The System for the Triage of Risks from Environmental and Socio-economic Stressors (STRESS): Methodological Challenges to Relative Risk Quantification and Combination

Center for Sustainability Science and Strategy

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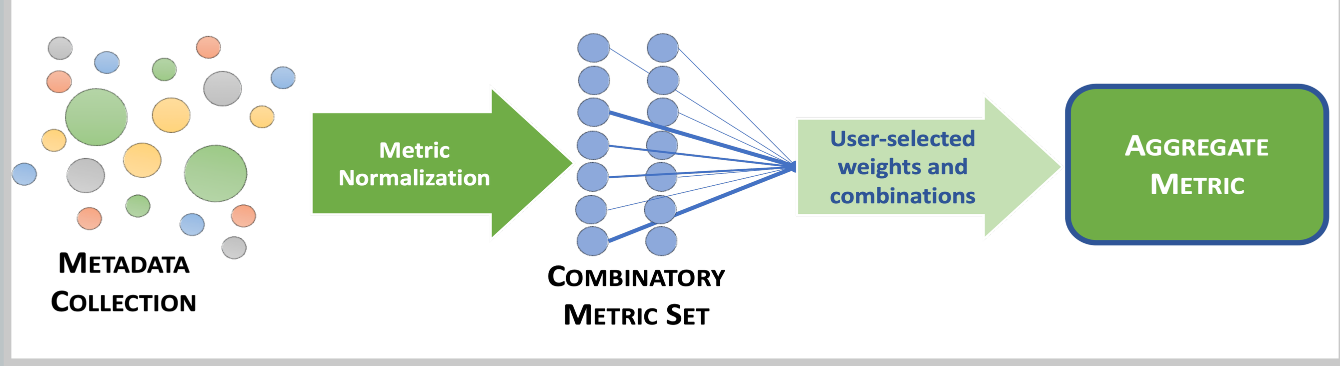
The STRESS Platform

Motivation:

- Risks to people, the environment, and resources are interdependent, compounding, and co-evolving.
- Deep investigation and projection requires resource-intensive research including computationally expensive, complex models.
- An efficient method to combine and analyze heterogenous data and identify "hotspot" regions where combined risks are particularly high is desirable.

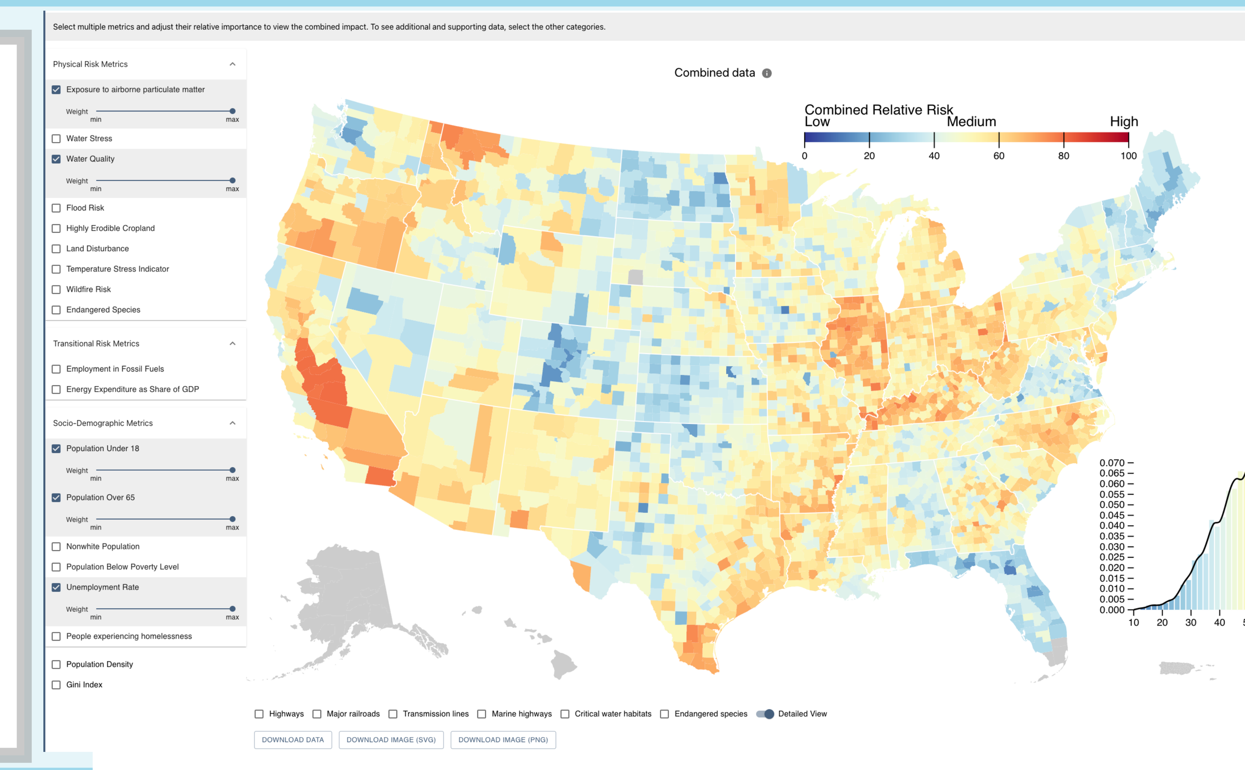
Conceptualization:



Tool:

User selected metrics are percentile ranked and combined as a weighted average to show 'hotspots' of relative risk.

This enables 'triage' of resources to where they are most needed.



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Methodological Questions:

What assumptions went into constructing 'relative risk' this way? What are the implications for using STRESS to inform decisions?

Case Study:

Can I identify 'hotspots' in Massachusetts with high heat, a large elderly population, and many people living in poverty?

I have the following data (std error in brackets):

County	Days over 100°F Heat Index	MERRA2 Temp* °C	NARR Temp* °C	ERA5 Temp* °C	Population Over 65	Population in Poverty
Barnstable	0	24.4	24.4	24.4	33.1 (0.1)	7.7 (0.4)
Berkshire	0	23.0	23.8	24.6	25.0 (0.1)	11.4 (0.7)
Bristol	1	24.4	24.7	25.0	17.8 (nan)	11.3 (0.3)
Dukes	0	24.4	24.4	24.7	26.5 (0.4)	4.4 (1.1)
Essex	0	24.0	24.2	24.7	18.5 (0.1)	9.4 (0.2)
Franklin	1	23.2	23.2	24.5	24.6 (0.1)	12.1 (0.8)
Hampden	4	23.2	23.9	24.7	18.3 (0.1)	16.3 (0.5)
Hampshire	4	23.2	23.2	24.7	19.4 (0.1)	11.3 (0.5)
Middlesex	4	24.0	24.4	25.0	16.3 (0.1)	7.7 (0.2)
Norfolk	2	24.2	24.4	25.0	17.8 (0.1)	6.7 (0.2)
Plymouth	1	24.4	24.5	24.9	19.8 (0.1)	7.1 (0.3)
Suffolk	4	24.0	24.2	24.9	13.3 (0.1)	16.2 (0.3)
Worcester	1	23.8	24.4	25.0	17.0 (0.1)	10.3 (0.3)

*The hottest average monthly temperature from 2000-2019. This is the heat metric currently in STRESS.

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References: Schlosser, C.A., C. Frankenfeld, S. Eastham, X. Gao, A. Gurgel, A. McCluskey, J. Morris, S. Orzach, K. Rouge, S. Paltsev and J. Reilly (2022): Assessing Compounding Risks Across Multiple Systems and Sectors: A Socio-Environmental Systems Risk-Triage Approach. Front. Clim., 24 April 2023 Sec. *Climate Risk Management* Volume 5 - 2023 | https://doi.org/10.3389/fclim.2023.1100600

Wright, T., Klein, M., & Wieczorek, J. (2014). *Ranking Populations Based on Sample Survey Data* (Statistics #2014-12; Research Report Series). United States Census Bureau..

Key questions:

Normalization

There are many ways to normalize metrics so that they are all in the same units. Does it matter which we use?

- Percentile v. min-max v. z-score
- Compare a county to all counties in the country or just within the state?

What do different normalizations assume about the nature of relative risk?

Uncertainty

Normalizations do not include the margins of error from input datasets.

- One county's uncertainty can change another county's normalization

How do we translate the quantified uncertainty in input data into quantified uncertainty in normalized values?

Measurements

There are many ways to define & measure something like 'high heat':

- Temperature vs heat index
- Days over a threshold vs average

The same definition can have multiple datasets

- NARR v. MERRA2 v. ERA5 re-analyses

Is there a rigorous way to decide? Should we decide or should users?

Results:

Top 3 counties in MA & combinatory risk scores from different normalizations of ERA5 Temperature Data, Population over 65, & Population in Poverty.

Statewide comparison				Countrywide comparison			
Min-Max		Percentile		Min-Max		Percentile	
County	Risk Score	County	Risk Score	County	Risk Score	County	Risk Score
Bristol	60.2	Bristol	62.8	Barnstable	30.5	Franklin	45.3
Suffolk	58.2	Berkshire	61.5	Franklin	29.7	Berkshire	44.1
Hampden	56.7	Hampden	60.3	Hampden	29.7	Barnstable	39.7

- Franklin has the highest risk according to country-wide percentile rankings (STRESS's default) but is not in the top 3 using either statewide ranking.
- Normalizations using the same methods but different comparison sets each only have agreement about one of three 'top 3 counties'

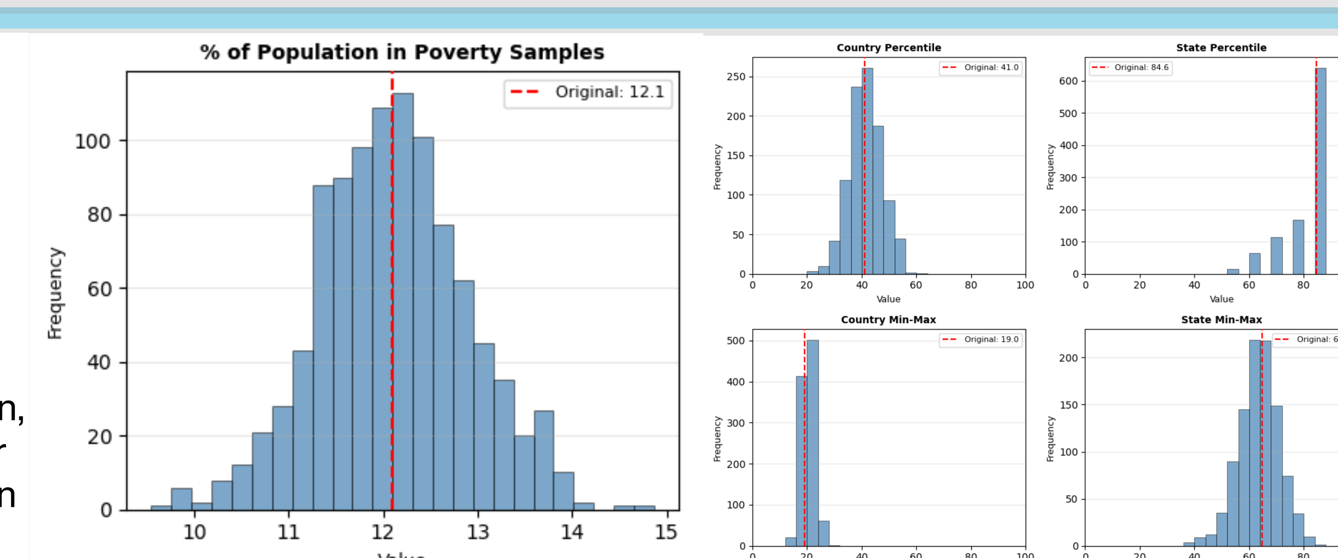
By bootstrapping we can quantify uncertainty in normalized values.

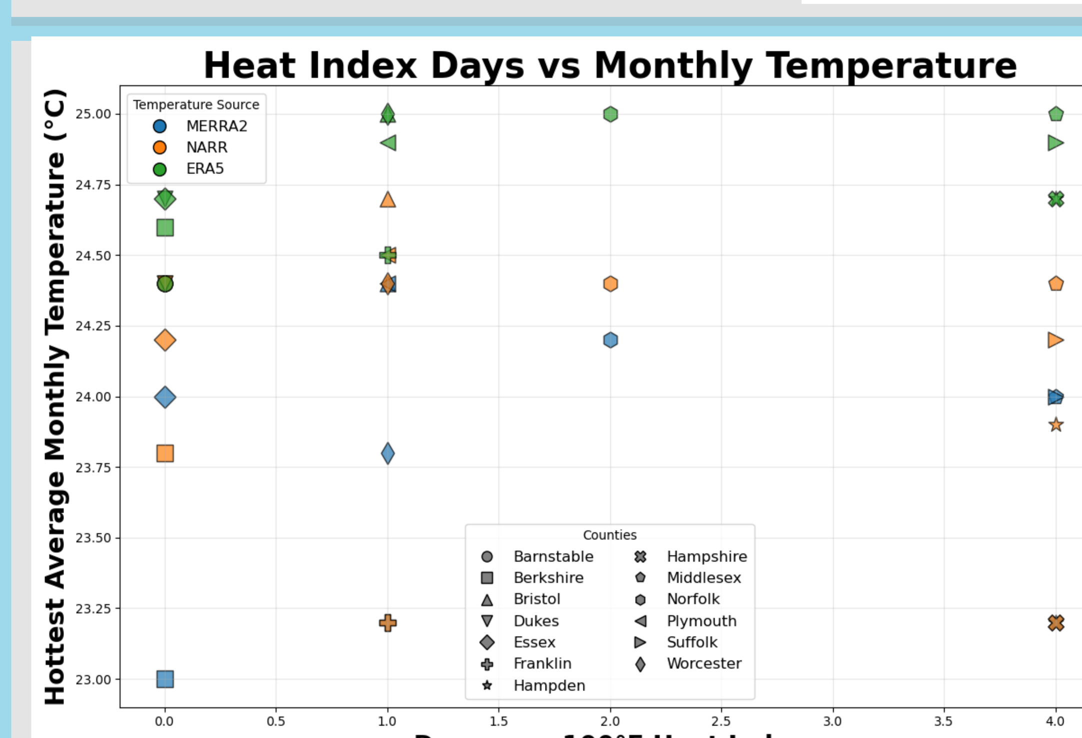
Method:

1. For every location k, randomly draw $\hat{\theta}_k^*$ B times from $N(\hat{\theta}_k, \mathrm{S.E.}_k^2)$
2. Use any method to calculate normalized values for each location k for all B draws.

1000 Samples & Normalized Values for Poverty from Uncertainty Bootstrapping for Franklin County:

(Confidence intervals, mean, and standard deviations for different normalizations can also be calculated.)





- Different sources give different temperatures for the same county.
- Many counties have the same number of days over 100°F, but different temperatures from the same temperature source.
- There is not a clear relationship between days over 100°F and hottest average monthly temperature.

Takeaway:

Although it is mechanically easy to normalize and combine metrics, the resultant risk hotspots are sensitive to many subtle tweaks. We should be cautious when making decisions based on identified hotspots.