The Impact of Climate Change on Extreme Events

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- Report:
  - Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention
  - Apurva Sanghi

Goal

- Measure how climate change affects future extreme events
- Reflect any underlying changes in vulnerability in future periods
- Estimate damage functions for each type of extreme event
- Measure future extreme events caused by climate change

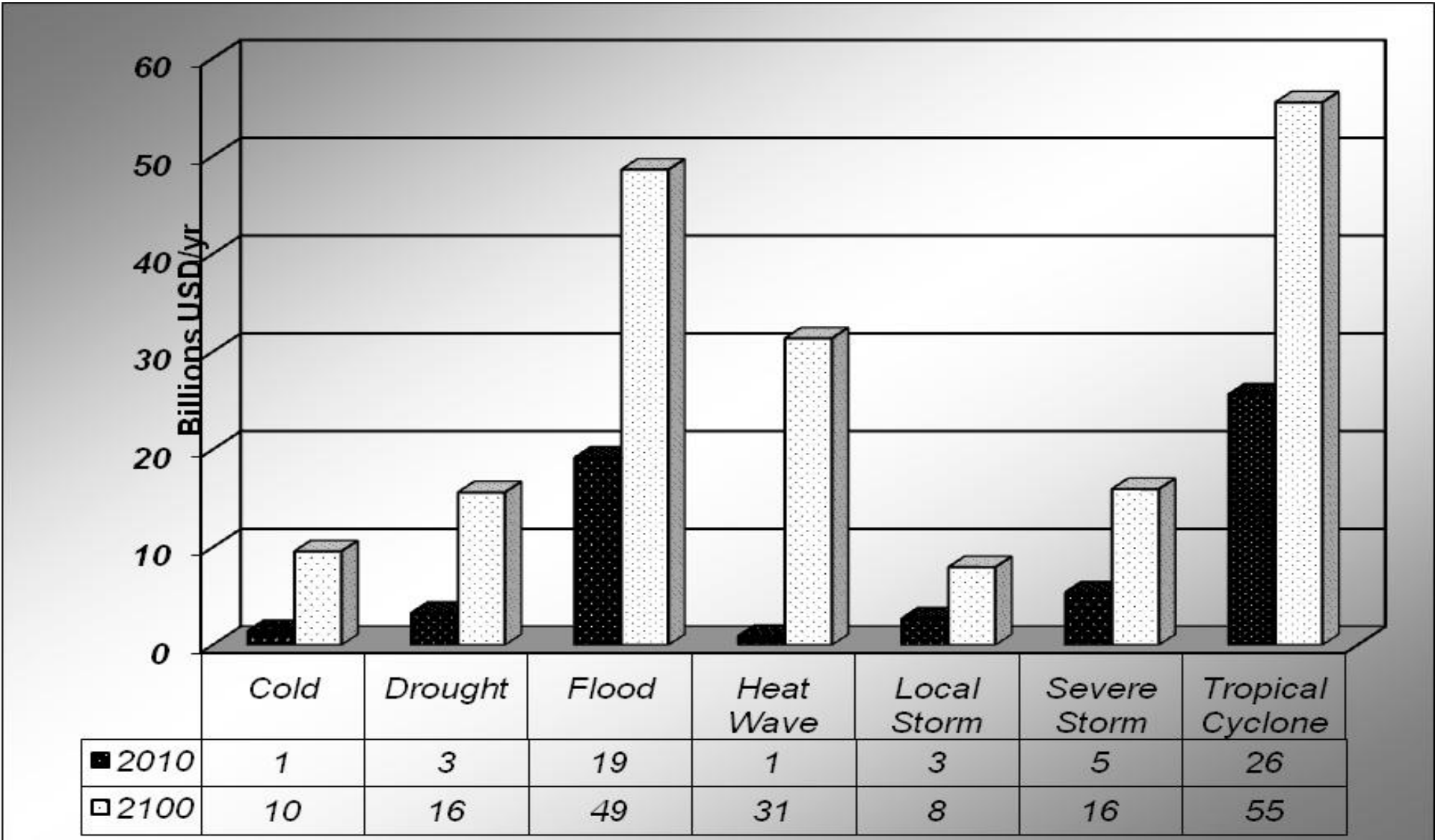
Extreme Events Examined

- Cold Events
- Drought
- Flood
- Hail
- Heat Waves
- Tornadoes
- Thunderstorms
- Tropical cyclones
- Severe Storms (extratropical)

Forecast Future Baseline Impacts

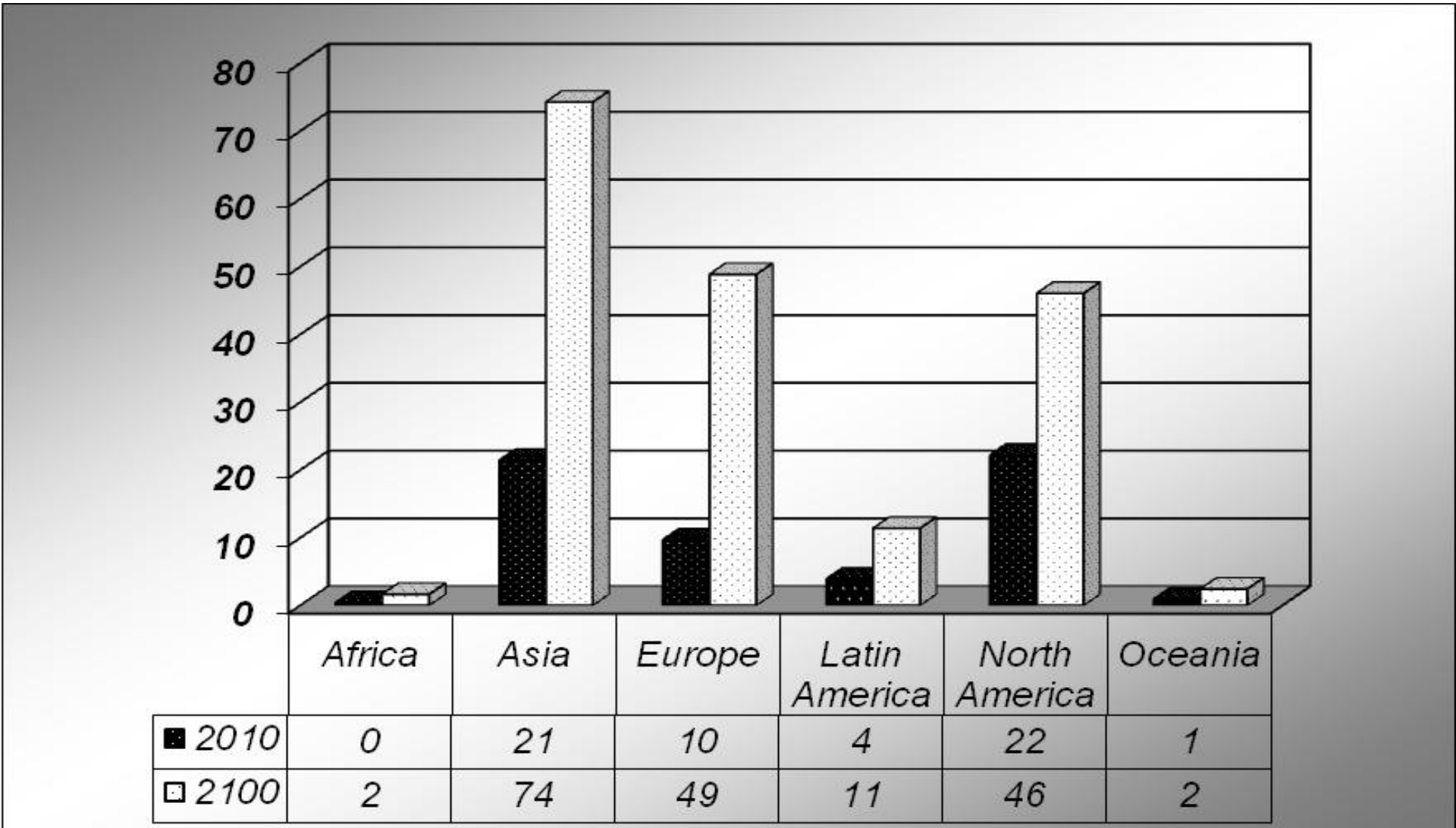
- Estimate damage function with EMDAT data
- Use forecasts of future income and population
- Forecast how damages and deaths will change as income and population increase

Current and 2100 Baseline Impacts of Extreme Weather Events



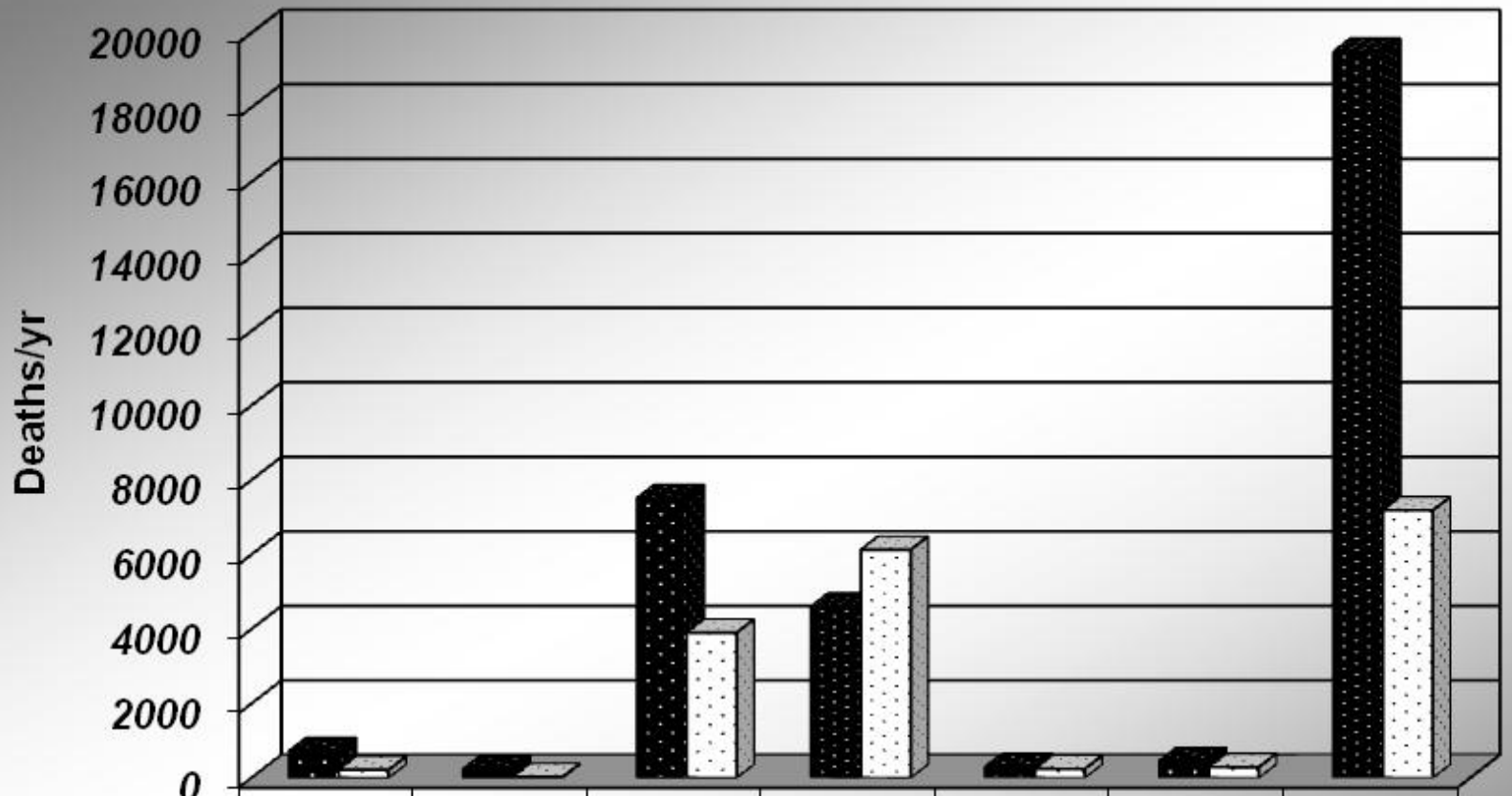
	Cold	Drought	Flood	Heat Wave	Local Storm	Severe Storm	Tropical Cyclone
2010	1	3	19	1	3	5	26
2100	10	16	49	31	8	16	55

Extreme Event Damages by Region



	Africa	Asia	Europe	Latin America	North America	Oceania
2010	0	21	10	4	22	1
2100	2	74	49	11	46	2

Current and Future Deaths by Extreme Event

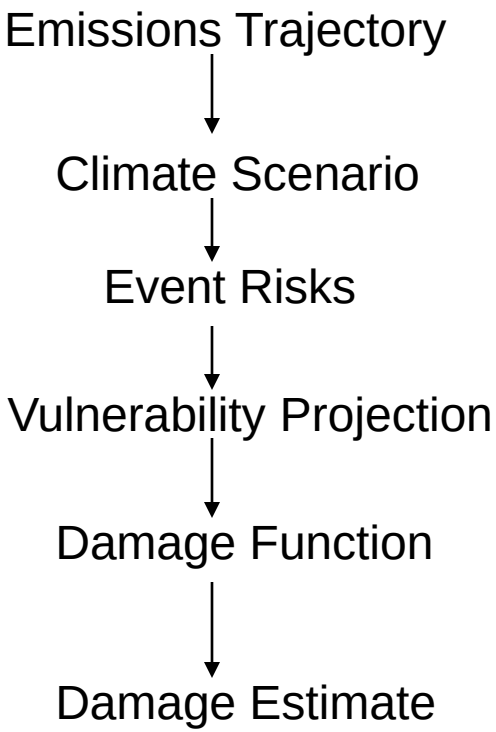


	Cold	Drought	Flood	Heat Wave	Local Storm	Severe Storm	Tropical Cyclone
2010	716	234	7508	4598	295	451	19486
2100	215	25	3898	6123	239	287	7180

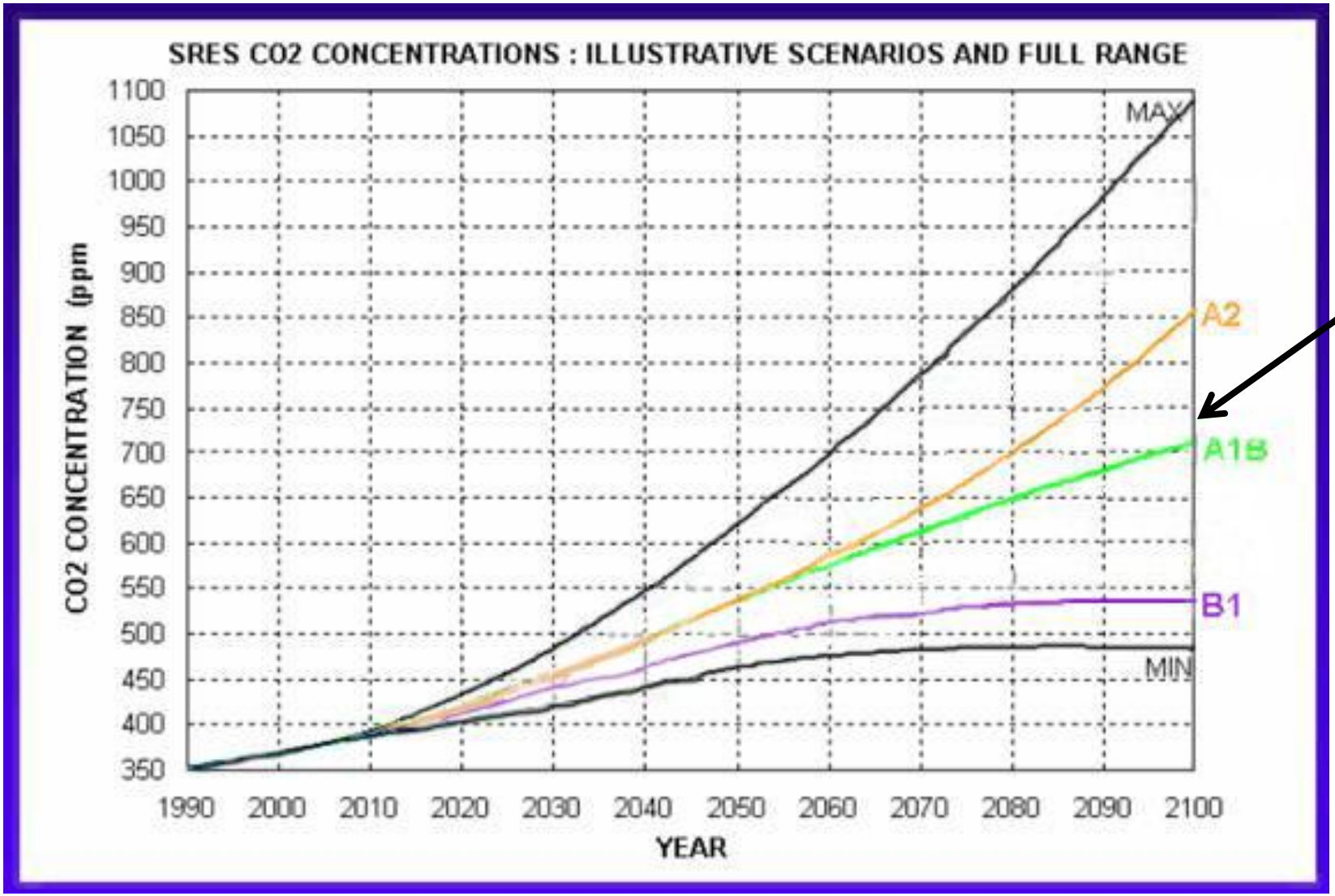
Past Climate Results

- IPCC 1996 guesses CC increases US tropical cyclone damages by 0.02% of GDP and world damages of 0.002% of GWP
- Nordhaus 2006 estimates CC doubles US tropical cyclone damages (0.06% of GDP)
- Narita et al 2007 estimate CC doubles world tropical cyclone damages by 0.006% GWP
- Stern guesses CC increases all extreme event damages by 5% of GWP

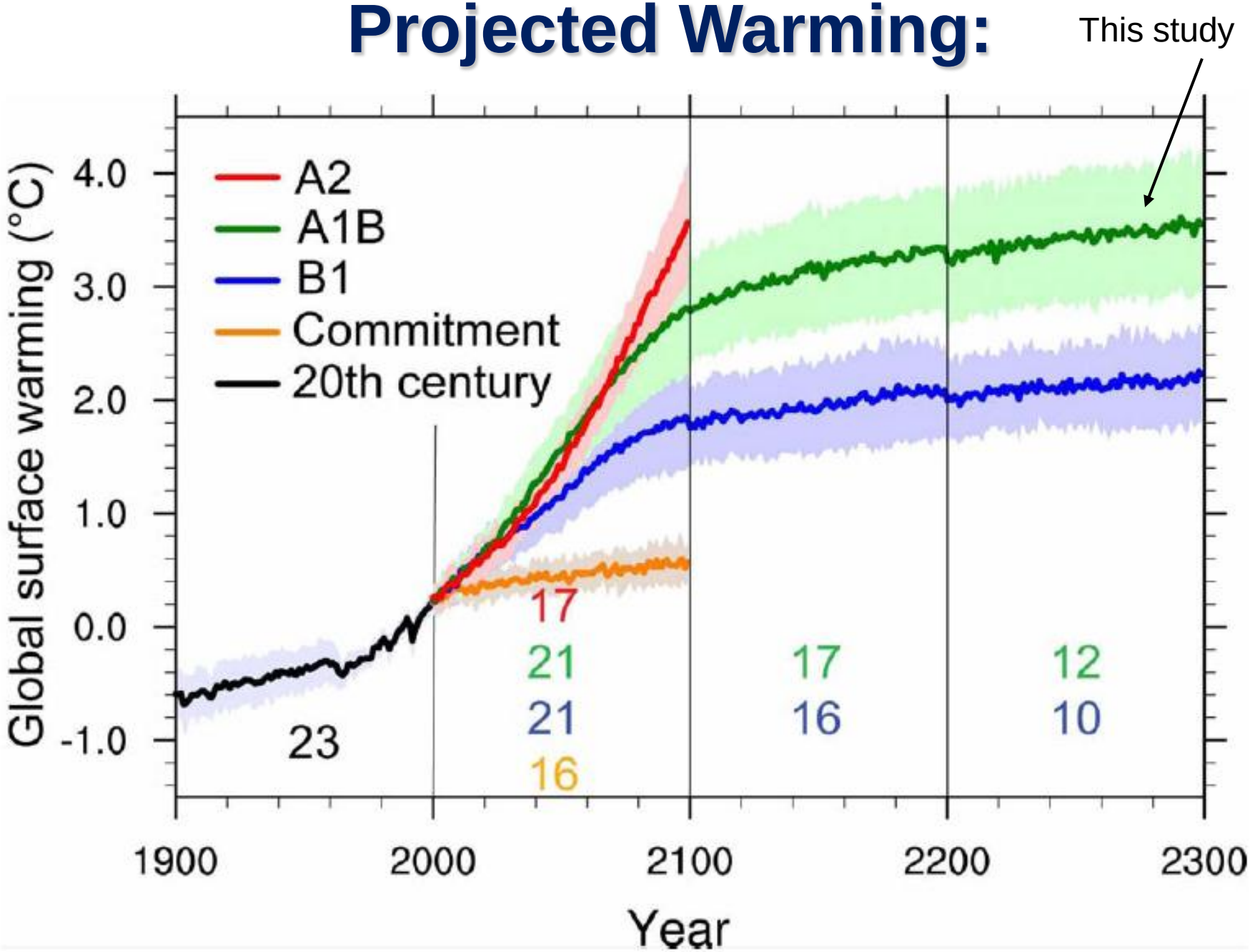
Integrated Assessment Model



IPCC Emissions Scenarios



Projected Warming:



Using Climate Models to Estimate Changing Incidence of Extreme Events

- Some events can be inferred directly from climate model output
  - Heat waves and cold snaps
  - Droughts and certain kinds of floods
  - Large-scale non-tropical wind storms
- Some must be inferred indirectly, by using sub-models (e.g. “downscaling”)
  - Tropical cyclones, thunderstorms, tornadoes, hail storms

Climate Models

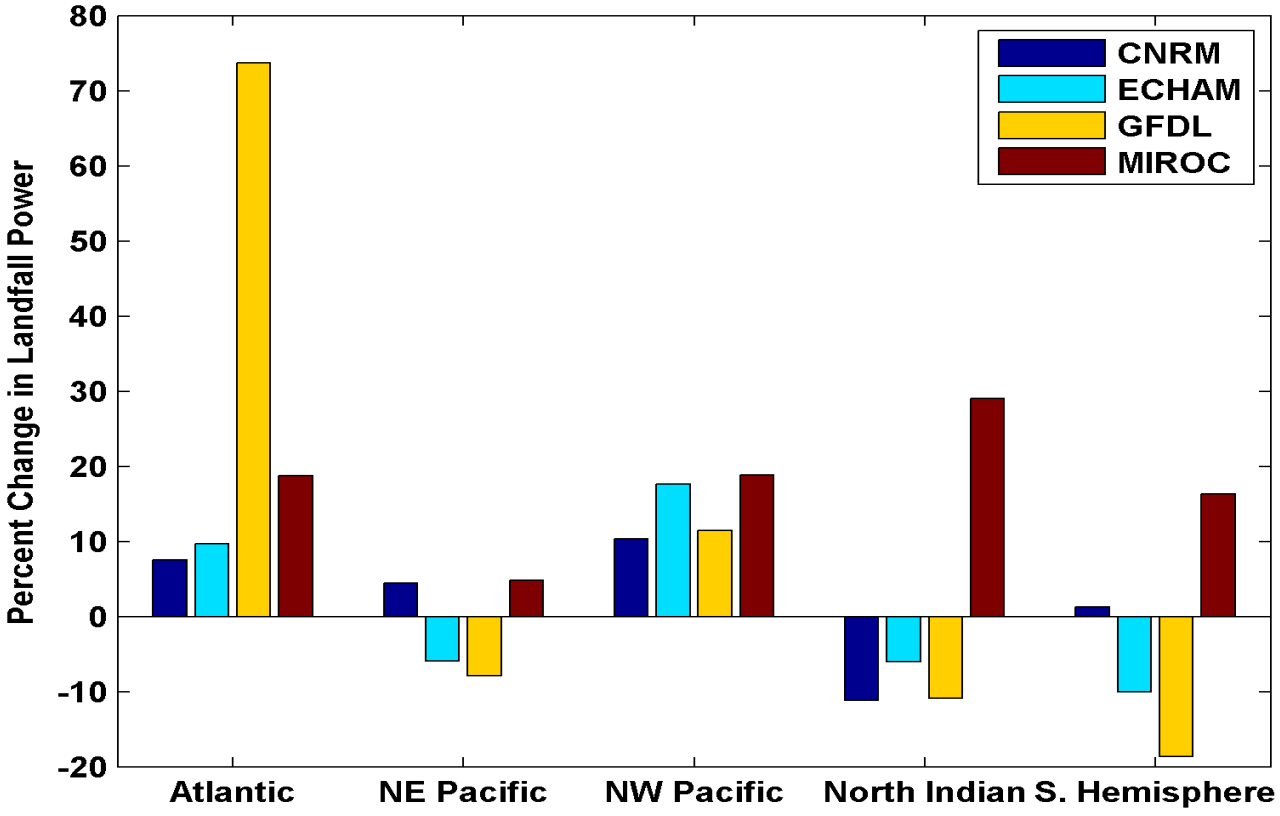
- CNRM
- ECHAM
- GFDL
- MIROC (tropical cyclones only)

Tropical Cyclone Generator

- **Step 1**: Seed each ocean basin with a very large number of weak, randomly located cyclones
- **Step 2**: Cyclones are assumed to move with the large scale atmospheric flow in which they are embedded, taken from the global climate model
- **Step 3**: Run a detailed cyclone intensity model for each event, and note how many achieve at least tropical storm strength
- **Step 4:** Using the small fraction of surviving events, determine storm statistics.

Details: Emanuel et al., Bull. Amer. Meteor. Soc., 2008

Tropical Cyclone Power by Ocean Basin



US Tropical Cyclone Damage Function

	Constant	Minimum Pressure	Income	Populat. Density
Damage Model	607.5 (10.39)	-86.3 (9.96)	0.370 (0.45)	0.488 (1.53)
Fatality Model	247.5 (4.10)	-33.3 (3.69)	-2.35 (1.74)	1.28 (2.78)

International Tropical Cyclone Damage Function

	Constant	Income	Populat. Density
Damage	15.17 (22.77)	0.415 (6.44)	-0.21 (3.04)
Fatality	6.25 (18.20)	-0.477 (14.01)	0.07 (1.86)

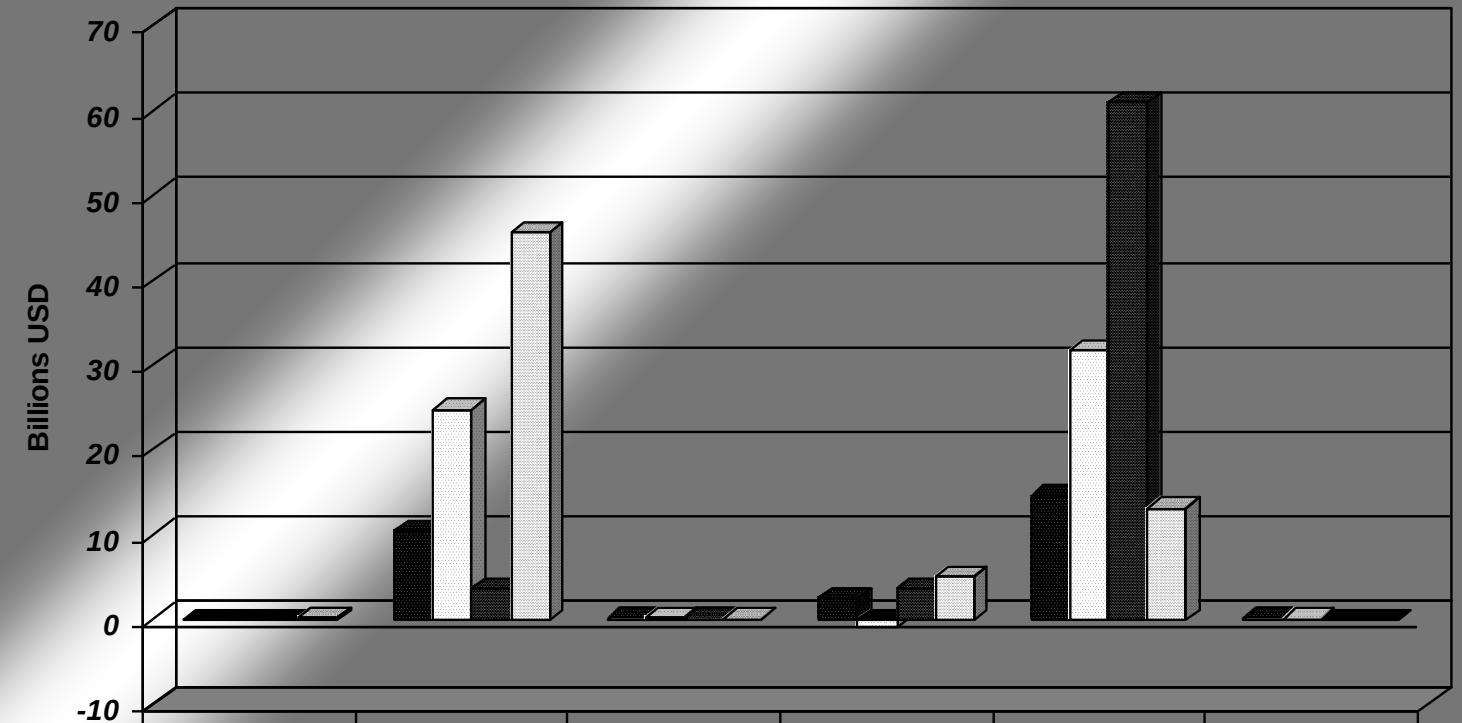
Baseline Tropical Cyclone Global Damages

- Current Damages: $26 billion/yr
- Future Damages: $55 billion/yr
- Current Global Deaths: 19,500/yr
- Future Global Deaths: 7,200/yr
- Change in 2100 because of higher population and income
- Current climate for baseline estimates

Climate Change Impacts on Tropical Cyclones in 2100

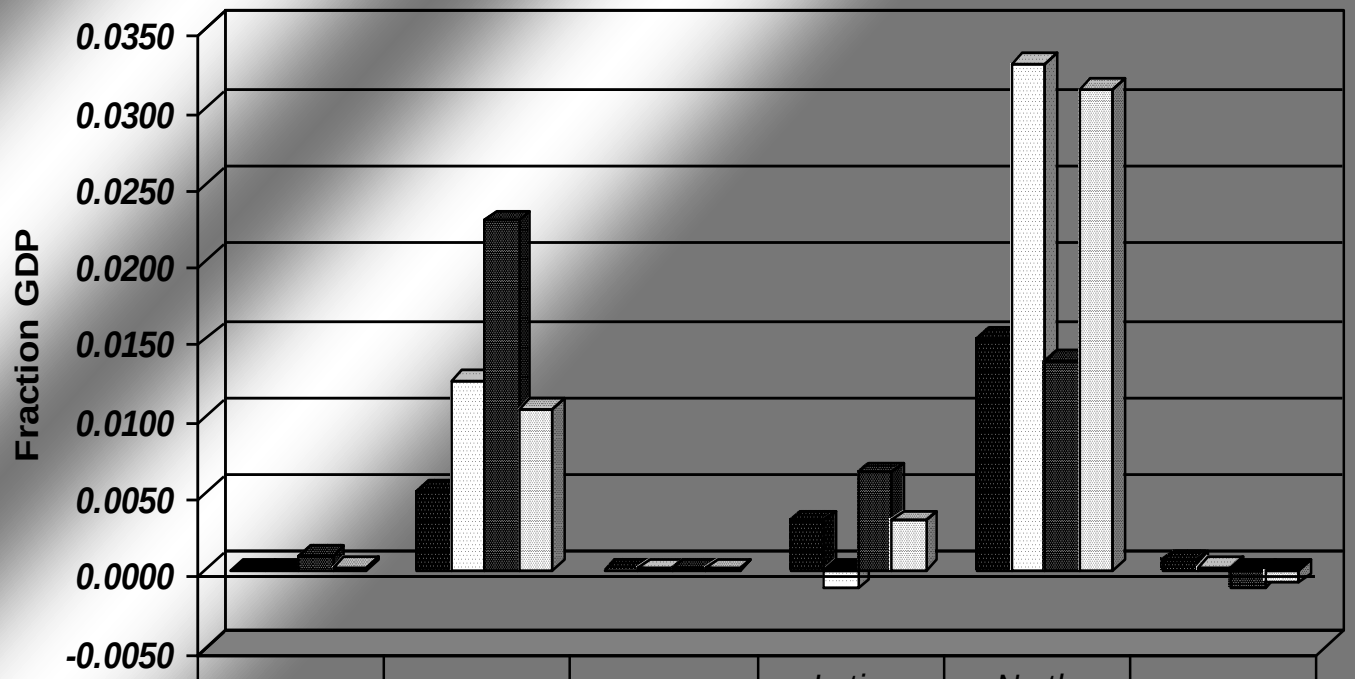
	CNRM	ECHAM	GFDL	MIROC
Damages (billions)	$19.9	$54.7	$70.2	$69.7
Deaths	760	-1500	-3300	1300

Impact of Climate Change on Regional Cyclone Damage



	Africa	Asia	Europe	Latin America	North America	Oceania
CNRM	0	10	0	3	15	0
ECHAM	0	25	0	-1	32	0
GFDL	0	4	0	4	61	0
MIROC	0	46	0	5	13	0

Climate Change Cyclone Impacts as a Percent of GDP



	Africa	Asia	Europe	Latin America	North America	Oceania
CNRM	0.0000	0.0051	0.0000	0.0032	0.0150	0.0006
ECHAM	-0.0001	0.0122	0.0000	-0.0012	0.0328	0.0002
GFDL	0.0009	0.0226	0.0000	0.0063	0.0136	-0.0011
MIROC	0.0002	0.0104	0.0000	0.0032	0.0311	-0.0009

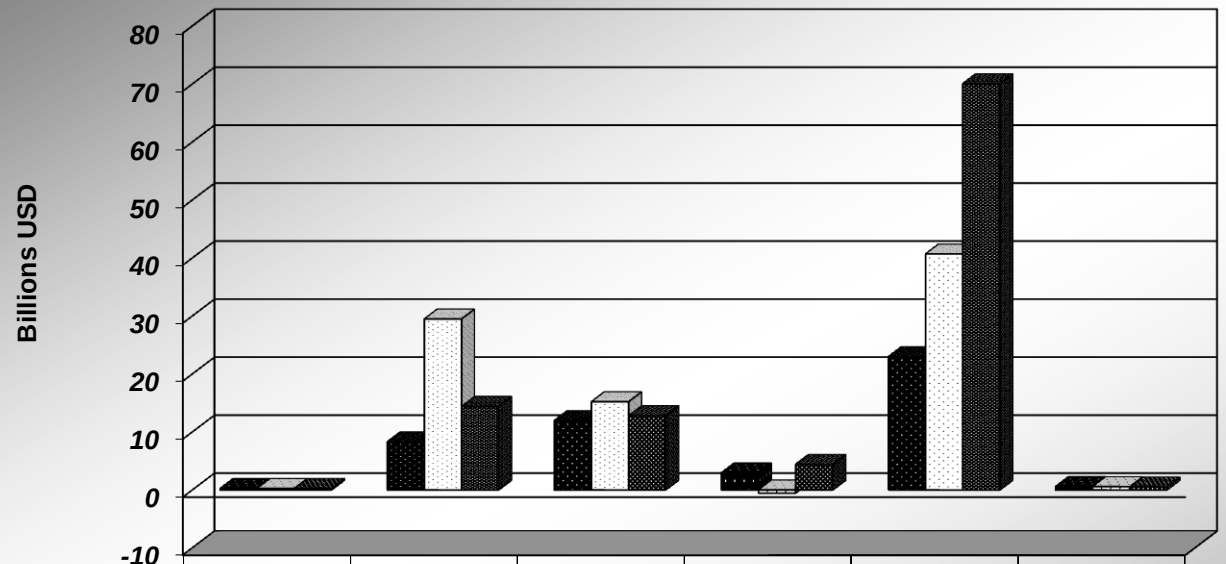
Climate Change Impact by 2100 on All Extreme Events

	CNRM	ECHAM	GFDL
Damages ($billion/yr) (%GDP)	$47.0 (0.008%)	$85.6 (0.015%)	$102.5 (0.018%)
Deaths (per year)	1750	-500	-2277

Climate Change Damages by Event

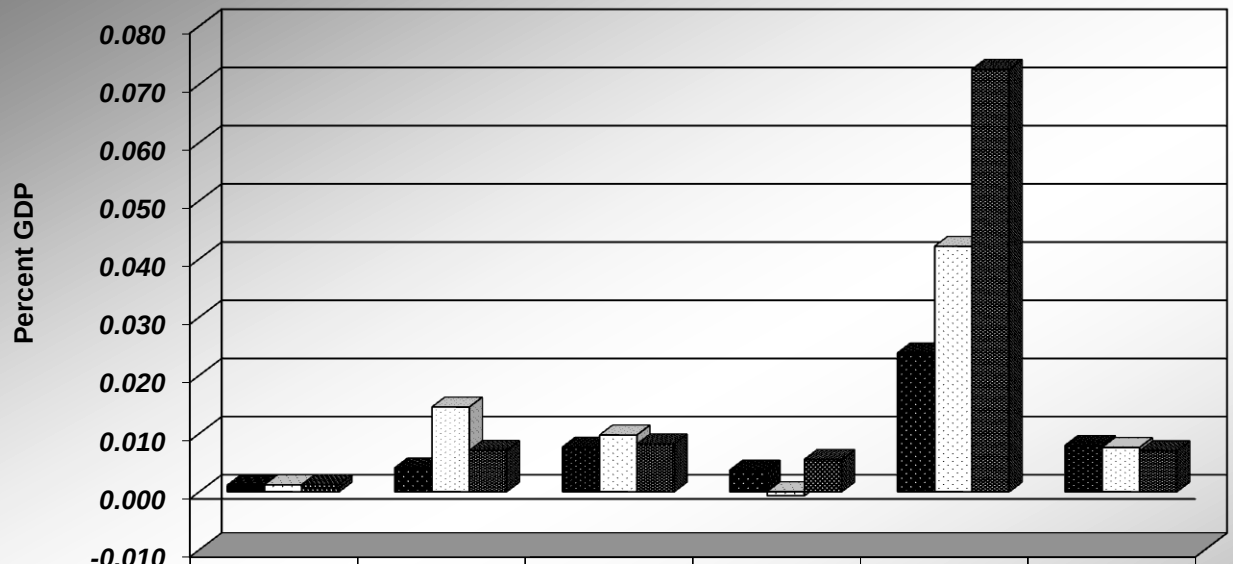
	Cold	Drought	Flood	Heat	Local Storms	Severe Storms	Tropical Cyclone
CNMR	3	0	0	3	6	16	20
ECHAM	3	0	0	6	6	16	55
GFDL	6	0	1	5	6	16	70

Climate Change Extreme Event Damages by Region



	Africa	Asia	Europe	Latin America	North America	Oceania
CNMR	0	8	12	3	23	1
ECHAM	0	29	15	-1	41	1
GFDL	0	14	13	4	70	1

Climate Change Extreme Event Damages in % GDP



	Africa	Asia	Europe	Latin America	North America	Oceania
CNMR	0.001	0.004	0.008	0.004	0.024	0.008
ECHAM	0.001	0.015	0.010	-0.001	0.042	0.008
GFDL	0.001	0.007	0.008	0.006	0.073	0.007

Limitations

- Non hurricane impacts uncertain
- Country scale may be too coarse- need finer scale
- Need better data about damages and extreme events
- Ecosystem effects are not measured
- Adaptation is not explicitly modeled

Summary

- Predicted climate change impacts from all extreme events (including tropical cyclones) range from $47 to $100 billion/yr by 2100
- Equivalent to 0.008 to 0.018 percent of GWP by 2100
- Climate change has mixed effect on fatalities because tropical cyclone deaths may fall more than other deaths increase

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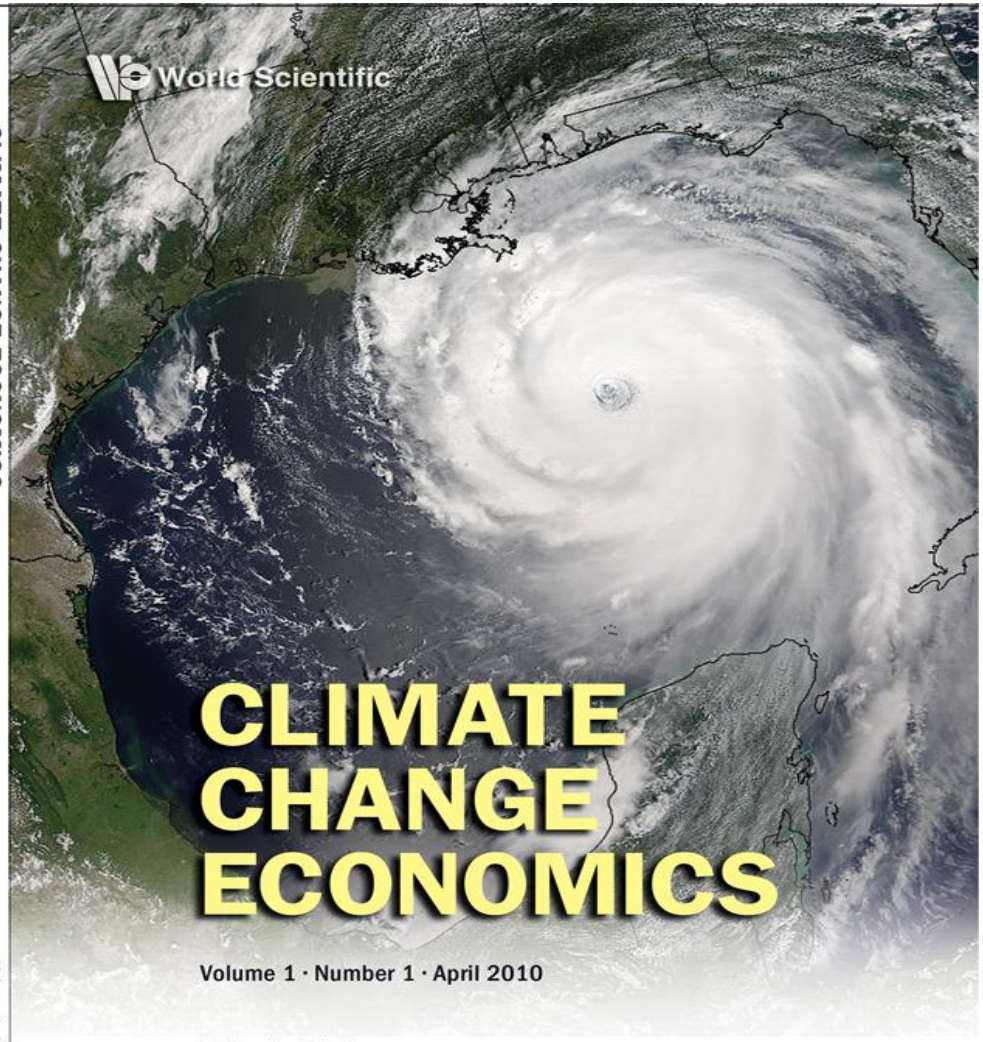

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