Estimating Climate-related Risk to Infrastructure: Examples from Alaska and California

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Personal Views of Peter Larsen

Presentation Outline

I. Different regions and climate-related impacts, but similar risk estimation framework

II. "Estimating Future Costs of Alaska Public Infrastructure at Risk from Climate Change"

III. "Estimating Future Costs to California Energy Infrastructure from Projected Climate Change"

IV. Research frontiers…..

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Different Regions, but Similar Risk Estimation Methods.

- Climate change impacts California and Alaska in very different ways.

- However, the methods used to quantify risk for these two regions are similar….

  (1) *Assemble* database of infrastructure type, count, location, etc. and first-order climate data;

  (2) *Correlate* projected climate/extreme events to physical impact on infrastructure (e.g., efficiency loss, structural depreciation);

  (3) *Simulate* range of future climate conditions (temperature, etc.);

  (4) *Evaluate* range of infrastructure impacts with/without adaptation.

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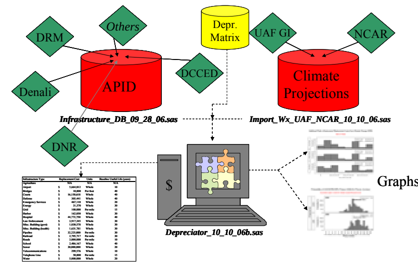
Different Regions, but Similar Risk Estimation Methods....



Method/Assumptions	Alaska	California
Damage function shape	Linear with extreme events multiplier	Linear
Type of infrastructure	“Critical” public infrastructure	Energy infrastructure
Adaptation scenario	Yes	No
Future population/infrastructure growth	No	No
Number of (AO)GCMs	Three	Three
Future climate simulation method	Monte-carlo	Deterministic
IPCC SRES Scenario(s)	A1B	A2 & B1
Climate base period	1980-1999	1961-1990
Spatial resolution for infrastructure	Community-level	Latitude/Longitude
Spatial resolution for climate model output	5.6° Lat/Lon	0.125° Lat/Lon
Impact estimation method	True economic depreciation (Samuelson 1964)	Efficiency/capacity loss (e.g., Li et al. 2005; Maulbetsch and DiFilippo 2006; Kehlhofer et al. 2009)

Alaska Example

Project:	"Estimating Future Costs of Alaska Public Infrastructure at Risk from Climate Change"
Researchers:	P. Larsen, S. Goldsmith, O. Smith, M. Wilson, K.Strzepek, P. Chinowsky, and B. Saylor

- Initial research conducted at ISER-UAA/U. of Colorado from 2006-2008. Funded by National Commission on Energy Policy, University of Alaska Foundation, RuralCAP, others.

- Estimated discounted future costs of replacing infrastructure assuming no climate change and rapid climate change (with and without event-based adaptation).

- Projected climate change could increase public infrastructure costs by 10-20% above "normal" wear and tear, but estimates were preliminary.

- Adapting structures strategically now will save billions of dollars over the next few decades.

Climate Change and Alaska Infrastructure

Image: Vladimir Romanovsky, UAF 2007

Increased damage to community infrastructure from coastal erosion, flooding, and thawing permafrost…

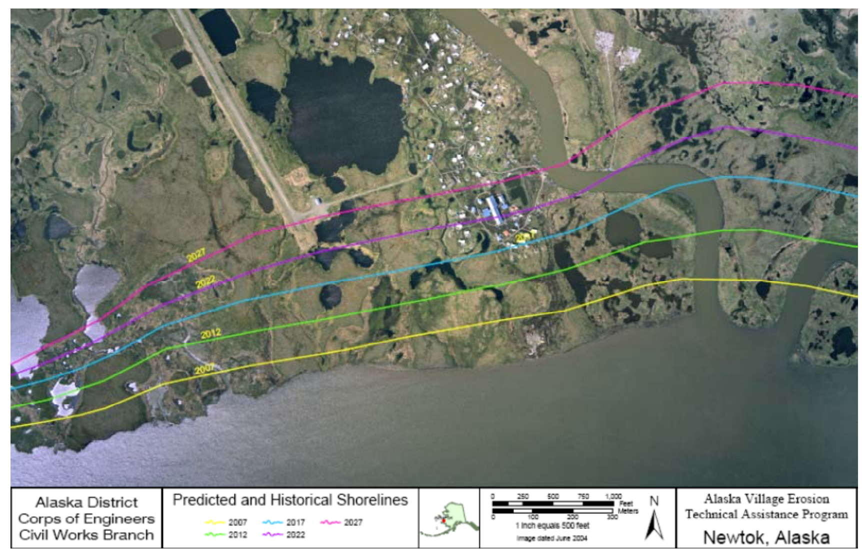
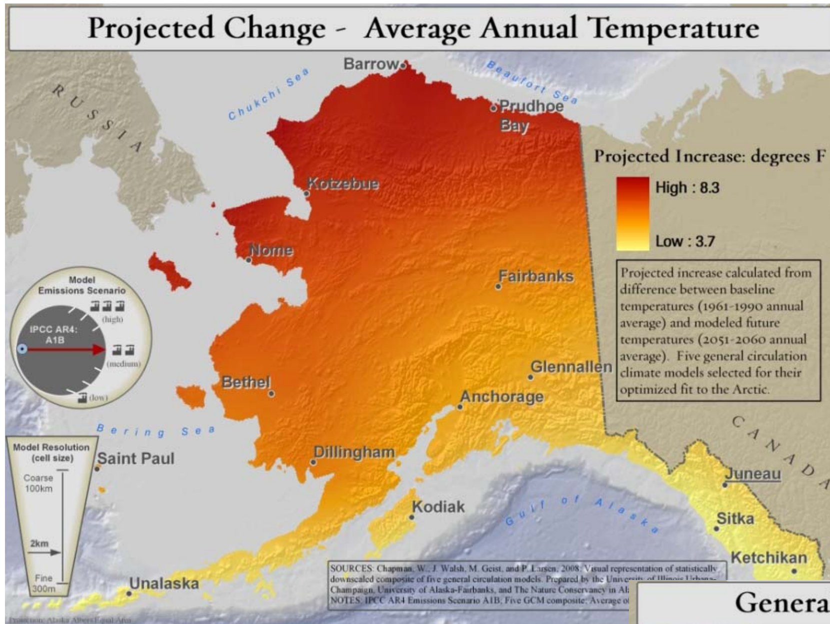
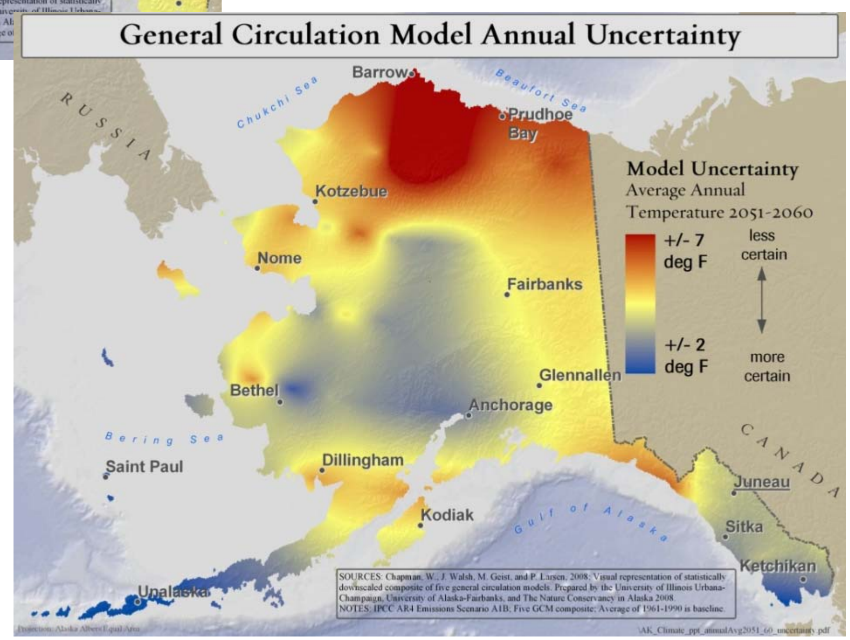


Image: Bruce Sexauer, U.S. ACE 2006

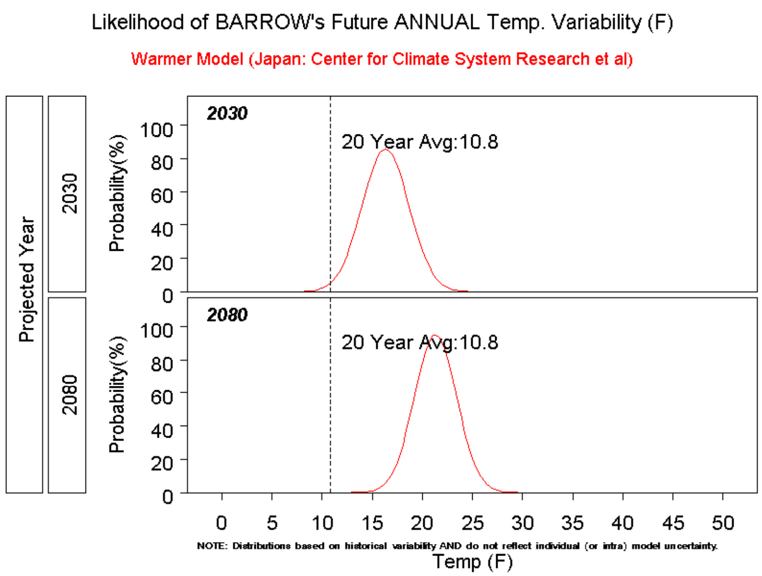
Projected Change (mid-century; model composite; A1B scenario)



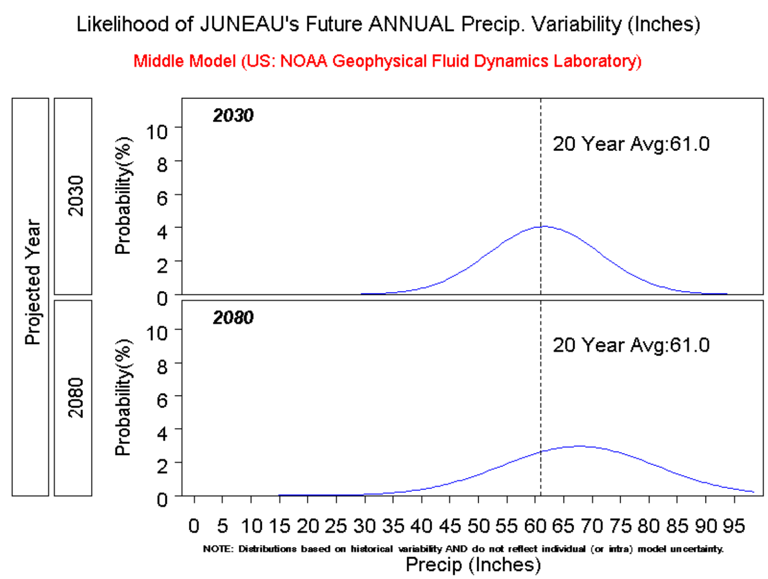
Significant change is projected for Alaska, especially above Arctic circle….



Across Model Uncertainty (mid-century; A1B scenario; composite)



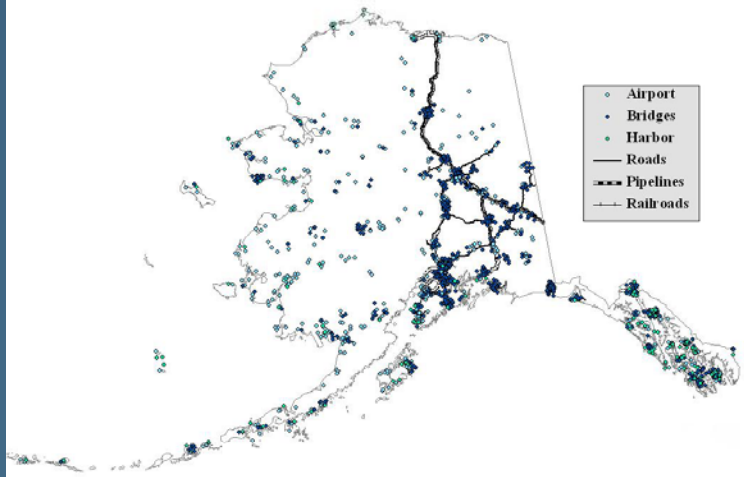
Simple Monte-carlo simulation employed to project "bounded" likelihood of future temperature and precipitation…..

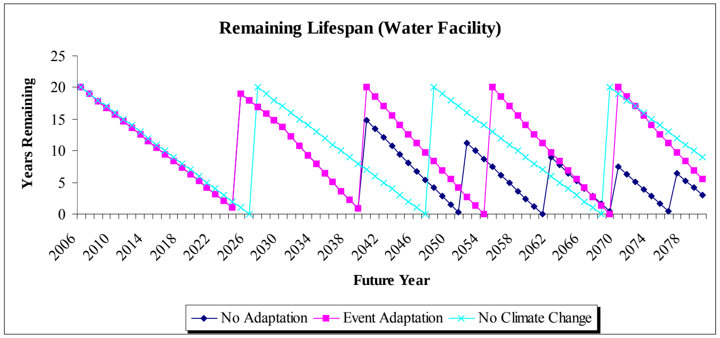


Evaluating the Lifecycle of Alaska Infrastructure

Summary of Useful Life Reduction of Infrastructure (Due to Thawing Permafrost)	
Basic permafrost condition	**Reduction in years of life (%) per degree increase (F)**
Continuous permafrost	0.5 %
Discontinuous permafrost	0.2 %
Sporadic permafrost	0.1 %
Isolated patches	0.0 %

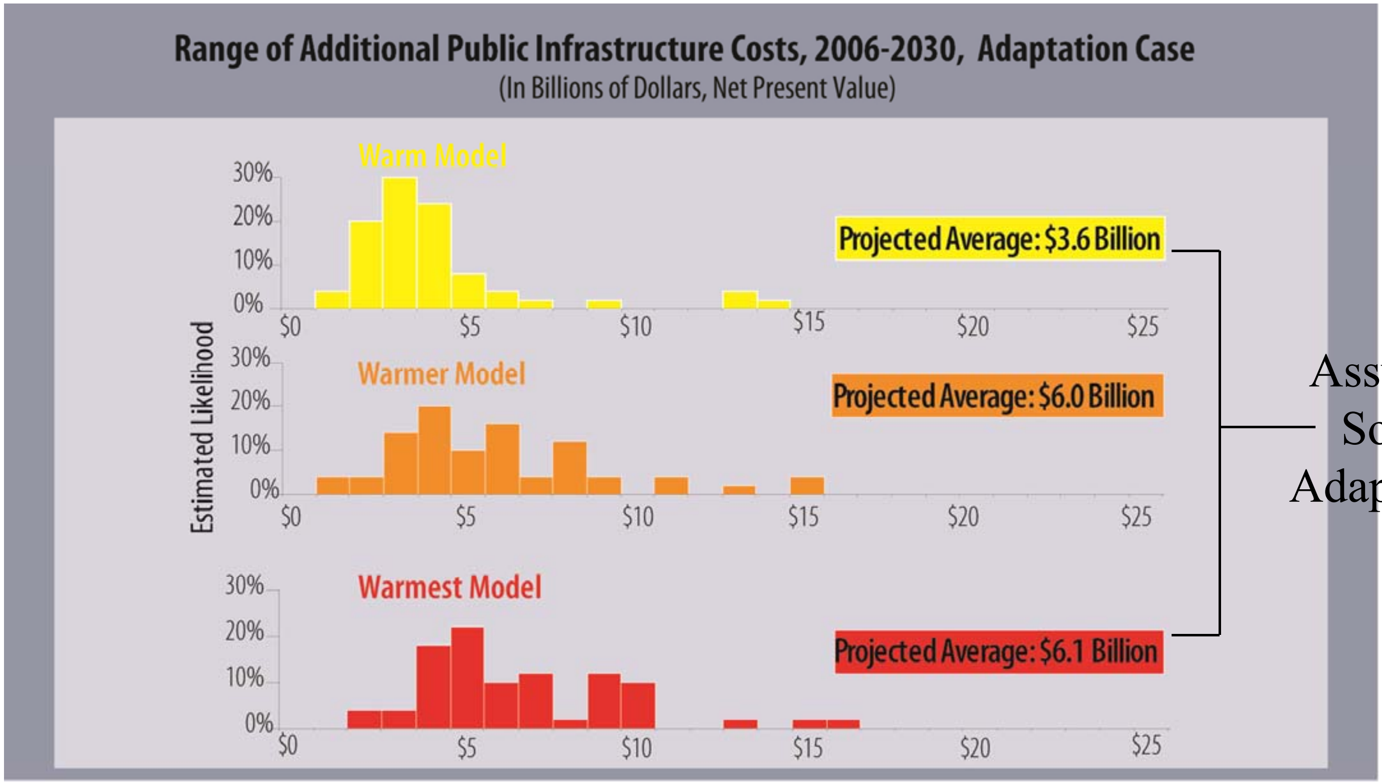
Temp./precip. increases are assumed to be linearly correlated to infrastructure lifespan reductions….





Summary of Useful Life Reduction for Infrastructure (Due to Coastal Exposure)	
Coastal Location	**Reduction of life (%) per degree increase (F)**
Exposed	7.5 %
Protected	1.0 %
Interior	0.0 %

Prelim. Estimate of Additional Costs to Alaska's Public Infrastructure



Assumes Some Adaptation

- Published preliminary estimates in *Global Environmental Change*, but major research improvements were suggested…..

California Example

Project:	"Estimating Risk to California Energy Infrastructure from Projected Climate Change"
Researchers:	Sathaye, J., L. Dale, P. Larsen, G. Fitts, S. Lewis, K. Koy, and A. Lucena.

- Research conducted at LBNL/UC Berkeley from 2009-2011. Funded by California Energy Commission (Guido Franco). Advisory group made up of utility staff and academic researchers.

- Estimated range of climate-induced capacity losses for CA transmission lines, gas-fired power plants, and substations. Mapped energy infrastructure that might be at risk from sea-level rise, wildfires, and estimated changes in peak demand for electricity.

- Some coastal power plants and substations may be at risk to flooding due to sea level rise/inundation. Substation, transmission line, and gas-fired power plant capacity could decrease by several percent over the coming decades. The likelihood of wildfires impacting transmission lines is projected to increase.

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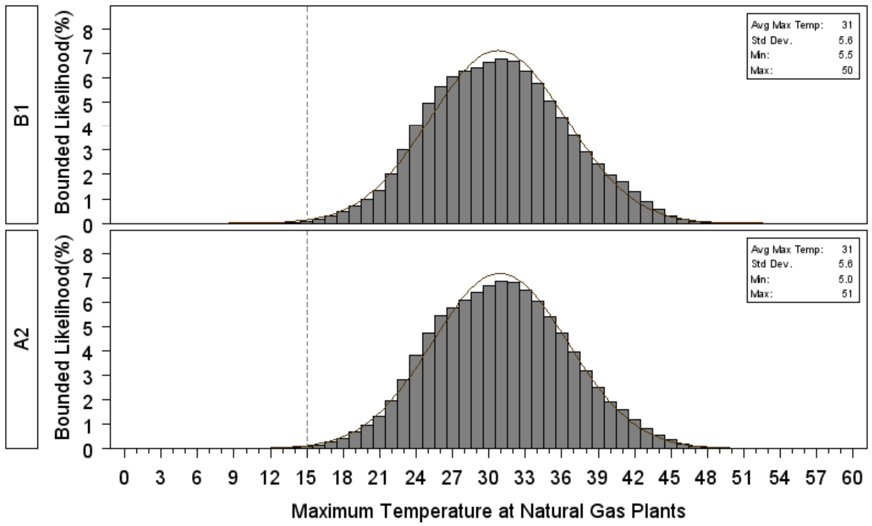
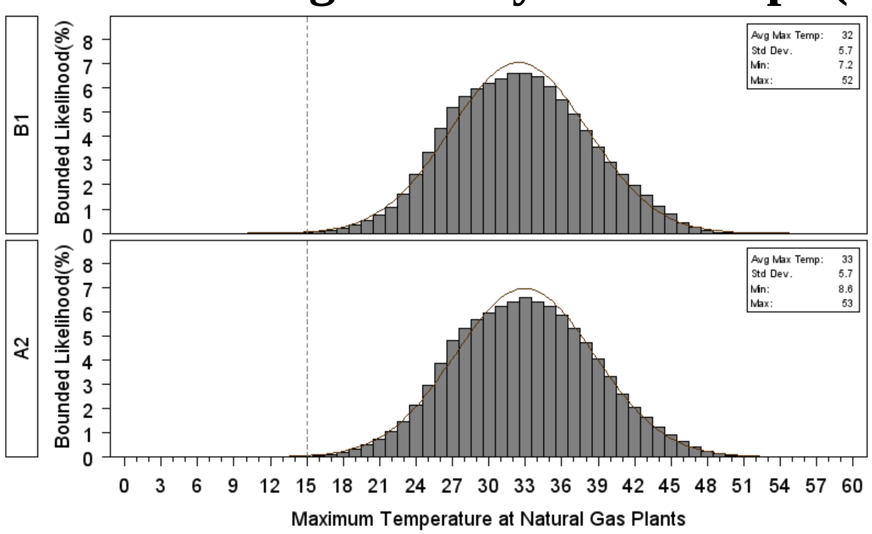
Climate Data at CA Natural Gas-fired Power Plants

1961-1990 August Daily Max Temps (C)



2035-2064 August Daily Max Temps (C)



Histogram of August daily maximum temperatures at *all* CA natural-gas fired power plants (3 GCMs + 2 SRES scenarios)

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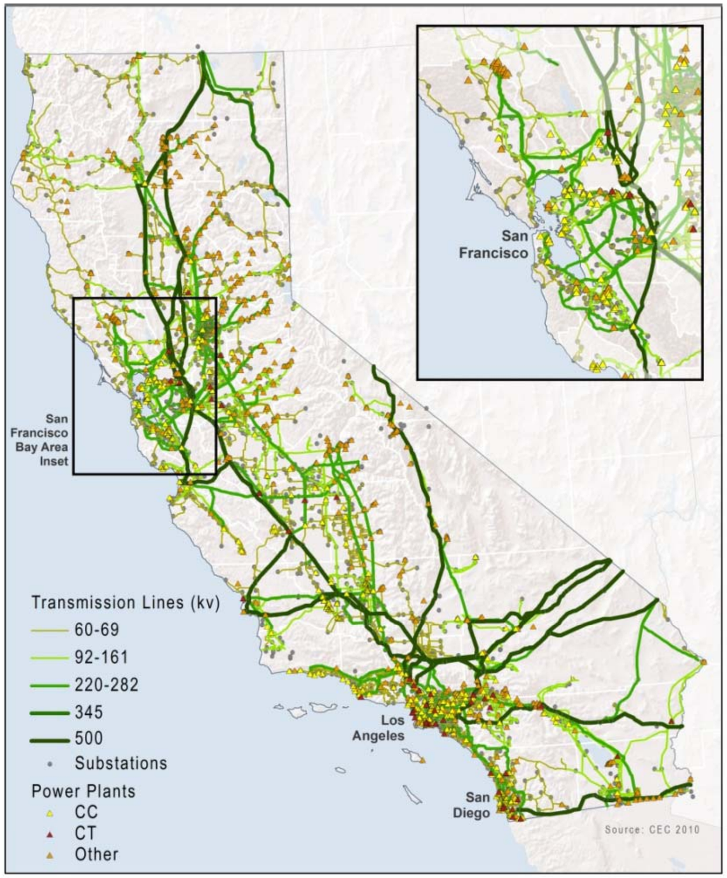
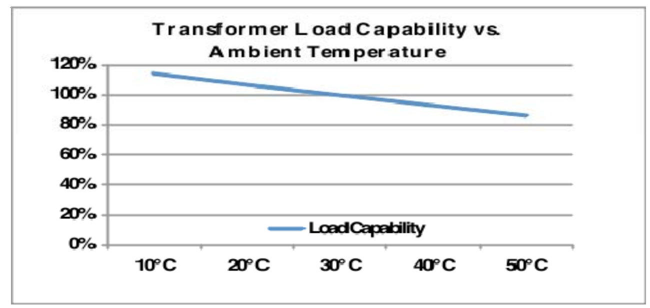
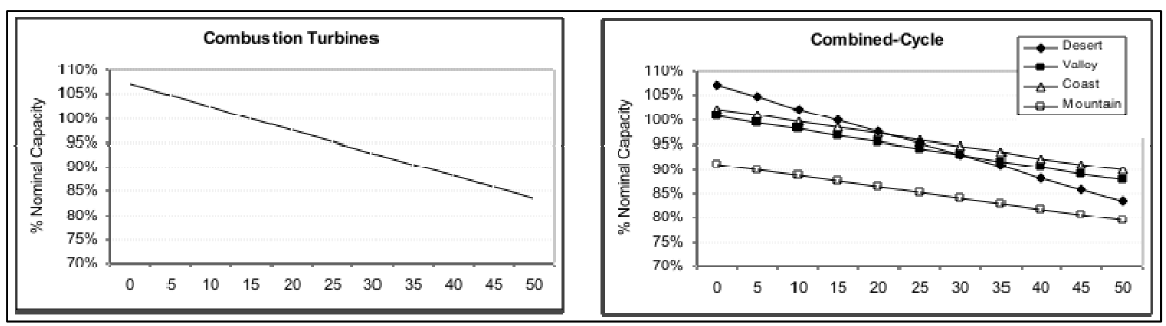
Evaluating Capacity Changes at CA Electricity Infrastructure

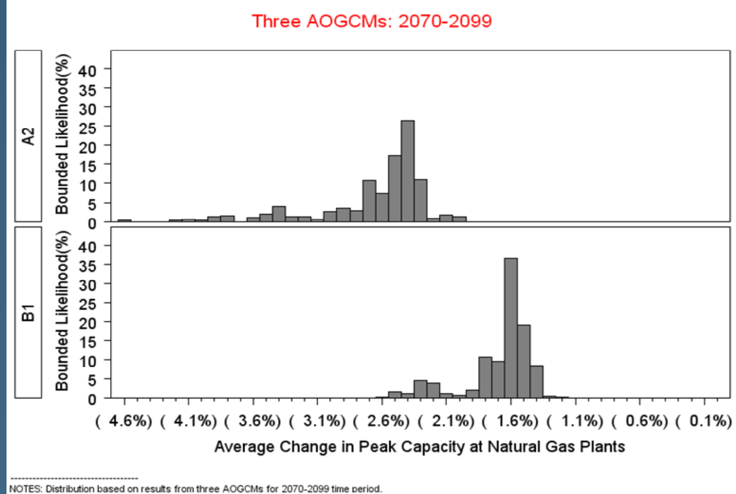


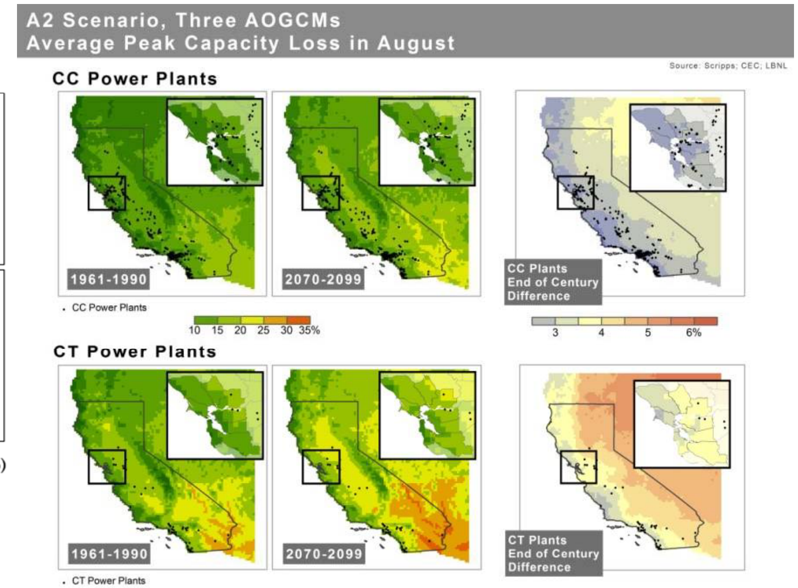
Temperature increases are assumed to be linearly correlated to capacity losses at natural-gas fired power plants and substations….





Prelim. Estimate of Daily Capacity Losses at CA Gas-fired Power Plants





- Manuscript is currently being peer-reviewed.
- Other energy infrastructure impacts evaluated include capacity changes at substations and transmission lines, sea-level rise, wildfire risk to transmission lines, and changes to peak electricity demand.

Research Frontier #1: Incorporate *Statistical* Uncertainty in Impact Analyses

Harvard Economics Professor Martin Weitzman noted in a seminal 2008 paper that *fat-tailed structural uncertainty about climate change, coupled with a lack of information about high-temperature damages, can potentially outweigh the influence of discounting in a cost-benefit analysis framework.*

Suggestions for California, Alaska and beyond….
Agencies/resource planners interested in estimating economic costs/benefits from climate change should consider climate model statistical uncertainty in their analysis or their impact estimates will be severely biased.

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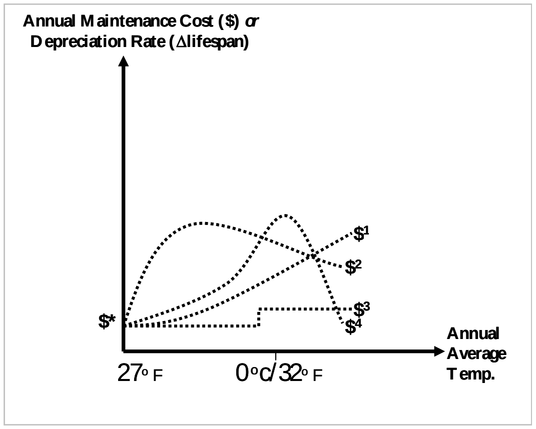
Research Frontier #2: Develop Local Structural Damage Functions

The original Alaska economics model speculated on the GENERAL relationship between climate drivers and infrastructure lifespan for the entire state. We also assumed a linear relationship for how temperature changes may affect CA electricity system capacity.

Suggestions for California, Alaska and beyond…

Agencies, engineers, and planners interested in estimating societal impacts from climate change should develop regional/local damage intensity functions that relate climate change impacts to changes in useful life, capacity, capital and O&M costs, and efficiency.



Damage functions are rarely (never?) linear, but there is little research on this subject (Hitz and Smith 2004)

Research Frontier#3: Catalog Local Infrastructure Characteristics

The original infrastructure database that was assembled for Alaska under-counted the amount of public infrastructure by tens of billions of dollars (Goldsmith and Foster 2008). The California Energy Commission has been updating the location of CA transmission lines and we do not have detailed information about the type of cooling equipment currently installed at CA power plants and substations. Vertical error in infrastructure elevation data can lead to biased impact projections.

Suggestions for California, Alaska, and beyond…

Agencies, engineers, and planners interested in conducting a climate risk assessment should spend a significant amount of time cataloging infrastructure location, elevation, characteristics, costs, age, and expected lifespan. This information is extremely useful for economists, engineers, and hazard planners.

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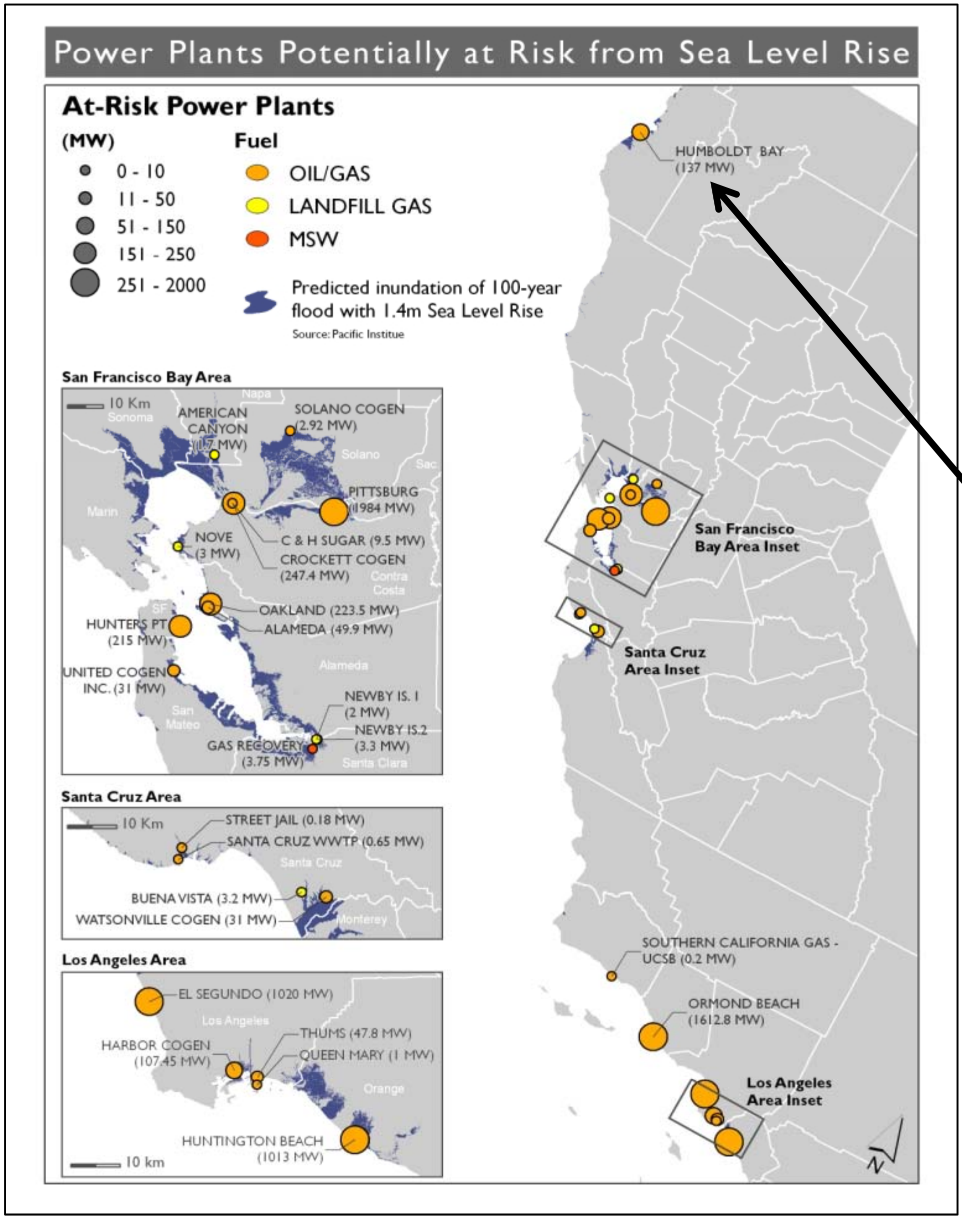
The Importance of Groundtruthing….



Site visit to Humboldt Bay revealed that this power plant might not be as affected by sea-level rise as originally thought…..

Additional Information

- All materials for the Alaska study can be accessed at: www.iser.uaa.alaska.edu
- Geospatial Innovation Facility/CEC's CalAdapt website located here: http://cal-adapt.org/
- California Energy Commission: http://www.energy.ca.gov/
- Lawrence Berkeley National Laboratory: www.lbl.gov

Congratulations to Saul Perlmutter!