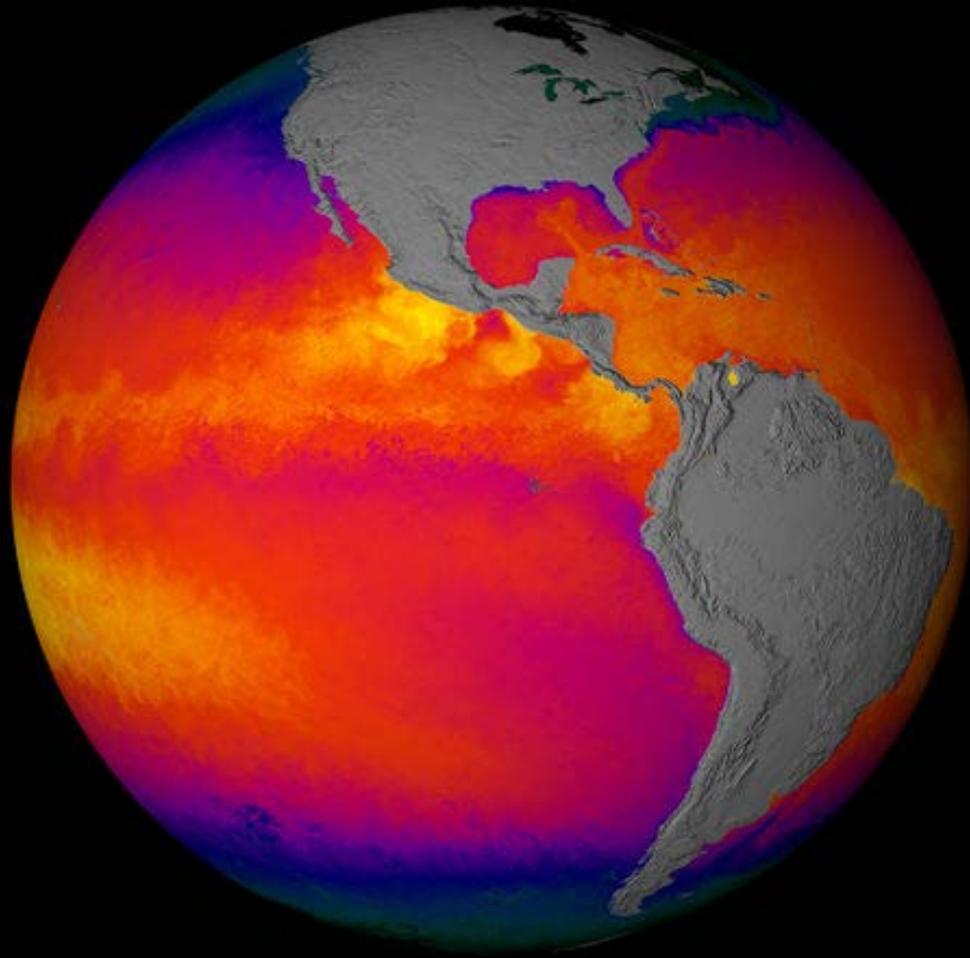
1970

1980

1990

2006

Think Cool

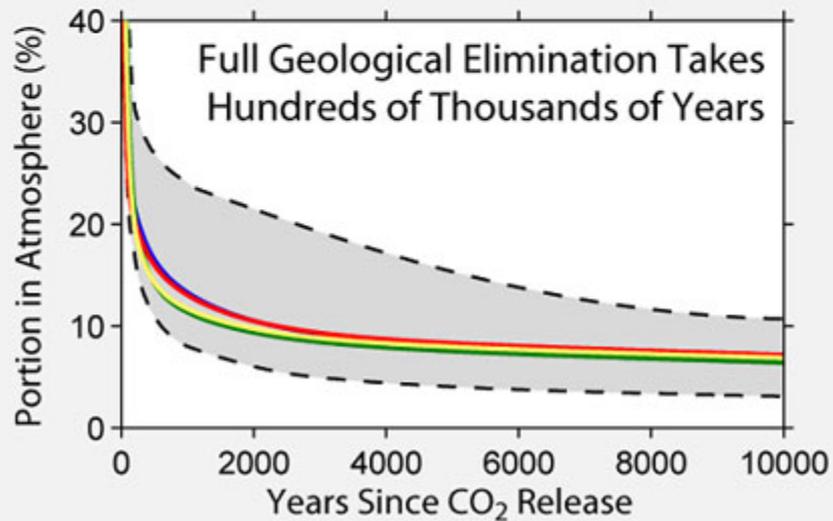
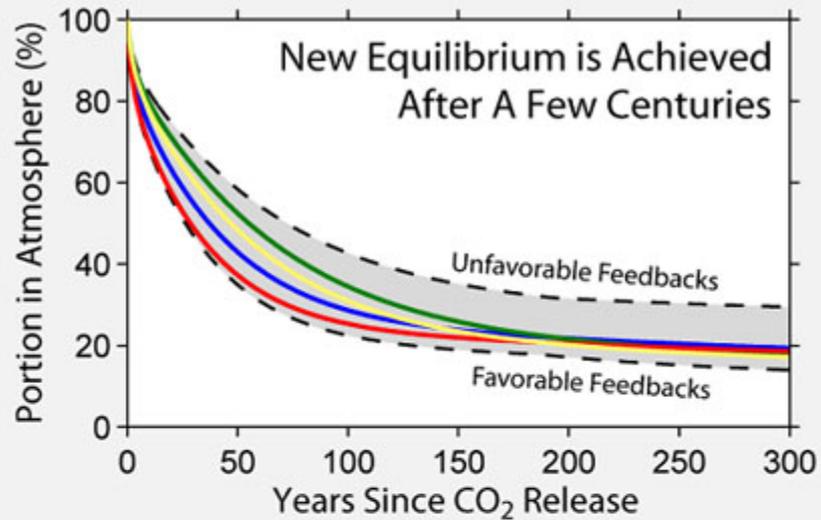


Any Questions ???.....

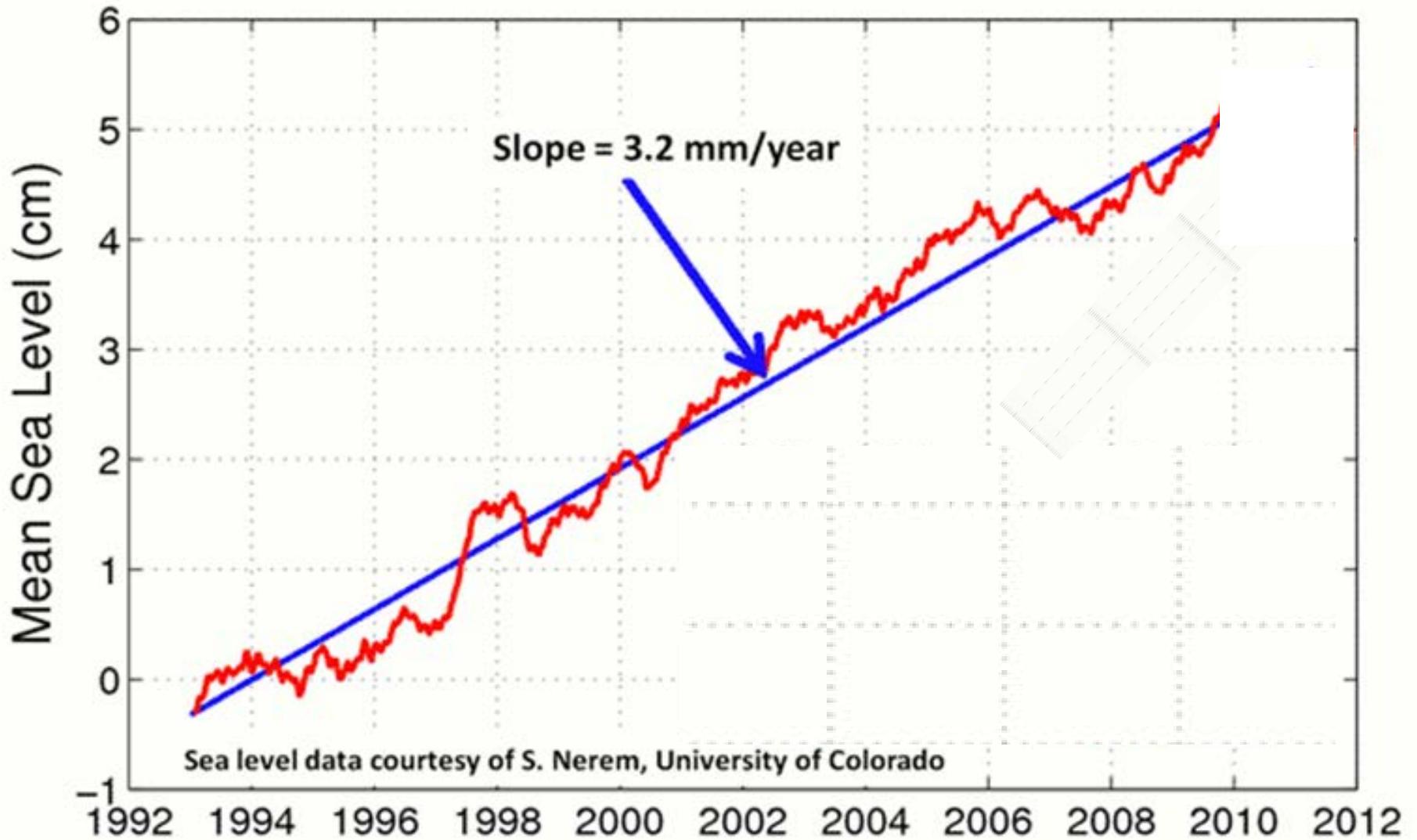
Solar Radiation Management (geo-engineering)

- Stratospheric sulfur aerosols
- Reflective aerosols, dust, metals
- Increase reflectivity of clouds
- Reflective sheeting in deserts
- Space mirrors
- Launching billions of reflective balloons into stratosphere
- Reforestation in tropical habitats (absorb more CO_2)
- Deforestation in high latitudes (exposes snow -> reflectivity)
- Building a 1000 km diffracting space lens between sun and earth
- Light-colored floating litter/garbage in the mid Pacific gyre
- Etc....
- Etc....
- Etc....

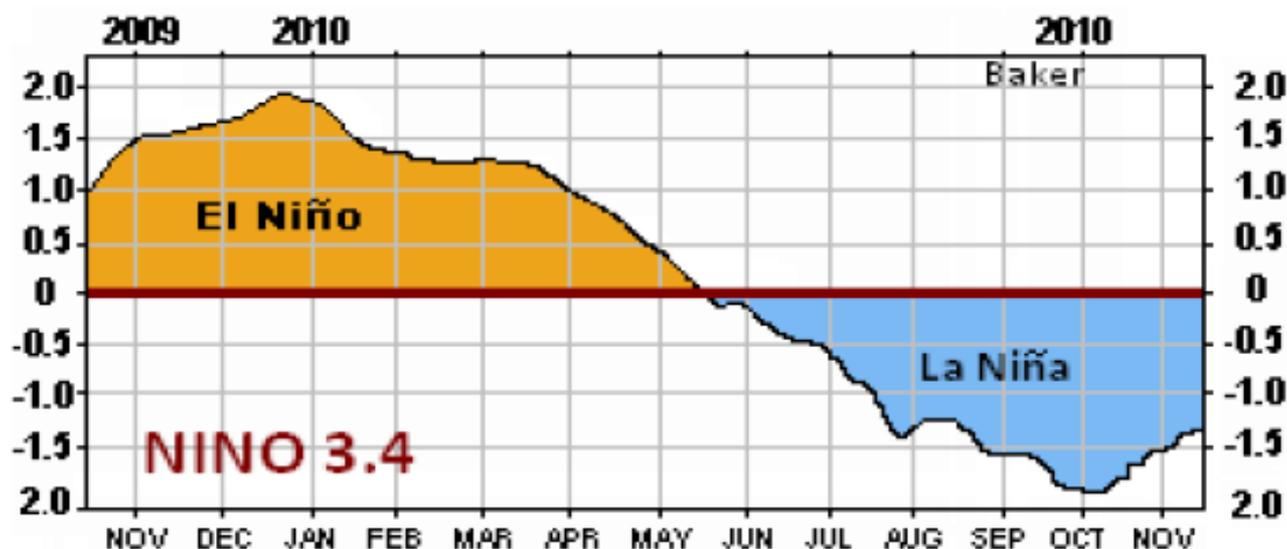
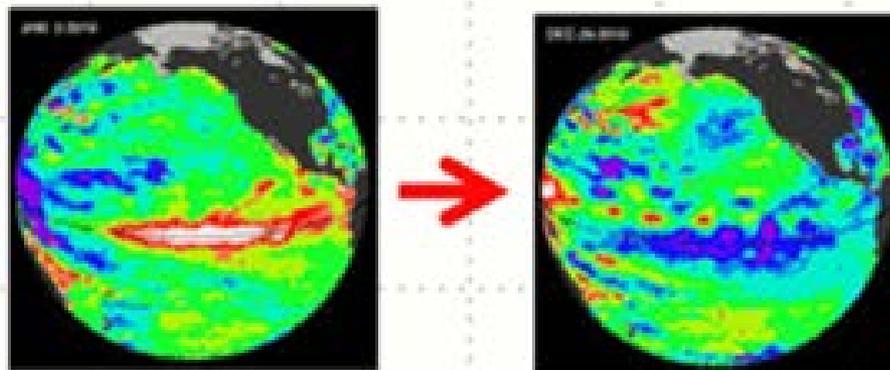
Carbon Dioxide Residence Time



Global Sea Level Drops 6 mm in 2010

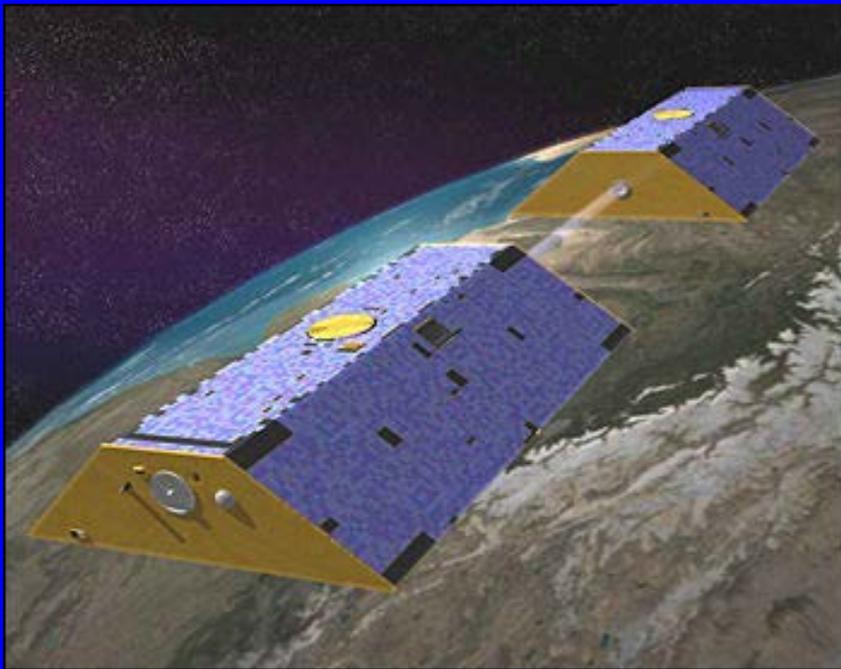


El Nino '10 becomes La Nina '10



**SST Anomaly (degrees C) for NINO 3.4
as of Nov 16, 2010**

Source: NOAA/Climate Prediction Center

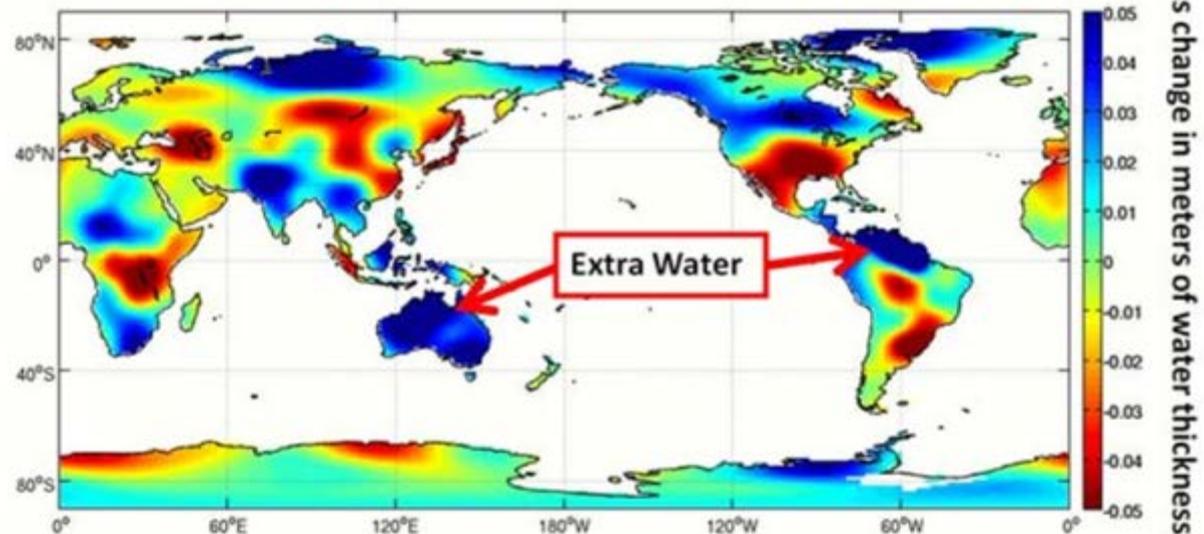


GRACE Twin Satellites

Gravity Recovery and Climate Experiment (GRACE)

NASA/German Aerospace Center
(NASA/JPL CalTech)

GRACE Shows Change in Water from March 2010 to March 2011



The red line in this image shows the long-term increase in global sea level since satellite altimeters began measuring it in the early 1990s. Since then, sea level has risen by a little more than an inch each decade, or about 3 millimeters per year. While most years have recorded a rise in global sea level, the recent drop of nearly a quarter of an inch, or half a centimeter, is attributable to the switch from El Niño to La Niña conditions in the Pacific. The insets show sea level changes in the Pacific Ocean caused by the recent El Niño and La Niña (see <http://sealevel.jpl.nasa.gov/science/elninopdo> for more information on these images). Image credit: S. Nerem, University of Colorado