Welcome to the *Climate-Safe Infrastructure* Webinar Series

Supporting AB2800 and the Work of California's Climate-Safe Infrastructure Working Group

February 22, 2018 | 12-1pm

Hosts

Juliette Finzi Hart | USGS

Co-Facilitator of CSIWG's work

Email: jfinzihart@usgs.gov

Susi Moser | Susanne Moser Research & Consulting

Co-Facilitator of CSIWG's work

Email: promundi@susannemoser.com

AB 2800 (Quirk): Purpose

Examine how to integrate scientific data concerning projected climate change impacts into state infrastructure engineering, including oversight, investment, design, and construction.

Project Decision Making		
Climate Change Impacts Science	Engineering Standards, Project Planning and Design	Project Construction Maintenance and Monitoring

AB 2800 (Quirk): Scope of Assessment and Recommendations

The working group shall consider and investigate, at a minimum, the following issues:

(1) **informational and institutional barriers** to integrating climate change into infrastructure design.

(2) **critical information needs** of engineers.

(3) **selection of appropriate engineering designs** for different climate scenarios.

The *Climate-Safe Infrastructure* Webinar Series

Purpose

- Hear from others elsewhere with relevant experience and expertise.

- Hear from CSIWG members.

- Educate and engage with interested stakeholders on climate change and infrastructure issues.

Sample of Webinar Topics

- What climate science can offer

- Various sectoral perspectives

- Processes of changing engineering standards and guidelines

- Holistic infrastructure planning and management

- Financing climate-safe infrastructure

- And others…

A Couple of Housekeeping Items

- Please type your questions for presenters into the chat box

- We will try to answer as many as possible after the presentations

- Answers to remaining questions will be posted on the website

Today's Webinar:
Forward-Looking Climate Science for Use in Infrastructure Engineering: Possibilities and Limits

Dan Cayan, Ph.D. | Researcher | Climate-Safe Infrastructure Working Group Member

Scripps Institution of Oceanography

Patrick Barnard, Ph.D. | Research Geologist
USGS Pacific Coastal & Marine Science Center

Nicolas Luco, Ph.D. | Research Structural Engineer | USGS Geologic Hazards Team

Morgan Page, Ph.D. | Geophysicist

USGS Earthquake Science Center

Climate Model Projections for Decision Making in California
AB2800 Webinar   22 Feb 2018

Dan Cayan, David Pierce, Julie Kalansky

Scripps Institution of Oceanography

University of California San Diego

From what we've been hearing in the WG meetings and the literature we've read so far...
   the two main obstacles to incorporating forward-looking climate science by engineers into design and standards
   seem to be 1) inadequate understanding of how GCMs are developed (e.g., the science embedded therein and how
   models are validatied/groundtruthed) and 2) what options we have in areas where there remains (for the
   foreseeable future) large ranges of uncertainty. We're giving you a longer time for your presentation since we
   have the most requests for what we'd like you to cover, which include:

What types of information go into GCMs ... of these, what types of information are we most confident in,
   which ones the least? As part of this, we would be interested in hearing about how validation usually
   happens (i.e. do most modelers do some sort of hindcast to make sure the models match historic
   projections... then they push forward? do they ground truth their models? what about judging "skill" - how
   is that done? what do we know about which models are better than others?) [we just learned about some
   Australian approach to weighing models by skill; maybe you can speak to the value of such approaches]

Then you could discuss what's currently available in California ... (we heard in the meeting the need for information
   on intensity and duration of rain fall and run-off; more SLR info (!!!!) so you should definitely address those)

Then spend some time discussing the trends that we expect to see and perhaps the growing variability around
   the extremes ...of the extremes - which ones do we understand the most; which the least. Where do you expect
   significant progress in the next 3-5 years? What do you expect to remain extremely uncertainty?

Finally - if time permits - you could discuss what information we could turn to for either information that hasn't
   yet been modeled and/or has huge uncertainty.... perhaps discussing spatial analogs (e.g. if we're expecting less
   night time cooling... we could look at how places in the middle east address this impact on their energy infrastructure)
   or historical analogs or very big historical extremes.

Schematic for Global Atmospheric Model

Horizontal Grid (Latitude-Longitude)

Vertical Grid (Height or Pressure)
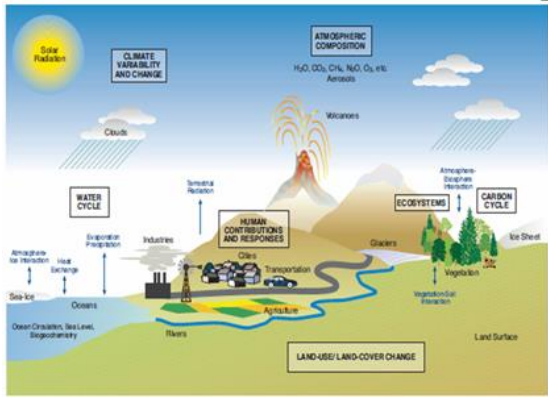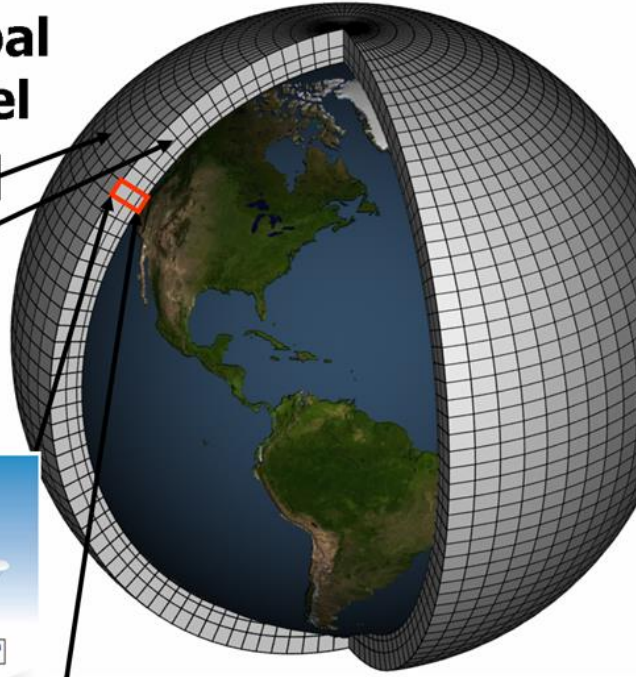
Global Climate Models

Continued development, more processes

Skillfully simulate Earth's surface temperature;
   historical decade-scale temperature well replicated
   demonstrate that GHG's have driven warming in recent decades

Uncertainties
   model approximations
   drivers of climate change (e.g. GHGs, aerosols)
   natural variation

More Certain Future outcomes:
   warming earths' surface
   overall speed up of hydrological cycle, atmospheric humidity
   sea level rise
   loss of snow pack
   increase in some forms of extremes (e.g. drought, heavy precip)

Less Certain Future outcomes
   changes in overall precipitation
   changes in storminess
   changes in wind patterns

GCM Evaluation
global metrics
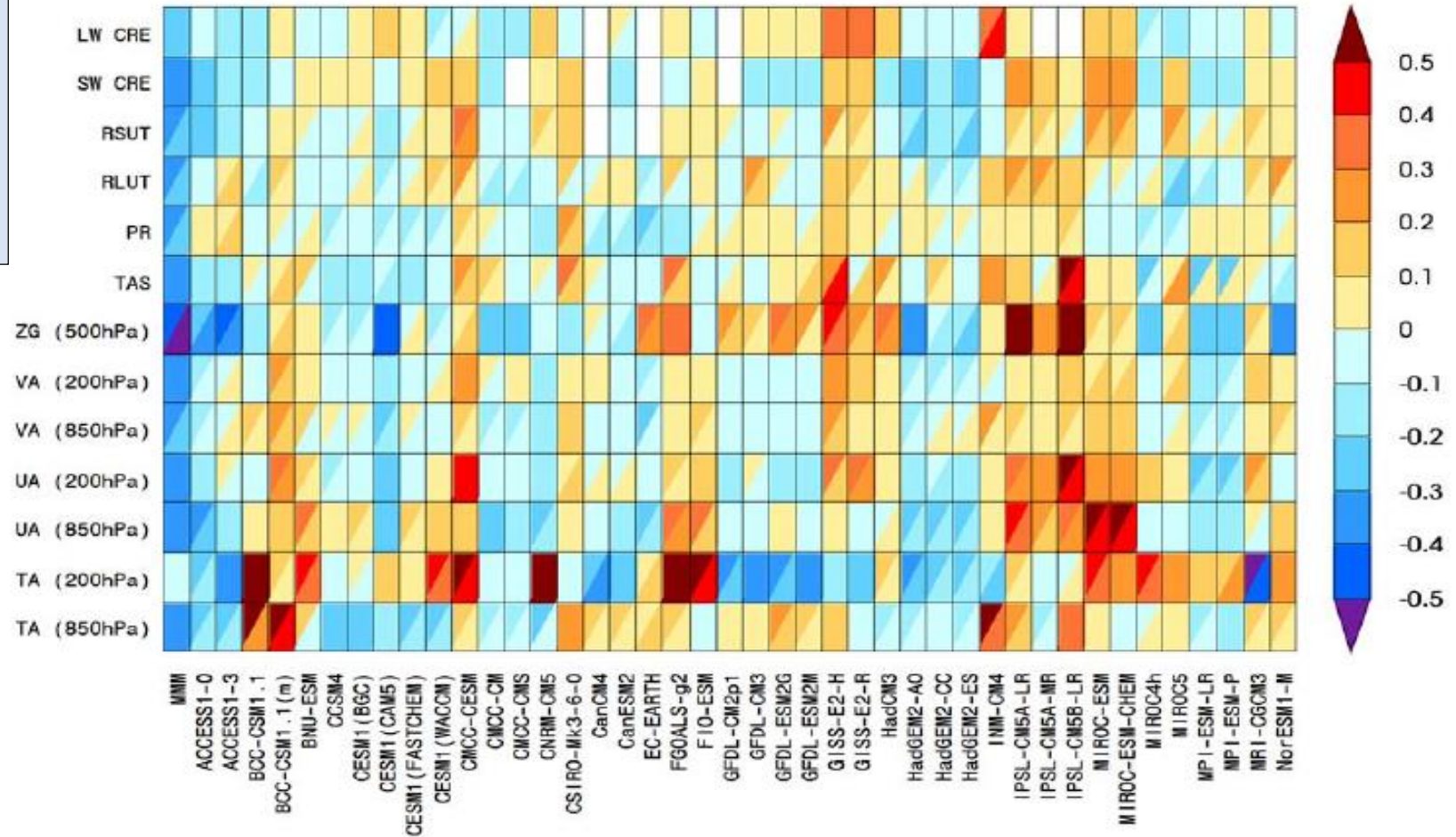
Figure 9.7: Relative error measures of CMIP5 model performance, based on the global seasonal-cycle climatology (1980–2005) computed from the historical experiments. Rows and columns represent individual variables and models, respectively. The error measure is a space–time root-mean-square error (RMSE), which, treating each variable separately, is portrayed as a relative error by normalizing the result by the median error of all model results (P. Gleckler, Taylor, & Doutriaux, 2008). For example, a value of 0.20 indicates that a model's RMSE is 20% larger than the median CMIP5 error for that variable, whereas a value of –0.20 means the error is 20% smaller than the median error. No color (white) indicates that model results are currently unavailable. A diagonal split of a grid square shows the relative error with respect to both the default reference data set (upper left triangle) and the alternate (lower right triangle). The relative errors are calculated independently for the default and alternate data sets. All reference data used in the diagram are summarized in Table 9.3.

Peter Gleckler: from IPCC AR5 Working Group I, draft, not for distribution

Identifying GCMs for California Water Managers

- For many purposes, an ensemble of global models is required

- Using all 40+ available Global Climate Models (GCMs) isn't practical

- Remove (cull) GCMls that don't adequately represent historical conditions i
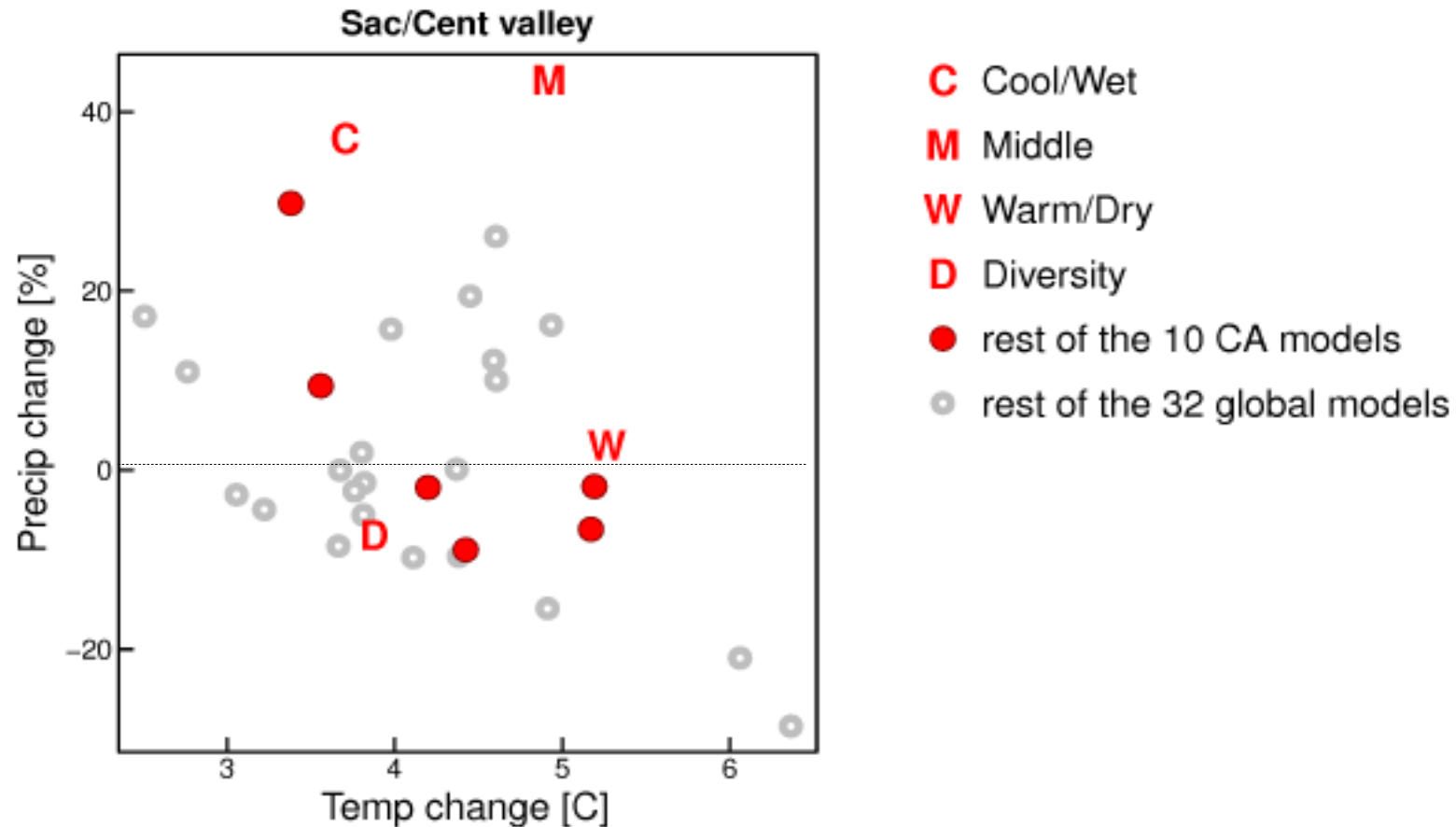
40+ GCMs

Global Climatology Assessment

Gleckler et al IPCC 5th Assessment Report evaluated modeled historical
- Radiation
- Temperature
- Pressure, wind

~20 GCMs

Regional Assessment
Rupp, Mote et al Southwestern U.S.
- Temperature & Precipitation
- Pressure patterns, El Niño structure

~15 GCMs

CA/NV Extremes Assessment
Cayan et al CNAP, SW CSC Group
- Dry and Wet Precipitation extremes
- Heat waves and cold snaps
- El Niño spatial & temporal patterns

~12 GCMs

Numbers of GCMs to be retained after Global, Regional Mean and Regional Extremes Assessments are a preliminary estimate

A subset of GCMs for
California Water Resources Assessment

Temperature Change and Precipitation Change near Sacramento
RCP8.5, 2070-2099 vs. 1950-2005 all 32 GCMs, and selected 10 GCMs, 4 GCMs

rcp85, 2070–2099

Sac/Cent valley

C Cool/Wet
M Middle
W Warm/Dry
D Diversity
● rest of the 10 CA models
○ rest of the 32 global models

Downscaling
from global climate model output to regional climate simulations

two techniques
dynamical
statistical

Precipitation [inches/year]
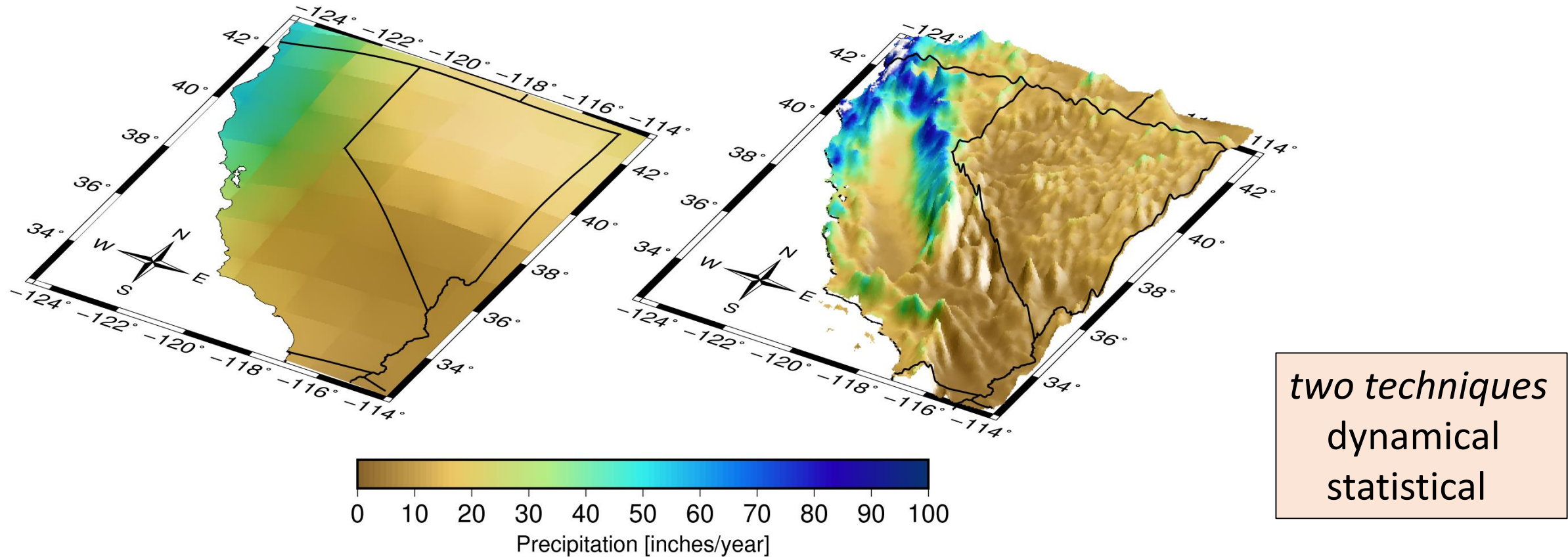
Figure 1   Annual precipitation in California and Nevada (inches) in a global climate model with a resolution of 100 miles (left), and after using a statistical model to account for the effects of topography at a 3.6 mile resolution (right). The global model only has a few grid cells over the entire state of California, so does not resolve the coastal mountain ranges, interior valley, or Sierra Nevada Mountains on the border with Nevada. The precipitation field in the right panel, by contrast, captures the wet conditions on the west slopes of the mountains, and the dry, rain shadow region to the east of the mountains. The vertical scale has been exaggerated for clarity, and by the same amount in both panels.

LOCA statistical downscaling designed to simulate extremes:
extreme precipitation LOCA vs Observed
historical CanESM2 1yr and 20 yr maximum precipitation
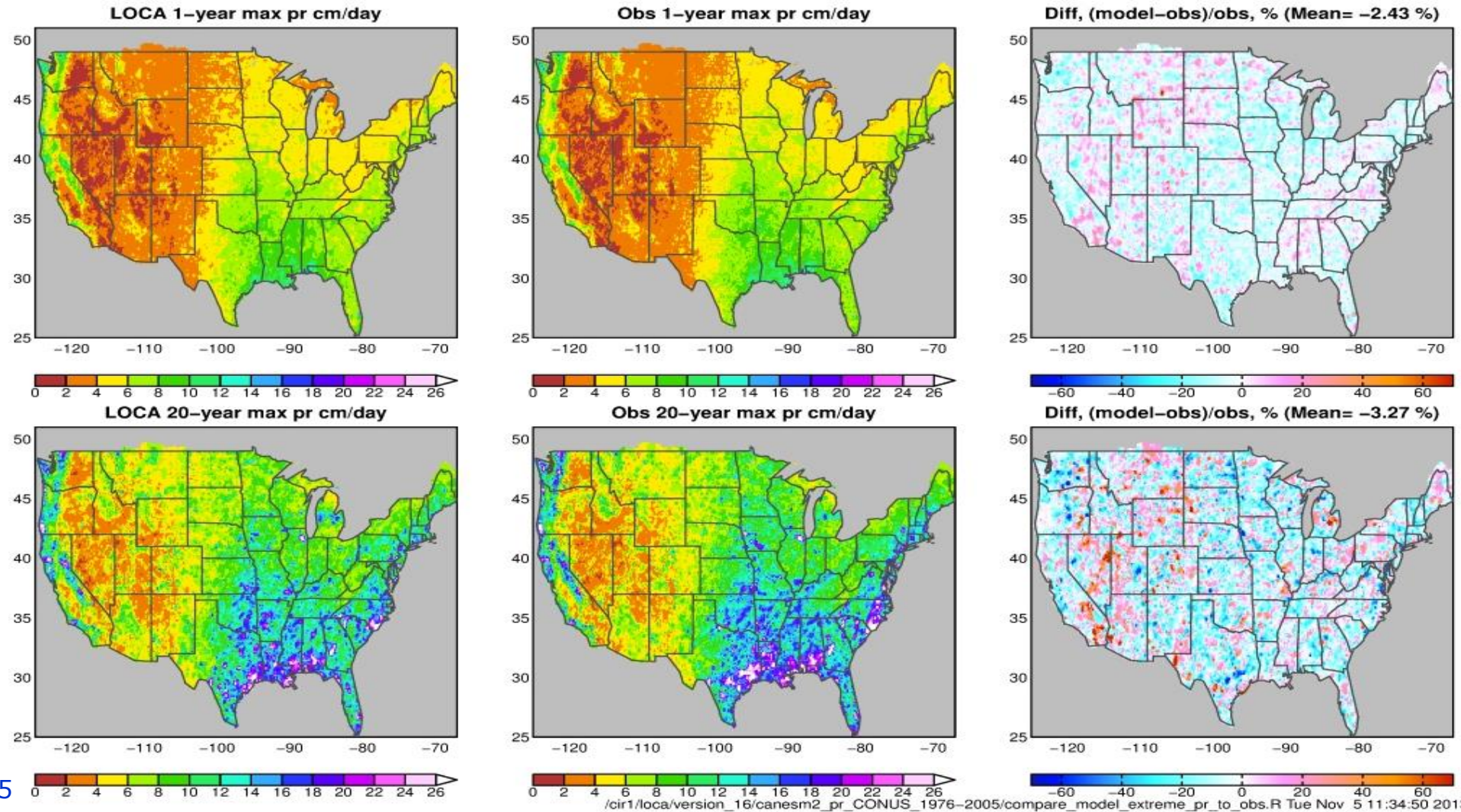
Hottest Day of the Year will likely get hotter!

from 32 downscaled CMIP5 GCMs averaged over San Diego County
moderate (RCP 4.5) and high (RCP 8.5) greenhouse gas emissions scenarios

RCP 8.5 greenhouse loading excesses over
RCP 4.5 become increasingly large, especially
after 2050.

Dark lines are averages over 32 models,
Clouds show range of model results for each year

David Pierce, SIO

tasmax yearly *maximum*
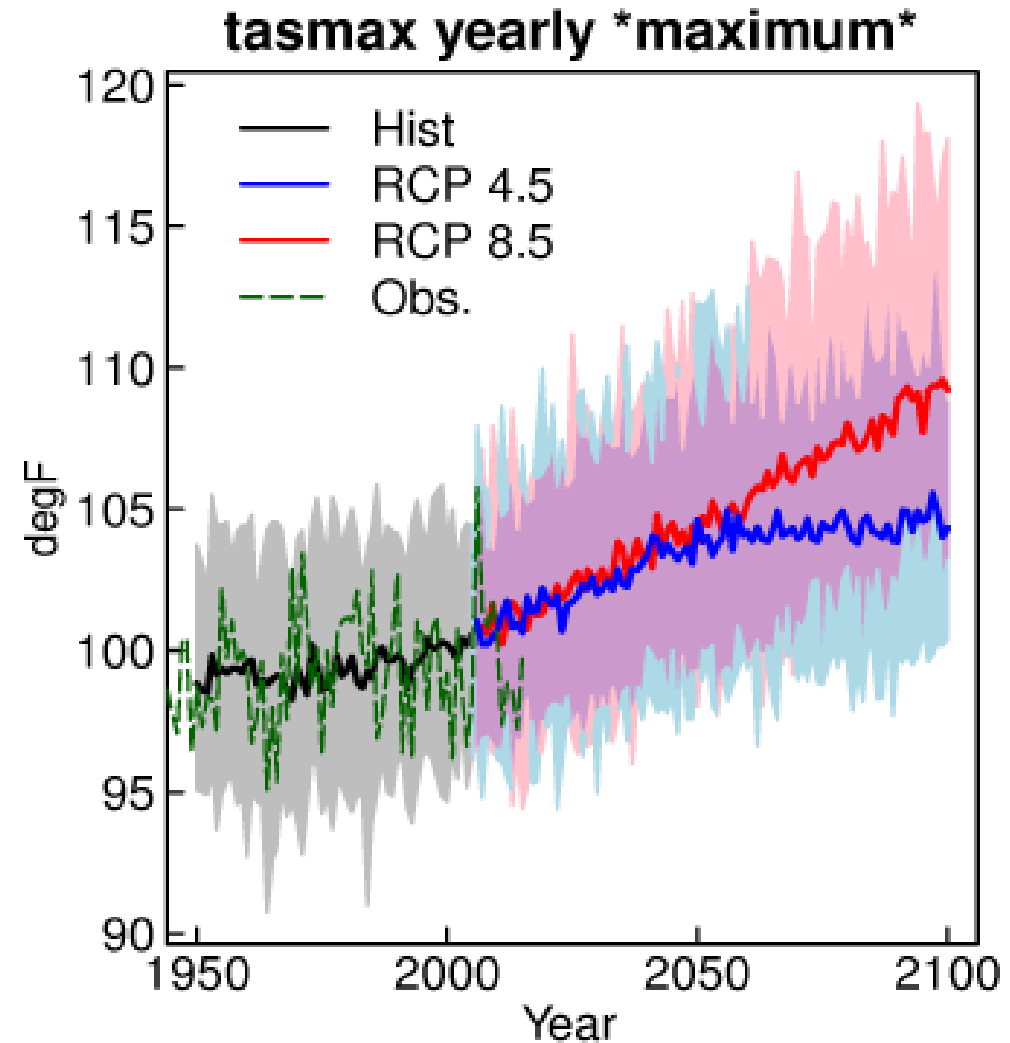
Hottest day of the year, historical vs. end of century (deg F)

Change in hottest day of the year (deg F):

David W. Pierce, Scripps Institution of Oceanography
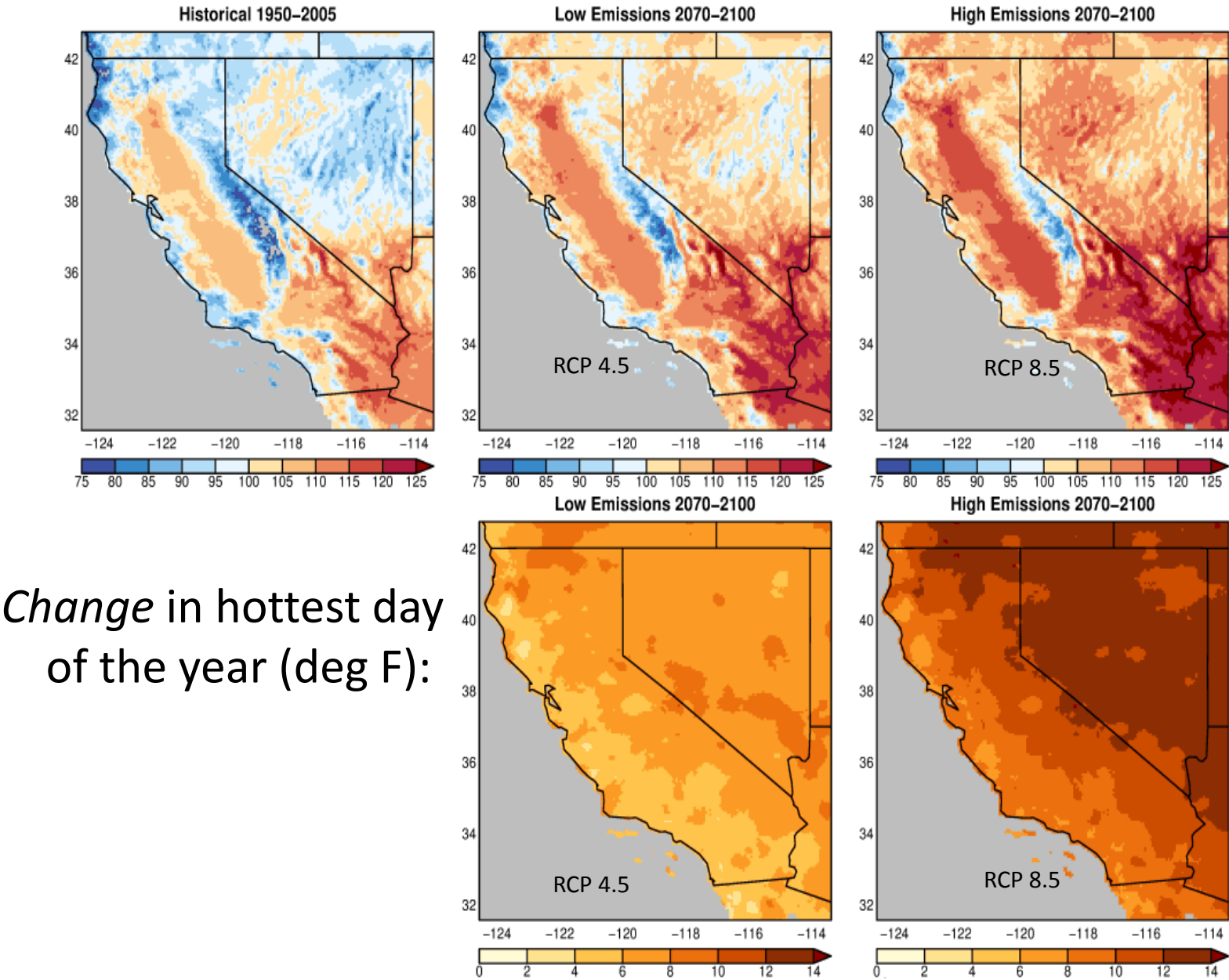
Figure 5

Range of Number of Days/year >= threshold (deg F): RCP 8.5

(range encompasses 2/3rds of years)
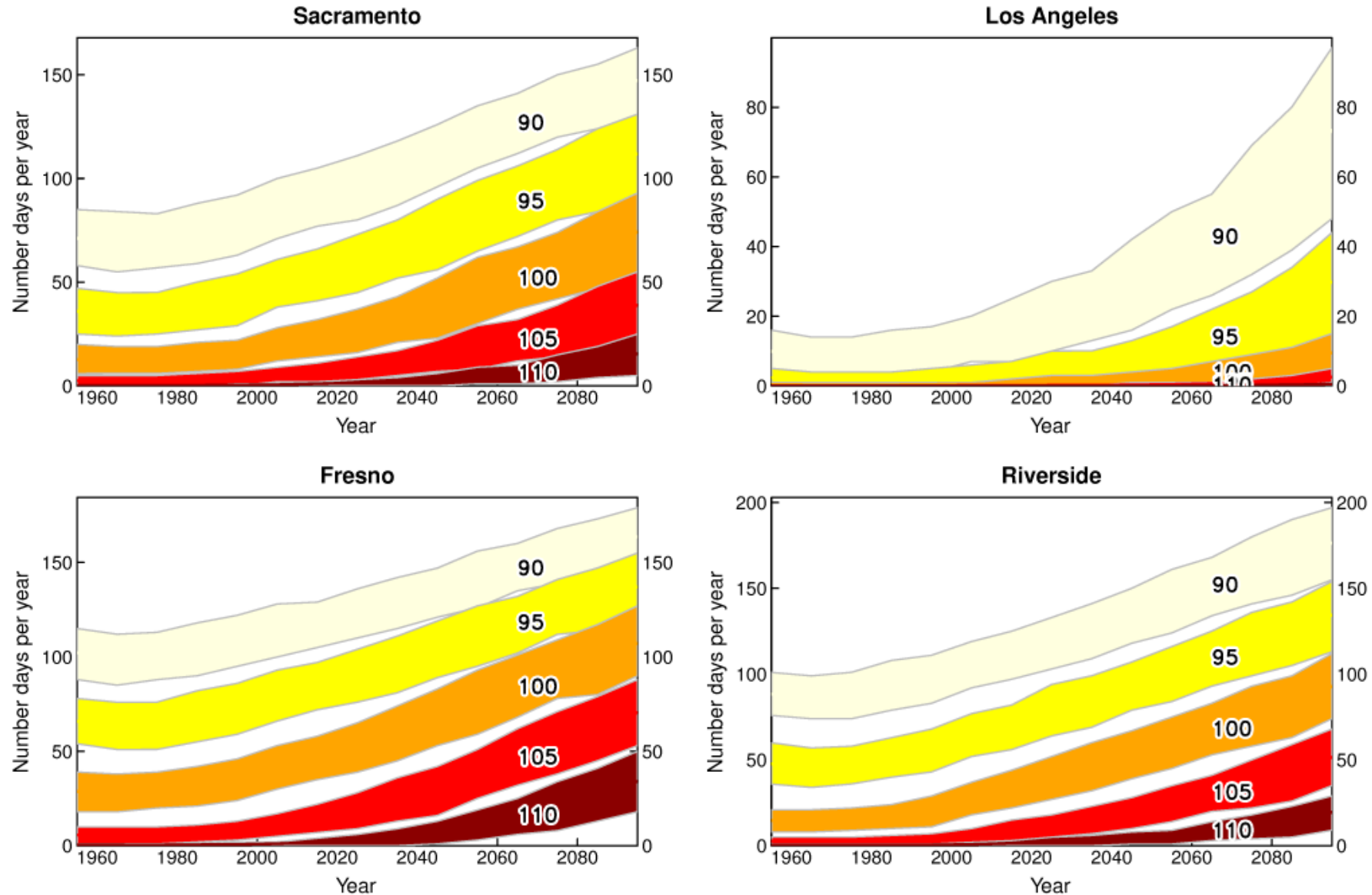
Figure 6

California

Figure 7

David W. Pierce Scripps Inst. Oceanography
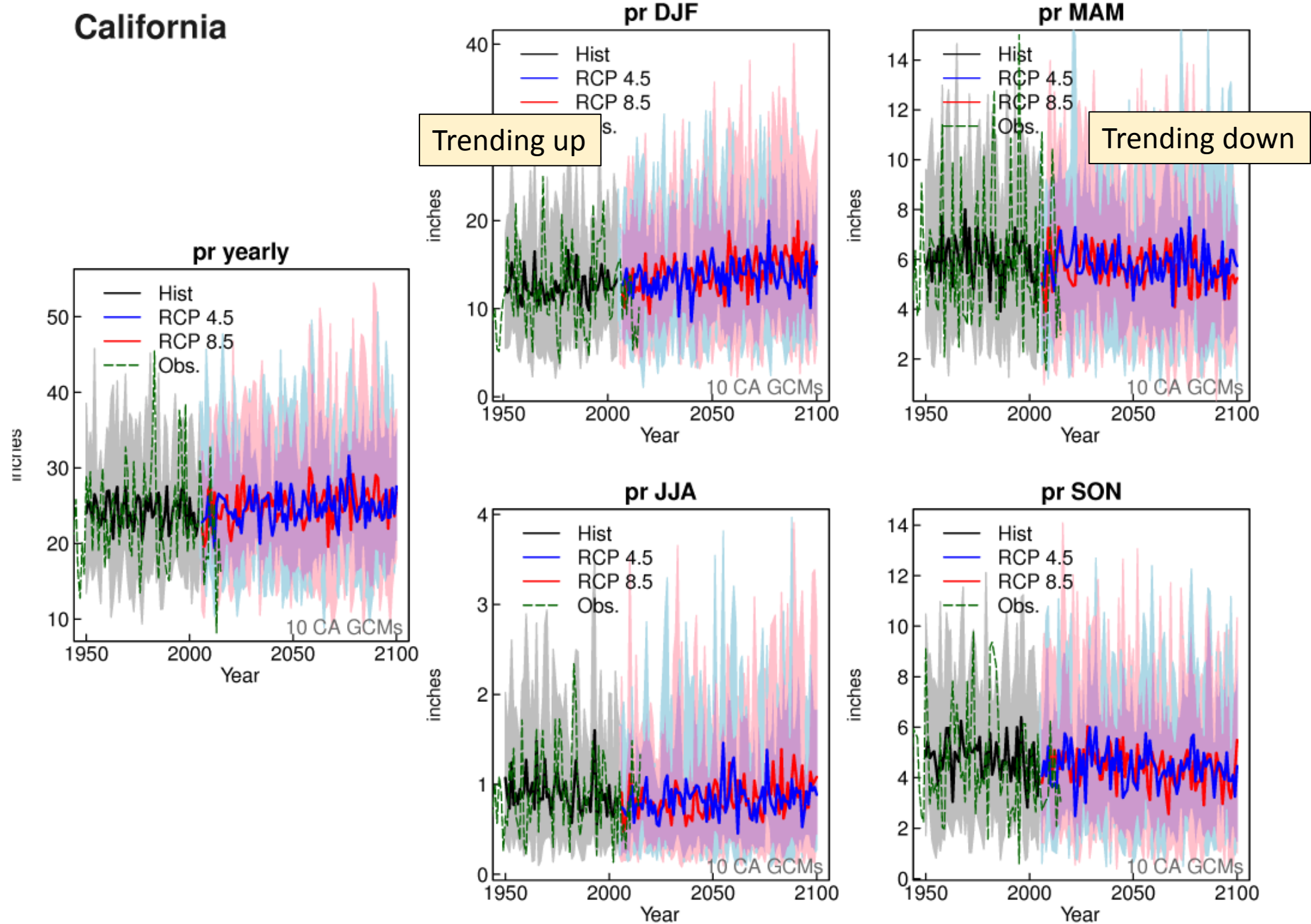
Figure 12a

Frequency of Dry Years, California   32 GCMs
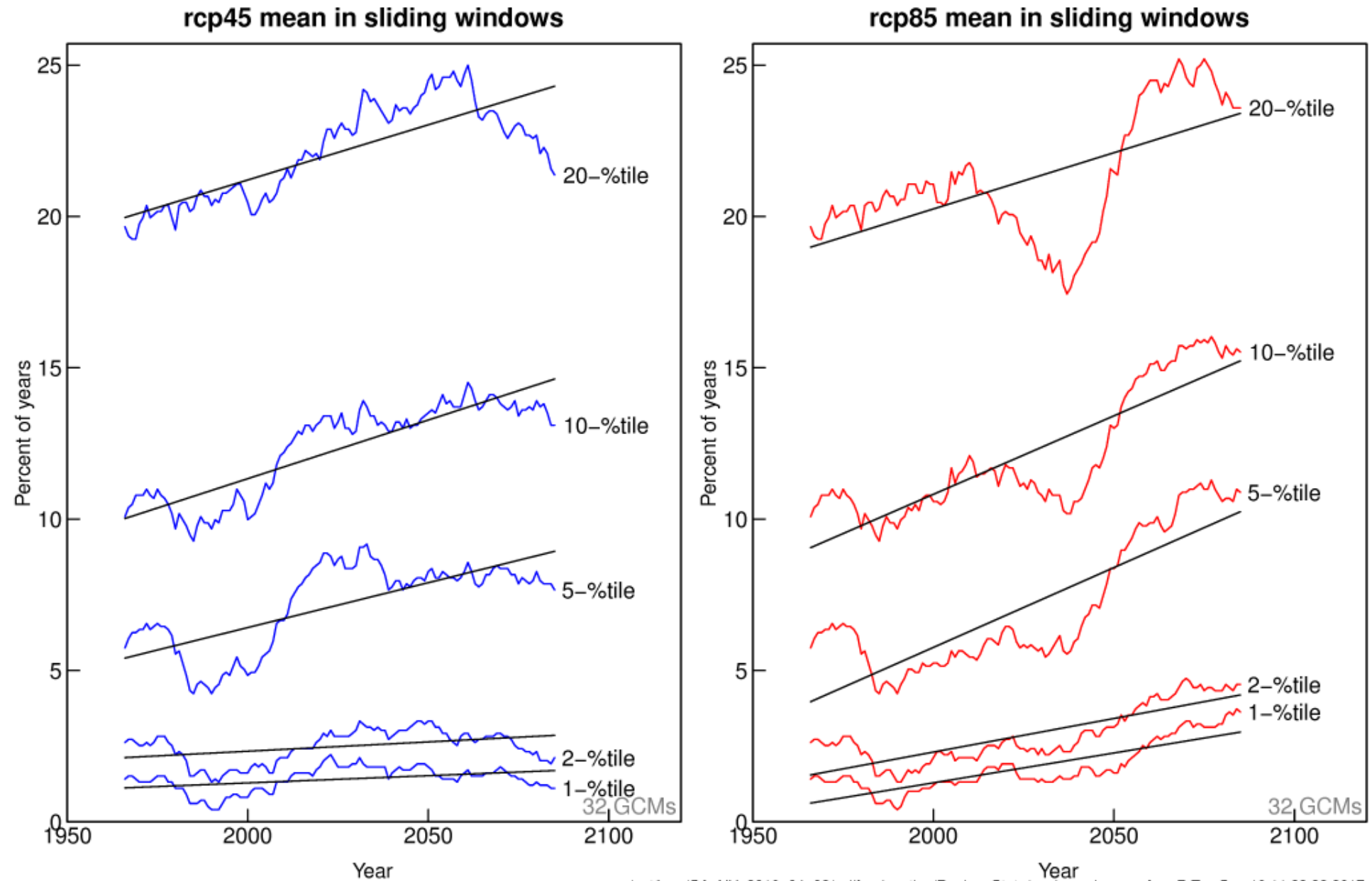
Figure 11

Avg wettest day/year, 1976–2005 (inch) · Avg wettest day/yr (inch), 2070–2100 rcp45 · Avg wettest day/yr (inch), 2070–2100 rcp85 · Change in avg wettest day/yr (%) rcp45 · Change in avg wettest day/yr (%) rcp85
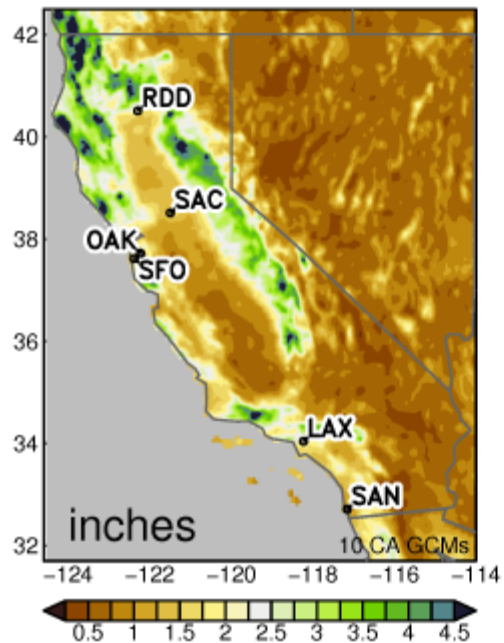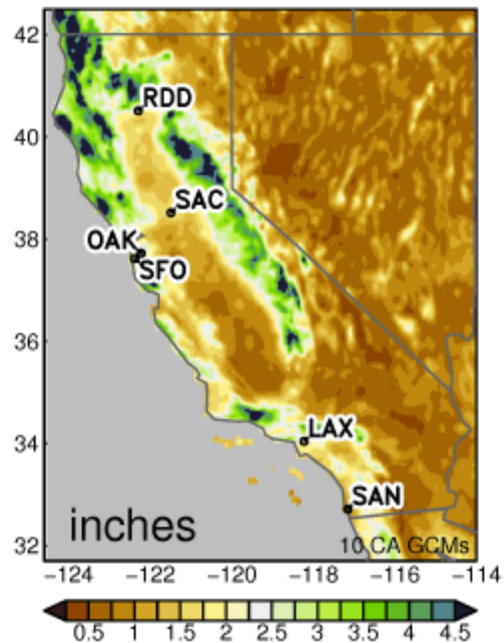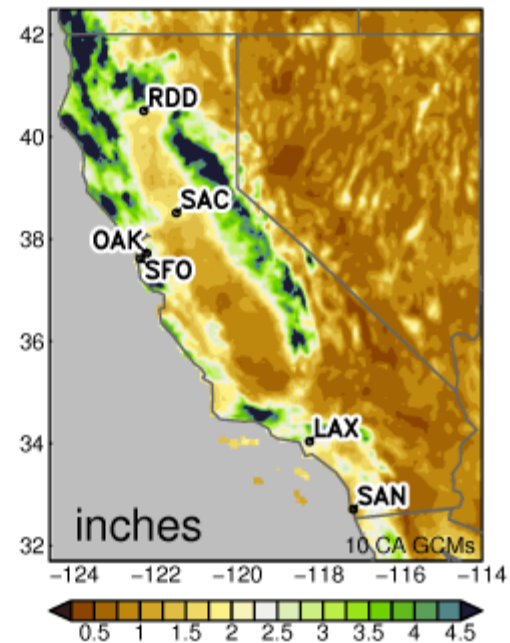
/net/loca/CA_NV_2016–04–02/california_atlas/Region_State/avg_highest_day_year_pr_v2.R Tue Sep 19 11:36:38 2017
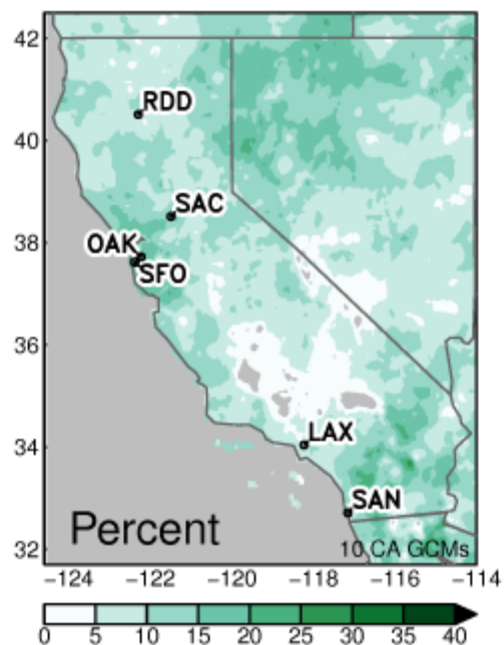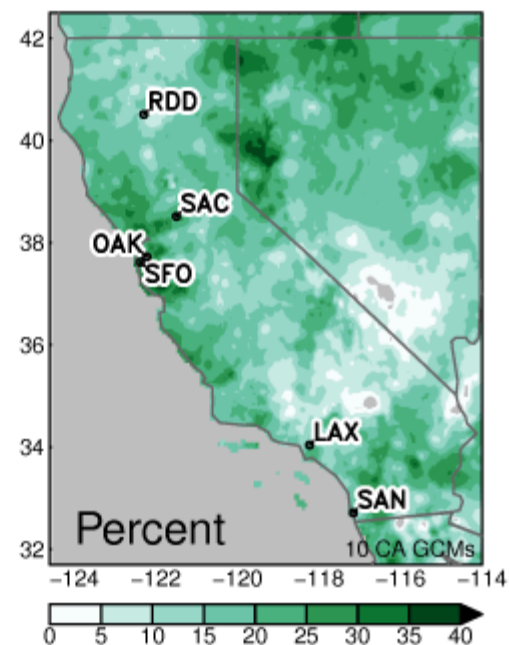
Relative humidity min (day) change by 2070–2100 w.r.t. 1950–2005, RCP 8.5
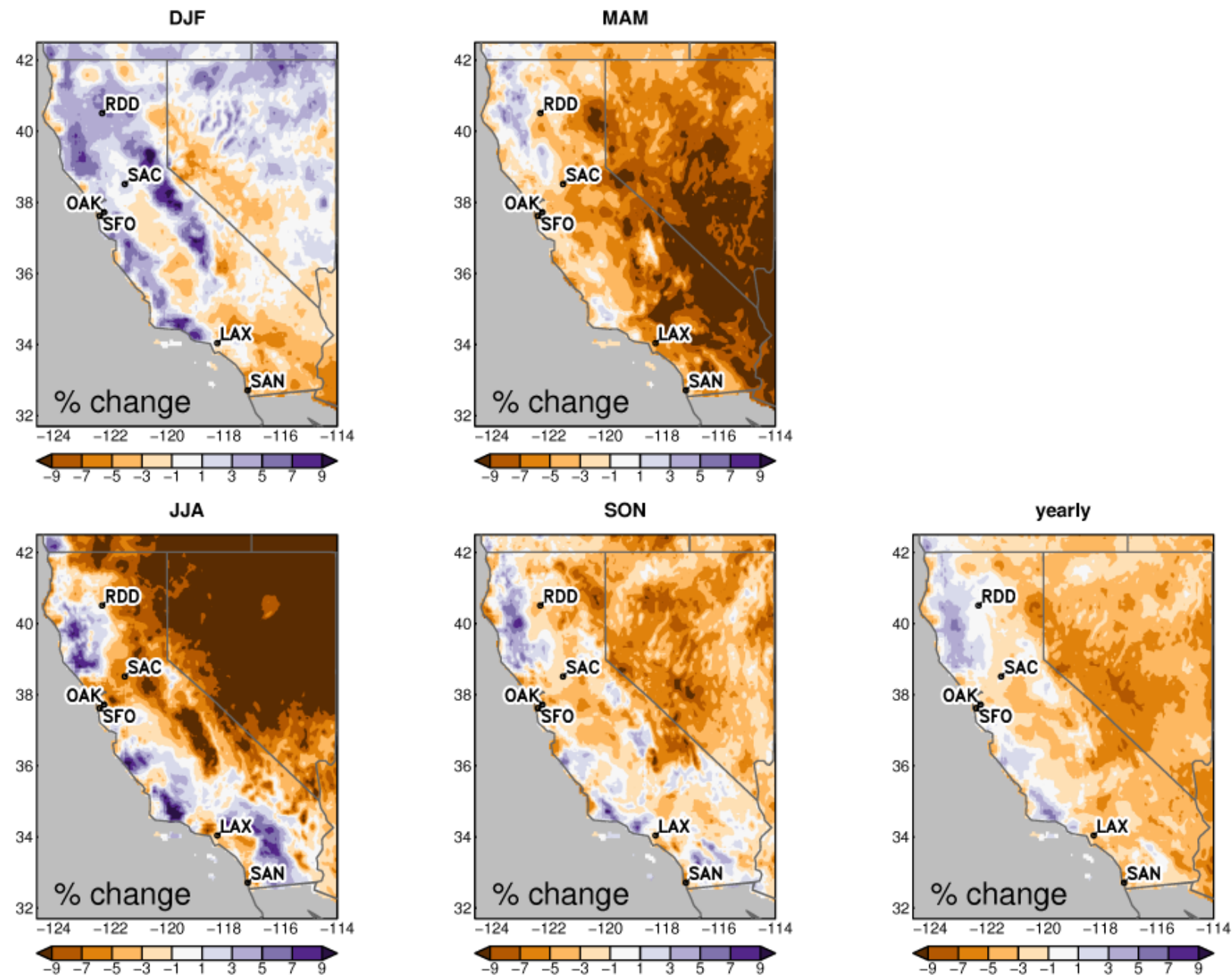
Figure 14

California April 1 SWE from climate simulations
Odds a year is above the average historical median (11.86cm; 1961–1990)
32 BCSD (16 SRESA2 and 16 SRESB1)   Median Apr 1 SWE 11.9cm

over 21ˢᵗ Century occurs a marked decline of chances of reaching
or exceeding historical median
Snow Water Equivalent Sierra Nevada+

2030 SWE   2060 SWE   2090 SWE

April SWE: 95%   April SWE: 64%   April SWE: 48%
(of 1995-2005 avg)
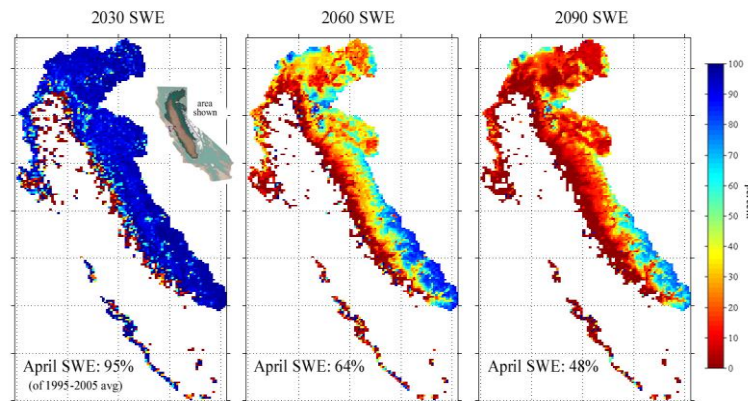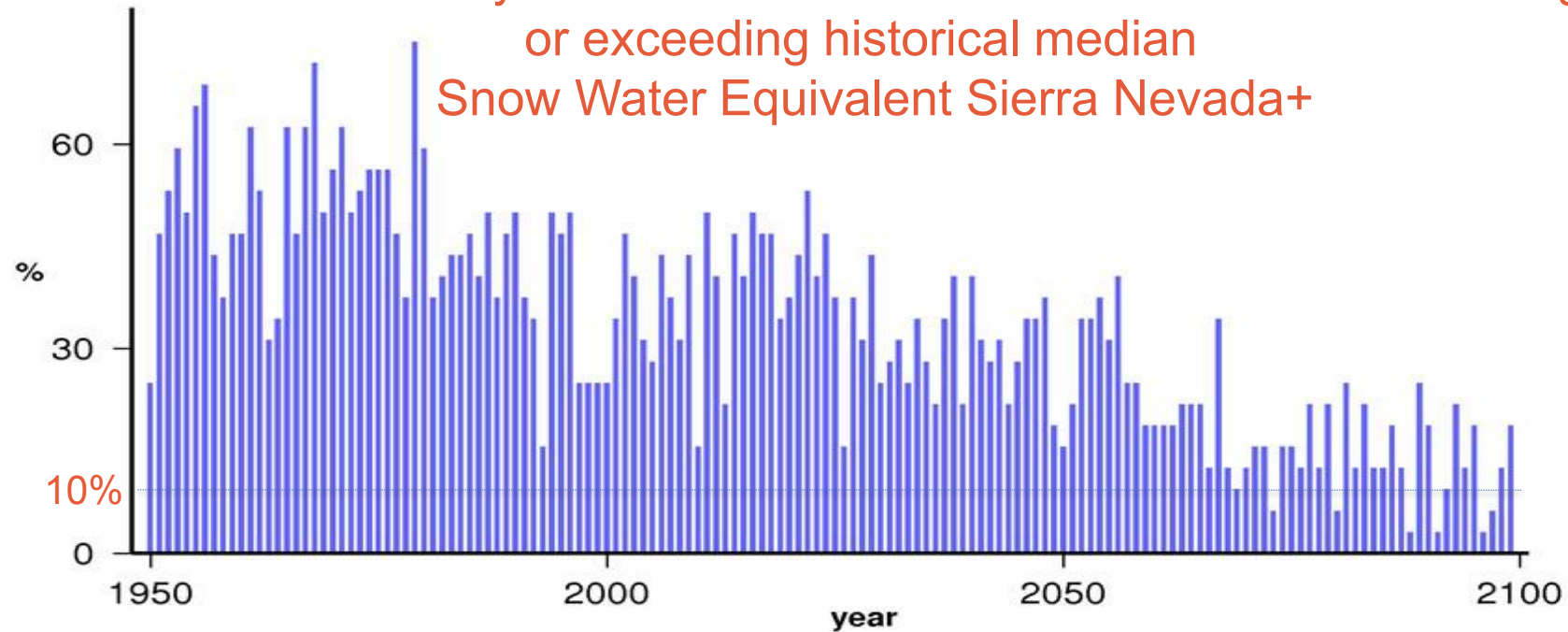
California April 1 SWE from climate simulations
Odds a year is below the historical 10th percentile (3.60cm; 1961–1990)
32 BCSD (16 SRESA2 and 16 SRESB1) 10ᵗʰ % Apr 1 SWE 3.6cm

….and, chances of historical 10ᵗʰ percentile or less
SWE increases greatly

40%

La Jolla
Max SL 5.1 (ft)

see *Rising Seas in California* (2017) and new State SLR Guidance

Sea Level Rise is very likely

projected rate and magnitude have
broad range of possible outcomes

greatest impacts when coupled w/ large
storms, high tides, El Niño conditions

Regional Climate Change is being evaluated in the Fourth National Climate Assessment (NCA4) and the Fourth California Climate Change Assessment

Numerous Other Variable and Measures are being investigated:

Amongst those:
    winds
    wildfire occurrence
    waves
    coastal effects
     .
     .
     .

Coastal Flooding and Uncertainty

Patrick Barnard
United States Geological Survey
Pacific Coastal and Marine Science Center
Santa Cruz, CA

Capitola, January 2008

Collaborators and funders:

How Big is the Problem?

- **Over 1 billion people are expected to live in the coastal zone by 2050**

- **27 million people presently live in CA coastal counties**

- **Over 3 million people in CA at risk of flooding from SLR and storms by the end of the century, in addition to ~$2 trillion in property**

- **Impact by 2100 could be ~5% of CA GDP**

- **Bay Area accounts for two-thirds of projected impacts**

Getty Images

H. Ling

Foster City
0.25 m SLR + 100 year storm

≋ **USGS**
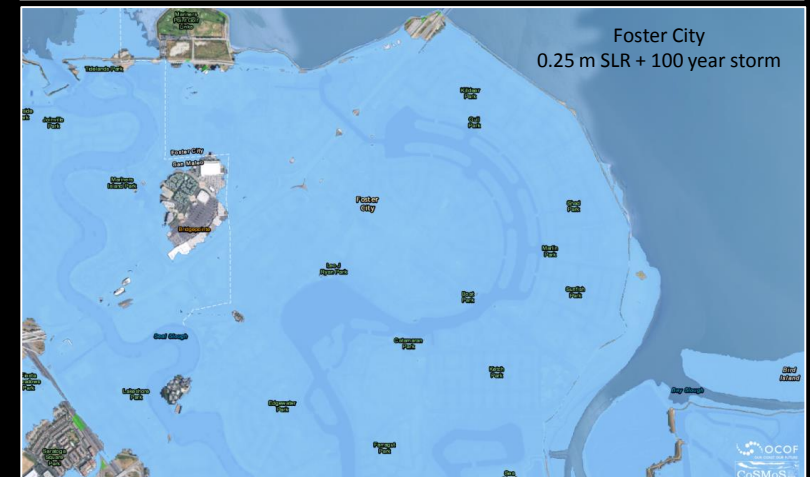
Coastal Storm Modeling System (CoSMoS)
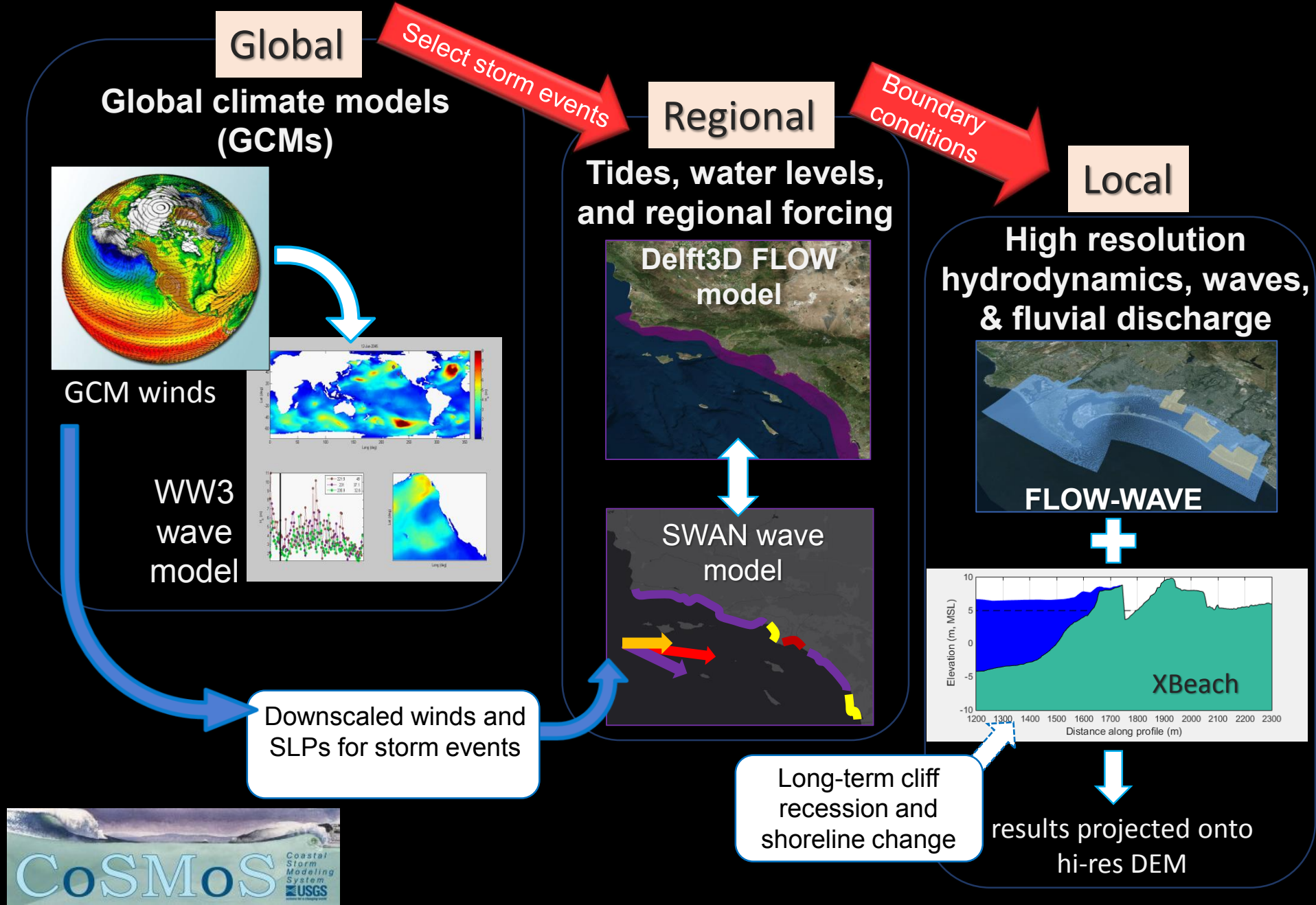
Wave Modeling – Ensemble Approach

1. Global forcing using the latest CMIP5 climate models
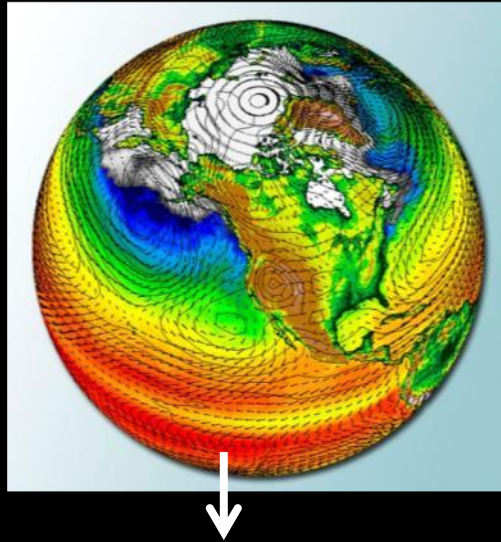
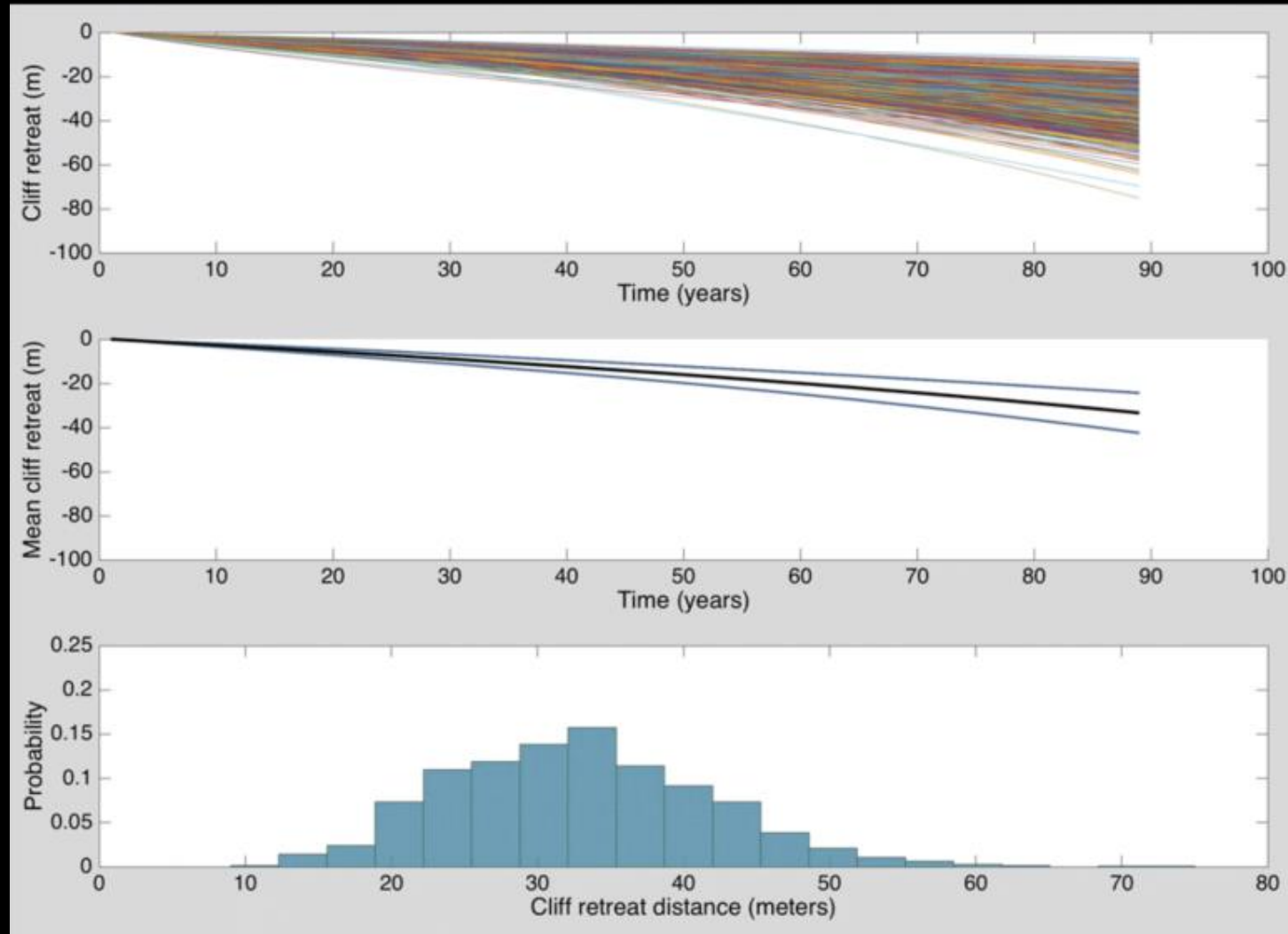| Modeling Center	model	model resolution
Beijing Climate Center, Meteorological Administration, China (BCC)	BCC-CSM1.1	2.8° x 2.8°
Institute for Numerical Mathematics, Russia (INM)	INM-CM4	2° x 1.5°
Model for Interdisciplinary Research on Climate - AOEI, NIES, JAMSTEC, Japan (MIROC)	MIROC5	1.4° x 1.4°
NOAA Geophysical Fluid Dynamics Laboratory	GFDL-CM3	2.5° x 1.5°

2. Drives global and the regional ENP wave models (WAVEWATCH3)

global grid

eastern north Pacific grid (ENP)
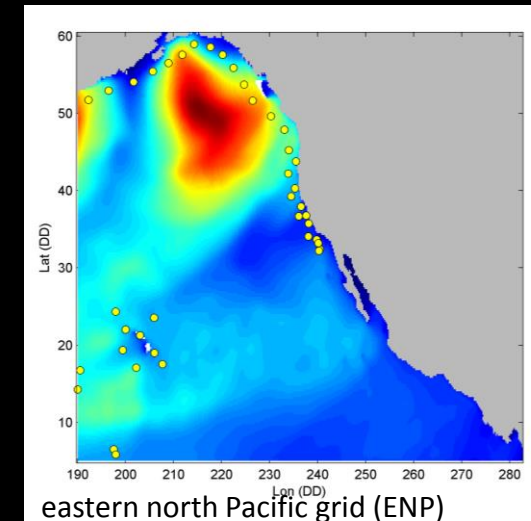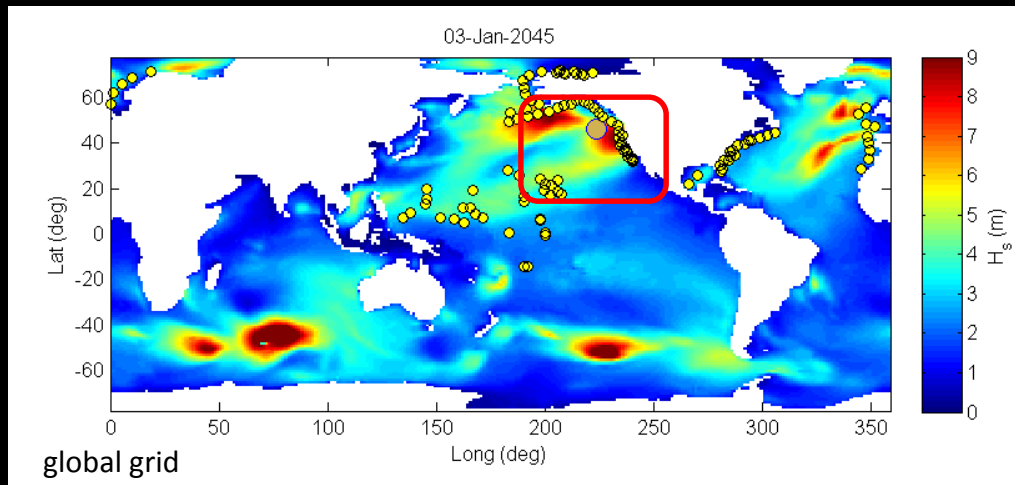
Long-term Morphodynamic Change: Sea Cliffs

1-D model ensemble (Limber et al., in review)

Cliff Retreat

2100 cliff edge position

SLR scenario (m)
- 0.2
- 0.5
- 1.0
- 1.5
- 2.0
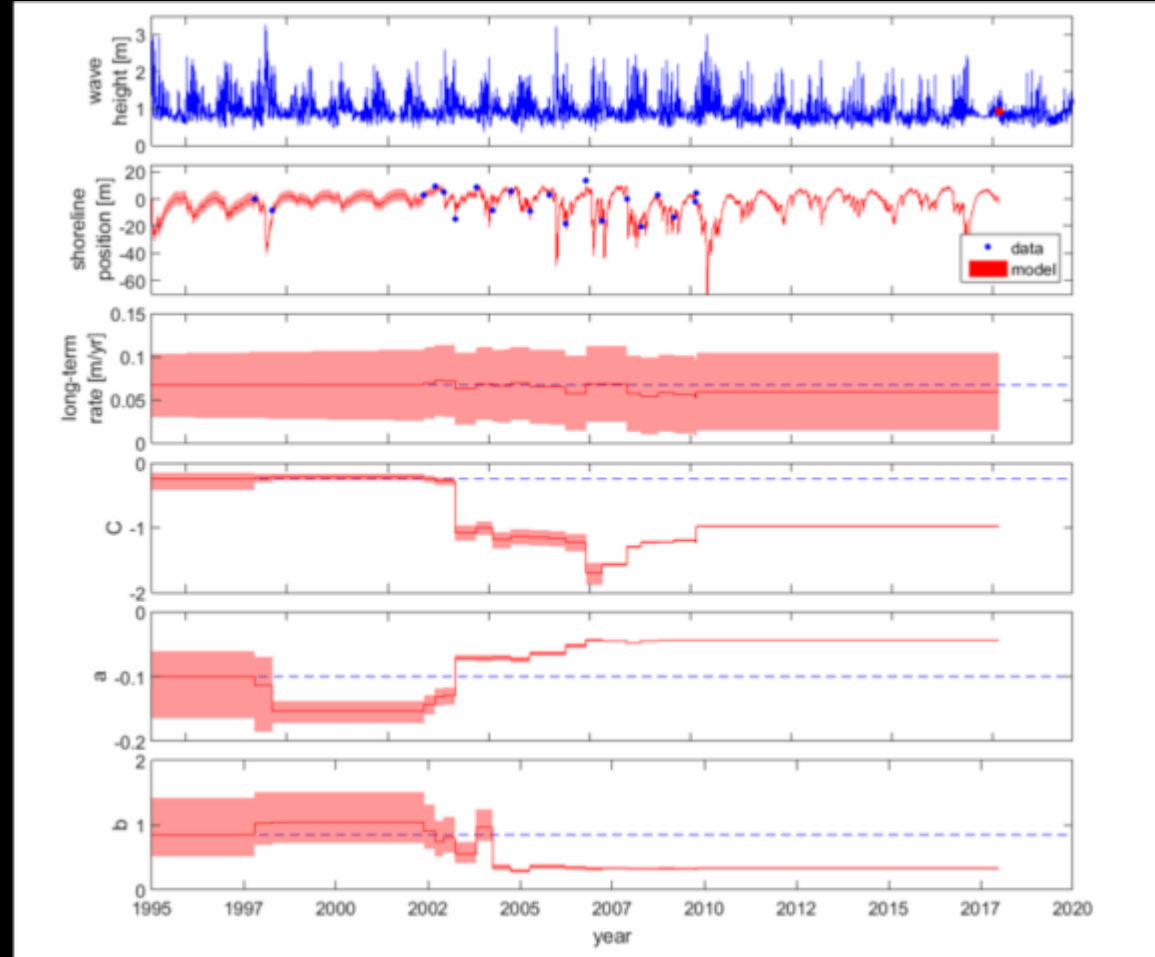- model transect

CoSMoS — Coastal Storm Modeling System, USGS

Google earth

CoSMoS-COAST: Coastal One-line Assimilated Simulation Tool

- A (hybrid) numerical model to simulate long-term shoreline evolution
- Modeled processes include:
  - Longshore transport
  - Cross-shore transport
  - Effects of sea-level rise
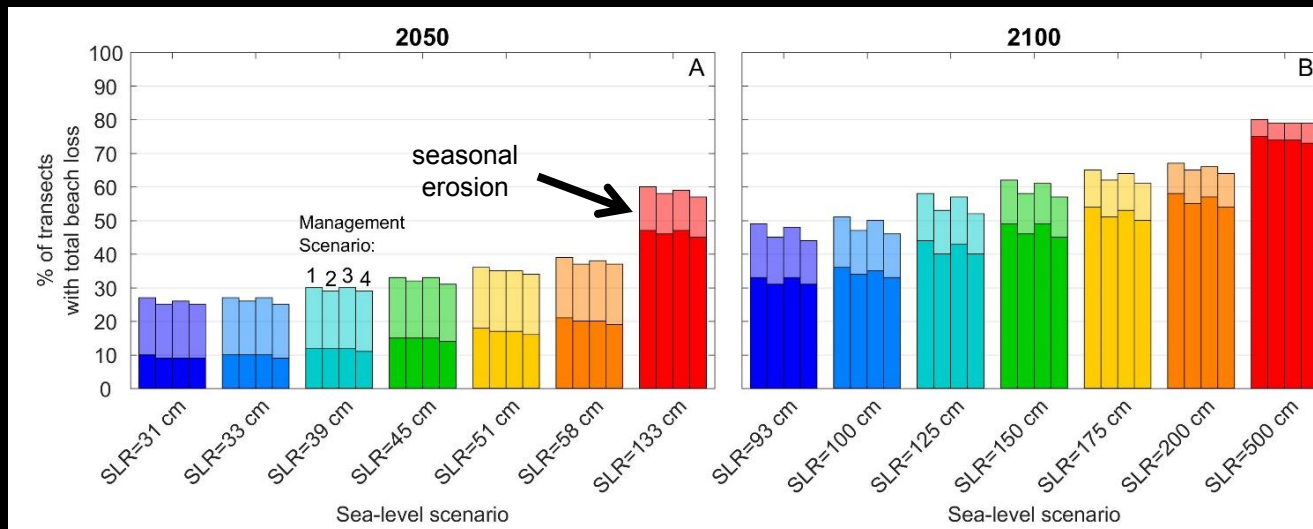 - Sediment supply by natural & anthropogenic sources

Vitousek, S., Barnard, P.L., Limber, P., Erikson, L.H. and Cole, B., 2017. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. *Journal of Geophysical Research-Earth Surface*, http://dx.doi.org/10.1002/2016JF004065

Projected Beach Change- SoCal

- Many beaches will erode considerably (avg. = ~50 m)

- 31 to 67% of beaches completely eroded*

Vitousek, S., Barnard, P.L., Limber, P., Erikson, L.H. and Cole, B., 2017. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. *Journal of Geophysical Research-Earth Surface*, Volume 122, 25 pp., http://dx.doi.org/10.1002/2016JF004065

≋ USGS

Flooding Uncertainty

0.75 m SLR + 100 yr storm
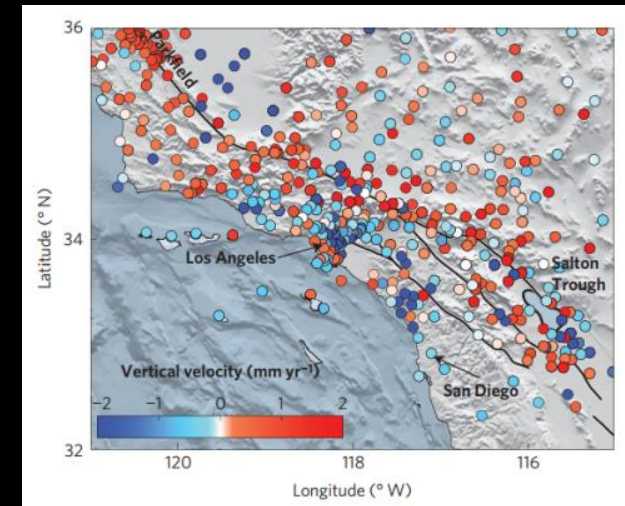
$$\varepsilon = \pm M \pm DEM \pm VLM \pm Marsh$$

Model uncertainty

Vertical accuracy of DEM

(Dewberry 2012)

Vertical land motion
Howell et al., 2016

Marsh accretion/erosion

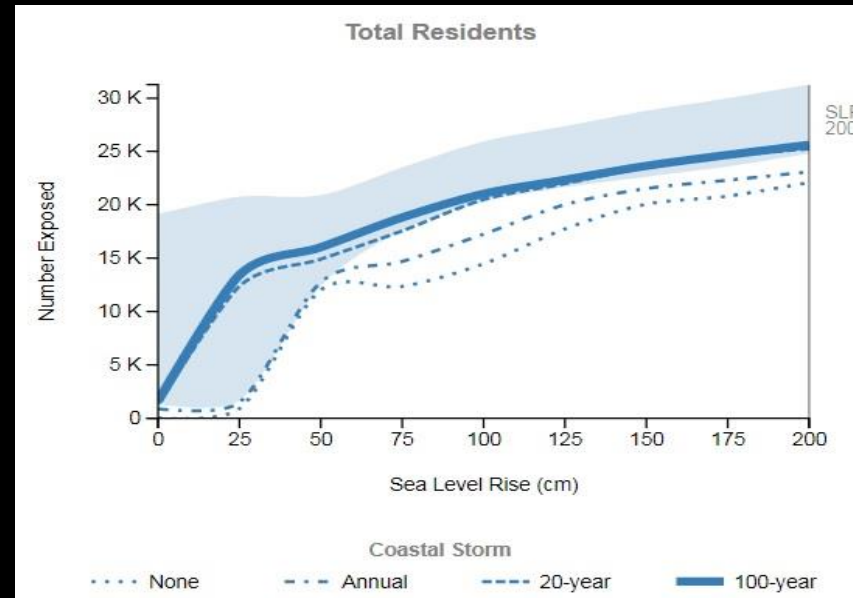*SF Bay only*;
PRBO

≋USGS

Socioeconomic Impacts
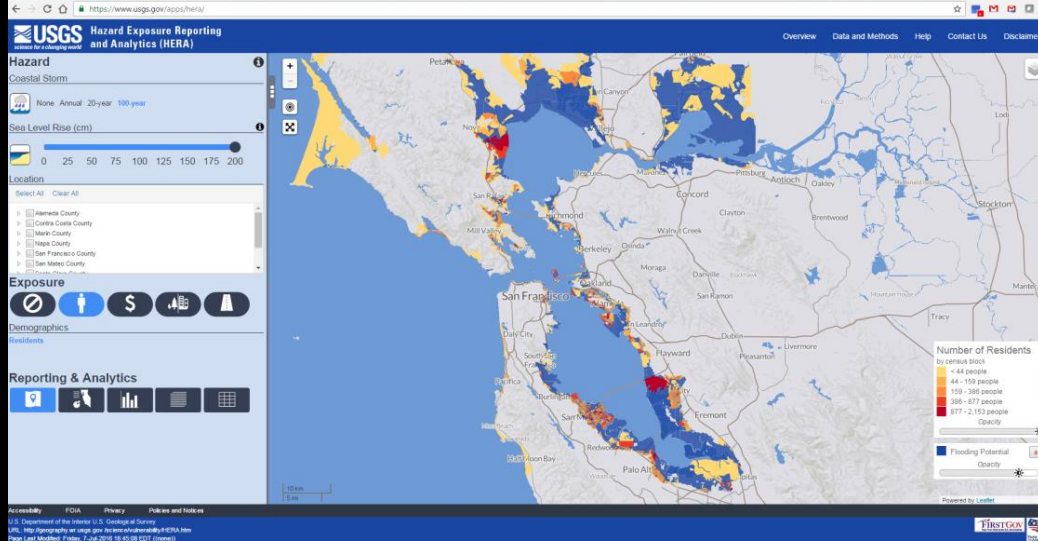
Hazard Exposure Reporting and Analytics (HERA)

(2 m SLR + 100 year storm)

- 600,000+ residents
- $150 billion in property
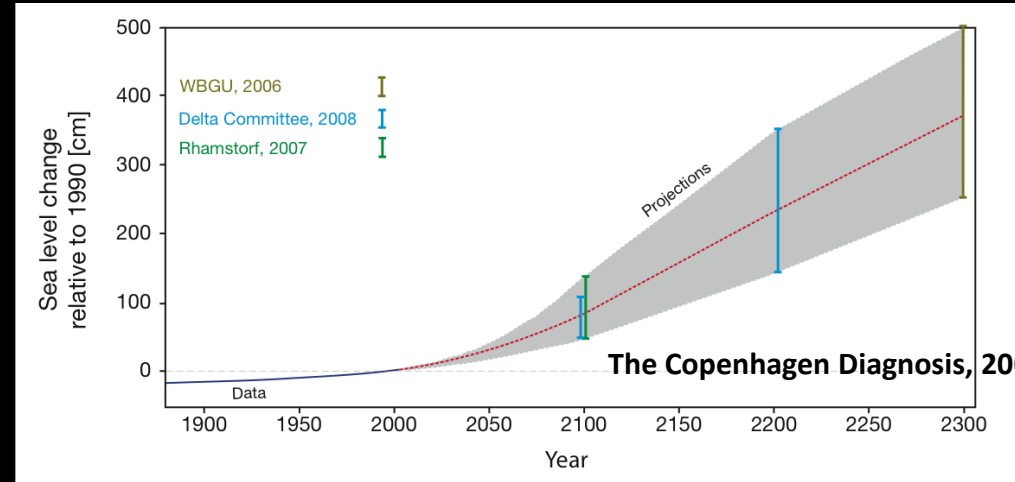- 4,700 km of roads
- 350 critical facilities

Redwood City example

- Clear tipping points
- Uncertainty decreases with time
- Vertical land motion deflects uncertainty band upwards

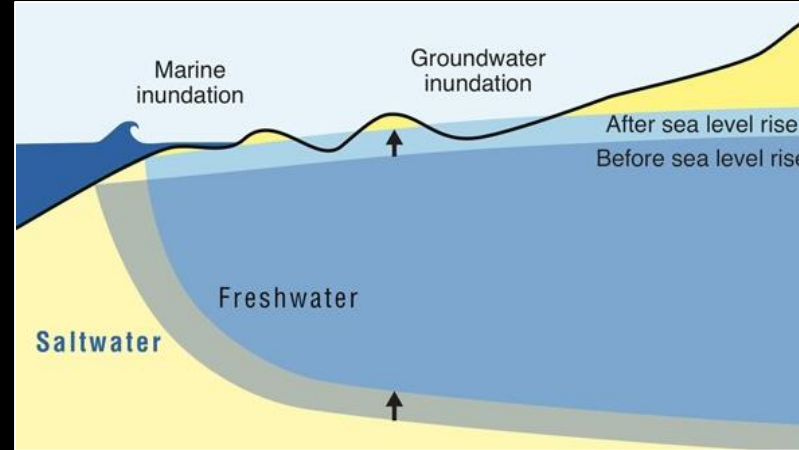*www.usgs.gov/apps/hera*

Other Sources of Uncertainty

- Sea level rise amount and timing

- El Niño frequency

- Wave climate/ storm patterns

- Beach morphology

- Human intervention

Groundwater Impacts

- ## Major issues
  - ### Inundation
  - ### Shallower coastal groundwater
  - ### Saltwater intrusion

- ## Groundwater inundation
  - ### May exceed overland flooding and happen much sooner
  - ### Low-lying areas most vulnerable

USGS

Summary

- Critical infrastructure abounds along the coast

- Exposure is significant regardless of uncertainty range

- Data-driven approaches reduce uncertainty

- Cascading effects are poorly understood

*For more information, contact Patrick Barnard: *pbarnard@usgs.gov*

USGS CoSMoS website: *http://walrus.wr.usgs.gov/coastal_processes/cosmos/*

Our Coast - Our Future tool: *www.ourcoastourfuture.org*

HERA Tool: www.usgs.gov/apps/hera
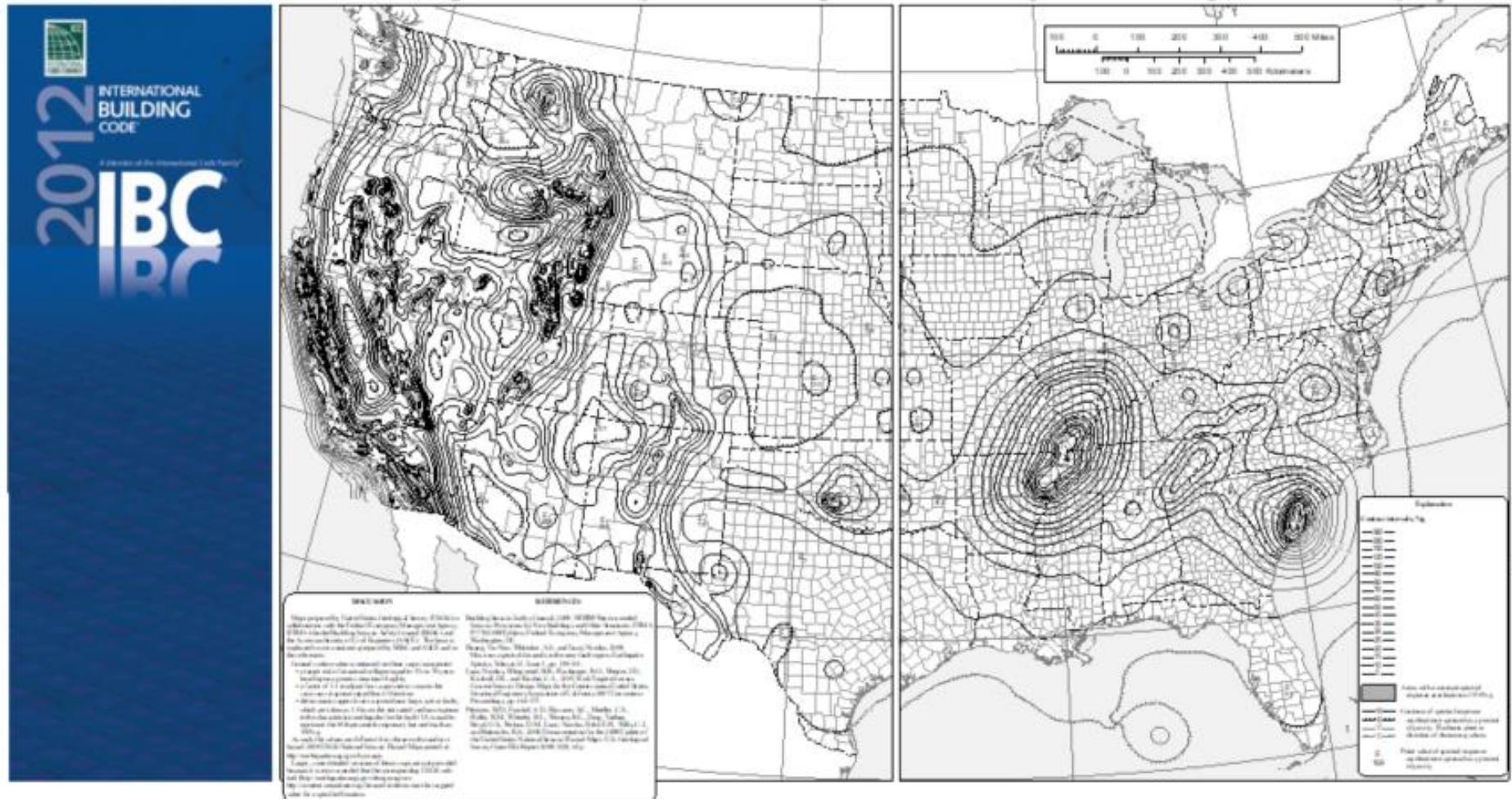
Design of Buildings to Withstand Earthquakes

California Assembly Bill 2800 Webinar

Nicolas Luco, PhD
Research Structural Engineer
U.S. Geological Survey, Golden, CO
National Seismic Hazard Mapping Project

USGS
science for a changing world

International Building Code

FIGURE 1613.3.1 RISK-TARGETED MAXIMUM CONSIDERED EARTHQUAKE (MCE_R) GROUND MOTION …

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"MCE" vs. MCE$_R$ Ground Motion

"Maximum Considered Earthquake"	Risk-Targeted MCE Ground Motion
Uncertain and/or conservative	Includes uncertainty & targets a tolerable level of collapse risk

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Probabilistic Seismic Hazard Analysis

ENGINEERING SEISMIC RISK ANALYSIS

By C. Allin Cornell

ABSTRACT

This paper introduces a method for the evaluation of the seismic risk at the site of an engineering project. The results are in terms of a ground motion parameter (such as peak acceleration) versus average return period. The method incorporates the influence of all potential sources of earthquakes and the average activity rates assigned to them. Arbitrary geographical relationships between the site and potential point, line, or areal sources can be modeled with computational ease. In the range of interest, the derived distributions of maximum annual ground motions are in the form of Type I or Type II extreme value distributions, if the more commonly assumed magnitude distribution and attenuation laws are used.
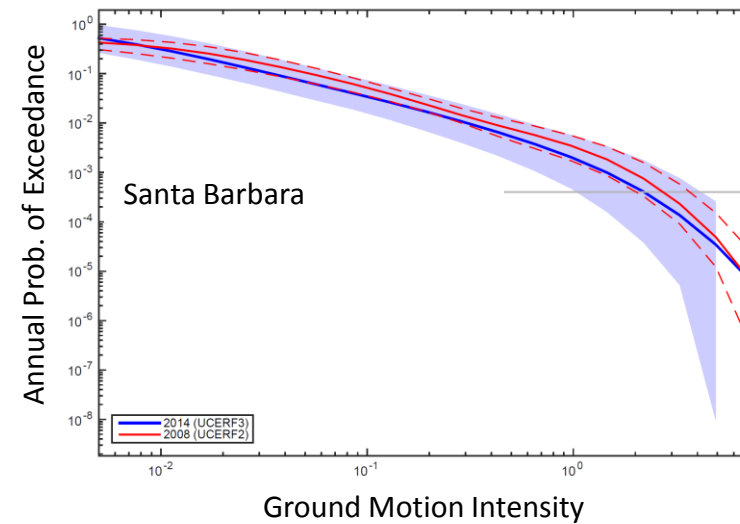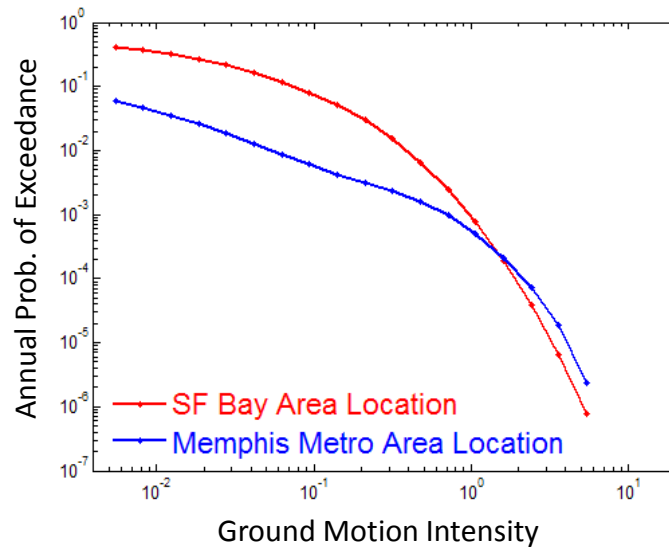

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Primary Output from PSHA
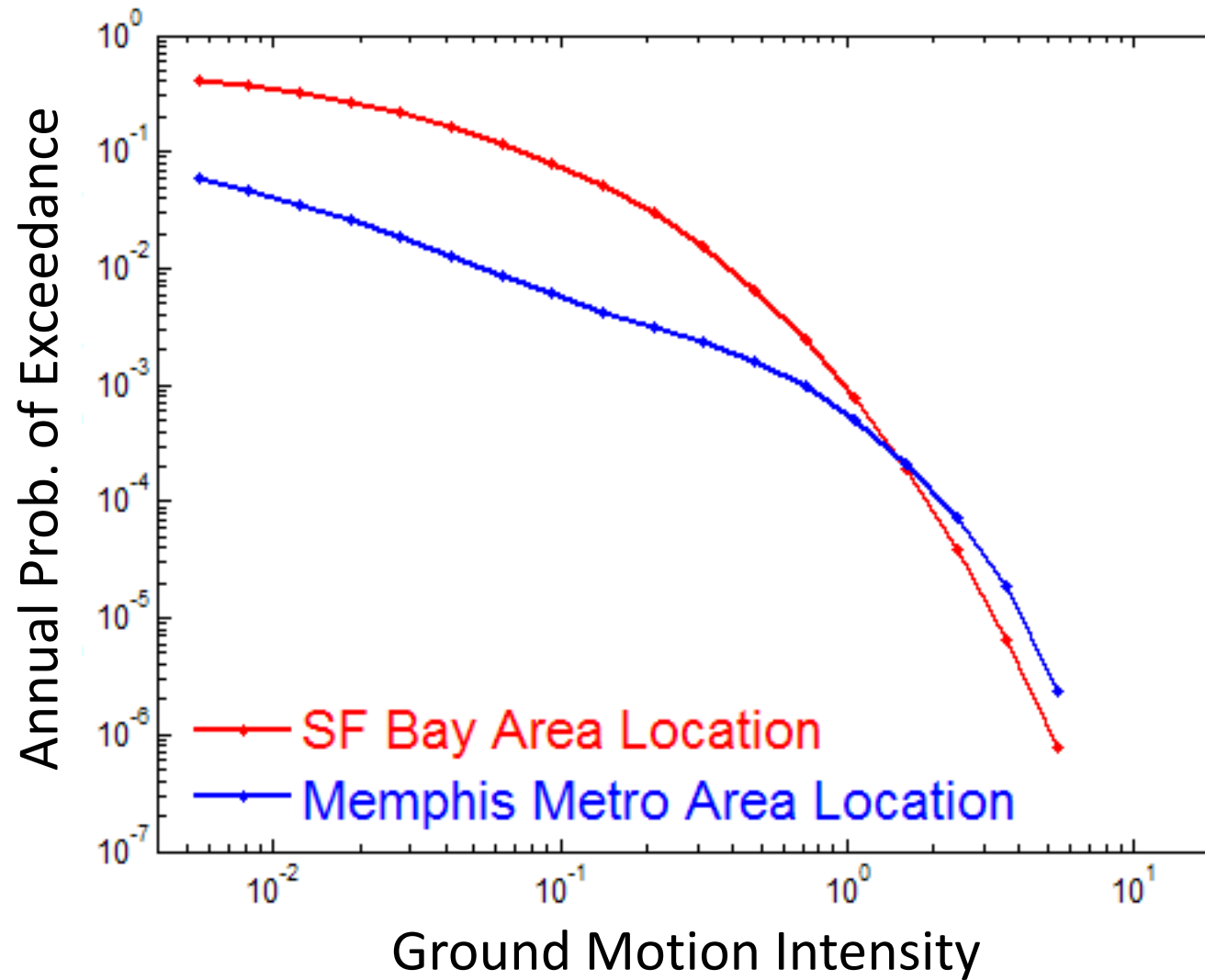
Aleatory & Epistemic Uncertainty

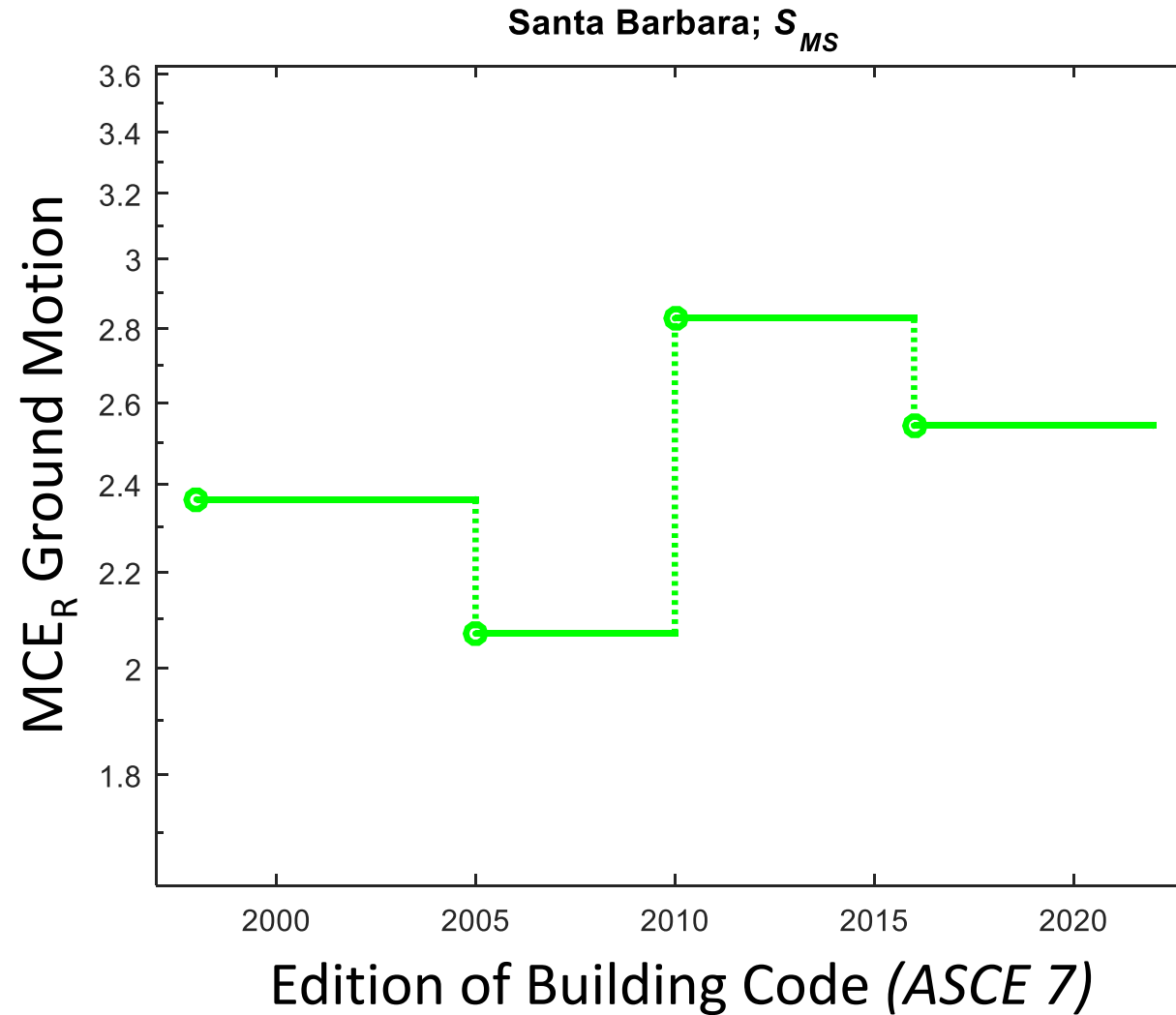| Aleatory Uncertainty, e.g., …	Epistemic Uncertainty, e.g., …
• in whether or not an earthquake occurs • in earthquake magnitude (M) • in ground motion for a given M (and distance, etc.)	• in chance of earthquake based on limited data • in maximum M • in ground motion from different models

California Assembly Bill 2800 Webinar

"Design of Buildings to Withstand Earthquakes," N. Luco, USGS   *February 22, 2018*

Instability over Time

Santa Barbara; S_{MS}

Instability w.r.t. Uncertainty
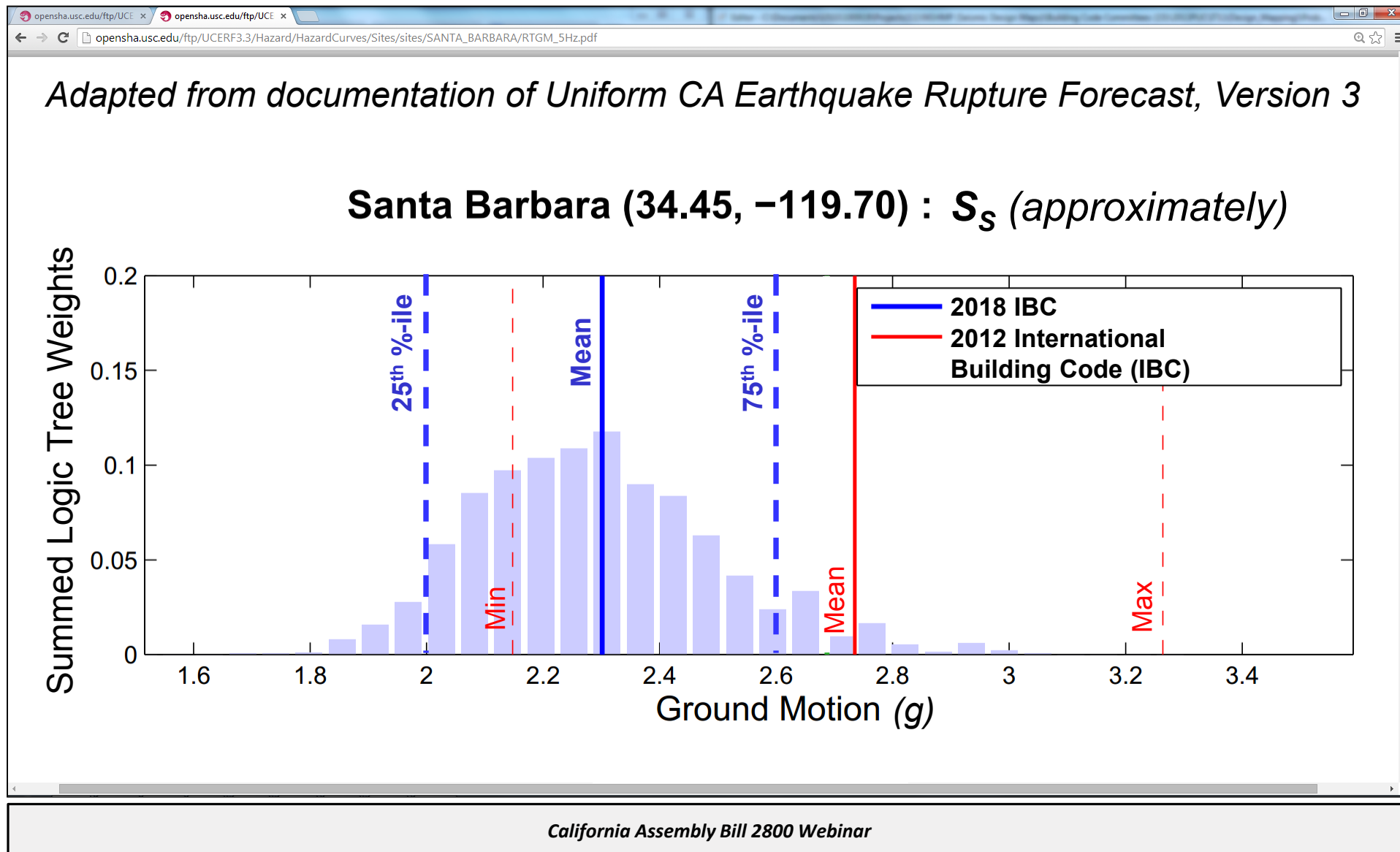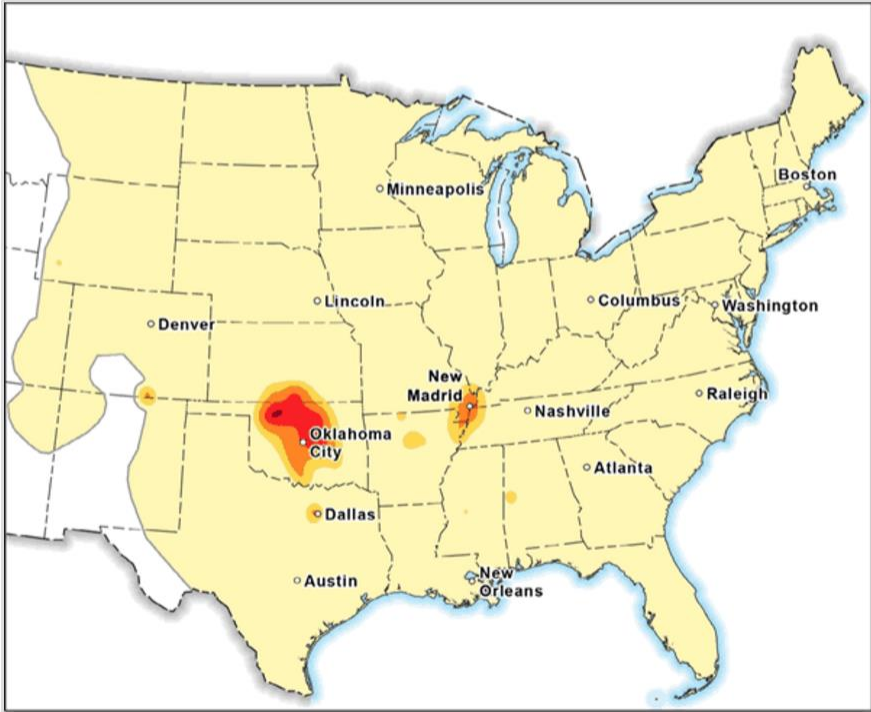
Subjective (but Informed) "Zone Maps"

Seismic Design Category (SDC)
- A
- B
- C
- D
- E
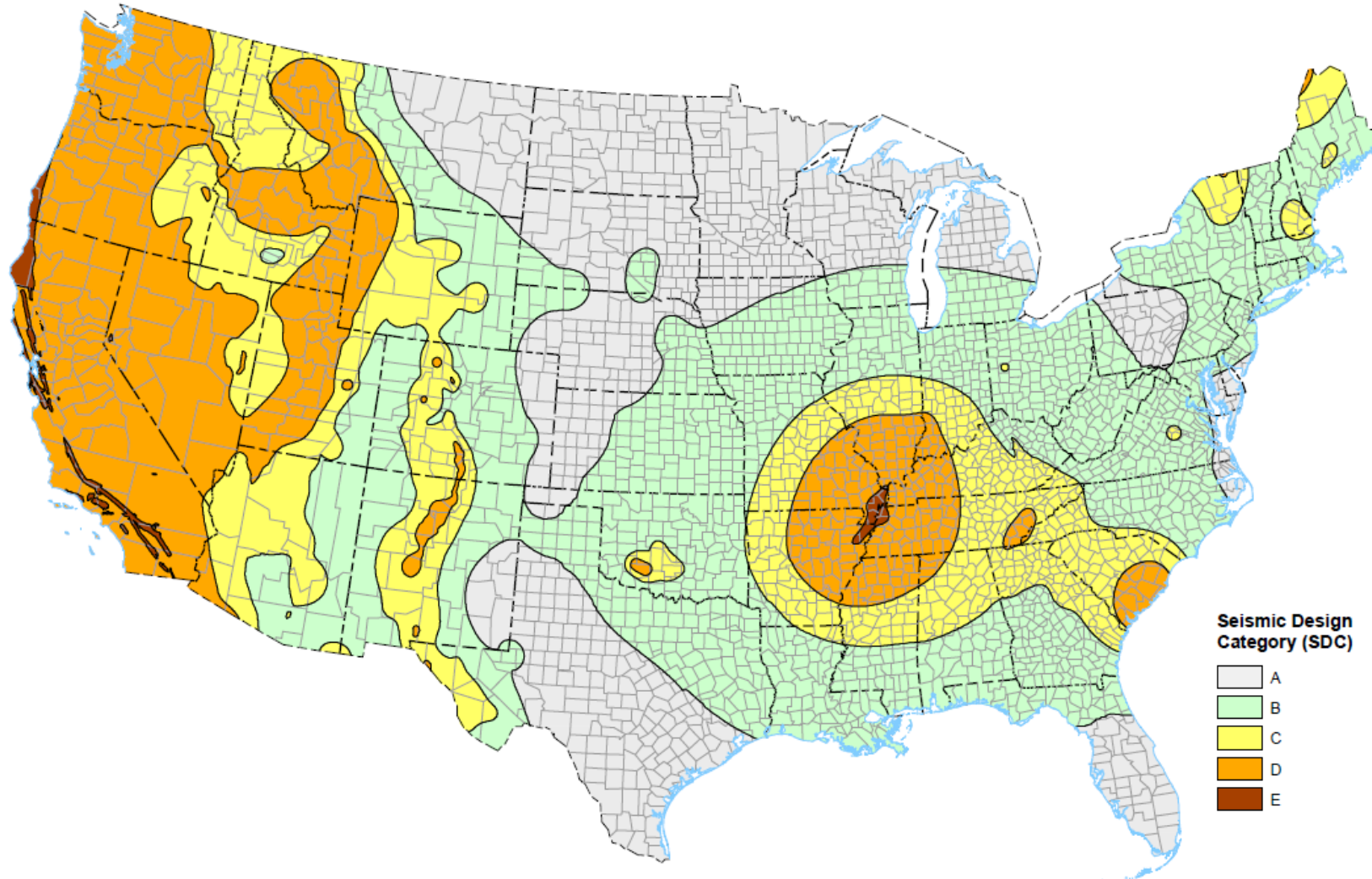
California Assembly Bill 2800 Webinar

Induced-Seismicity PSHA

Induced-Seismicity PSHA

Induced Seismicity in Groningen

**Assessment of Hazard,
Building Damage and Risk**

November 2017

By Jan van Elk and Dirk Doornhof

Effect van eerdere maatregelen

Bevingen M > 1,0 Hele veld   < 1,5 < 2,0 < 2,5 < 3,0 < 3,5 < 4,0

Bevingen M > 2,0 Hele veld   < 2,5 < 3,0 < 3,5 < 4,0

Observaties
- In 2014 ingezette dalende trend zet door.
- Voor de zwaardere bevingen nog meer dan voor lichtere.
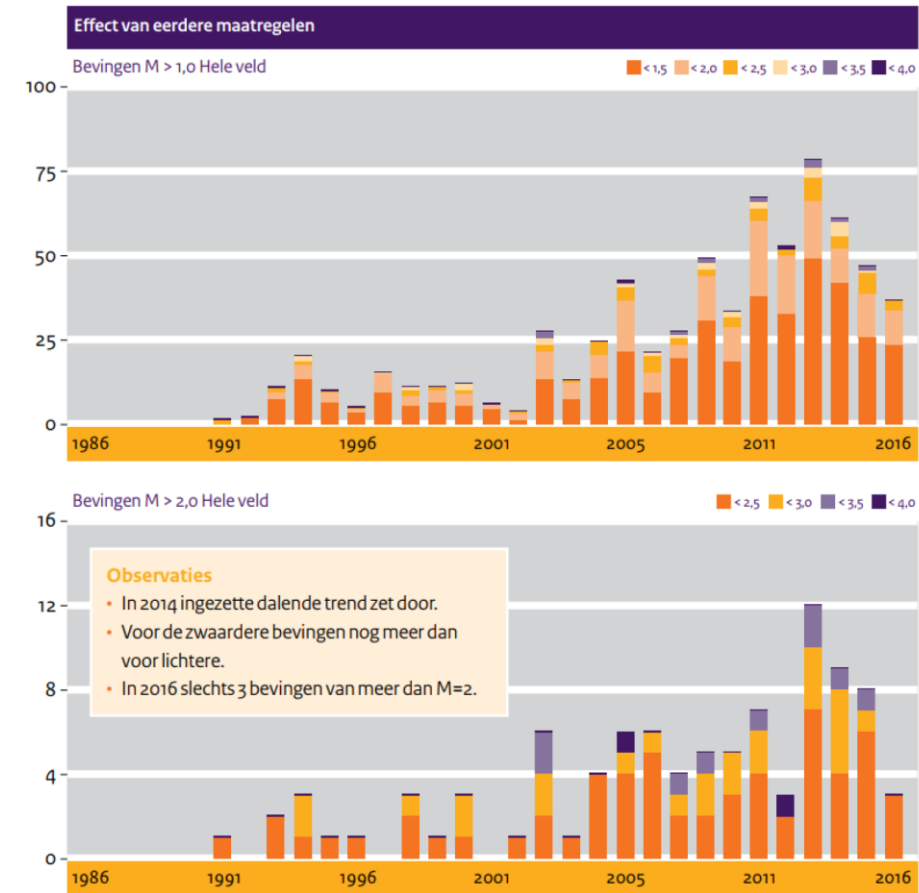- In 2016 slechts 3 bevingen van meer dan M=2.

Figure 2.1 The number of earthquakes with magnitude $M_L \geq 1$ (above) and $M_L \geq 2$ (below). The figure was taken from the annual report of SodM (Ref. 47). Observations: The decreasing trend in seismicity from 2014 onwards has persisted in 2016 for both heavier and lighter earthquakes. In 2016 there were only three earthquakes larger than $M_L \geq 2$.

(source: SodM)

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PSHA Analog for Rock Falls
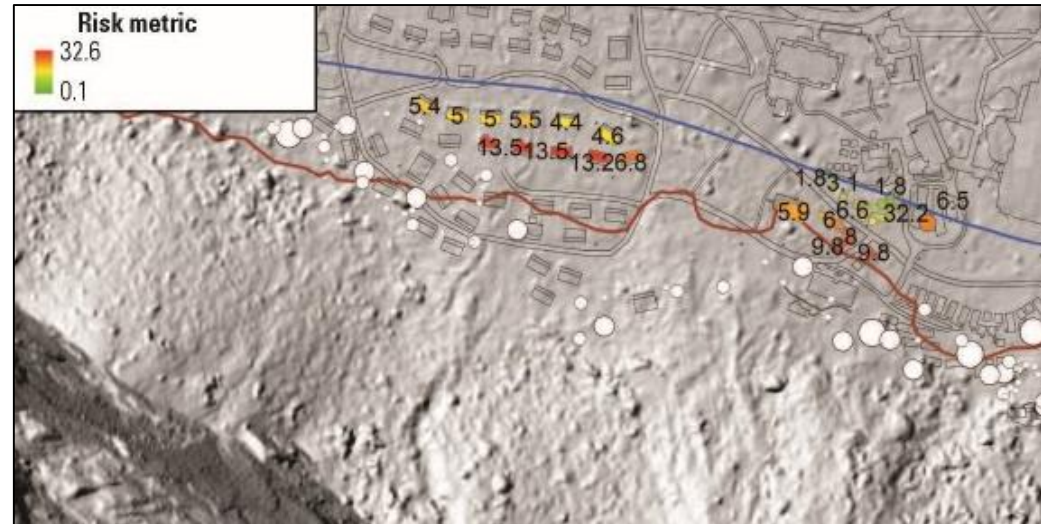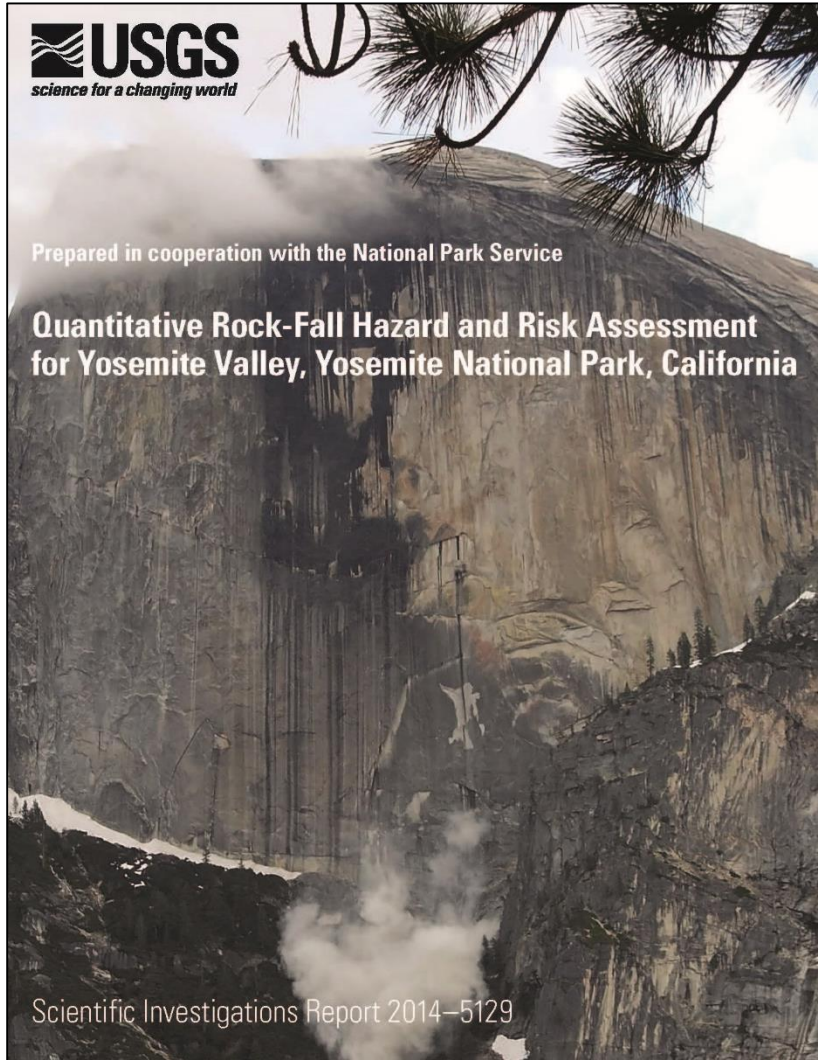
Summary

- Through collaboration of earthquake scientists and engineers, building codes account for the uncertainties (via PSHA)

- Instability of PSHA outputs over time due to epistemic uncertainties have become an issue, but are being addressed

- One-year induced-seismicity PSHA outputs have not yet been incorporated into building codes, but are being discussed

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Discussion and Q&A

Morgan Page   Patrick Barnard   Dan Cayan   Nico Luca

Thank you!

- The ***Climate-Safe Infrastructure*** Webinar Series continues at least through July 2018; ca. 1 webinar every 2-3 weeks

- Next several webinars will focus on sector-specific infrastructure vulnerabilities and solutions (dates TBD)

- Track webinars and progress of CSIWG at:
  http://resources.ca.gov/climate/climate-safe-infrastructure-working-group/

- Send questions or requests to Elea Becker Lowe at:
  Elea.Beckerlowe@resources.ca.gov