Estimating Future Costs of Alaska Public Infrastructure at Risk to Climate Change

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About The Nature Conservancy….

- The Nature Conservancy works in more than 30 countries, including all 50 United States.
- To date, the Conservancy has nearly one million members and has protected over 130 million acres of land.
- We have concluded that climate change threatens all the conservation investments we have made to date and poses an extremely serious threat to our mission.
- The Alaska field office is currently designing a comprehensive strategic plan to address Arctic climate change including initial program development, scientific research, collaboration, and outreach activities with key policymakers.
- In the future, the Conservancy may be interested in developing more policymaking tools similar to what is described in the following presentation.

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A Forward-thinking Quote….

“ Expected values of [infrastructure]relocation and rehabilitation can be developed, given estimates of per-mile design and construction costs. A *master plan* of climate-change-induced major relocation and rehabilitation projects can be formed with this information.”

-United States Arctic Research Commission, 2003

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Some Background….

- ISER-UAA has built a policymaking tool to estimate the *additional* replacement costs to public infrastructure due to climate change.

- Preliminary model runs show a plausible range of costs by infrastructure type and area. Under any scenario, the cost of Alaska infrastructure at risk to climate change could total at least several billion of today's dollars over the next few decades.

- Results presented today represent state-of-knowledge as of Summer 2007. ISER-UAA is in the process of enhancing model assumptions…

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Caveat Emptor

- Experimental Policymaking Tool
- ISER Alaska Public Infrastructure Database
- Climate Projections and Economic Uncertainty
- Economic Activity and the Disconnect with Societal Well-being
- *Preliminary* Estimates of Costs, Depreciation Rates, and Lifespans

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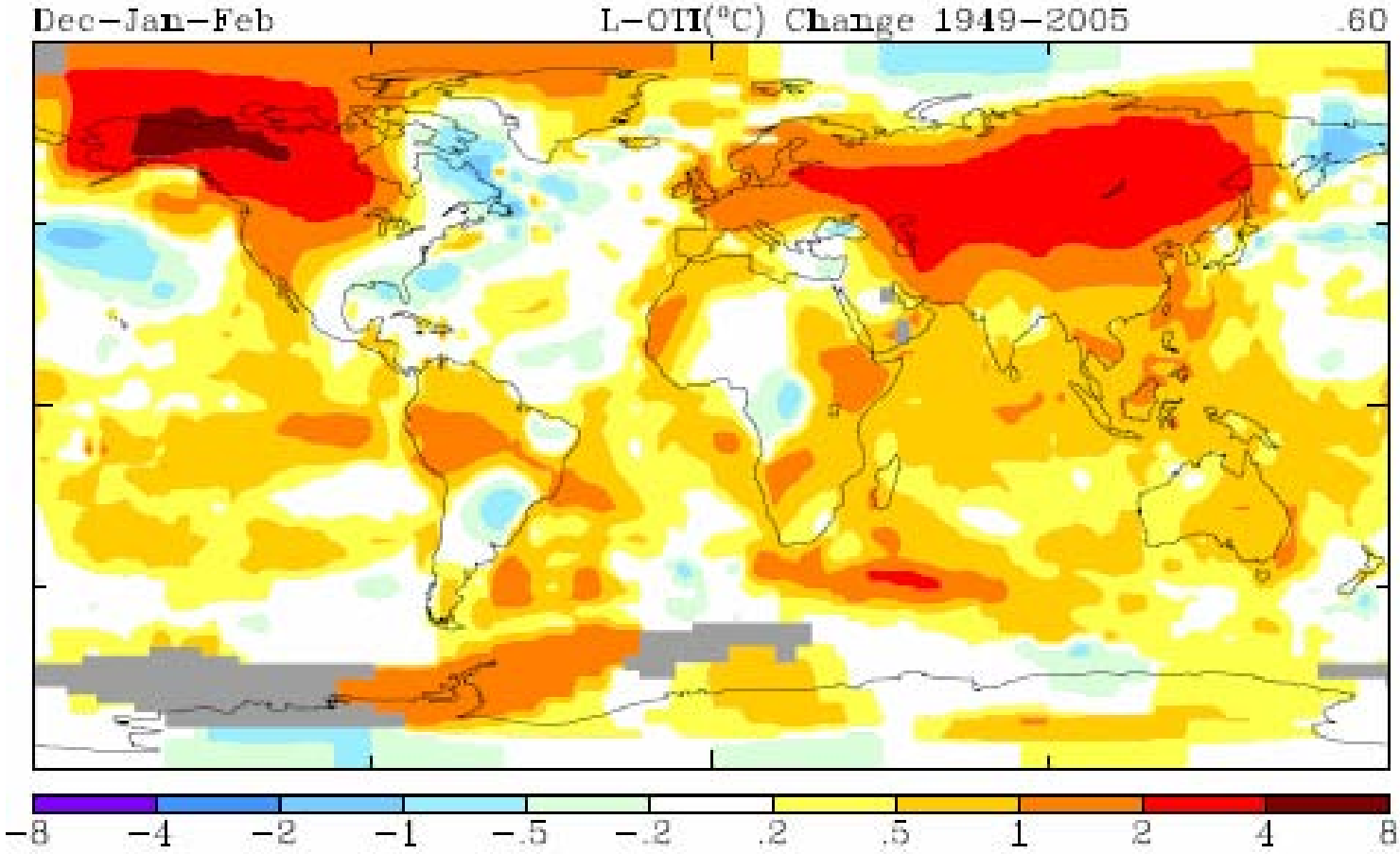
Alaska's Changing Climate



Source: NASA, GISS (2007)

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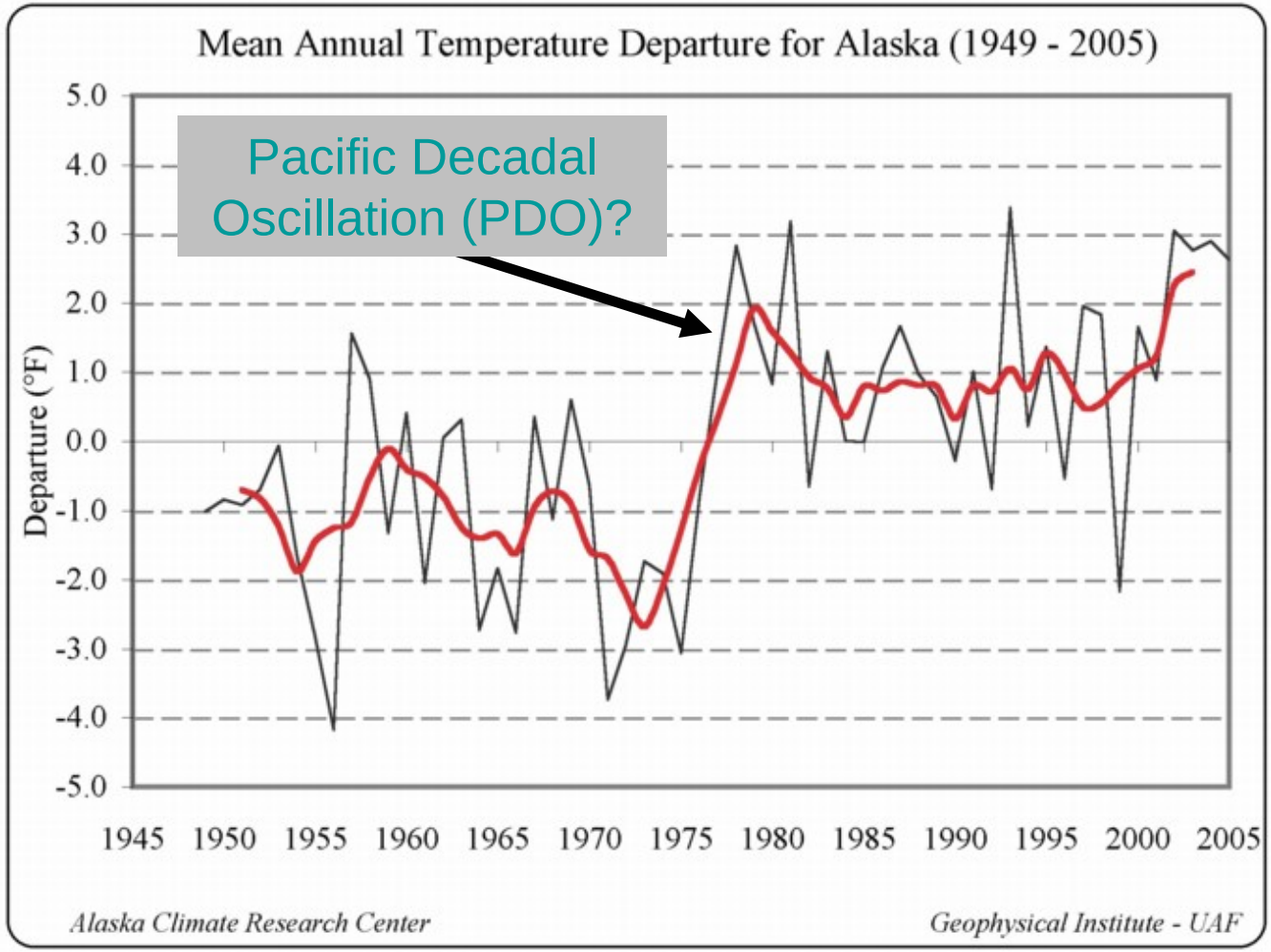
Alaska's Changing Climate (cont.)



Source: UAF, Geophysical Institute (2006)

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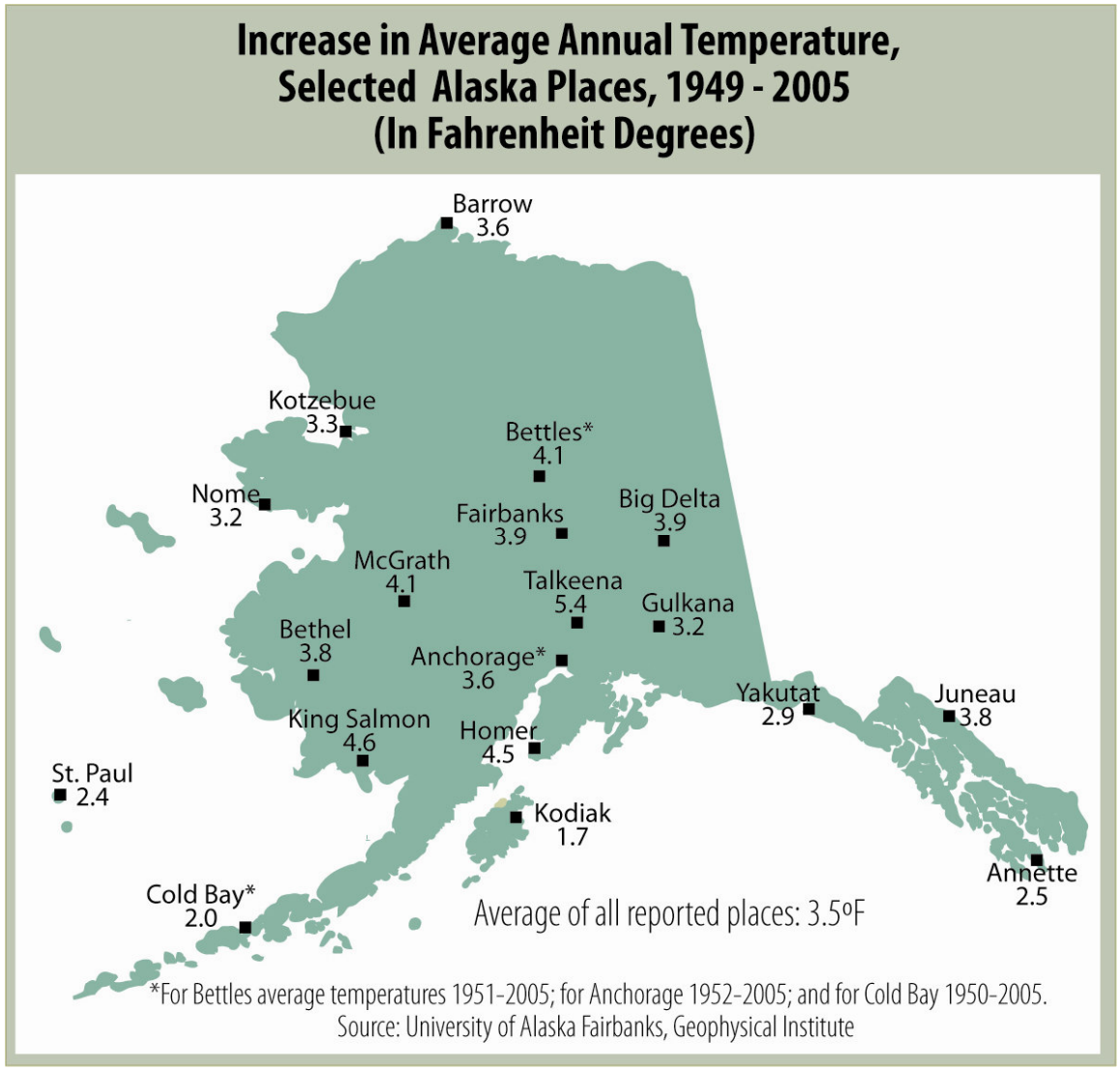
Alaska's Changing Climate (cont.)



Source: UAF, Geophysical Institute (2006)

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Climate Change Impacts Structures

- *Thawing Permafrost*
- *Changes in Sea-level (inundation and subsidence)**
- *Accelerated Coastal Erosion*
- *Increased Likelihood of "Extreme Events"*

* Effect not considered in ISER economic analysis.

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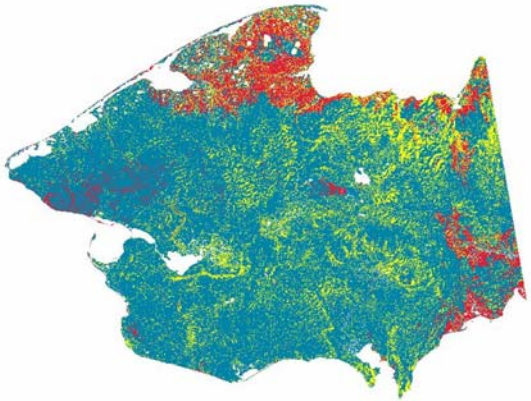
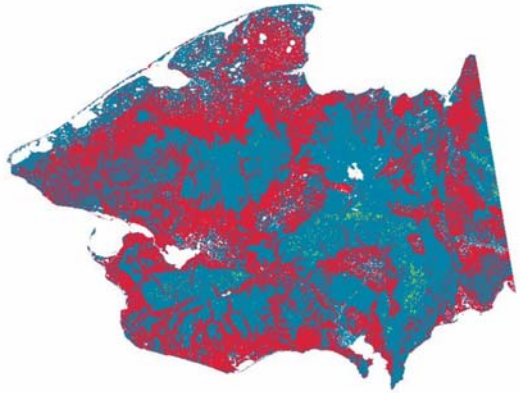
Example: Thawing Permafrost

Projected Permafrost Distribution, Seward Peninsula, Alaska (Hinzman et al, 2007)

Early 21st Century



Late 21st Century



Sinkhole Created by Thawing Permafrost (Romanovsky and UCAR, 2007)

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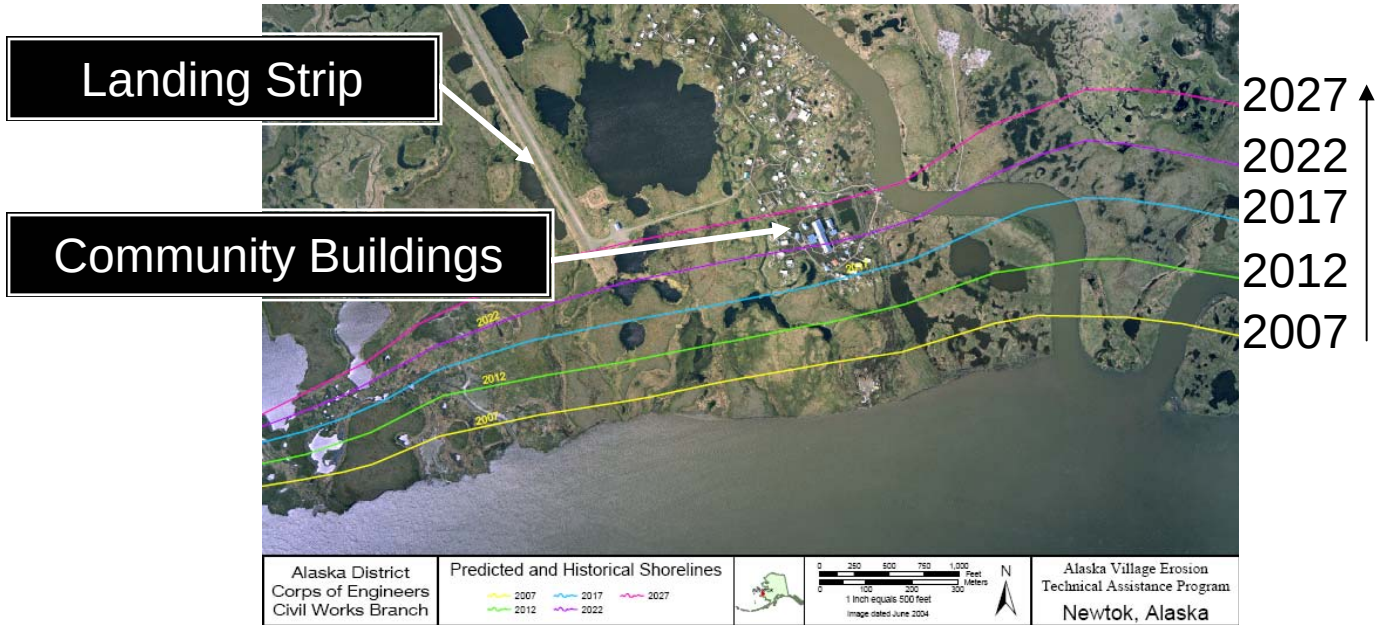
Example: Coastal Erosion

Projected Coastal Erosion at Newtok, Alaska (USACE, 2006)



Coastal Storm Activity Undermines Foundations in Western Alaska (USACE,

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Introducing "ICICLE"

I: *ISER*
C: *Comprehensive*
I: *Infrastructure*
C: *Climate*
L: *Lifecycle*
E: *Estimator*

↓

1. **Alaska Public Infrastructure Database**
2. **NCAR/PCMDI Climate Projections**
3. **Useful Life Adjustment Matrix**

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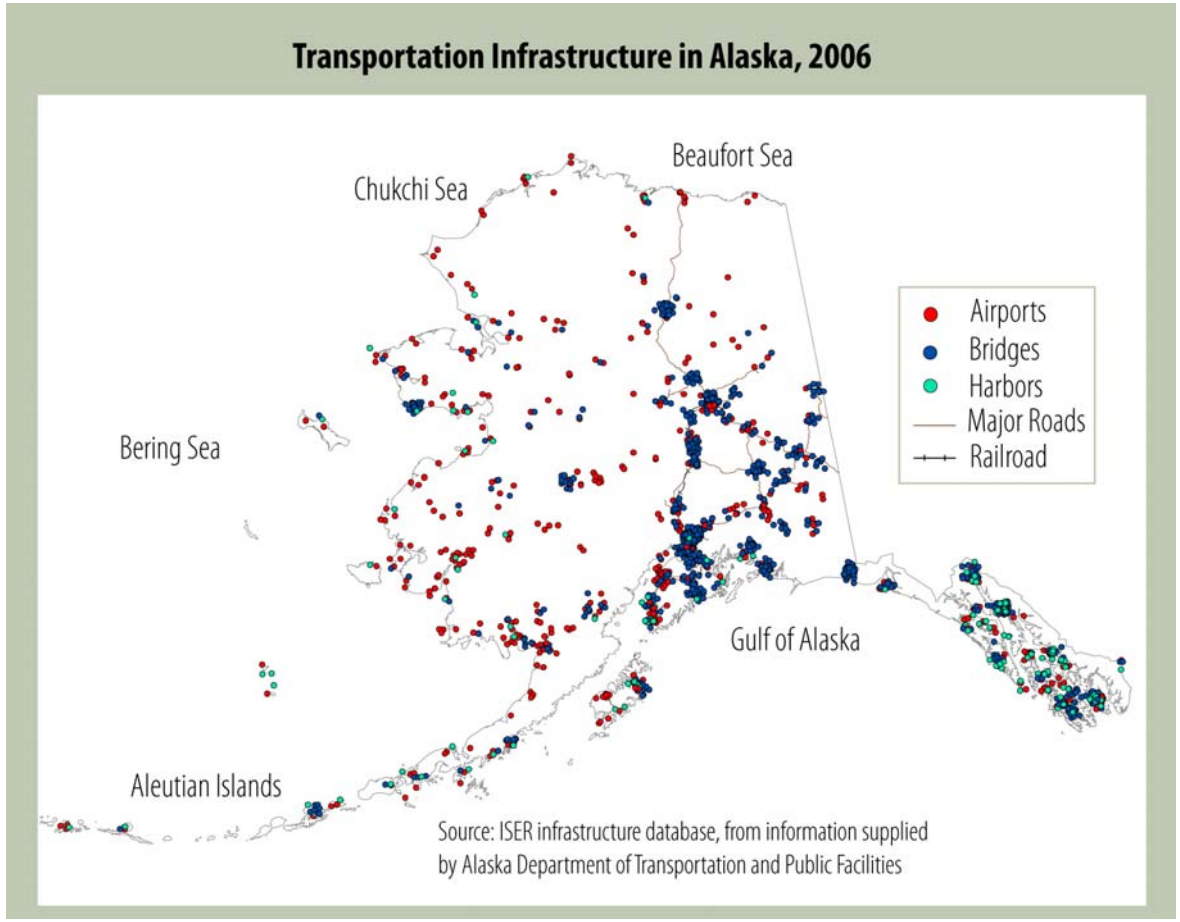
Public Infrastructure Database



- Community Buildings
- Hospitals
- Telecommunications/Electric Systems
- Water/Wastewater Systems
- Bridges
- Harbors
- Schools
- Roads
- Airports/Landing Strips

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Assumptions about Structure Lifespan, Counts, and Costs

Preliminary Public Infrastructure Database[a]: Counts, Useful life, and Estimated Replacement Costs					
Type of Infrastructure	**Count/Length**	**Useful Life (years)**	**Replacement Cost per Unit**	**Units**	**Total Replacement Costs**
Airports	252	20	$20 million	Whole	$5.04 billion
Bridges	853	40	$10,000	Per Foot	$1.7 billion
Court facilities	42	40	$16 million	Whole	$678 million
Defense facilities[b]	178	40	$305 thousand	Whole	$54 million
Emergency Services (Fire stations, other)	232	20	$467 thousand	Whole	$108 million
Energy (Fuel tanks, other structures off power grid)	233	30	$32 thousand	Whole	$7 million
Misc. government buildings	1,569	30	$1 million	Whole	$1.6 billion
Power grid (lines, transformers substations)[b]	68/768 miles	15	$100 thousand	Per Mile	$77 million
Misc. health buildings (clinics, other non-hospital)	345	30	$1.6 million	Whole	$563 million
Harbors	130	30	$10 million	Whole	$1.3 billion
Public hospitals	18	40	$44.7 million	Whole	$806 million
Law enforcement facilities (police and troopers stations, prisons, other correctional)	66	30	$4 million	Whole	$259 million
Alaska Railroad	45/819 miles	30	$2.8 million	Per Mile	$2.3 billion
Roads	10,476/9,564	20	$1 million (unpaved) $3 million (paved)	Per Mile	$18.7 billion
Schools	519	40	$2.5 million	Whole	$1.3 billion
Sewer systems	123	20	$30 million	Whole	$3.7 billion
Telecommunications (towers, satellites, other)	274	10	$300 thousand	Whole	$82 million
Telephone lines[b]	20/222 miles	15	$50 thousand	Per Mile	$11.1 million
Water systems	240	20	$5 million	Whole	$1.2 billion
Totals:	**15,653**				**$39.4 billion**

Note: Real discount rate 2.85% for all types of infrastructure

[a]Preliminary database compiled from publicity available information in 2006.

[b]The count and the replacement costs in these categories are obviously low. In part for security reasons, little public information is available about the size and value of defense facilities.

Source:

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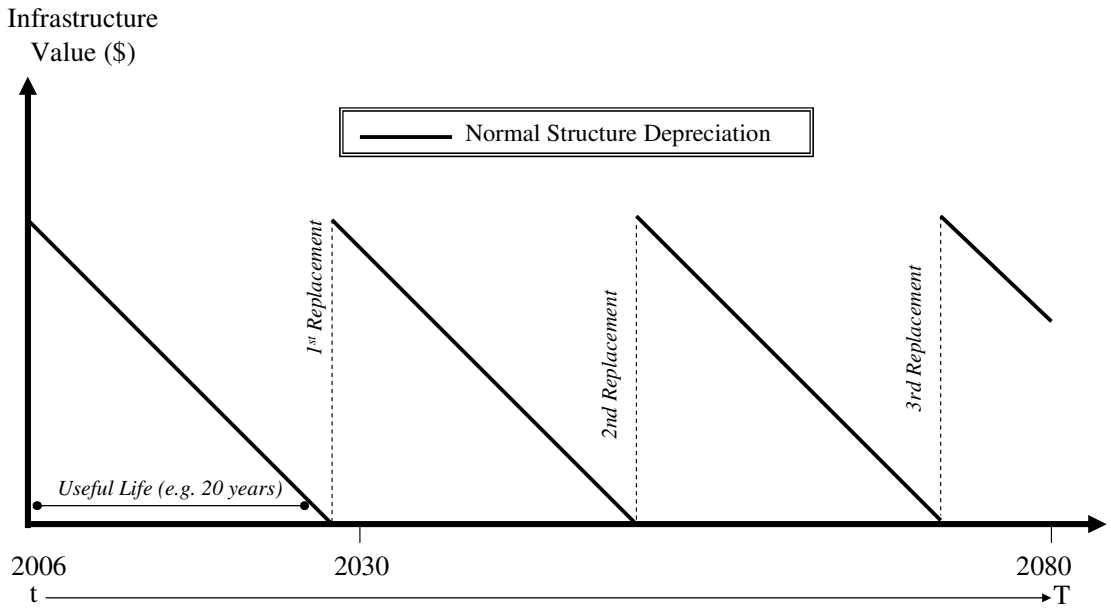
Calculating Baseline Replacement Costs of Alaska's Public Infrastructure



- Depreciate infrastructure using standard financial techniques and average documented lifespans/average replacement costs of various asset classes (bridges vs. schools, etc.).
- Calculate present value of baseline scenario to 2030 and 2080 ($32.1 billion to 2030).

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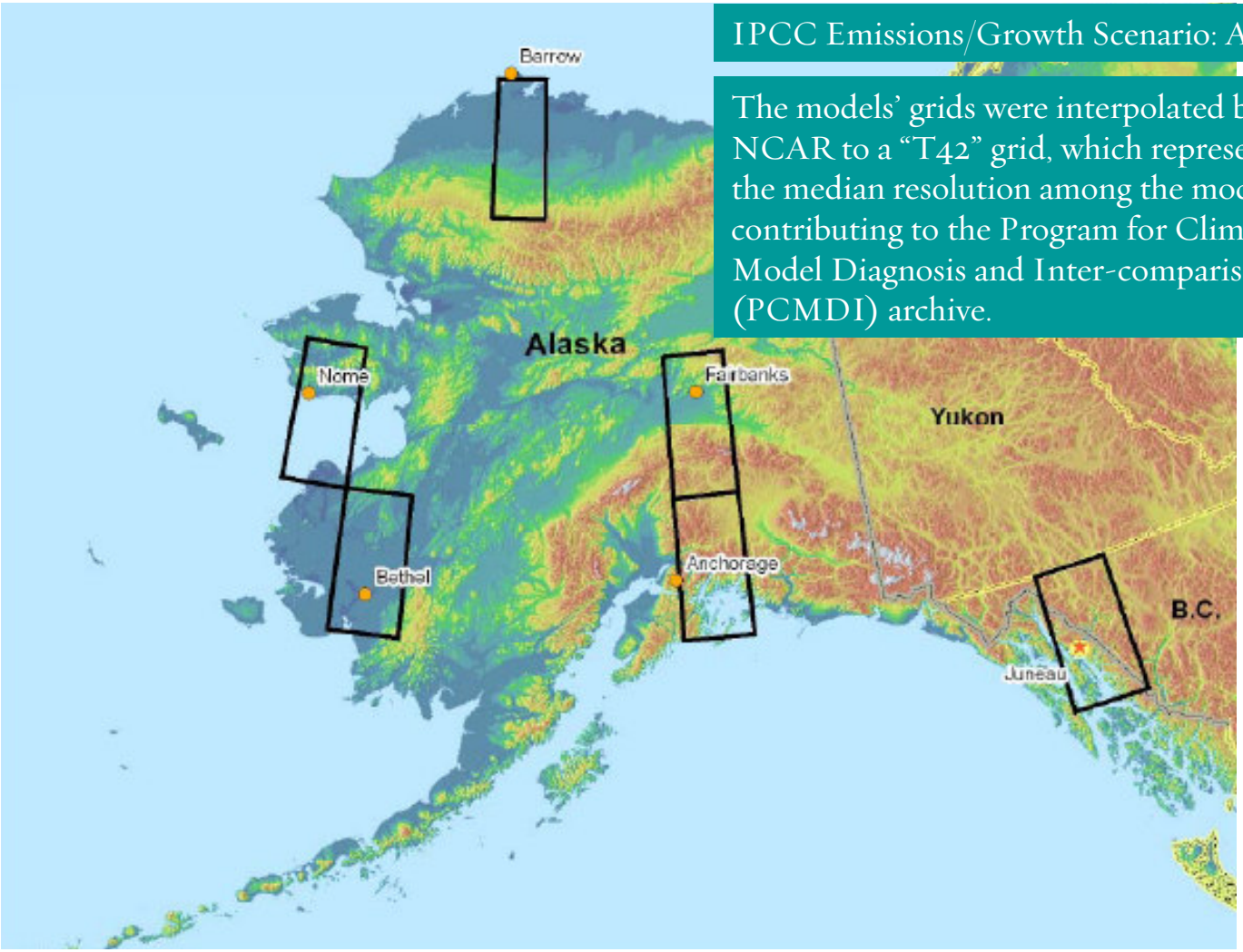
Incorporating Climate Projections



IPCC Emissions/Growth Scenario: A1B

The models' grids were interpolated by NCAR to a "T42" grid, which represents the median resolution among the models contributing to the Program for Climate Model Diagnosis and Inter-comparison (PCMDI) archive.

Source: Stratus Consulting Inc., NCAR (2006)

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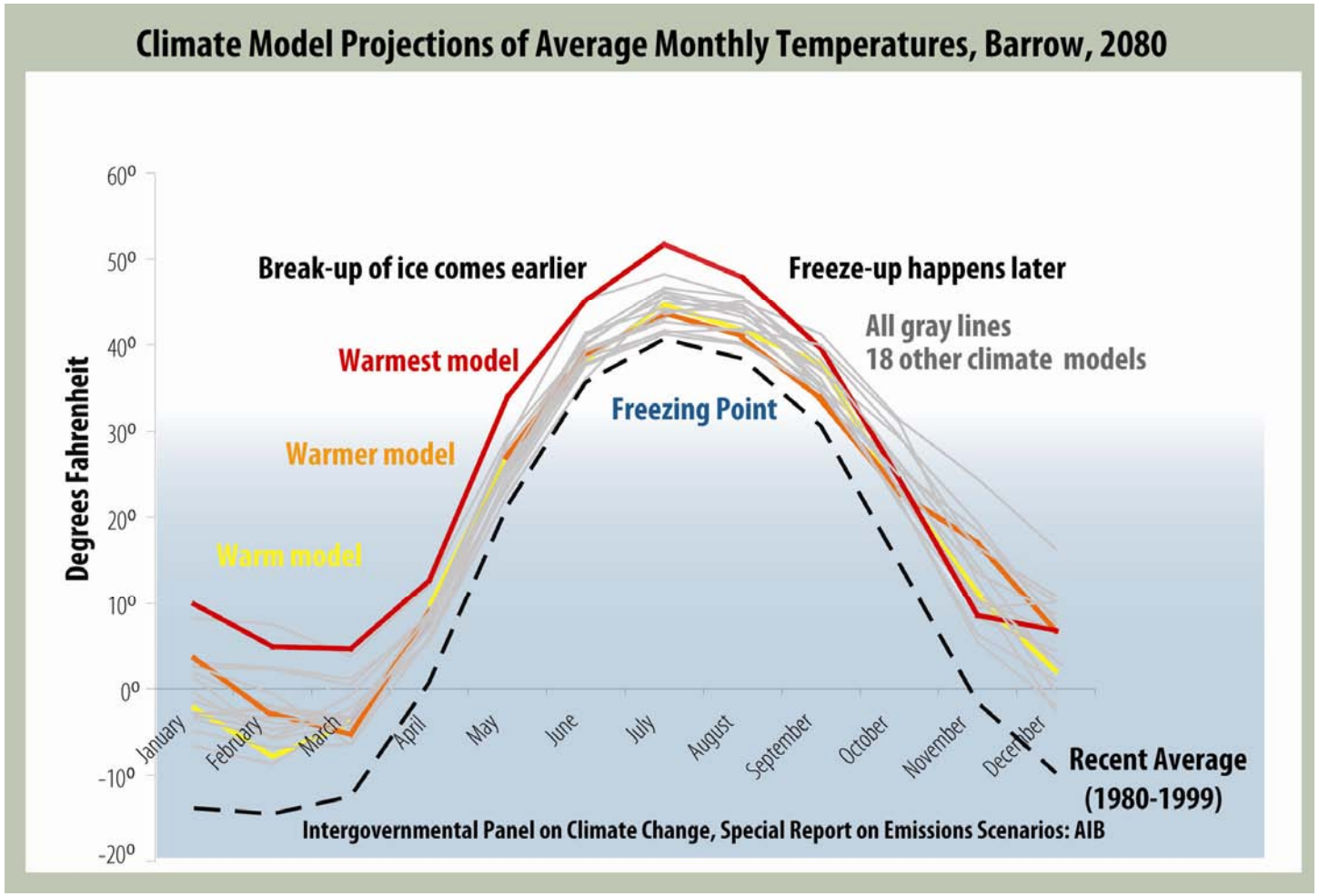
Climate Projections (cont.)



Source: Lawrence Livermore National Lab.; NCAR/ISSE; UAA/ISER (2006)

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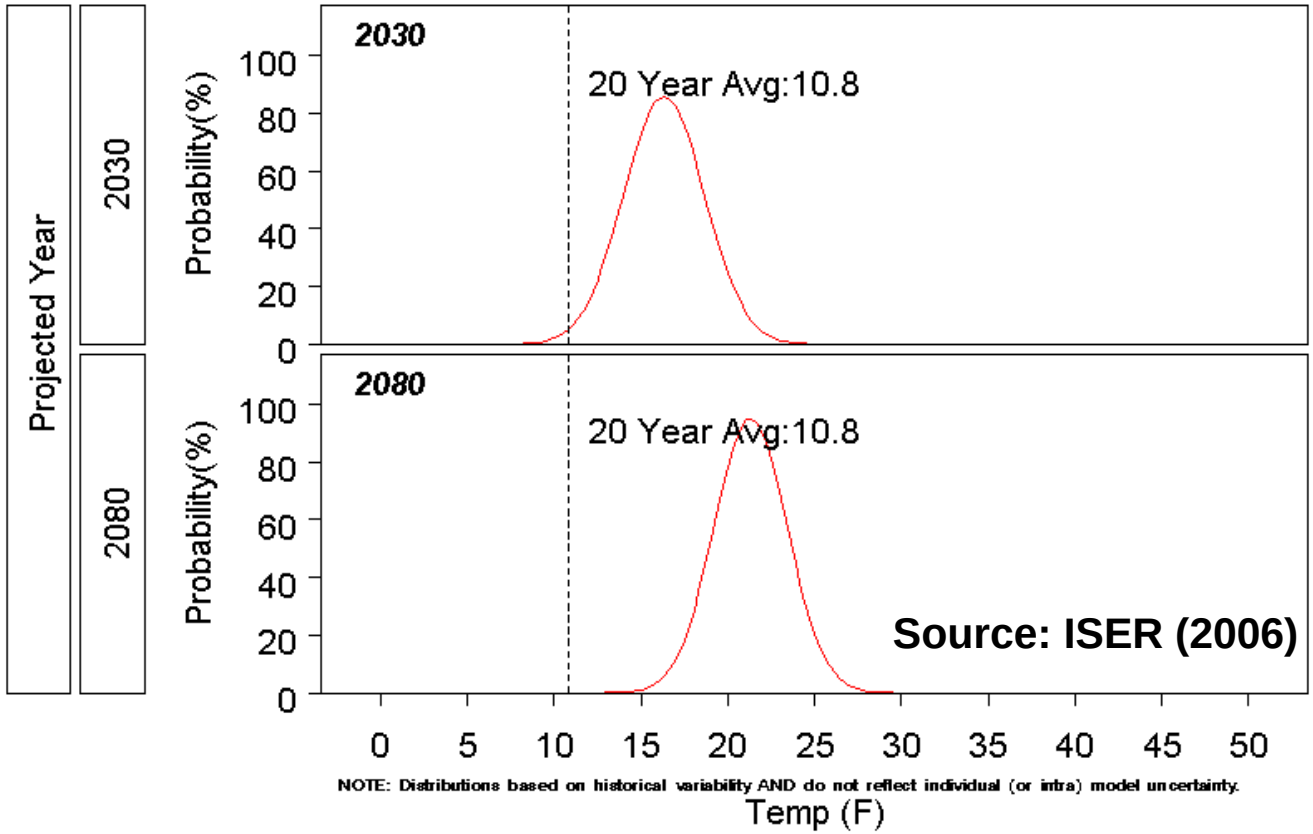
Climate Projections (cont.)



- Likelihood distributions produced by conducting repeated multivariate (temp. and precip.) Gaussian Monte-carlo simulations using historically observed climate variability.

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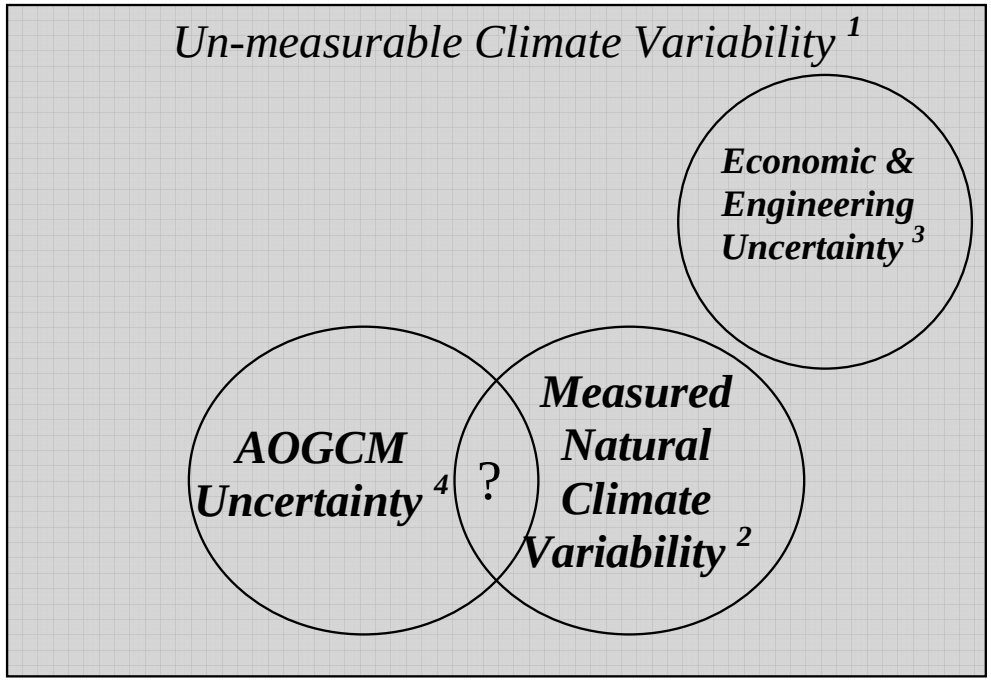
Conveying Statistical Uncertainty

Euler Diagram of

Theoretical Climate-Economic-Engineering Uncertainties



- To date, the ICICLE model incorporates two forms of statistical uncertainty including:
  1) a range of AOGCM projections (i.e., warm, warmer, warmest) and
  2) historical climate variability observed at the applicable region.

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Useful Life Adjustment Matrix

Reduction in Useful Life (%) per Degree Increase in Annual Temperature

Subclass	Topography	Permafrost Free	Isolated Permafrost	Discontinuous Permafrost	Continuous Permafrost
Courts, Defense, Emergency Services, Energy, Hospitals, Law Enforcement, Misc. Buildings, Schools	Coastal (Exposed)	-5.0%	-5.1%	-5.2%	-5.5%
	Coastal (Protected)	-1.0%	-1.1%	-1.2%	-1.5%
	Interior	0.0%	-0.1%	-0.2%	-0.5%
Airports, Bridges, Grid, Harbors, Railroads, Roads, Sewers, Telecommunications, Telephone, Water	Coastal (Exposed)	-7.5%	-7.6%	-7.7%	-8.0%
	Coastal (Protected)	-1.0%	-1.1%	-1.2%	-1.5%
	Interior	0.0%	-0.1%	-0.2%	-0.5%

Reduction in Useful Life (%) per Inch Increase in Annual Precipitation

Subclass	Topography	Permafrost Free	Isolated Permafrost	Discontinuous Permafrost	Continuous Permafrost
Courts, Defense, Emergency Services, Energy, Hospitals, Law Enforcement, Misc. Buildings, Schools	Coastal (Exposed)	-5.0% to 0%	-5.0% to 0%	-5.0% to 0%	-5.0% to 0%
	Coastal (Protected)	-5.0% to 0%	-5.0% to 0%	-5.0% to 0%	-5.0% to 0%
	Interior	-5.0% to 0%	-5.0% to 0%	-5.0% to 0%	-5.0% to 0%
Airports, Bridges, Grid, Harbors, Railroads, Roads, Sewers, Telecommunications, Telephone, Water	Coastal (Exposed)	-7.5% to 0%	-7.5% to 0%	-7.5% to 0%	-7.5% to 0%
	Coastal (Protected)	-7.5% to 0%	-7.5% to 0%	-7.5% to 0%	-7.5% to 0%
	Interior	-7.5% to 0%	-7.5% to 0%	-7.5% to 0%	-7.5% to 0%

- Engineering rules-of-thumb detailing how structures could respond to climate change.
- Assumptions for this component of ICICLE are *very* preliminary with ongoing research currently being conducted by ISER-UAA.

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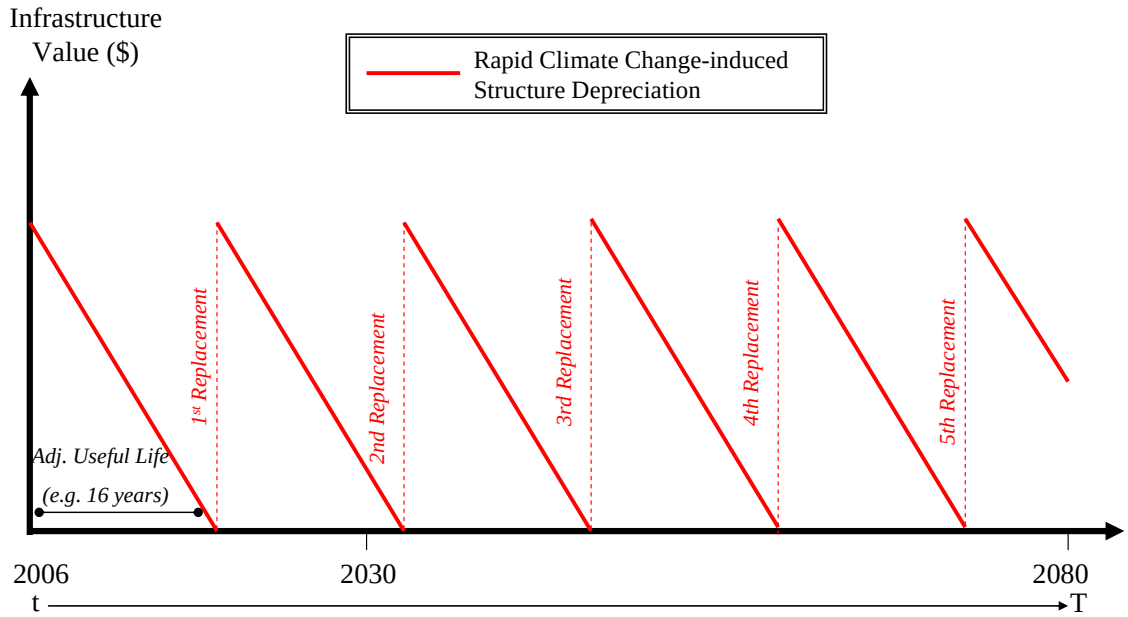
Calculating the Exposure of Alaska Infrastructure to Climate Change



- ACCELERATED CASE: Depreciate infrastructure using techniques that proxy shortened (lengthened) asset lifespan due to coastal erosion, thawing permafrost, flooding, etc.

- Additional Replacement Costs from Climate Change = Present Value of Costs from Climate Change Scenario – Present Value of Costs from Baseline Scenario (+3.6 to +7.0 billion to 2030; no adaptation).

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"ICICLE" Functional Form

r = Real Discount Rate (i.e. 2.85%)
i = Year
j = Infrastructure Type

Base Case	Climate Change
$\theta_j = \dfrac{\text{Replacement Value}_j}{\text{Basecase Useful Life}_j}$	$\Delta_j = \dfrac{\text{Replacement Value}_j}{\text{Adjusted Useful Life}_j}$
$\text{PV}_{\text{Base}} = \sum_{j=1}^{20} \sum_{i=2006}^{2030} \dfrac{\theta_j}{(1+r)^{i-2006}}$	$\text{PV}_{\text{Climate Change}} = \sum_{j=1}^{20} \sum_{i=2006}^{2030} \dfrac{\Delta_j}{(1+r)^{i-2006}}$

$$\boxed{\Phi_{2030} = \text{PV}_{\text{Climate Change}} - \text{PV}_{\text{Base}}}$$

Φ_{2030} = Additional Public Infrastructure Replacement Costs from Climate Change

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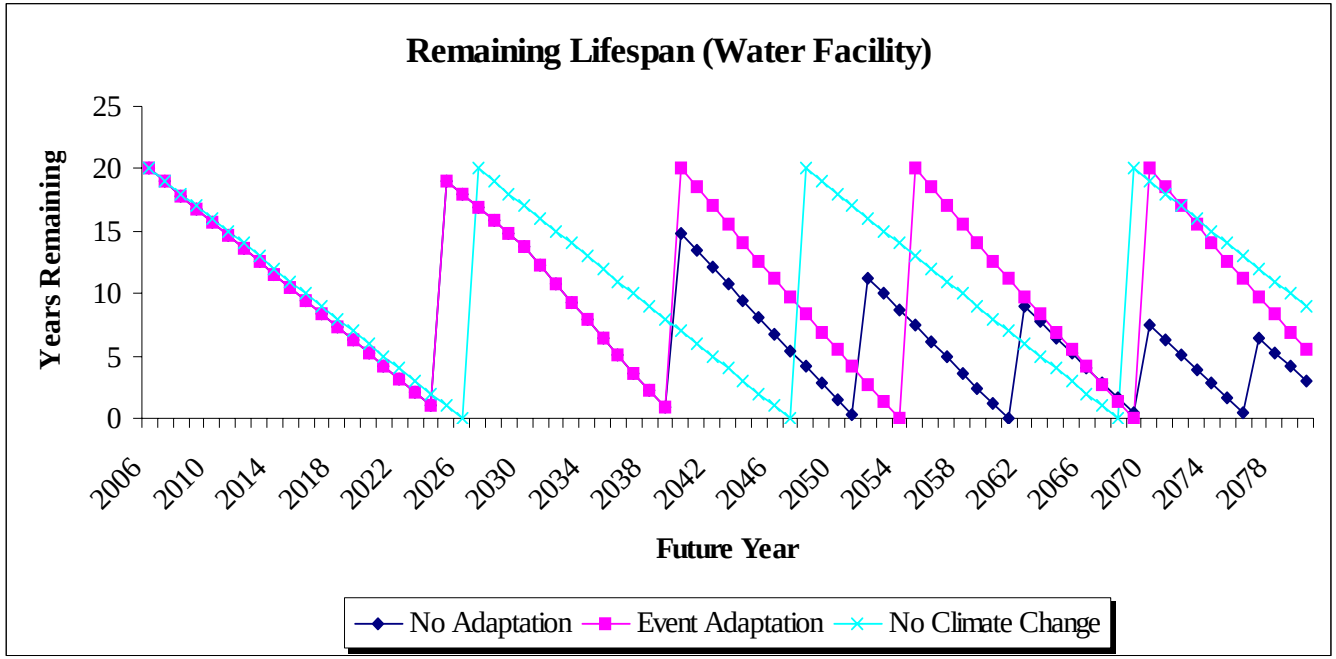
Assuming Planners Adapt Structures to a Changing Climate



- Adaptation algorithm activates when 20% of structure value is damaged from climate change impacts.
- Assumed adaptation cost of +5% above original replacement cost.
- One adaptation scenario considered in this preliminary analysis.

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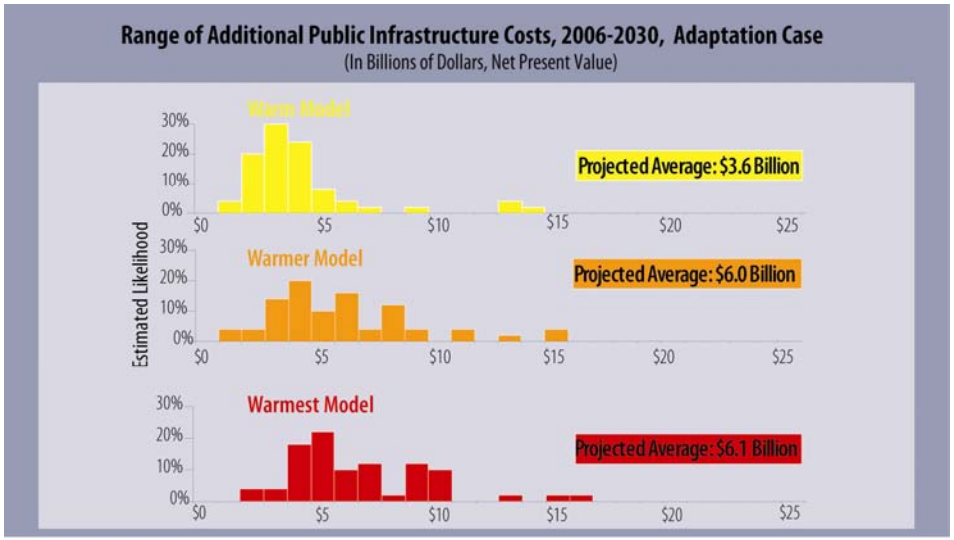
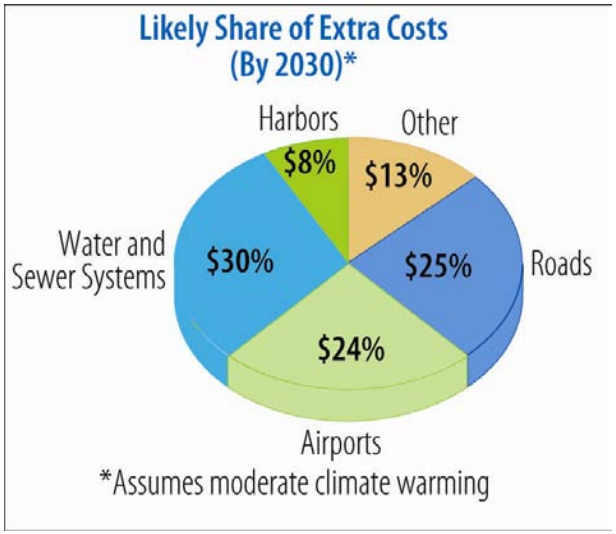
Cost of Alaska's Public Infrastructure at Risk to Climate Change



Assumes Adaptation



Source: ISER (2007)

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Potential Model Refinements

- Incorporate downscaled AOGCM ensembles with standard deviations (John Walsh/IARC got the ball rolling….).
- Conduct statewide survey of public facilities.
- Develop non-linear functions relating structural useful life changes to projected climatic changes.
- Disaggregate baseline structural cost and useful life assumptions.
- Identify additional adaptation assumptions.
- Model new infrastructure based on state economic forecasts.
- Use alternative statistical distributions to proxy “extreme events” (Dave Atkinson/IARC is already experimenting with this type of analysis).
- Consider alternative financial methods when discounting future impacts back to the present.
- Develop economic modeling scenarios.
- Consider economic “benefits” of improving public infrastructure.
- Get more up-to-date permafrost maps with projections of future coverage.

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Conclusion

- Effects of climate change are being observed in many parts of Alaska. In addition to public infrastructure, other social and natural systems may be vulnerable to climate change.

- Future projections show a consensus of significant changes in the foreseeable future, particularly for the Northern and Western part of the state.

- Damages to infrastructure could be large (i.e. *several billions of today's dollars*), but there is little reliable information "on the ground" detailing the degree and location of impacts.

- This version of ICICLE estimates that Alaska public infrastructure costs could increase +10 to +20% over the next few decades from climate change assuming some level of adaptation.

- This research was sponsored by the University of Alaska Foundation, the National Commission on Energy Policy, the Alaska Conservation Foundation, and the Rural Alaska Community Action Program.

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Additional Information

- All materials for this ISER-UAA study can be accessed at: www.iser.uaa.alaska.edu

- SNAP and ACCAP collaboration

- Citation for this copyrighted manuscript:

  Larsen, P., S. Goldsmith, O. Smith, M. Wilson, K. Strzepek, P. Chinowski, and B. Saylor (2007) "Estimating the Future Costs of Alaska Public Infrastructure at Risk from Climate Change" In submission, August.

Questions?

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