Evaluating the Impacts of Sea-Level Model Structural Uncertainty on Coastal Adaptation

Kelly Feke, Carolina Estevez Loza, & Tony Wong, School of Mathematics and Statistics, Rochester Institute of Technology

tony.wong@rit.edu

Introduction

- Sea-level rise and coastal flooding pose significant risks to coastal communities
- Efficacy of strategies to manage these risks depends on:
  - uncertainty in future emissions pathways
  - uncertainty in future socioeconomic change
  - uncertainty in geophysical factors (e.g., climate sensitivity)
  - uncertainty stemming from numerous plausible representations of processes within a computational model, so which structure is employed or "correct" is uncertain (i.e., **model structural uncertainty**)
- Model averaging can address this, but introduces new uncertainties (e.g., *Is the "correct" model within the set of models used?* But also… *There* ***isn't*** *a "correct" model…*)
- Can be preferable to ***characterize*** deep uncertainties through multiple probability density functions (pdfs) instead of attempts to ***quantify*** it.
- So, we use the **U.S. Gulf of Mexico coast** as a case study region to ask:
  What are the relative impacts of scenario and model structural deep uncertainties on coastal adaptation and impacts?

Workflow

Sea-level projections using CMIP6 models

Antarctic & Greenland ice sheets, thermal expansion, and glaciers and ice caps contributions to global sea levels[1]

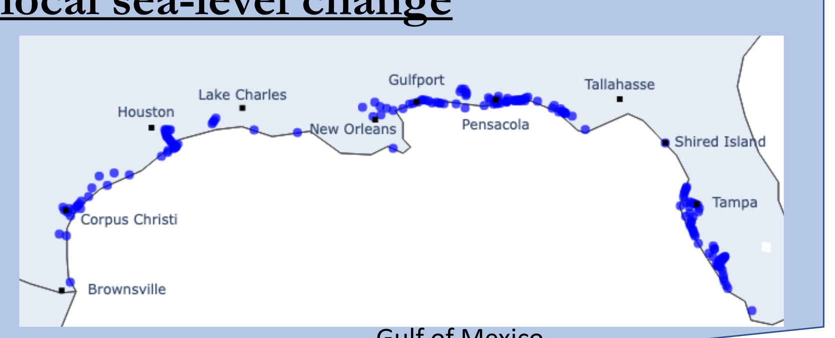
Deep uncertainties

Structural: 20 GCM configurations (see **CMIP6 Models Used ↘**)

Scenario: 3 SSP-RCP pathways (1000 simulations x SSP1-2.6, SSP2-4.5, SSP5-8.5)

Downscaling to local sea-level change

Local sea level ***fingerprints*** to get local sea-level change due to global contributions from ice sheets, thermal expansion, glaciers/ice caps for **U.S. Gulf of Mexico Coast**



Local coastal impacts using MimiCIAM

Mimi Coastal Impact and Adaptation Model[2] to estimate net present value (NPV) of total adaptation costs from **protection** or **retreat**, and damages from **inundation, wetland loss,** and **flooding**

ANOVA and partial η^2 & ω^2 effect sizes

Effect sizes η^2 & ω^2 quantify portion of variance in output explained by group membership (which model/scenario?), accounting for variance explained by other variables

$$\eta^2 = \frac{SS_{between}}{SS_{between} + SS_{within}}$$

ω^2 is similar, corrects for sample vs population bias

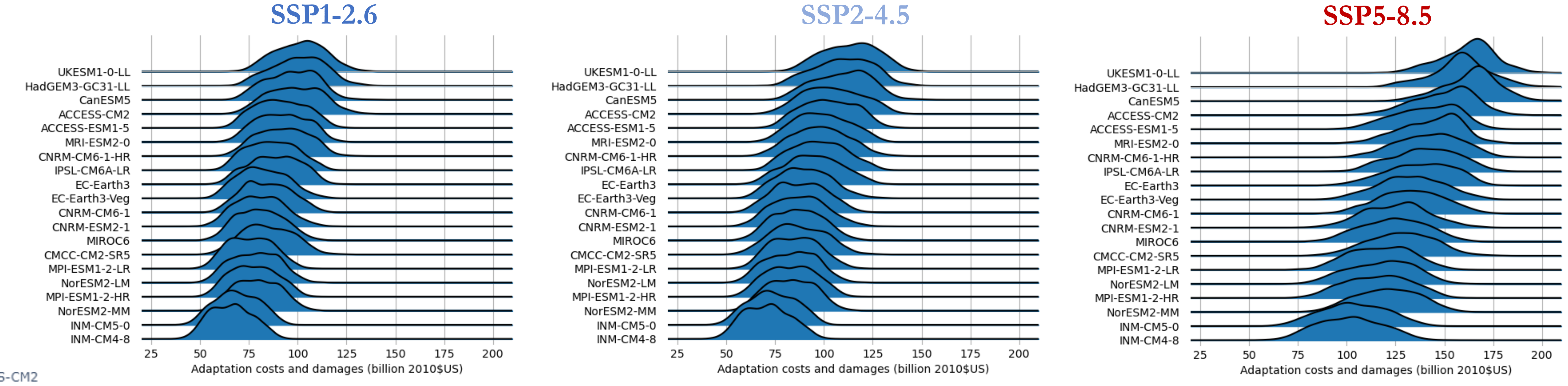
General guidelines:

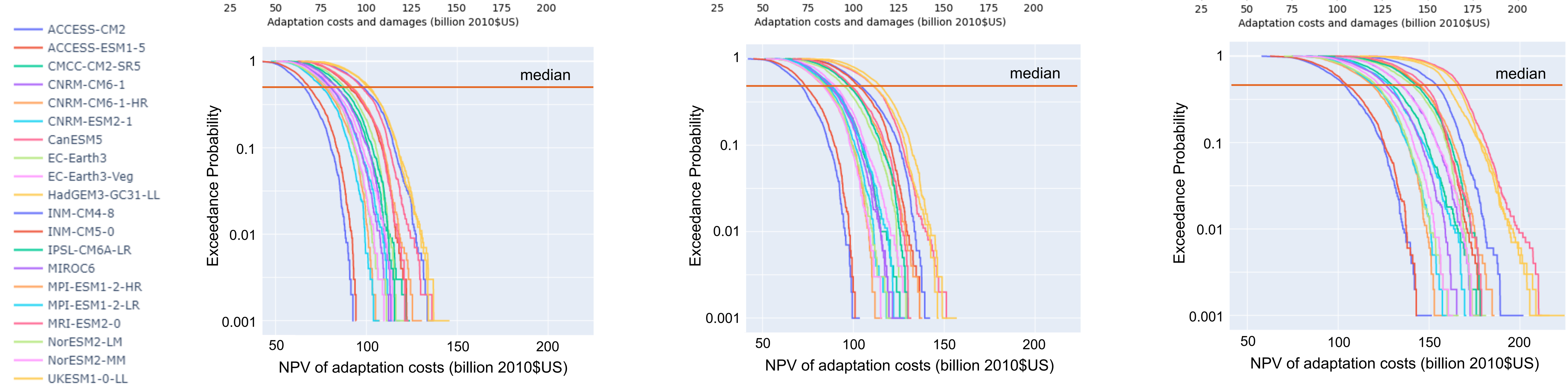
Effect size	η^2 or ω^2
Small	0.0099
Medium	0.0588
Large	0.1379

Results

Net present value (NPV) of total least-cost adaptation costs for U.S. Gulf of Mexico coast

SSP1-2.6 **SSP2-4.5** **SSP5-8.5**





Analysis of Variance in NPV, stemming from scenario and model structural uncertainties

Overall model

Uncertainty	partial η^2	partial ω^2
model	0.60	0.60
scenario	0.70	0.70
model:scenario interaction	0.09	0.09

Conditioned on SSP1-2.6

Uncertainty	η^2	ω^2
model	0.16	0.16
	Moderate/large effect[3]	

Conditioned on SSP2-4.5

Uncertainty	η^2	ω^2
model	0.19	0.19
	Moderate/large effect	

Conditioned on SSP5-8.5

Uncertainty	η^2	ω^2
model	0.68	0.68
	Large effect	

CMIP6 Models Used

Model	Center	Model (cont.)	Center
ACCESS-CM2	CSIRO & ARCCSS	INM-CM4-8	INM
ACCESS-ESM1-5	CSIRO & ARCCSS	INM-CM5-0	INM
CanESM5	CCCma	IPSL-CM6A-LR	IPSL
CMCC-CM2-SR5	CMCC	MIROC6	MIROC
CNRM-CM6-1	CNRM & CERFACS	MPI-ESM1-2-HR	MPI-M
CNRM-CM6-1-HR	CNRM & CERFACS	MPI-ESM1-2-LR	MPI-M
CNRM-ESM2-1	CNRM & CERFACS	MRI-ESM2-0	MRI
EC-Earth3	EC-Earth-Cons.	NorESM2-LM	NCC
EC-Earth3-Veg	EC-Earth-Cons.	NorESM2-MM	NCC
HadGEM3-GC31-LL	MOHC	UKESM1-0-LL	MOHC

Take-aways

- Substantial variation in adaptation costs across models…
  - even in the median/low quantiles
  - even when conditioned on a single scenario
- Effect size on NPV from **model structural uncertainty** comparable to **scenario uncertainty**
- When conditioned on scenario…
  - … have a **moderate/large effect size** in low & moderate GHG/socioeconomic scenarios (SSP1-2.6, SSP2-4.5), and
  - … a **large effect size** in high-end scenario (SSP5-8.5)

Digital version of this poster:

References

1. Hermans *et al.* 2021, doi: 10.1029/2020GL092064
2. Wong *et al.* 2022, doi: 10.1029/2022EF003061
3. Cohen 1988, doi: 10.4324/9780203771587

Acknowledgements

This material is based upon work supported by the National Science Foundation under Award No. DMS-2213432. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

GC33F-1218