Which Scenario Should We Design For? Insights from House Elevation for the Multiple PDF Problem

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HOUSE ELEVATION

Households elevate their homes to manage flood risks, but regulations and guidance are silent on key questions [1, 2].

- Q1 How to adapt guidance to building characteristics or household preferences?
- Q2 How does nonstationary hazard change guidance?
- Q3 Which model of nonstationary hazard should be used?

(a) Selinsgrove, PA

(b) Houston, TX

(c) Plaquemines Parish, LA

(d) Dare County, NC

Figure 1: 📷: (a) JDG, (b) Google Maps, (c) Mitch Epstein / New York Times (d) Rob Nichols.

CASE STUDY: NORFOLK, VA

We model a *hypothetical* house in Norfolk, VA, where sea level rise drives nonstationary future flood hazard, following the approach of [1].

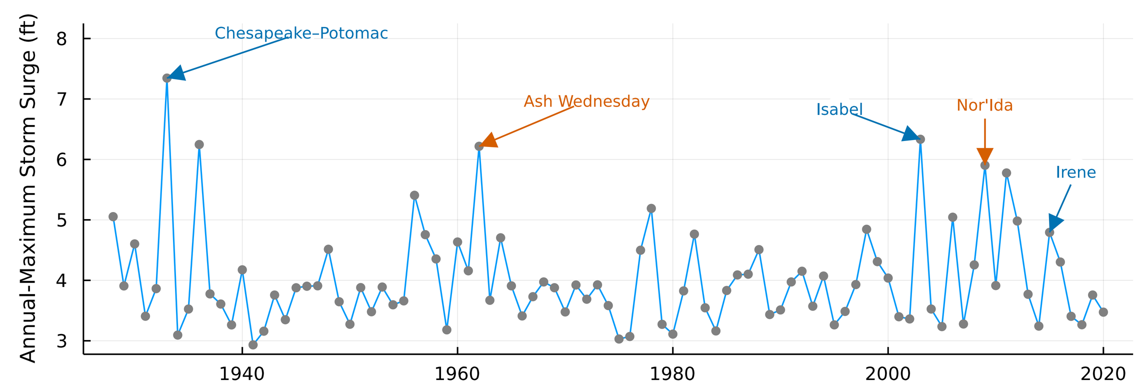

Figure 2: Time series of annual maximum of storm surge (after subtracting mean sea level) at Sewells Point, VA (NAVD datum).

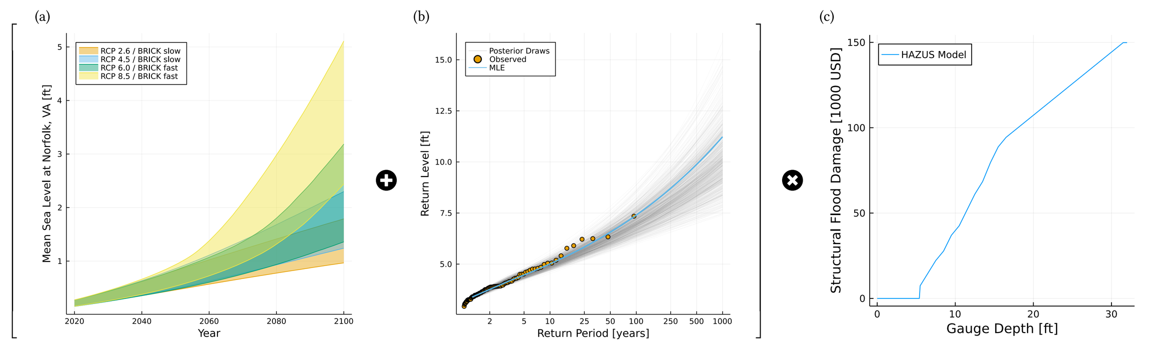

Figure 3: Neglecting hydrodynamics, we add sea level rise (a; see ref. [3]) to a Bayesian GEV model of storm surge (b) to get flood hazard. The convolution of hazard and fragility (c; see ref. [1]) yields an assessment of damages and tradeoffs (fig. 6).

ONE SIZE DOESN'T FIT ALL!

- ▶ Tailoring guidance to specific building characteristics can improve outcomes
- ▶ Elevating to "base flood elevation (BFE) plus a foot" is not always optimal [1, 2]
- ▶ Both over- and under-building can be costly [4, 5]

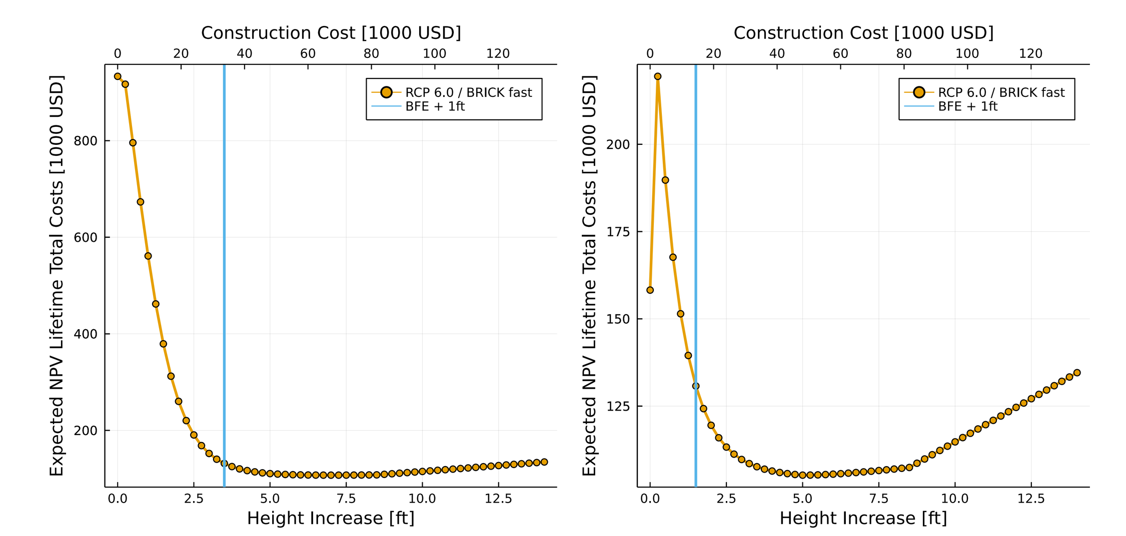

Figure 4: Tradeoffs between construction cost and expected NPV lifetime costs for houses initially situated (L) 2.5 ft and (R) 0.5 ft below the BFE under representative concentration pathway (RCP) 6.0 with fast BRICK dynamics. Note y-axes are not equal.

THE MULTIPLE PDF PROBLEM

Uncertainties from multiple model structures (*e.g.*, ice sheet dynamics) and/or scenarios (*e.g.*, emissions pathways) create multiple estimates of time-varing hazard, *i.e.* the ***Multiple PDF Problem***.

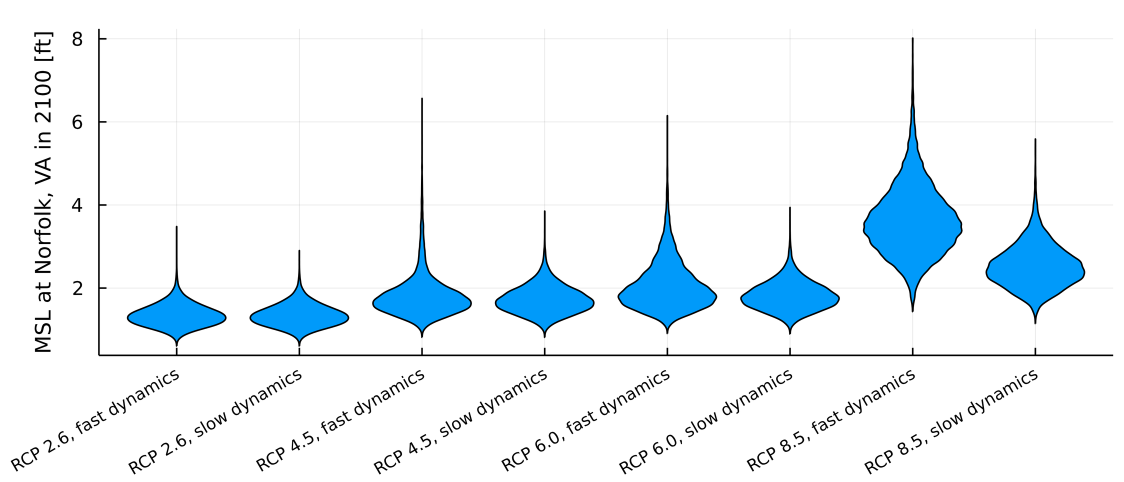

Figure 5: Sea level rise projections use the BRICK model [6]. We consider *eight time-dependent PDFs of sea level rise*: four RCP scenarios × two parameterizations of ice sheet processes.

Considering other models [3, 7, 8] would *compound* this problem. **Which PDF should long-lasting infrastructure like housing be designed for?**

REFERENCES

1. Zarekarizi, M. et al. *Nature Communications.* 2. Xian, S. et al. *Journal of Hydrology.* 3. Ruckert, K. L. et al. *Scientific Reports.* 4. Ansar, A. et al. *Big Is Fragile: An Attempt at Theorizing Scale.* (2019). 5. Doss-Gollin, J. et al. *Earth's Future.* 6. Wong, T. E. et al. *Geoscientific Model Development.* 7. Kopp, R. E. et al. *Earth's Future.* 8. DeConto, R. M. et al. *Nature.* 9. Gelman, A. et al. *British Journal of Mathematical and Statistical Psychology.*

IT MATTERS WHICH PDF YOU CHOOSE!

Any optimal strategy or Pareto frontier is conditional upon an (explicit or implicit) model of future outcomes (see ref. [9] for a more philosophical discussion).

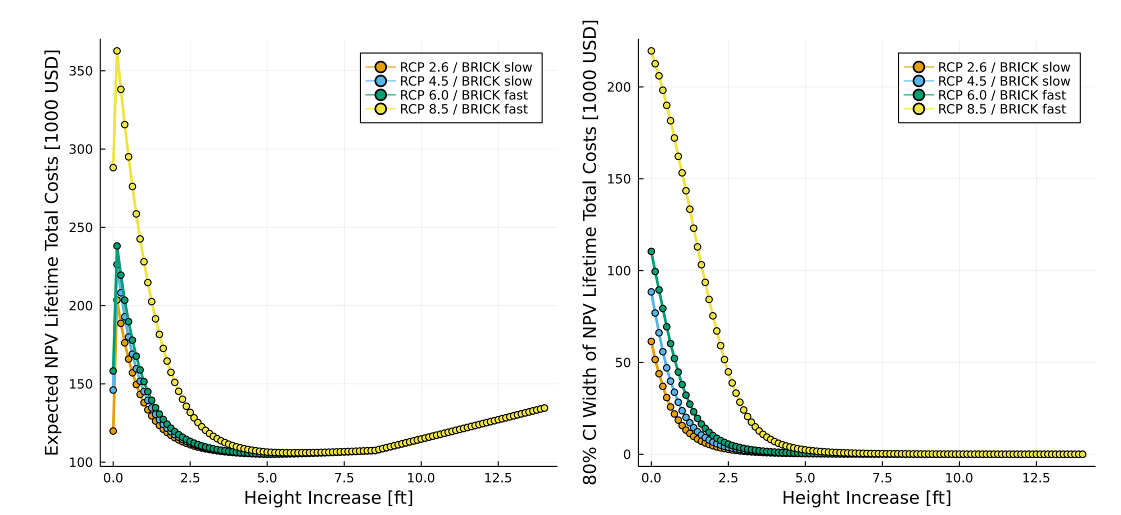

Figure 6: Tradeoffs between (L) construction cost and expected lifetime costs or (R) construction cost and the uncertainty of future lifetime costs depend on the model selected.

Weights assigned to PDFs or simulations, **including implicit uniform weights**, should be communicated transparently to facilitate critique and improvement

SYNTHESIZING PDFS FOR DECISION RELEVANCE

If there are only a few PDFs, then qualitative comparisions (*e.g.*, fig. 6) may be sufficient. With *many* PDFs (*e.g.*, fig. 5), further synthesis is needed.
We consider the *common case* of assessing decisions using simulations (SOWs) from each of K PDFs.

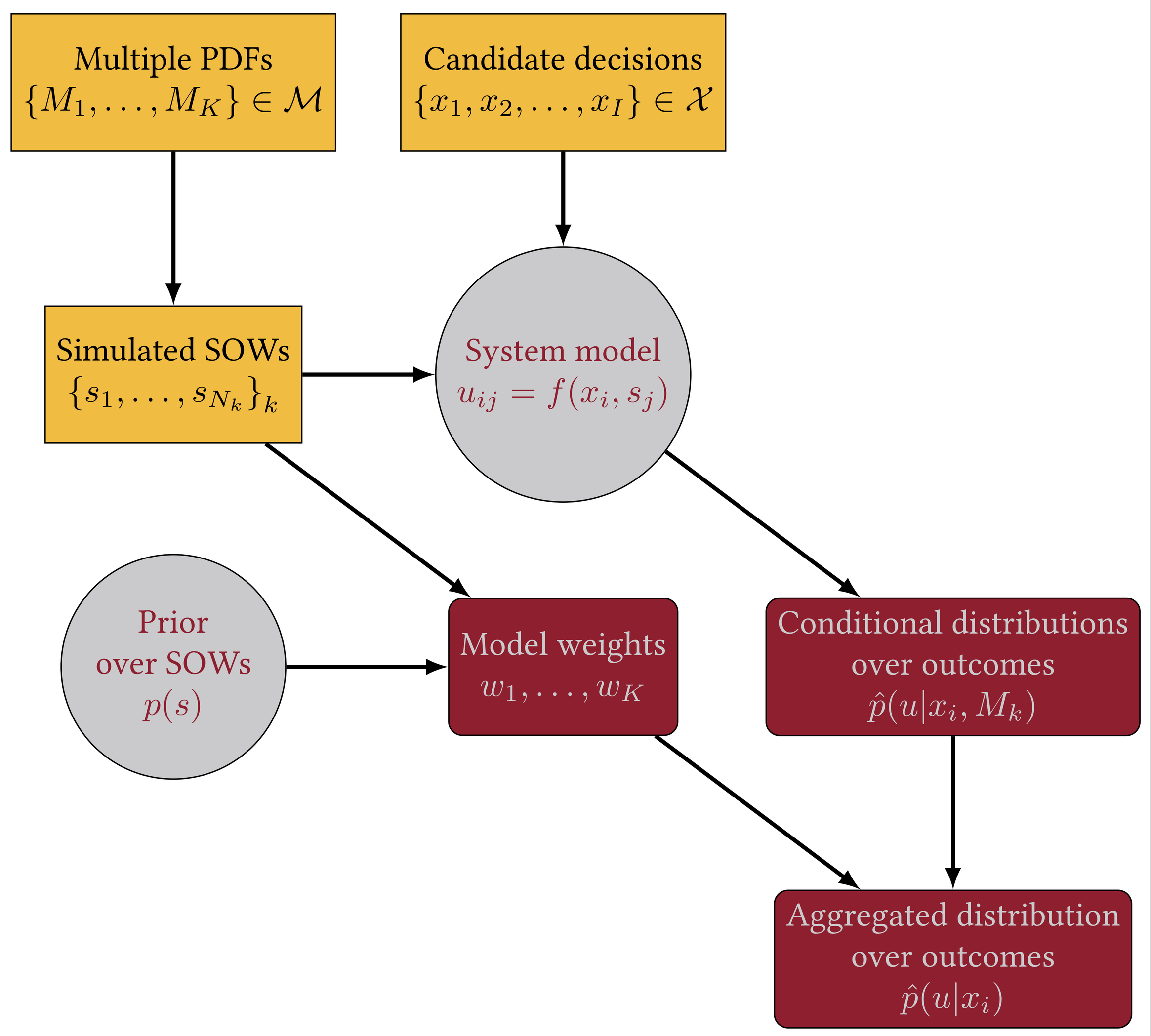

Figure 7: Sketch of the "Prior Model Averaging" framework.

WE'RE ALWAYS

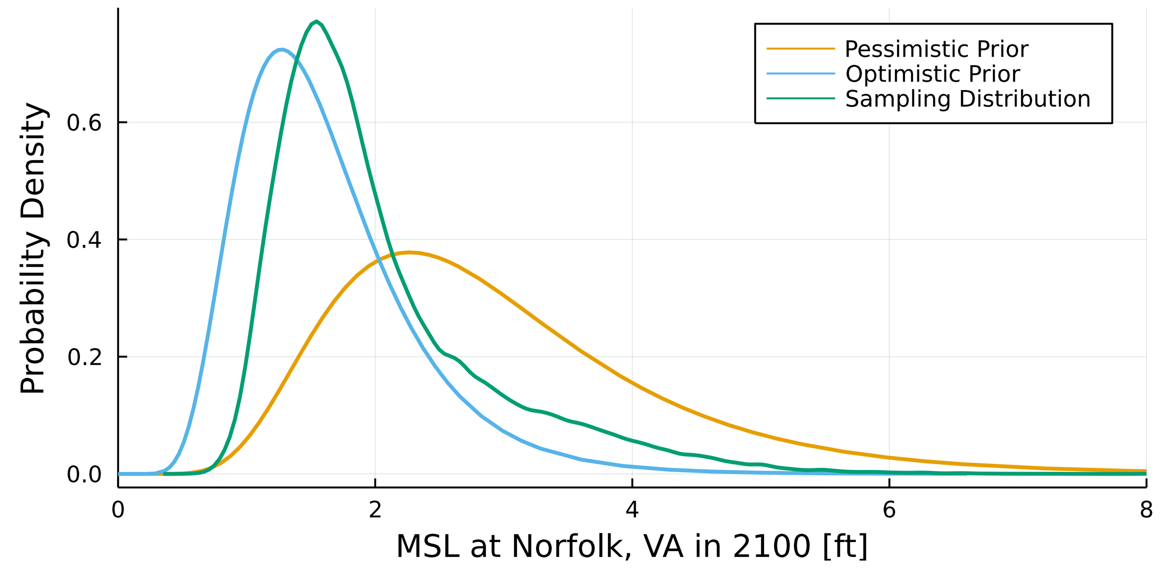

Figure 8: If we weight all scenarios equally, then our projection of MSL in 2100 follows the sampling distribution. This may or may not accurately reflect available information.

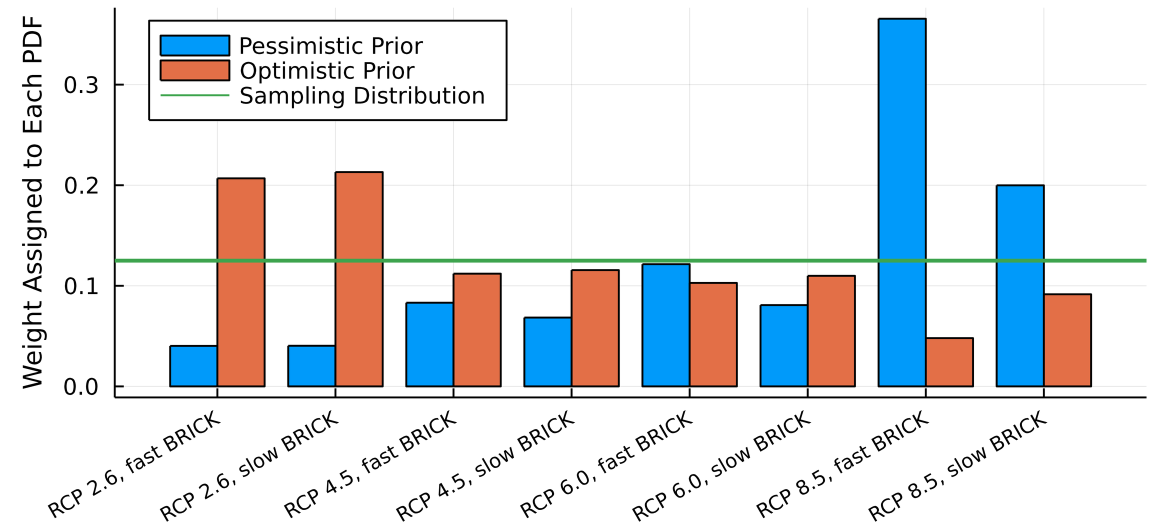

Figure 9: The prior model averaging approach (fig. 7) re-weights PDFs based on their distance, and that of other PDFs available, from the (ideally coproduced!) prior.

LOOKING AHEAD

This didactic example illustrates a need for better synthesis and communication of deep uncertainties for decision making. **LET'S COLLABORATE ON:**

- ▶ More complex models to capture more relevant metrics
- ▶ Better priors over nonstationary hazard
- ▶ Interacting, sequential decisions
- ▶ Inclusive assessment of ethical questions around scenario weighting

(a) Stormwater

(b) Bridge Clearance

Figure 10: House elevation is just one of many design problems where nonstationary hazards, subject to scenario and model structure uncertainties, drive outcomes. 📷: (a) JDG (b) D. Howard / Wikipedia.

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