Reducing Uncertainties in Flood Loss Estimates

…or… why your risk management strategy needs to consider low-frequency variability

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Thanks to ...

- Upmanu Lall
- David Farnham
- Michelle Ho
- Scott Steinschneider

and others

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Prediction objectives

Quantifying uncertainty: important but difficult

$$R = \mathbb{E}[P^*] + \lambda \mathbb{V}^{1/2}[P^*] \quad \text{where} \quad P^* = \Pr(X > X^*)$$

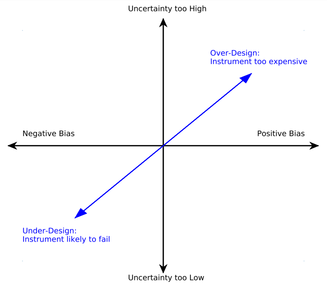


Figure 1: To adequately price flood risk, we need to capture the full probability distribution (Doss-Gollin et al., n.d.).

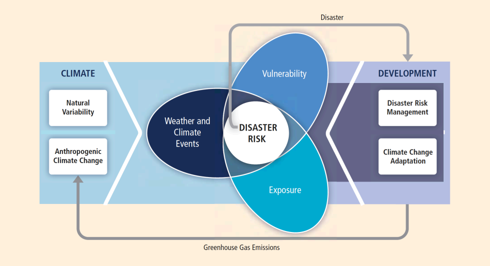


Figure 2: Depending on application, we can leverage information about large-scale climate, local environment, building characteristics, etc. to constrain flood risk estimates (fig: IPCC, 2012)

Consider uncertainty over instrument life

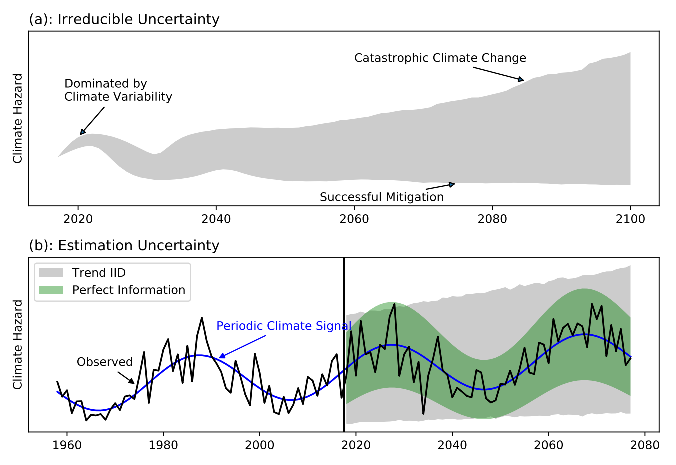


Figure 3: (a) Irreducible uncertainty cannot be resolved with better models or data and is dominated in the short term by chaotic behavior of the climate, and in the long term by the uncertainty in future climate change. (b) Informational uncertainty limits the potential to identify different climate signals. (Doss-Gollin et al., 2019, fig. 2).

Neglect LFV at your peril

El Niño: a cartoon of LFV

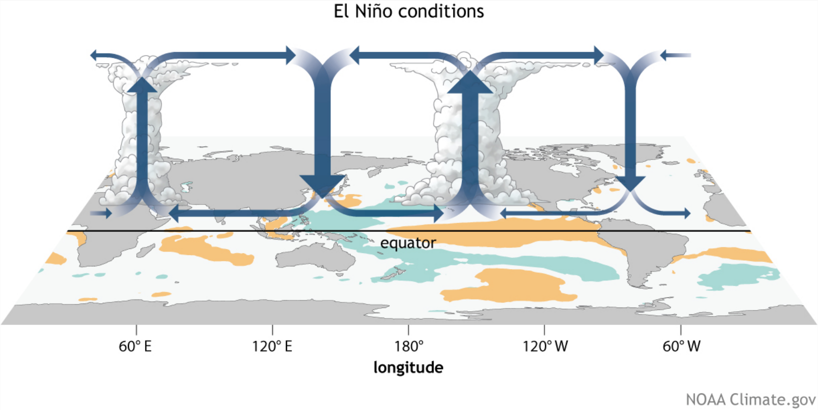


Figure 4: A sketch of how temperature anomalies in the equatorial Pacific affect global atmospheric circulations

Temporal structure: risk evolves over time

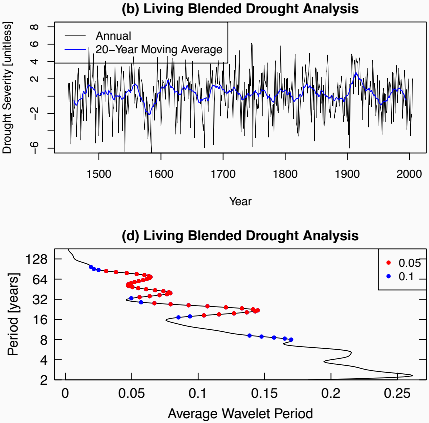


Figure 5: (b) 500 year reconstruction of summer rainfall over Arizona (Cook et al., 2010); and (b) a 100 year record of normalized, annual-maximum streamflow for the American River at Folsom. (d) The global wavelet power spectra of the time series shown in (b) (Doss-Gollin et al., 2019).

Spatial structure: portfolios have fat tails

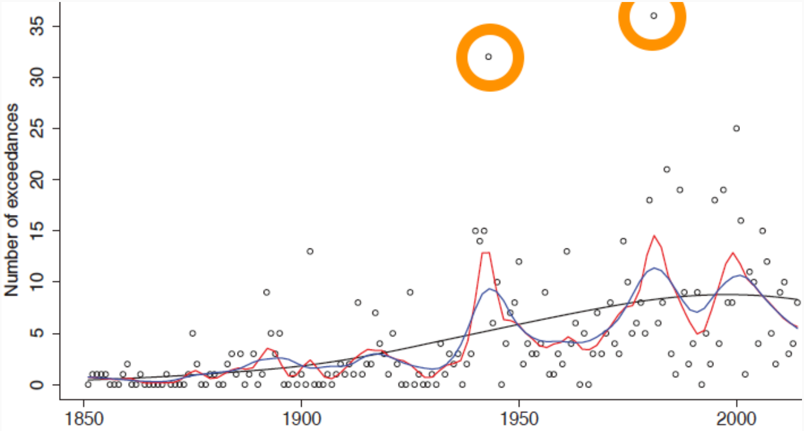
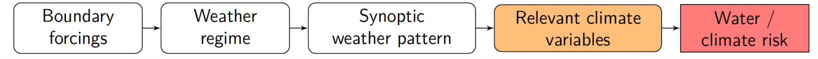


Figure 6: In a single year (1981), 40 assets owned by the Rio Tinto mining company collectively experienced 36 separate rainfall events which exceeded the nominal 10 year return period for 30 day precipitation (Bonnafous et al., 2017).

Case study: constraining long-range estimates of extreme rainfall in the Ohio River Basin

Robust understanding of mechanism enables estimation

Causal chain (see Hannachi et al., 2017; Nakamura et al., 2013)



Regional Extreme Precipitation

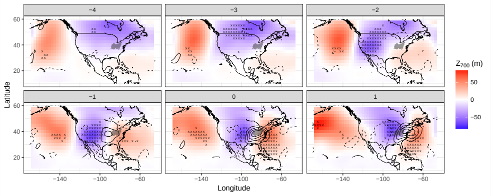


Figure 7: Daily anomaly composites of Z_{700} (shades) and Q_{700} (contours) for observed (reanalysis) record (Farnham et al., 2018, figure 4).

Flooding: persistent REPs

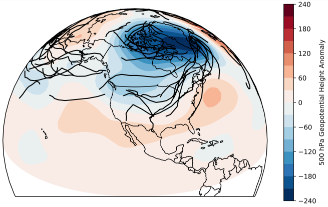


Figure 8: Z_{500} anomalies (contours) and extratropical cyclone tracks (lines) during April 2011.

GCM representation of REPs: 🗑

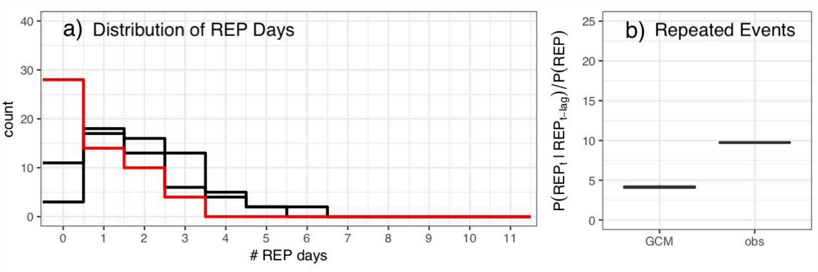


Figure 9: Figure 3. (a) Number of spring REP days by year for the observed record (red) and the two GFDL CM3 ensemble members (black). (b) Probability of REP event given that a REP event occurred the day prior (divided by the marginal probability) (Farnham et al., 2018, fig. 3).

Thus quantile-quantile methods don't work!

But GCM representation of large-scale climate patterns: 👍

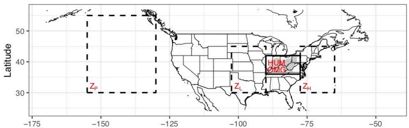


Figure 10: The indices used in the model capture geopotential height, temperature, and vertical velocity and are all credibly simulated in the GCM (Farnham et al., 2018, fig. 6)

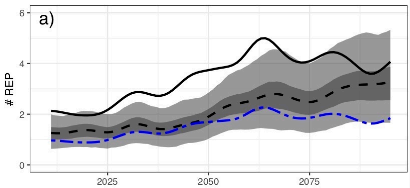


Figure 11: Estimated future REP hazard (Farnham et al., 2018, fig. 9a).

1. Build indices X for mechanism (fig. 10)
2. Validate that indices are credibly simulated
3. Build model $p(\text{REP}|X)$
4. Estimate future indices X from GCM
5. Calculate REP estimates for future (fig. 11)

Neglected (but interesting) case studies

Ask me about ...

- Constraining sub-seasonal to seasonal estimates of flooding in Paraguay
- Using household-level data to understand drivers of flood loss during Hurricane Harvey

Summary

Summary

1. Consider informational uncertainty over instrument lifespan
2. Ignore low-frequency variability at your peril
3. Computers aren't magic
4. Physical understanding + statistical model + sanity checks $\Rightarrow$ better estimates

References i

Bonnafous, Luc, Upmanu Lall, and Jason Siegel (2017). "A Water Risk Index for Portfolio Exposure to Climatic Extremes: Conceptualization and an Application to the Mining Industry". *Hydrology and Earth System Sciences* 21.4. DOI: `10.5194/hess-21-2075-2017`.

Cook, Edward R, Richard Seager, Richard R Heim Jr, Russell S Vose, Celine Herweijer, and Connie Woodhouse (2010). "Megadroughts in North America: Placing IPCC Projections of Hydroclimatic Change in a Long-Term Palaeoclimate Context". *Journal of Quaternary Science* 25.1. DOI: `10.1002/jqs.1303`.

Doss-Gollin, James, David J. Farnham, Scott Steinschneider, and Upmanu Lall (7, 2019). "Robust Adaptation to Multiscale Climate Variability". *Earth's Future* 7.7. DOI: `10.1029/2019EF001154`.

Doss-Gollin, James, David J Farnham, Michelle Ho, and Upmanu Lall (n.d.). "Adaptation over Fatalism: Leveraging High-Impact Climate Disasters to Boost Societal Resilience". Editorial. Editorial. Accepted to Journal of Water Resources Planning and Management.

References ii

Farnham, David J, James Doss-Gollin, and Upmanu Lall (2018). "Regional Extreme Precipitation Events: Robust Inference From Credibly Simulated GCM Variables". *Water Resources Research* 54.6. DOI: `10.1002/2017wr021318`.

Hannachi, Abdel, David M Straus, Christian L E Franzke, Susanna Corti, and Tim Woollings (2017). "Low-Frequency Nonlinearity and Regime Behavior in the Northern Hemisphere Extratropical Atmosphere". *Reviews of Geophysics* 55.1. DOI: `10.1002/2015RG000509`.

IPCC (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*.

Nakamura, Jennifer, Upmanu Lall, Yochanan Kushnir, Andrew W Robertson, and Richard Seager (2013). "Dynamical Structure of Extreme Floods in the U.S. Midwest and the United Kingdom". *Journal of Hydrometeorology* 14.2. DOI: `10.1175/JHM-D-12-059.1`.

Thanks!

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