

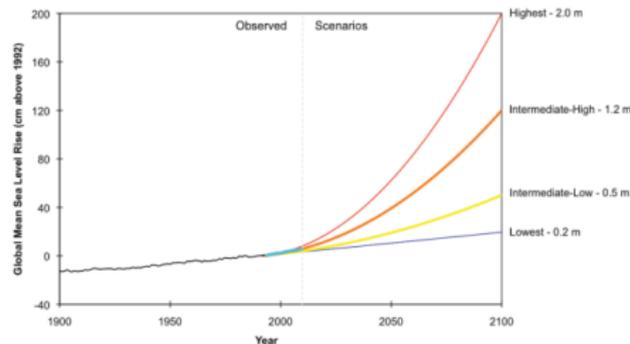
Sea Level Rise Induced Migration Could Reshape the U.S. Population Landscape

Mathew E. Hauer
Department of Geography
University of Georgia

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SEA LEVEL RISE

- ▶ Sea levels are expected to rise between 1m and 2m by 2100.
- ▶ 40% of the U.S. population lives in a coastal area.
- ▶ It is generally understood that sea level rise (SLR) could lead to widespread human migration.



SEA LEVEL RISE ASSESSMENTS

- ▶ SLR assessments that identify the number and locations of potentially displaced persons are common in the literature.
- ▶ Where will the millions of potentially displaced persons go?
- ▶ General hypotheses exist regarding SLR migration, but there are no studies modeling how SLR migration could effect population distributions across space.
- ▶ By focusing on coastal communities, we likely oversimplify SLR impacts and underestimate the scale and magnitude of these impacts.

ENVIRONMENTAL MIGRATION

- ▶ Environmental migration can be spurred by both press and pulse events, but it's the combination that spur migration over the long periods of time.
 - ▶ Press: drought or sea level rise
 - ▶ Pulse: tropical cyclones
- ▶ Migration destination decisions tend to be driven by established networks of social capital and kin networks.¹
- ▶ Press and pulse events operate independently of the “pull factors” associated with migration.
- ▶ Thus, climate migrants will likely constitute “enhanced,” or extra, normal out-migration.

³Findlay, A.M. 2011. “Migrant destinations in an era of environmental change.” *Global Environmental Change* 21:S50-S58.

RESEARCH QUESTIONS

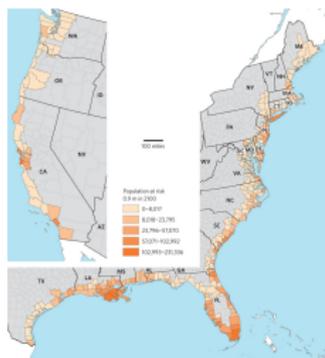
By combining estimates of the populations at-risk to sea level rise within a migration systems simulation I estimate both the number and destinations of potential sea level rise migrants in the United States over the coming century.

- ▶ Where will potential sea level rise migrants go?
- ▶ What areas are likely to see the greatest in-migration due to sea level rise?

METHODOLOGY

Two key parts: “Push” and “Pull”

- ▶ “Push”: from Hauer et al (2016)².
 - ▶ Projected populations at-risk to sea level rise in 319 US coastal counties by 2100 in a dynamically assessed, spatially-explicit small-area population projection model.
 - ▶ 13.1 million at-risk to SLR in the U.S. by 2100.

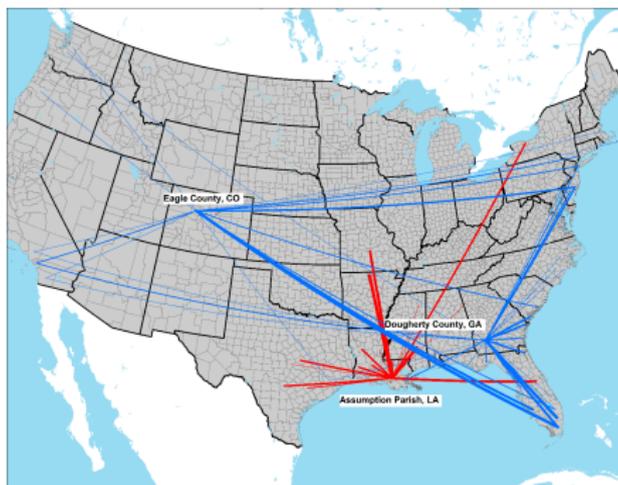


²Hauer, M.E., J.M. Evans, and D.R. Mishra. 2016. “Millions projected to be at risk from sea-level rise in the continental United States.” *Nature Climate Change*.

“PULL”

Flows come from a set of origin-destination matrices of simulated migration systems for all coastal counties affected by SLR (n=319) and all possible destinations (n=3,113).

- ▶ Data comes from the Internal Revenue Services' annual series of county-to-county migration flow data for the years 2004-2010.



SPATIO-TEMPORAL STABILITY

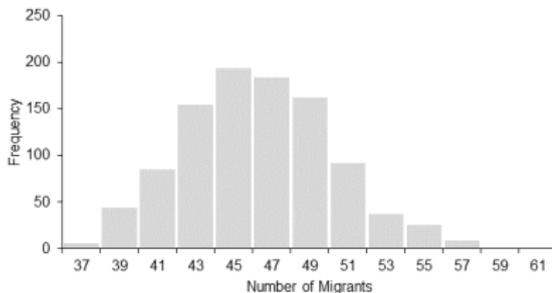
Bootstrap resample for each individual dyad origin-destination pair ($n=20,474$) to simulate possible yearly migration flows.

- ▶ Data exhibit spatio-temporal stability, as expected from the literature surrounding environmental migration.

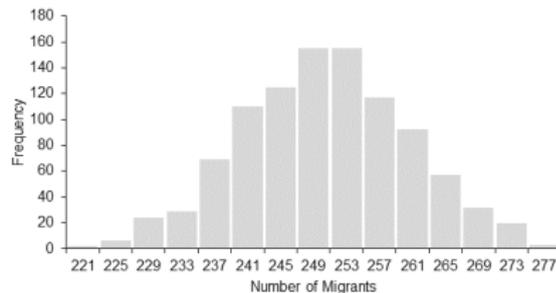
	n	2005	2006	2007	2008	2009	2010
2004	20,474	0.9916	0.9819	0.9606	0.9346	0.9556	0.9468
2005	20,474		0.987	0.9711	0.9479	0.9651	0.9574
2006	20,474			0.9817	0.9599	0.9744	0.9672
2007	20,474				0.9879	0.9913	0.9872
2008	20,474					0.9908	0.9896
2009	20,474						0.9937

BOOTSTRAP RESAMPLES

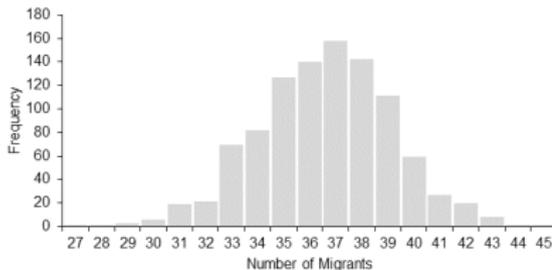
From Santa Clara CA to Calaveras CA



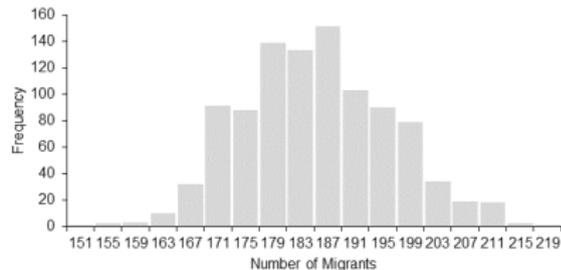
From Escambia FL to Escambia AL



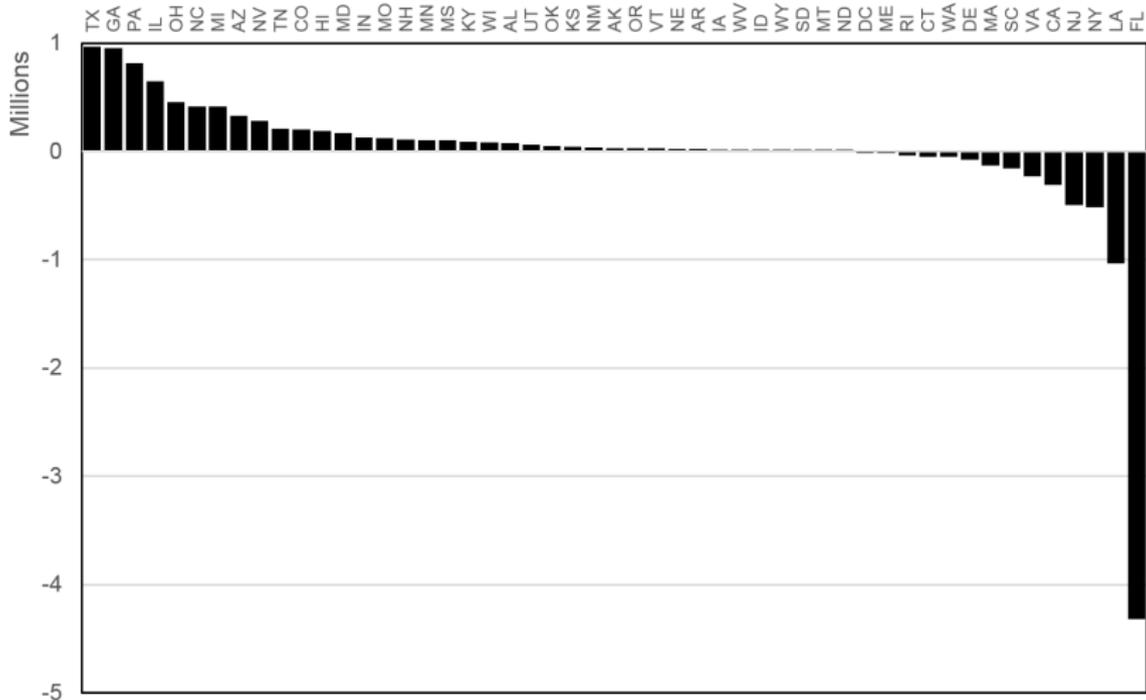
From King WA to Kenai Peninsula AK



From Baldwin AL to Escambia AL



NET CHANGE DUE TO 1.8M OF SEA LEVEL RISE



TOP DESTINATIONS OF MIGRANTS

Rank	MSA	SLR Migrants	+/-
1	Atlanta-Sandy Springs-Roswell, GA	968,350	108,948
2	Orlando-Kissimmee-Sanford, FL	942,285	107,366
3	Dallas-Fort Worth-Arlington, TX	709,897	55,765
4	Chicago-Naperville-Elgin, IL-IN-WI	629,360	81,195
5	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	343,036	46,361
6	Washington-Arlington-Alexandria, DC-VA-MD-WV	332,337	42,997
7	New York-Newark-Jersey City, NY-NJ-PA	329,488	44,133
8	Riverside-San Bernardino-Ontario, CA	293,611	22,855
9	Detroit-Warren-Dearborn, MI	280,639	36,553
10	Phoenix-Mesa-Scottsdale, AZ	266,471	25,054 [b]
Rank	County	SLR Migrants	+/-
1	Orange County, Florida	777,721	92,952
2	Dallas County, Texas	423,105	26,080
3	Cook County, Illinois	422,000	51,322
4	Gwinnett County, Georgia	294,035	21,483
5	Maricopa County, Arizona	263,605	23,176
6	Clark County, Nevada	256,397	24,228
7	Montgomery County, Maryland	246,527	28,351
8	Morris County, New Jersey	239,173	29,484
9	Polk County, Florida	231,019	24,918
10	Montgomery County, Pennsylvania	214,023	30,568

DISCUSSION

- ▶ Sea level rise (SLR) is expected to affect nearly 4.7x as many cities through migration than just inundation alone.
- ▶ The sheer magnitude of places affected could alter the U.S. population distribution.
- ▶ SLR is not just a coastal hazard but will have ripple effects across the entire continent.
- ▶ Additionally, this approach can be broadened to other climate stressors.
 - ▶ Parts of the Middle East and North Africa (MENA) could become “uninhabitable” by the end of the century, potentially spurring an exodus of 500 million people³.

⁵Lelieveld, J., et. al. 2016. “Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century.” *Climatic Change* 137(1):245-260.

THANK YOU!

