Assessing the Near-Term Risk of Climate Uncertainty: Interdependencies Among the U.S. States*

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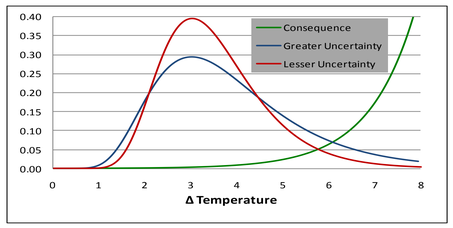
With Mark Ehlen, Geoffrey Klise, Verne Loose, Len Malczynski, Kevin Stamber, Vince Tidwell, Vanessa Vargas, Aldo Zagonel, Tim Trucano, David Robinson, Arnie Baker, Brian Adams, Elizabeth Richards, John Siirola, Mark Boslough, Mark Taylor, Ray Finely, Lillian Snyder, Dan Horschel, Steve Conrad, Andjelka Kelic, Jesse Roach, Marissa Reno, William Stubblefield, Laura Cutler, Anna Weddington, William Fogelman, Jim Strickland, and John Mitchiner of SNL.

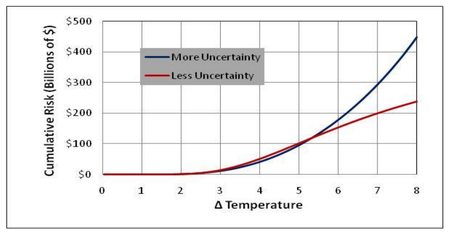
The justification for implementing climate change policy in the present hinges on the tangible near-term cost of inaction. It is the uncertainty associated with climate change that validates the need to act proactively.

To demonstrate a risk assessment methodology*, we simulated the interacting impacts among the continental U.S. states, detailing 70 economic sectors, including business and population migration, from 2010 to 2050 over the full range of volatile-climate-change exceedance-probabilities to assess risk. We only considered economic risk from water availability, assuming no policy interventions. At a global level, climate change will cause an increased water cycle, yet at mid-latitudes, the water cycle impact is area dependent. Water availability directly affects economic infrastructure, and economy-wide impacts stem largely from infrastructure interdependencies.

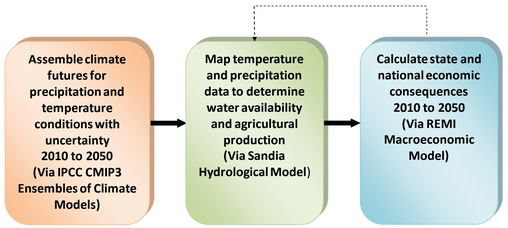
$$Risk = \int_T \int_P Consequence(t, p) \times e^{-r \times t} \times dp \times dt$$

p = probability; t = time; r = discount rate



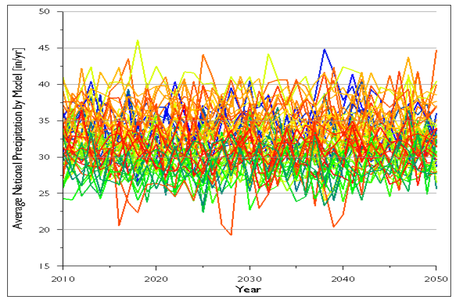


Risk combines uncertainty with consequence. Because of the asymmetric costs/consequences, the more the uncertainty, the more the risk. Although these curves are illustrative of the concept, the actual analysis includes the specific technology-level costs and impacts for each industry. This study underestimates the climate uncertainty and neglects many impact vectors. It **underestimates** the risk.

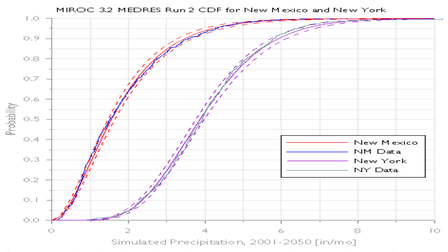


We used the WCRP Coupled Model Intercomparison Project (CMIP3) multi-model dataset to generate a proxy distribution of uncertainty. This distribution does not validly portray the actual climate uncertainty, but it does have less uncertainty than a complete experimental design. The trajectories of future precipitation uncertainty (compared to a 1960-2010 climate and economic baseline) determine water supply. We use the REMI model (REMI Inc.) to derive water demands from economic activity. Companies and consumers adjust to water availability by investments or process changes. These changes can cause increased costs or reduced production that have economic and employment consequences. To highlight internal U.S. interdependencies, for this specific analysis we assumed the rest-of-world conditions did not affect the U.S. (Current research includes interdependent, international risks.)

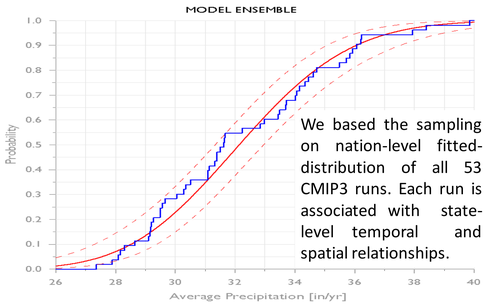
*Backus, George A., Thomas S. Lowry, Drake E. Warren, Mark Ehlen, Geoffrey T. Klise, Verne W. Loose, Leonard A. Malczynski, Rhonda K. Reinert, Kevin L. Stamber, Vincent C. Tidwell, Vanessa N. Vargas, Aldo A. Zagonel, **"Assessing the Near-Term Risk of Climate Uncertainty: Interdependencies among the U.S. States,"** *SAND Report,* April 2010.
https://cfwebprod.sandia.gov/cfdocs/CCIM/docs/Climate_Risk_Assessment.pdf



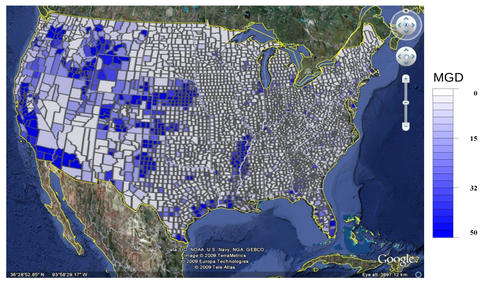
Annual U.S. National precipitation trajectories for the 53 A1B scenario model runs in the CMIP3 dataset, visually have no pattern.



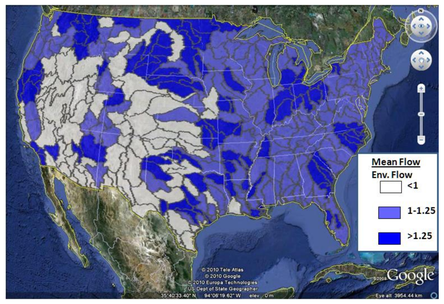
Gamma-distribution fits of state-level, climate simulations show a compelling pattern. Actual analysis includes annual volatility.



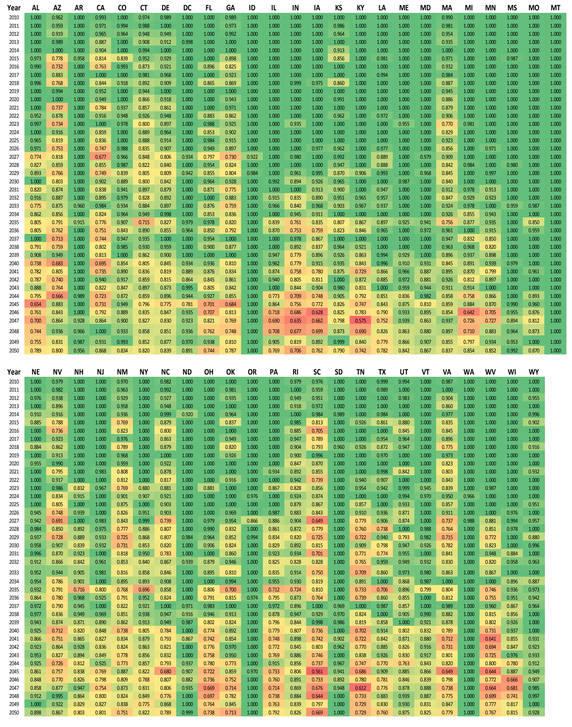
We based the sampling on nation-level fitted-distribution of all 53 CMIP3 runs. Each run is associated with state-level temporal and spatial relationships.



For each year and exceedance probability sample, we determined water demand by county for each industry, and water supply for 200 watershed basins covering the lower 48 states (historically calibrated using 23,000 stream-gauges) using the Sandia Hydrology model.

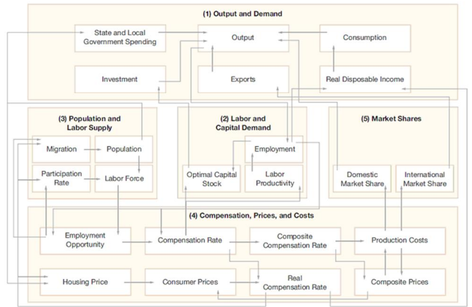


Water Availability (including environmental needs) 2004

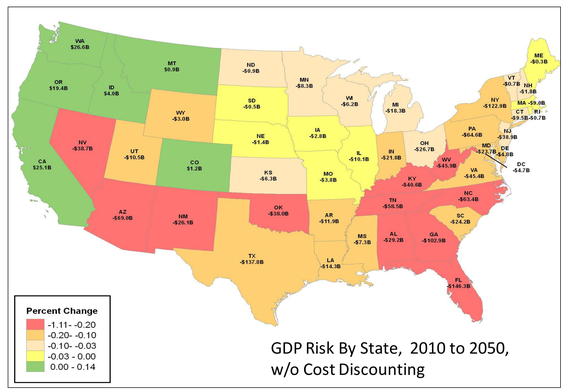


Water availability at the 1% exceedance probability by state and year. Mining as agriculture are affected much more severely.

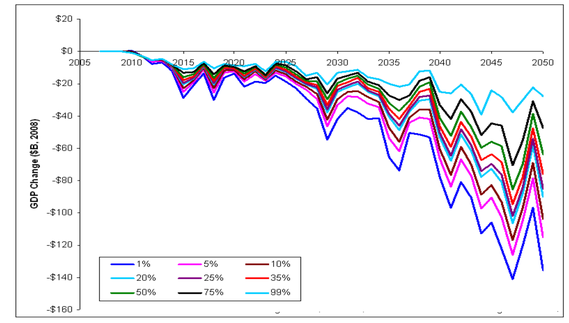
REMI Model Linkages (Excluding Economic Geography Linkages) REMI



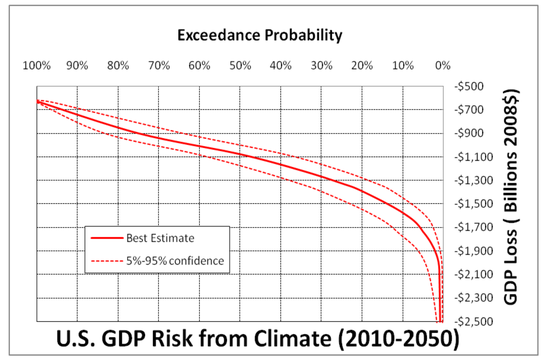
The REMI macroeconomic model determines impacts across the states. We use the official U.S. Department of Commerce forecast as the referent and calculate differential impacts. The REMI model is being use in an interpolative rather than a extrapolative mode.



GDP Risk By State, 2010 to 2050, w/o Cost Discounting



Volatility brings the future transiently into the present. In this example, the 50% exceedance-probability impact for the year 2049 is comparable to that of 2035 and 2028. Both earlier dates would have impacts greater than that of a "mean-value" trend line.



The above figure shows the U.S. Risk by exceedance probability. The risk is largely on the right side of the median. Due to the "fat tail" of the risk distribution, the "mean" is not a useful reference point.

Forestry and logging; Fishing, hunting	-$0.6	Water transportation	$0.0
Agriculture, forestry support activities; Other	-$0.3	Truck transportation, couriers	-$19.9
Oil and gas extraction	-$9.4	Transit and ground passenger transportation	-$0.6
Mining (except oil and gas)	-$86.3	Pipeline transportation	-$0.2
Support activities for mining	-$7.3	Tourist transportation; support activities	-$0.8
Utilities	$13.6	Warehousing and storage	-$2.1
Construction	-$30.8	Publishing industries, except Internet	-$12.4
Wood product manufacturing	-$1.1	Motion picture and sound recording industries	-$4.5
Nonmetallic mineral product manufacturing	-$3.3	Internet publishing, Information services	-$10.8
Primary metal manufacturing	-$2.4	Broadcasting, Telecommunications	-$28.1
Fabricated metal product manufacturing	-$3.7	Monetary authorities, funds, trusts, financials	-$34.1
Machinery manufacturing	-$4.2	Securities, commodity contracts, investments	-$39.9
Computer and electronic product mfg.	-$10.3	Insurance carriers and related activities	-$6.4
Electrical equipment and appliance mfg.	$1.4	Real estate	-$38.2
Motor vehicles, bodies & trailers, parts mfg.	-$8.8	Rental and leasing services	-$8.4
Other transportation equipment manufacturing	-$1.6	Professional and technical services	-$41.4
Furniture and related product manufacturing	-$3.6	Management of companies and enterprises	-$13.9
Miscellaneous manufacturing	$1.4	Administrative and support services	-$21.2
Food manufacturing	-$82.3	Waste management and remediation services	-$0.5
Beverage and tobacco product manufacturing	-$29.4	Educational services	-$2.2
Textile mills	$0.0	Ambulatory health care services	-$66.8
Textile product mills	-$1.0	Hospitals	-$5.5
Apparel manufacturing	$0.8	Nursing and residential care facilities	-$2.0
Leather and allied product manufacturing	-$2.3	Social assistance	-$2.0
Paper manufacturing	-$2.5	Performing arts and spectator sports	-$2.0
Printing and related support activities	-$0.6	Museums, historical sites, zoos, and parks	-$0.2
Petroleum and coal product manufacturing	-$3.6	Amusement, gambling, and recreation	-$5.9
Chemical manufacturing	-$18.2	Accommodation	-$3.8
Plastics and rubber product manufacturing	-$4.5	Food services and drinking places	-$19.9
Wholesale trade	-$45.3	Repair and maintenance	-$4.9
Retail trade	-$127.2	Personal and laundry services	-$11.2
Air transportation	-$4.1	Membership associations and organizations	-$2.0
Rail transportation	-$3.2	Private households	-$1.0

The above table displays the national-level risk by industry ($B) from 2010-2050. Locally, some industries, such as construction for modified facilities and transportation to compensate for lost production will benefit. Their support industries, such as electrical machinery, also see benefits.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. Laboratory Directed Research and Development (LDRD) funding supported this work. SAND Number: **2011-7846C**

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