Nonmarket impacts

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Topics

- Spatial and temporal aggregation in assessment of impacts understates impacts.
- Extreme local events account for most of non-catastrophic damages.
- Risk aversion should be accounted for.
- Impacts are multi-attribute. A univariate utility function, treating consumption as perfect substitute for environment, understates damages.

Two of the charge questions

Q: How is the value of non-market impacts currently represented in IAMs?

A: They are not meaningfully represented in current IAMs. But neither are many of the market impacts.

Q: What are the key challenges of quantifying and incorporating non-market impacts into IAMs?

A: The greatest challenge is *not* monetization. It is measurement of the physical impacts. One needs a disaggregated, bottom-up approach to the assessment of non-market impacts – and most market impacts, too.

Damages in DICE 2002

ECONOMIC IMPACT OF 2.5˚ C WARMING: ANNUAL DAMAGES IN THE US	
FROM NORDHAUS & BOYER (2002)	
	US TOTAL $ 1990 billions
MARKET IMPACTS	
Agriculture	4
Energy	0
Water	0
Sea Level	6
MARKET SUBTOTAL*	11
NONMARKET IMPACTS	
Health, water quality, human life	2
Human amenity, recreation, nonmarket time	-17
Ecosystem damages, species loss	0
Human settlements	6
Extreme and catastrophic events	25
NONMARKET SUBTOTAL*	17
MARKET + NONMARKET TOTAL*	28
* Totals do not add due to rounding.	

- Nordhaus & Boyer (2002) expressed as annual willingness to pay per US household (2006$)

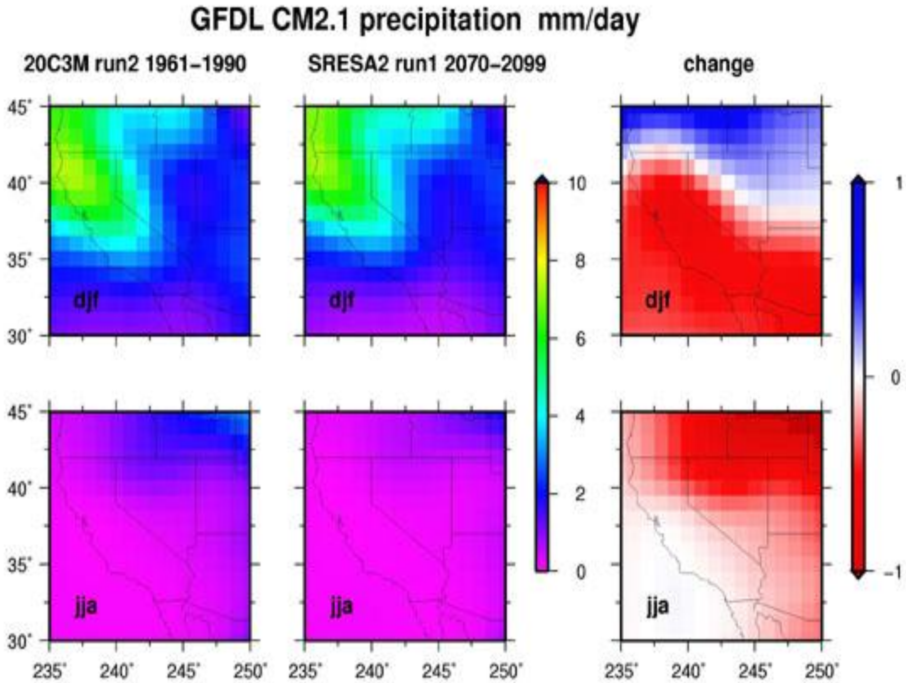
– Market impacts	$126
– Non-climate catastrophe non-market impacts	-$103
Subtotal	$ 23
– Climate catastrophe non-market impacts	$298
– Total	$321

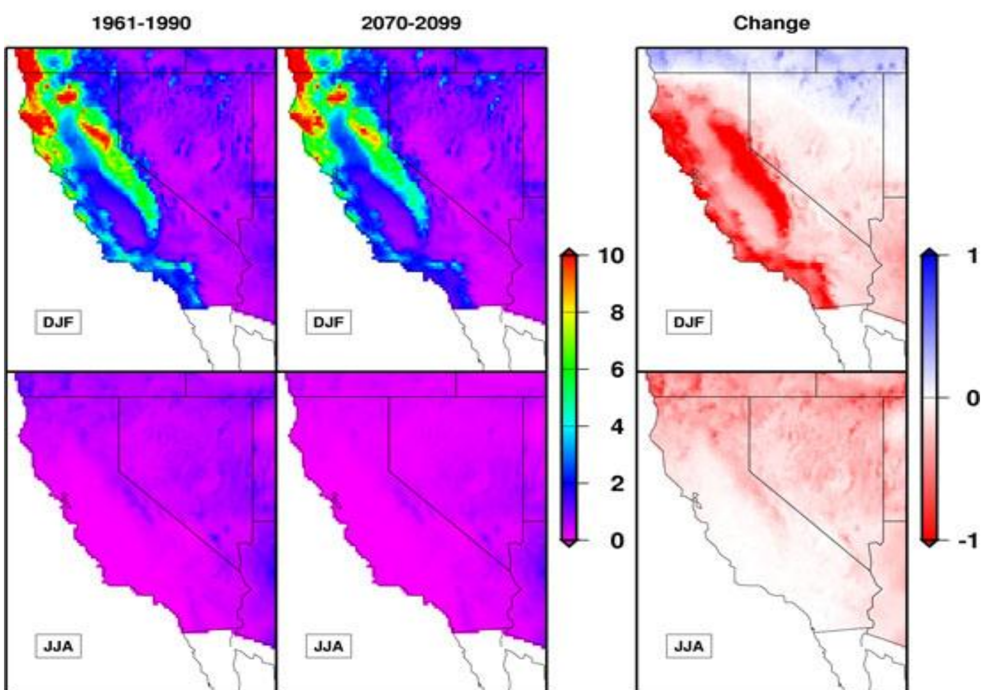
What is missing?

- – Averaging understates damages
- – Neglect of extremes understates damages
- – Assumption of symmetry of positive and negative impacts understates net damages
- – Neglect of tail dependence understates damages
- – Failure to allow for risk aversion understates damages
- – Ignoring distributional considerations & loss aversion understates damages

Climate impact studies

- California has been conducting impact assessments since ~2000.
- Three rounds of assessment have been completed (2002, 2006, 2009). Now on fourth round.
- Key feature of this and other recent work is spatial downscaling of GCM projections.
- Spatial downscaling has transformed impact studies in last decade.





Global Climate Models compute Climate on a coarse grid

So, a "downscaling" procedure was used to provide temperature and precipitation over a finer mesh that is more commensurate with the California landscape

A hydrologic model is used to simulate streamflow, soil moisture and other hydrologic properties

- Goal: “A more transparent representation of the pathways through which climate change may affect productivity and human well-being.”
- While mitigation is global, impacts and adaptation – both market and non-market – are *local*. They are spatially and temporally heterogeneous.
- Without adequate representation of the heterogeneity, there is neither a transparent nor an accurate characterization of impacts (damages).

Aggregation distorts conception of temperature change Hayhoe et al PNAS 2004

HOW TO CHARACTERIZE THE CHANGE IN TEMPERATURE, 2070-2099, USING HADCM3			
		EMISSION SCENARIO**	
		A1fi	B1
Change in global average annual temperature		4.1	2
Change in statewide average annual temperature in California*		5.8	3.3
Change in statewide average winter temperature in California*		4	2.3
Change in statewide average summer temperature in California*		8.3	4.6
Change in LA/Sacramento average summer temperature		~10	~5
*Change relative to 1990-1999. Units are ˚C			

- Spatial disaggregation is a major challenge for economic analysis.
  - CGE models are highly spatially aggregated.
- For given ΔT, yield effect differs by crop and location:
  - Impact on corn different than on wine grapes. Even for grapes, impact different in Napa County vs Fresno County.
  - Can't represent impact via one "representative farm"
- Two neighboring water districts:
  - Different water rights, different sources of supply, different cost structures, different crops grown, & different climate impact.
  - Water isn't fungible. Can't represent a heterogeneous area via a "representative farm" with a lumped, regional supply of water, without distorting the economic analysis.

- Aggregation: Treat all days with a temperature above 90^{o}F as the same, as opposed to, say, 90-94, 95-99, 100-105, etc [e.g. Deschenes and Moretti (2007)]

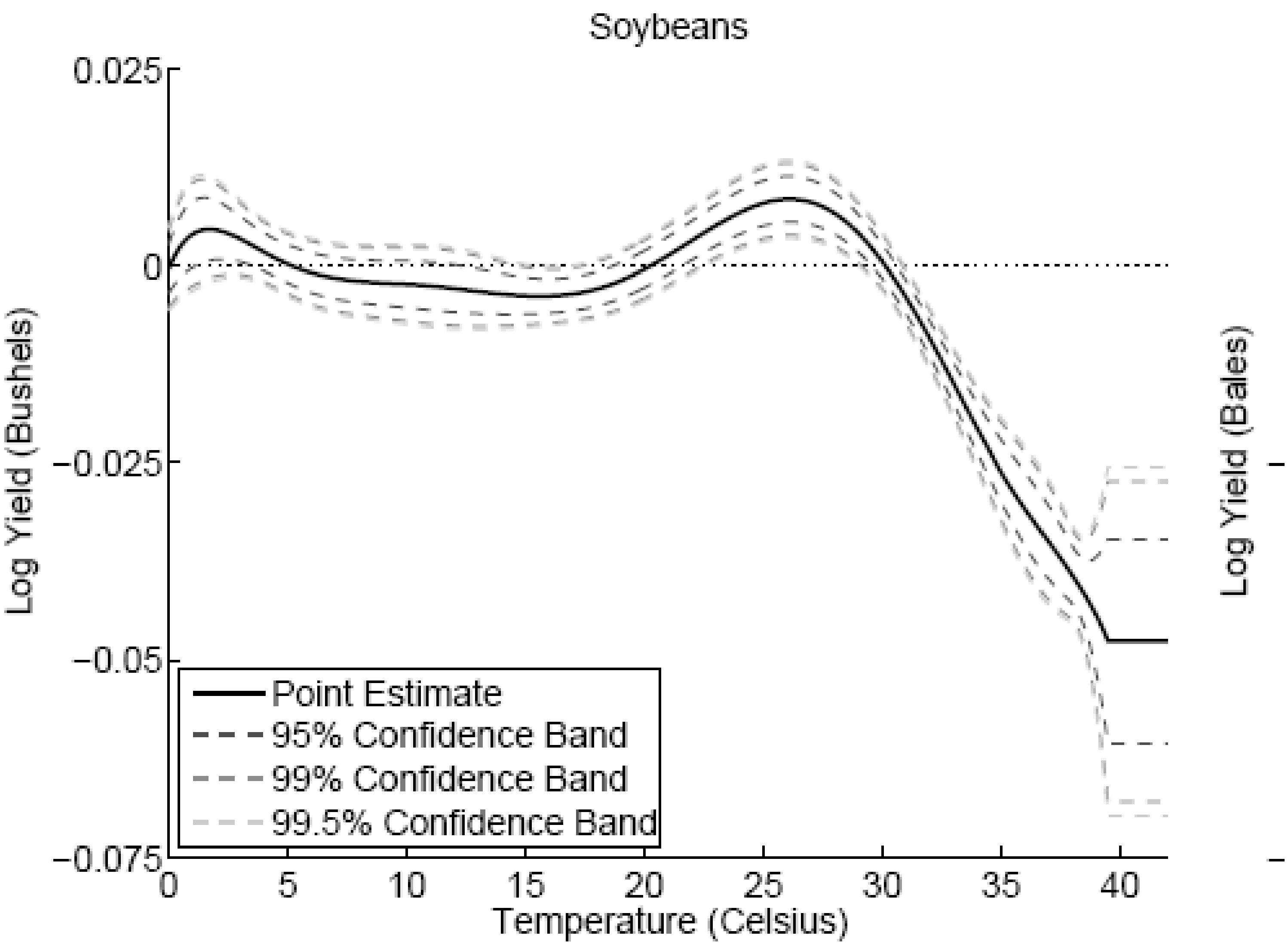
- General Consequence:
  - With convex damage function (increasing marginal damage), aggregation understates damages: $E\{D(\Delta T)\} > D(E\{\Delta T\})$.

Asymmetric negative & positive impacts

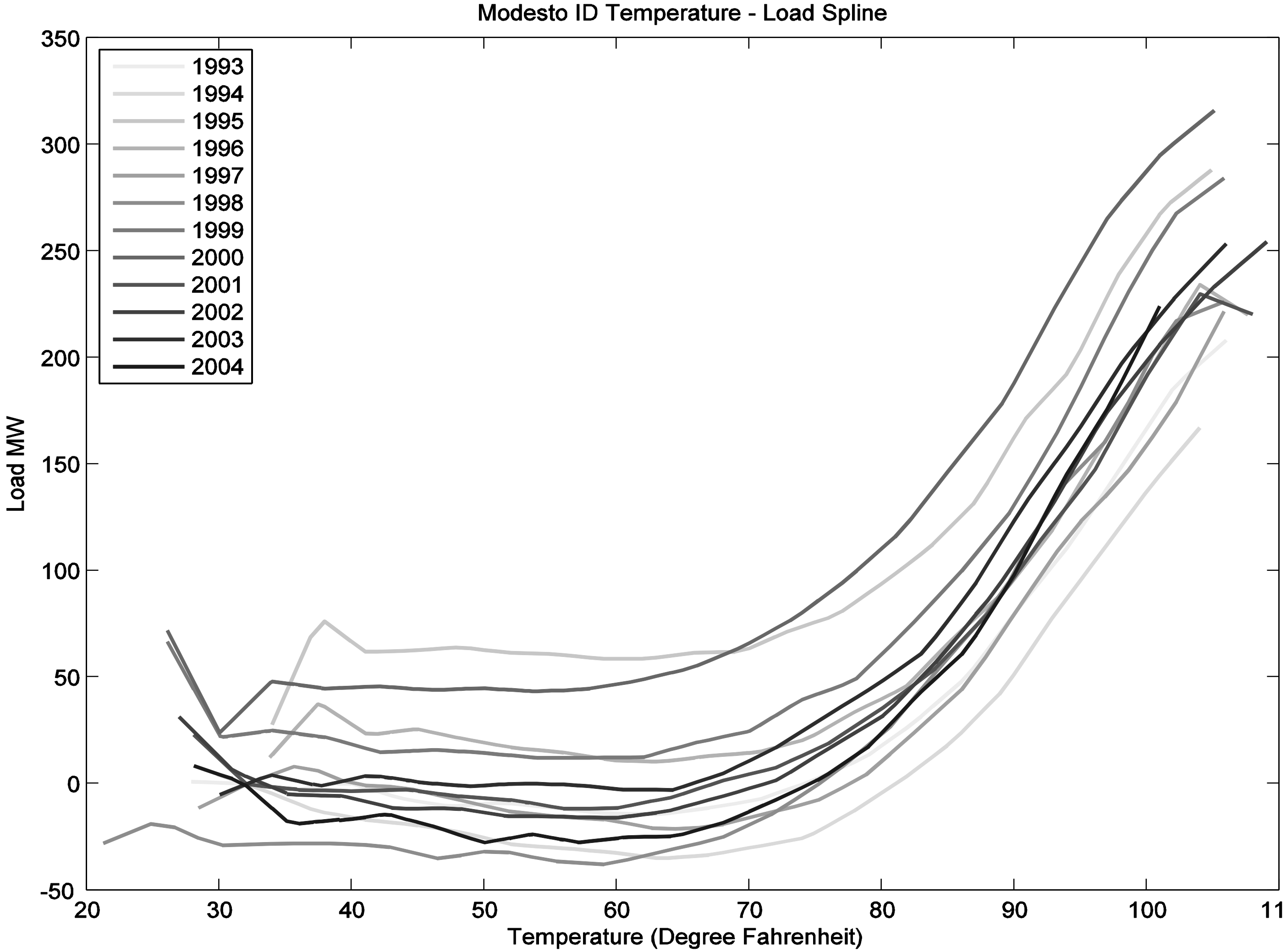
- In some cases there can be positive as well as negative impacts of climate change, depending on the degree of change.
  - Mild warming improves crop yield in cold climates, extreme warming kills crops.
  - Warming in winter reduces mortality, warming in summer raises mortality.
  - Warming in winter lowers energy bills for heating, while warming in summer raises energy bills for air conditioning.
- These effects are often represented by a quadratic, hill-shaped impact function.
- In the DICE model, Nordhaus assumes these positive and negative effects roughly cancel out.

- However, the empirical evidence suggests that the effect is generally *not* symmetric.
- Rather it is highly asymmetric
  - e.g. effect of temperature on crop yield
  - effect of temperature on energy use
- The empirical evidence suggests that, for crop yields, energy use and weather-related mortality in most countries, the negative impacts of higher temperatures greatly exceed the positive impacts of higher temperatures.

Asymmetric Relation of Temperature and Crop Yield
Schlenker & Roberts (PNAS, 2009)



Modesto Hourly Load/Temp (Aufhammer)



Nonlinear increase in flooding

- In winter storm, waves can be 5-6 ‘ higher than mean sea level. Therefore can have flood damage before sea reaches level of land.
- Scripps analysis based on an extreme wave: occurred 1 hour per year in San Francisco 1960-1980.
- By 2000, it was occurring 15-20 times per year.
- If the mean sea level at San Francisco rises by 20 cm between 2000 and 2100, expected to occur about 150-200 times per year.
- If it rises by 40 cm, an extreme hourly event would occur about 1,500 times per year.
- If it rises by 60 cm, an extreme hourly event would occur about 7,000 times per year.
- If it rises by 80 cm, an extreme hourly event would occur about 20,000 times per year.

- Most of the damages to agriculture from climate change are associated with the change in frequency of extreme events rather than the change in average temperature.
- This is probably true for many other types of impact as well.
- Weitzman has emphasized the issue of fat tails in context of updating a prior. There are also physical reasons – thresholds – why a fat tail may arise.

Modeling strategy

- The importance of disaggregation and the non-linearity of impacts has implications for the modeling strategy.
  - Need a US model as well as a global model
  - Rather than a single, integrated model, need a modular approach with a network of models
    - GCM
    - Spatial downscaling to areas within the US
    - Suite of sectoral models/analyses at loc
    - al level
    - Aggregate to national level for US
- This is more feasible if aim is to calculate SCC, rather than to determine optimal US emissions.

Implication: wrong damage function?

- The special role of extreme events affects the exponent in the damage function.
- Moreover, damages are represented as a function of the increase in temperature. But, it is likely that they are also an increasing (?convex) function of
  - The *trajectory* of increase in temperature (e.g., the increase measured in degree years).
  - The speed of increase in temperature.
- This would significantly change the economically optimal trajectory of emissions.

Reframing climate change in terms of risk

- Because the largest part of the damages from climate change is likely to be associated with extreme events, one should think of climate policy in terms of risk assessment and risk management.
- In assessing potential damages, there needs to be an allowance for risk aversion. This is largely absent in most of the existing economic literature on climate.

- The DICE model allows for risk aversion with respect to collapse of the thermohaline circulation, but not with regard to ordinary market and non-market losses.
- These are local impacts (fire, flooding, drought etc), but the local population which is exposed to them is likely to have some degree of risk aversion and some WTP to lower their exposure to these risks.
- There are limits to the extent to which these risks can be pooled
  - Non-financial outcomes (pain and suffering, etc)
  - Tail dependence
- Therefore, there should be some allowance for the public's risk aversion premium to avoid these risks.
- Moreover, the relevant risk concept is likely to be *downside* risk aversion.

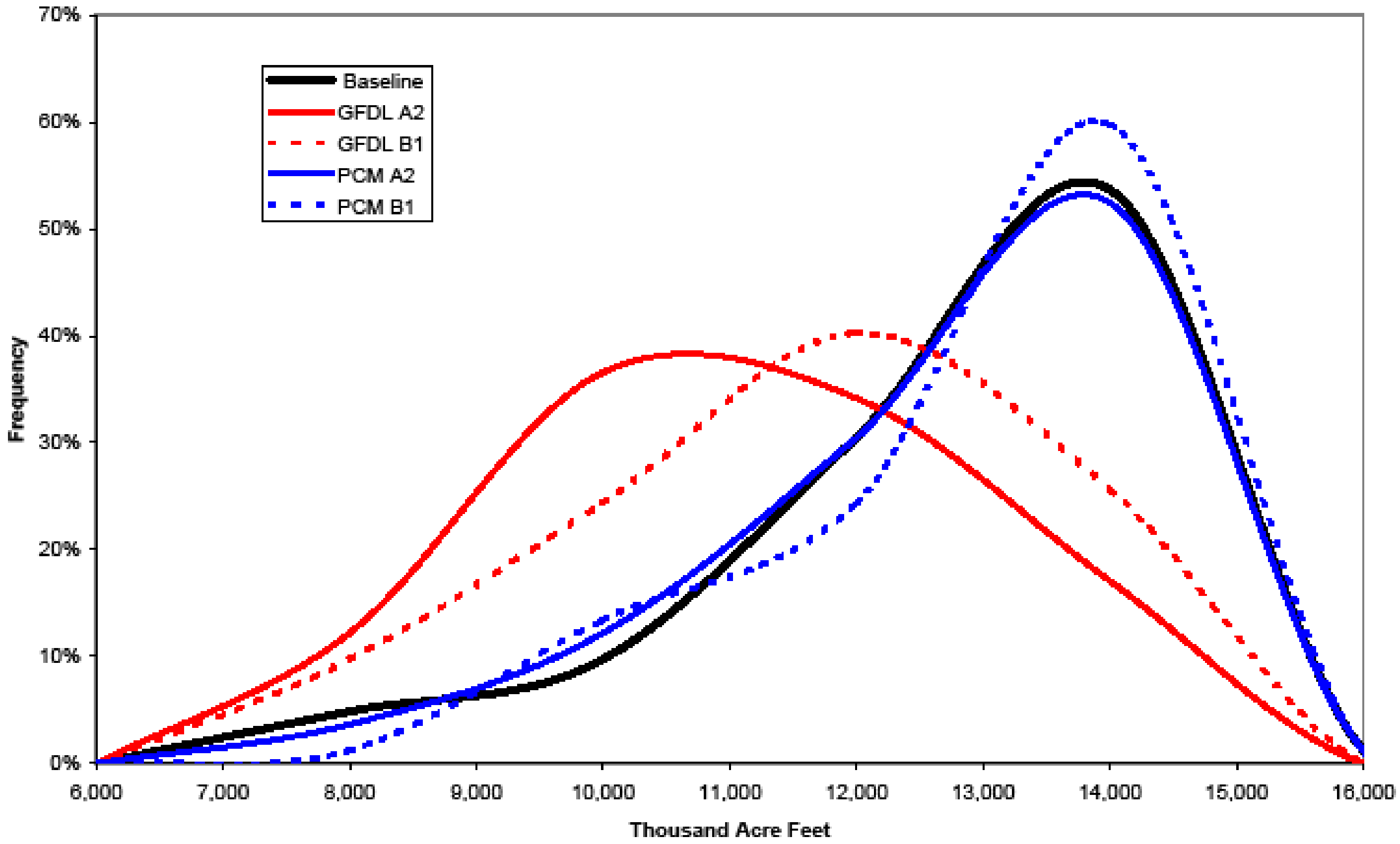
Downside risk

- This is a modification of the conventional theory of risk aversion.
- It is based on the notion that there is some asymmetry in risk attitudes towards outcomes.
- Downside outcomes (defined relative to some point) are weighed more heavily than upside outcomes.
- The concept was first applied in the financial literature in the 1970s – going broke is viewed differently than making a profit.
- It is likely to apply to many physical outcomes of climate change – e.g., asymmetry between having too little water and having too much.

Example of downside risk analysis
(Hanemann et al. 2009)

- Under the downscaled projections from the GDFL model (a medium-sensitivity GCM), but not the PCM model (a low-sensitivity GCM), there is a significant increase in downside risk with respect to water deliveries for agriculture in California's Central Valley.
- With downside risk aversion there is a significant risk premium associated with that change.

Annual deliveries to Central Valley agriculture, 2085



Downside risk-adjusted impact

CENTRAL VALLEY AGRICULTURE ANNUAL NET REVENUE 2085 ($ million)			
	MEAN	DOWNSIDE RISK FACTOR	ADJUSTED VALUE
BASELINE	$415	$132	$283
GFDL A2	$314	$178	$136
GFDL B1	$349	$163	$186
PCM A2	$397	$130	$267
PCM B1	$413	$126	$287
	LOSS COMPARED TO BASELINE		
GFDL A2	$101	$46	$147
GFDL B1	$66	$31	$97
PCM A2	$18	-$2	$16
PCM B1	$2	-$6	-$4

For GFDL, consideration of downside risk increases the estimate of loss by about 50%.
For PCM, consideration of downside risk reduces the estimate of loss.

Multivariate utility

- Use of an aggregate consumption function treating consumption as a perfect substitute for, or a separable from, “the environment” (non-market impacts) understates damages.
  - Weitzman (2009) “Additive Damages”
  - Sterner & Persson (2008) “A Sterner View”
  - Carbone & Smith (2008) “Evaluating Policy Interventions with General Equilibrium Externalities”
  - Fisher & Krutilla (1975)