An Age-segmented, County-level Migration Model for the Great Lakes Region.

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Background and Overview

- Many studies model climate migration generally.

- However, these attempts have two drawbacks:
  - 1) They lack a demographic feedback where climate migrants alter the demographic forcing (ie further mortality, fertility, and migration) in both their origins and destinations.

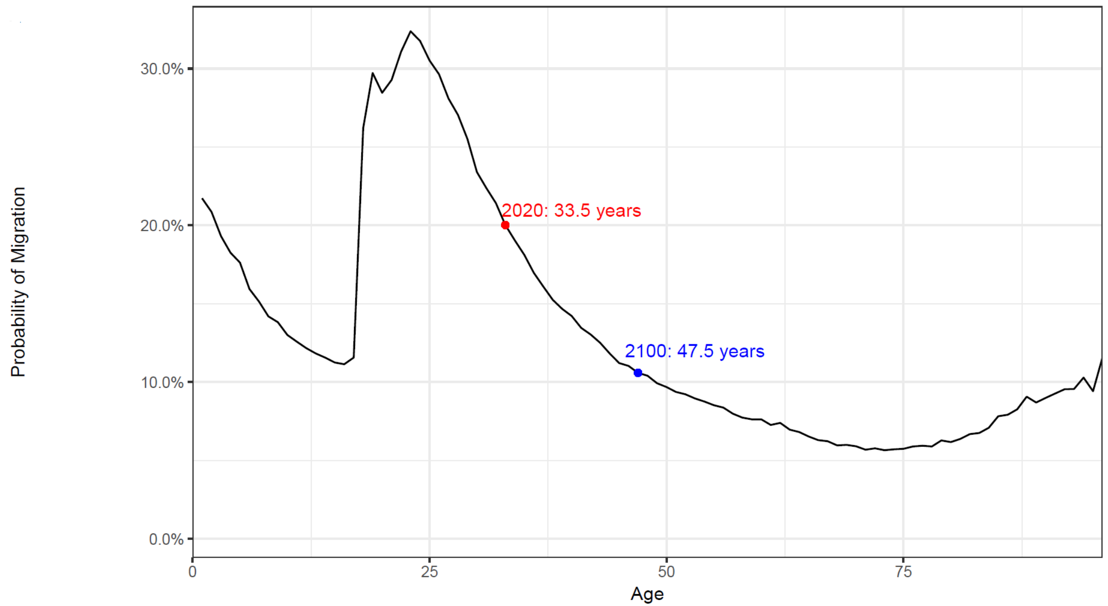
  - 2) Climate modelers focus on population aggregates (ie totals) in their models.

Background and Overview

- Migration propensity has a well-known age gradient. The US and global populations are expected to age this century.

- Could the combination of climate migration and population aging lead to “demographically stuck” people?

- Previous modeling attempts cannot address this question.



Background and Overview

- Many studies model climate migration generally.

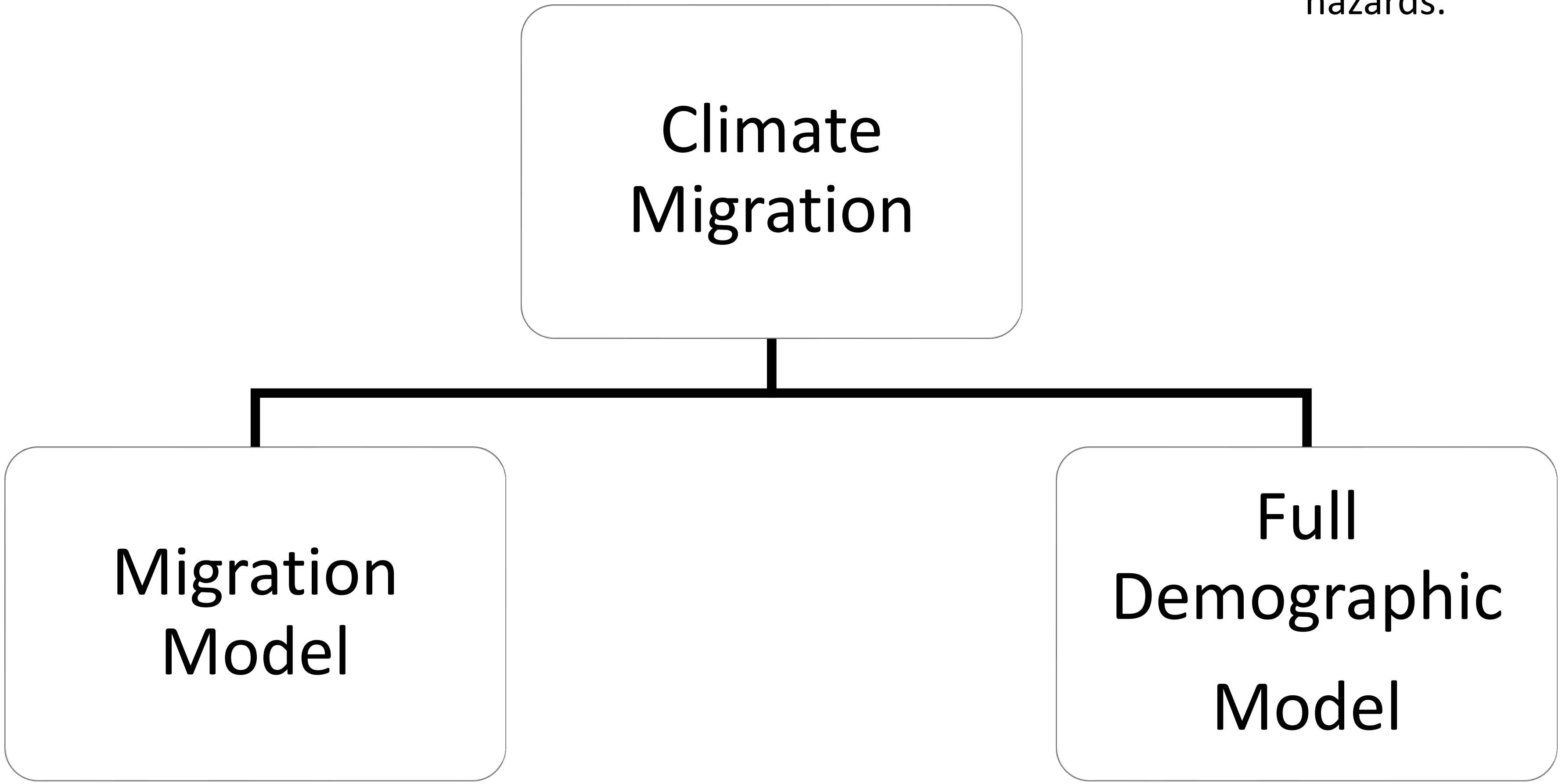
- However, these attempts have two drawbacks:
  - 1) They lack a demographic feedback where climate migrants alter the demographic forcing in both their origins and destinations.

  - 2) SLR modelers focus on population aggregates (ie totals) in their models.

- Thus, we are likely understating the demographic implications of climate migration.

Background and Overview

We focus on sea-level rise here and eventually heat/cold, but the approach can be broadened to other climate hazards.



We will share preliminary results on heat/cold later.

Environmental Migration

- We build a migration model based on 40 years of population data in all 3000 US counties.
- We search for environmental events since 1980 associated with large population declines.
- We then verify these events against the Spatial Hazard Events and Losses Database for the United States (SHELDUS) to ensure the “outliers” are associated with environmental hazards.
- We find 48, verifiable environmental events that include tornados, wind damage, winter weather, earthquakes, flooding, tropical cyclones, hail, and other environmental hazards.
- Finally, from this pool of displacement events, we build a simple migration model.

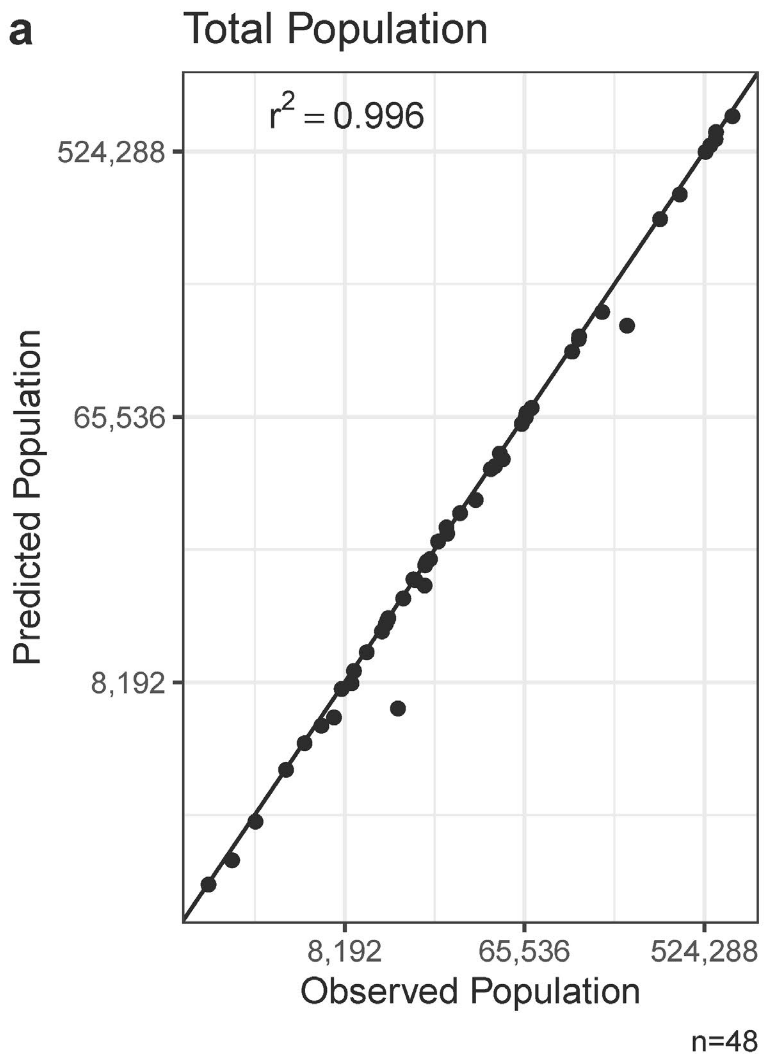
Statistical Outliers

- We search for large ($>4\sigma$) observed changes in a county population between 1980 and 2018 for negative statistical outliers (indicating population losses).
- We then search SHELDUS to see if these county-years we detect experienced a per capita hazardous loss in excess of the 50^{th} percentile.
- We detect 53 county-years with large population declines but 4 county-periods were either not in SHELDUS or experienced $<50^{th}$ percentile of losses. 1 additional county-year contained age-sex groups with 0 people, necessitating exclusion.
- This ultimately leaves us with 48 environmental events that include tornados, wind damage, winter weather, earthquakes, flooding, tropical cyclones, hail, and other environmental hazards.

How well does our Model perform?

- Single input is just % of population displaced

- Aggregating to total population yields remarkably accurate estimates.

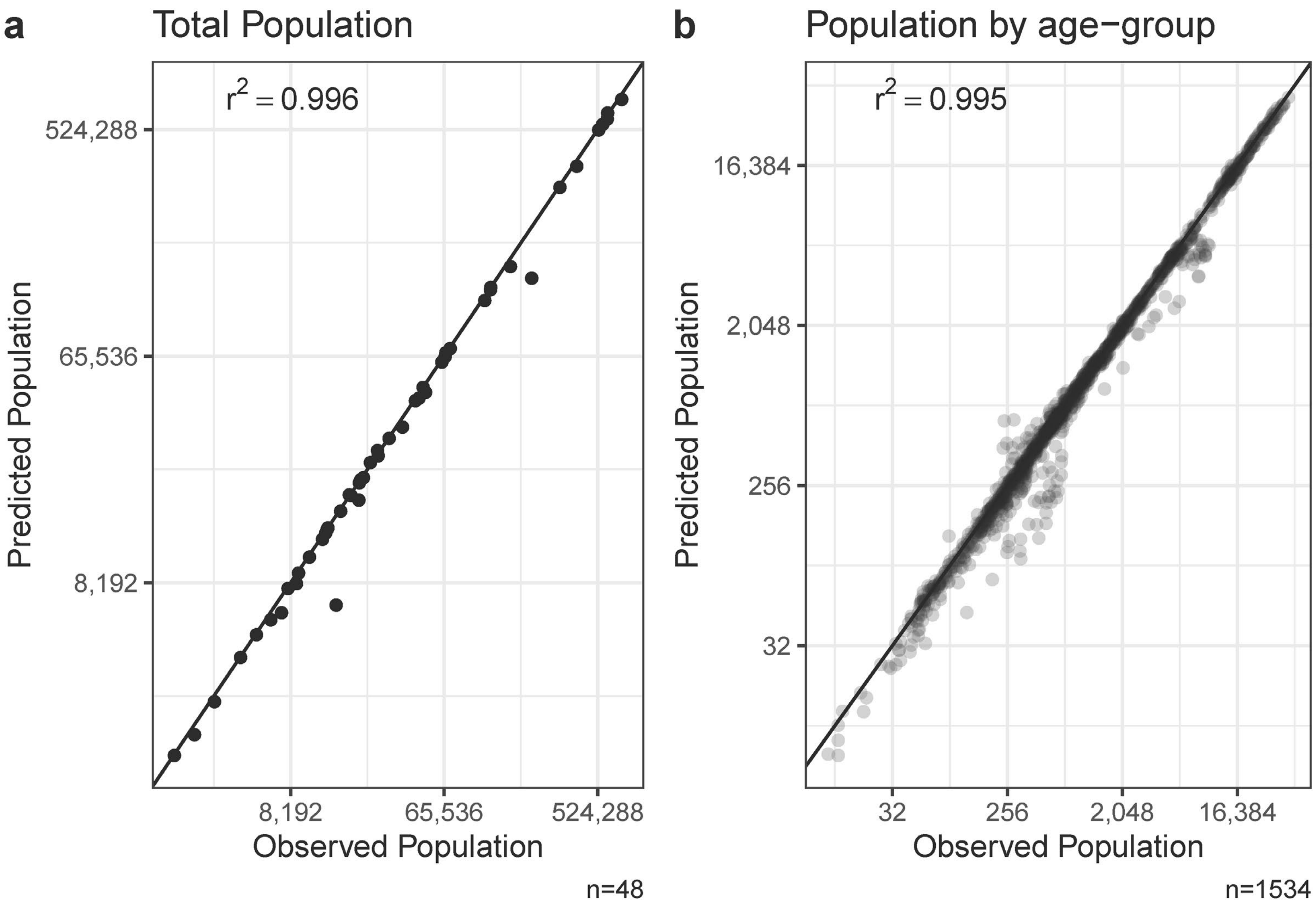


How well does our Model perform?

- Single input is just % of population displaced

- Aggregating to total population yields remarkably accurate estimates.

- Even individual age-sex groups have excellent performance



Environmental Migration Model

- Our model uses multiple environmental hazards, across multiple populations (<10k to >500k), and across multiple time periods (1980-2018).

- Performance is very good!

- To estimate migration all we would need is the % of the population we expect to migrate.

Demographic Model

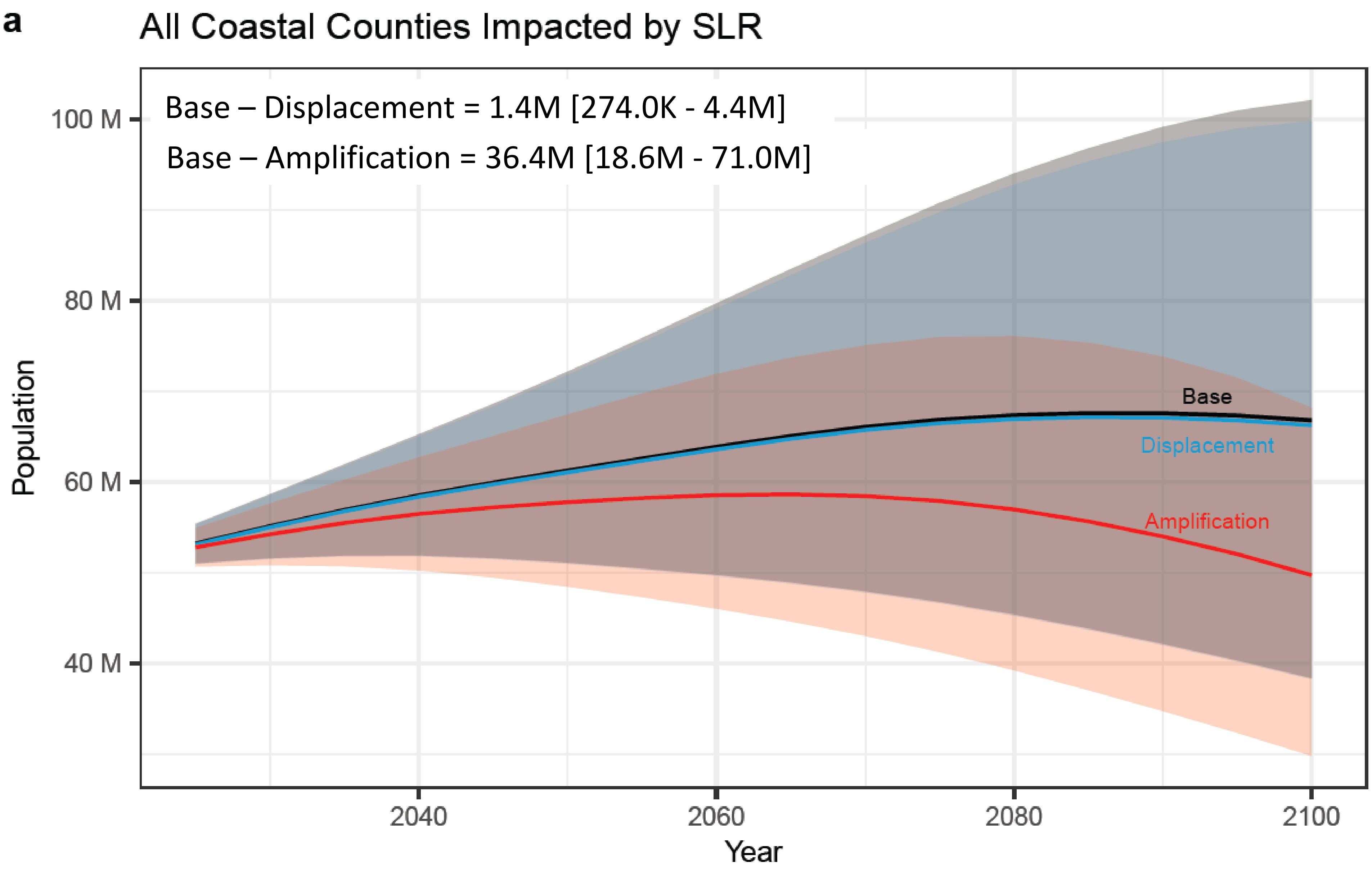
- We build multi-regional Leslie matrices to predict migration to/from every US county.

- We build three matrices:
  - Population ($\boldsymbol{P}$) which contains the population information.
  - Migration ($\boldsymbol{M}$) which contains the $p\left(M_{i\to j}\right)$.
  - Survival ($\boldsymbol{S}$) which contains the mortality/fertility information.

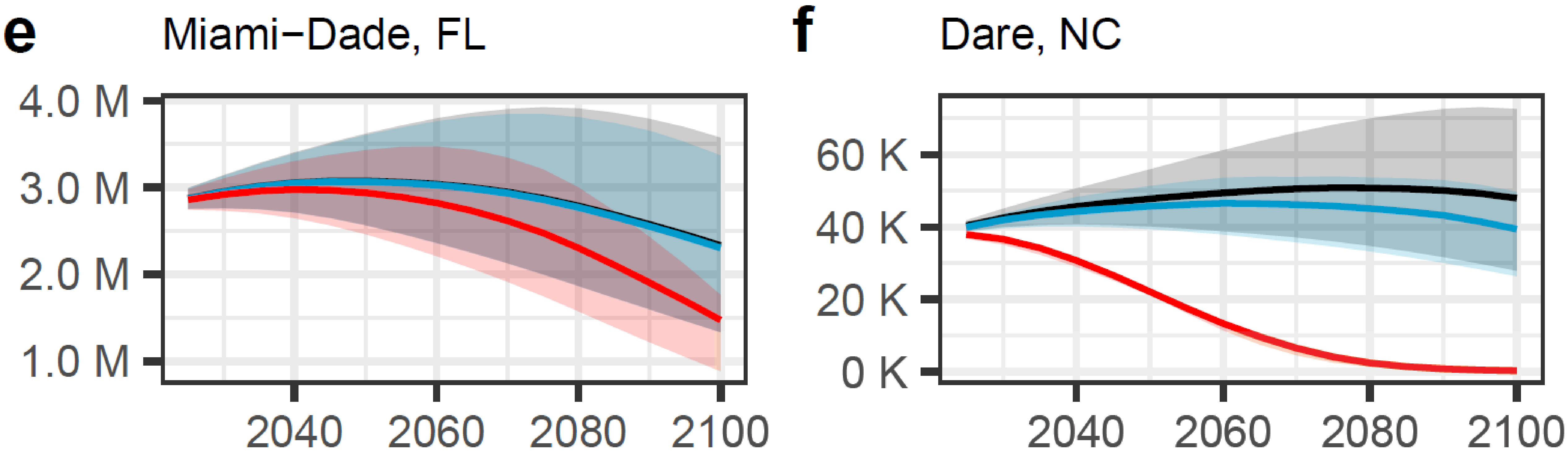
$$
\begin{array}{lll}
\text{Base} & : \mathbf{P}_{t+1}^{Base} & = \mathbf{S}_t \mathbf{P}_t^{Base} \\
\text{Displacement} & : \mathbf{P}_{t+1}^{Disp} & = \mathbf{M}_{ty} \mathbf{S}_t \mathbf{P}_t^{Base} \\
\text{Amplification} & : \mathbf{P}_{t+1}^{Amp} & = \mathbf{M}_{ty} \mathbf{S}_t \mathbf{P}_t^{Amp}
\end{array}
$$

Results

26x effect with component processes!!

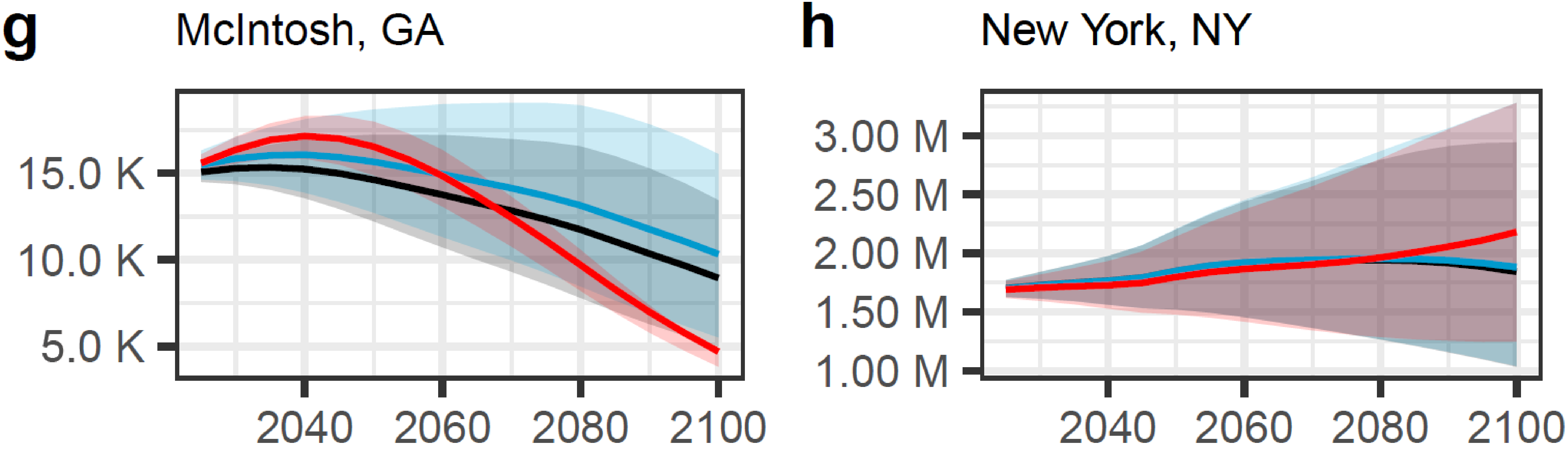


Results



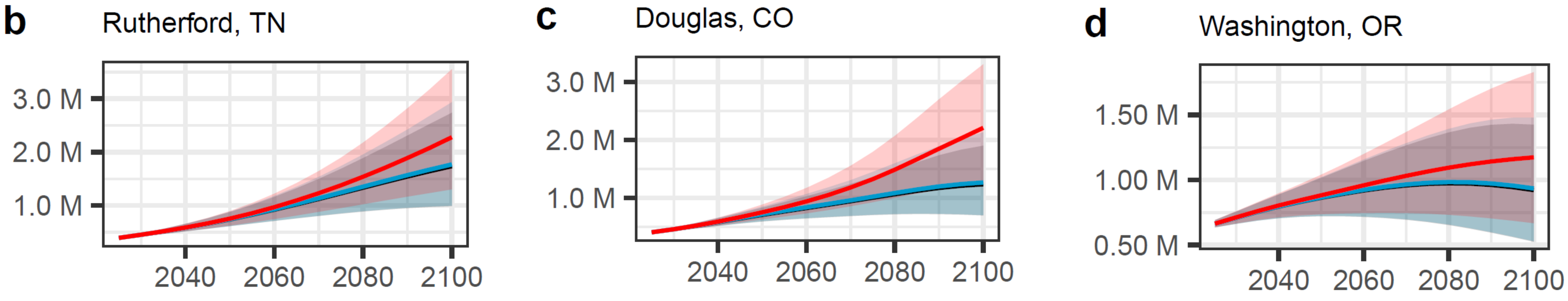
- It doesn't take much sea-level rise to have a major demographic amplification.

Results



- Demographic models reveal important non-linearities.
- McIntosh: Climate Destination -> Vulnerable County
- New York: Vulnerable County -> Climate Destination

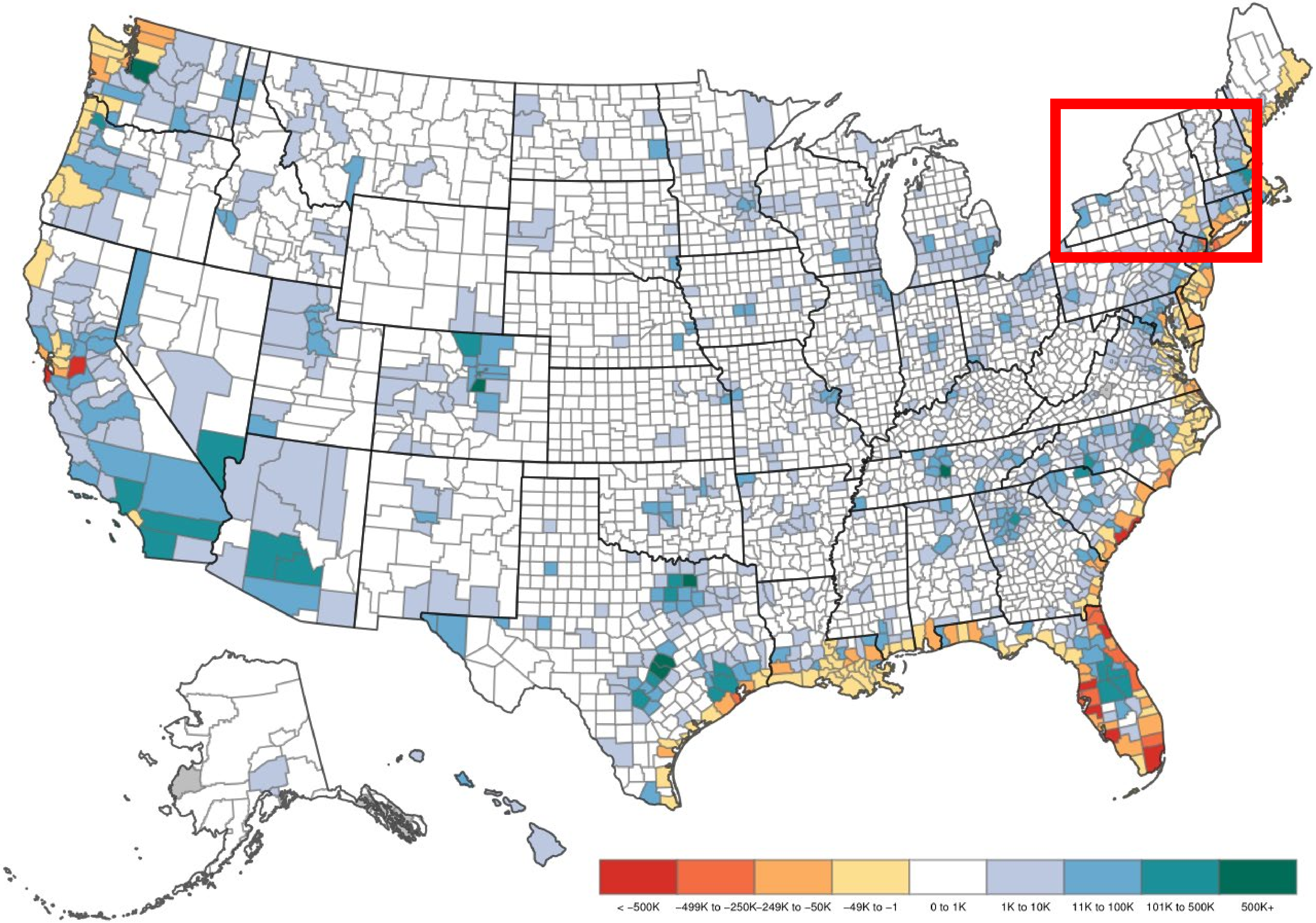
Results



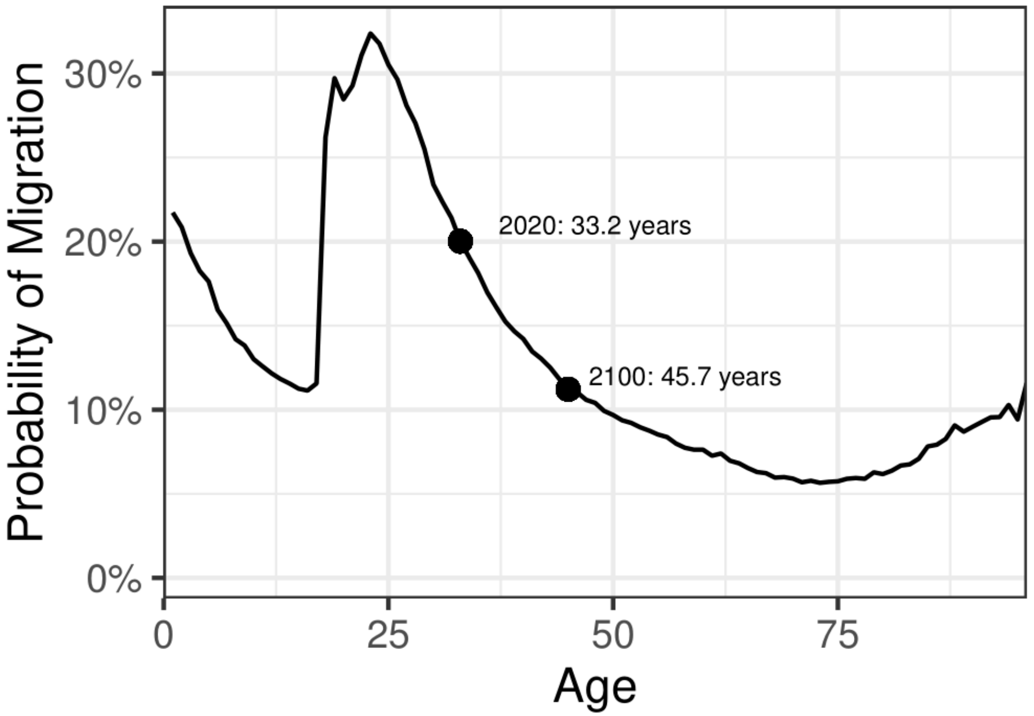
- Emergence of Climate Destinations (Nashville, outside Denver and Portland).
- Amplification much larger than simple displacement
  - Rutherford:
    - Amplification= +251.7K [142.3K – 403.7K]
      Displacement= + 12.9K [3.8K – 55K]

Result

- Amplification of both pop decline and growth



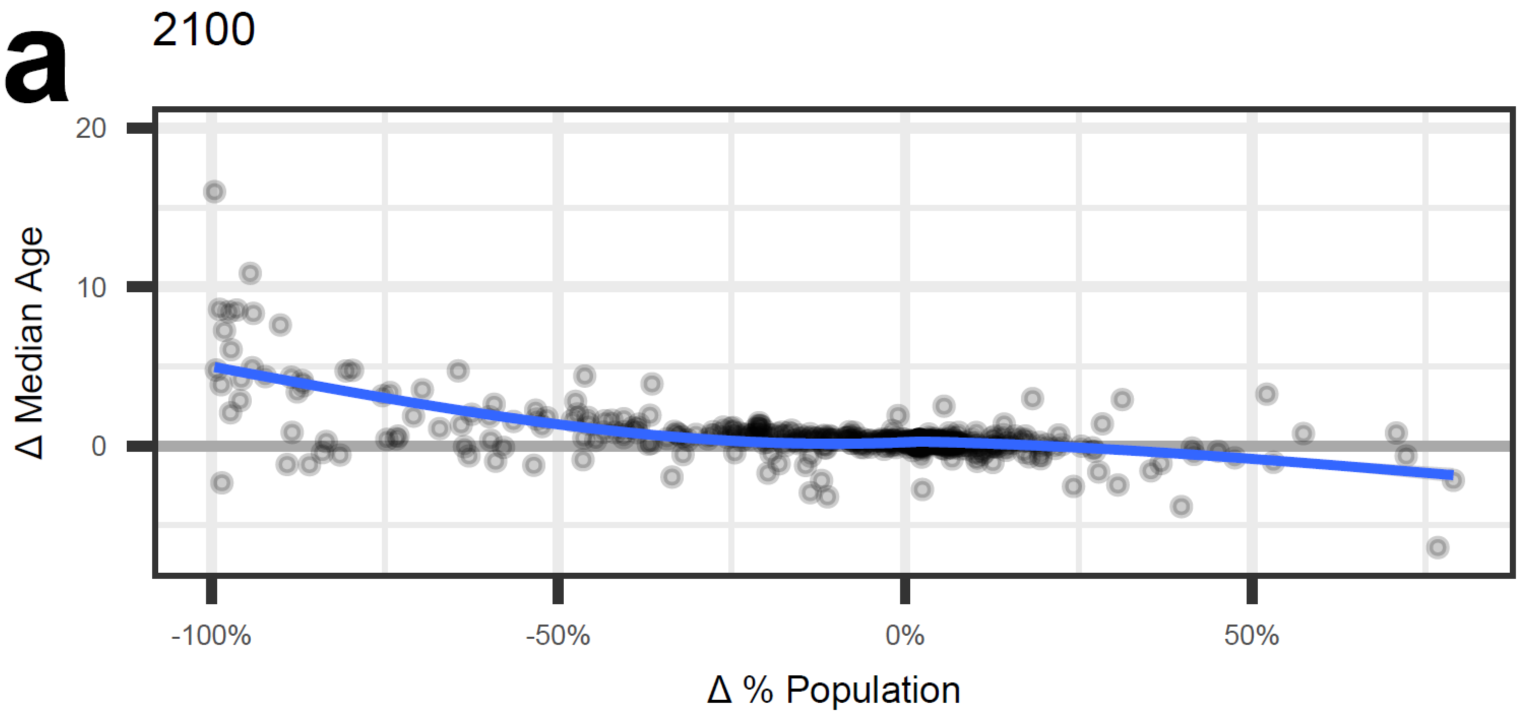
- Migration propensity follows a clear age schedule.
- US Population will age this century, implying lower migration in the future.



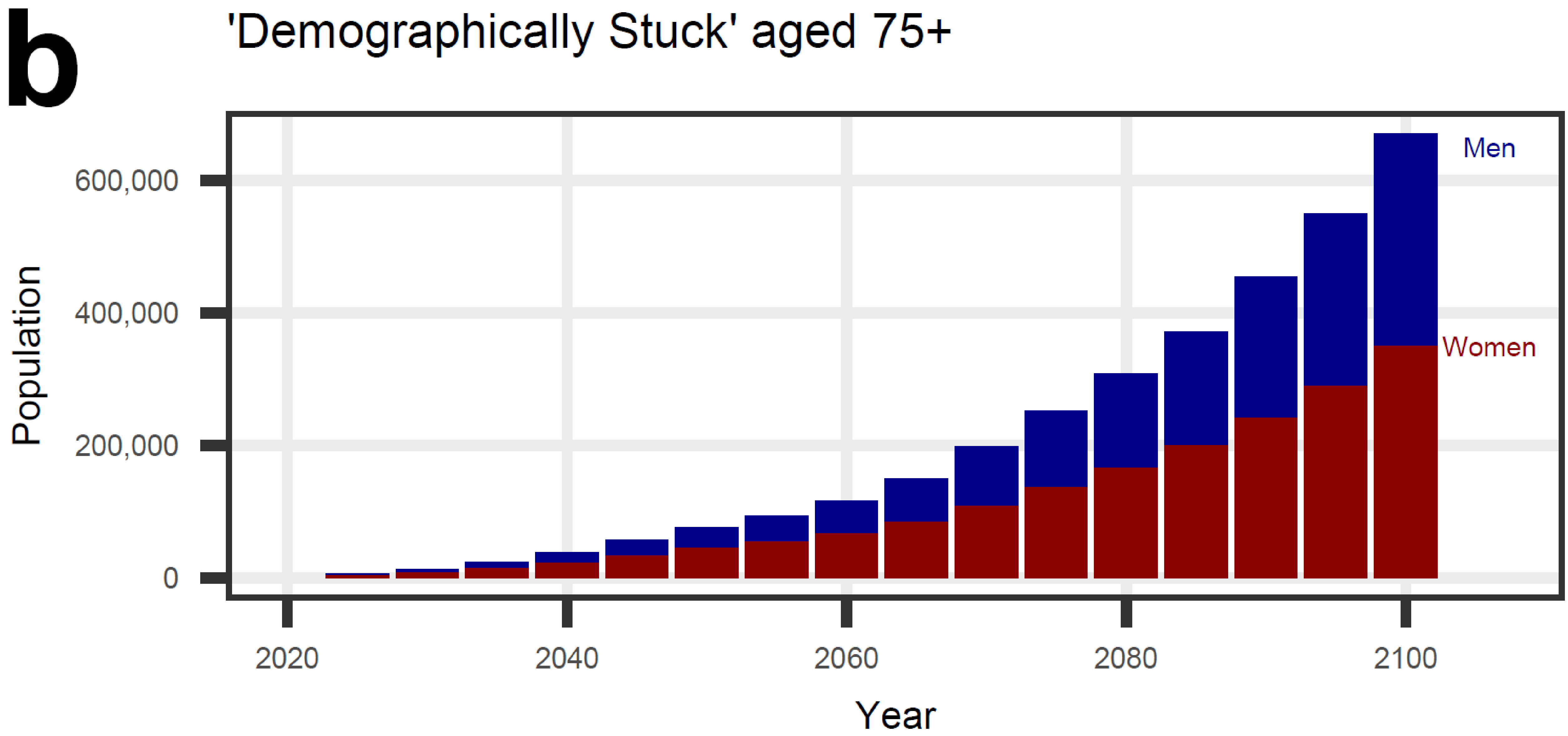
Results

- Could the combination of SLR and population aging lead to "demographically stuck" people?

- The more a county is impacted, the greater the population aging.



Recall, the oldest ages least likely to respond with environmental migration.


b
'Demographically Stuck' aged 75+
Men
Women
Population
600,000
400,000
200,000
0
2020
2040
2060
2080
2100
Year

New York Specific Results

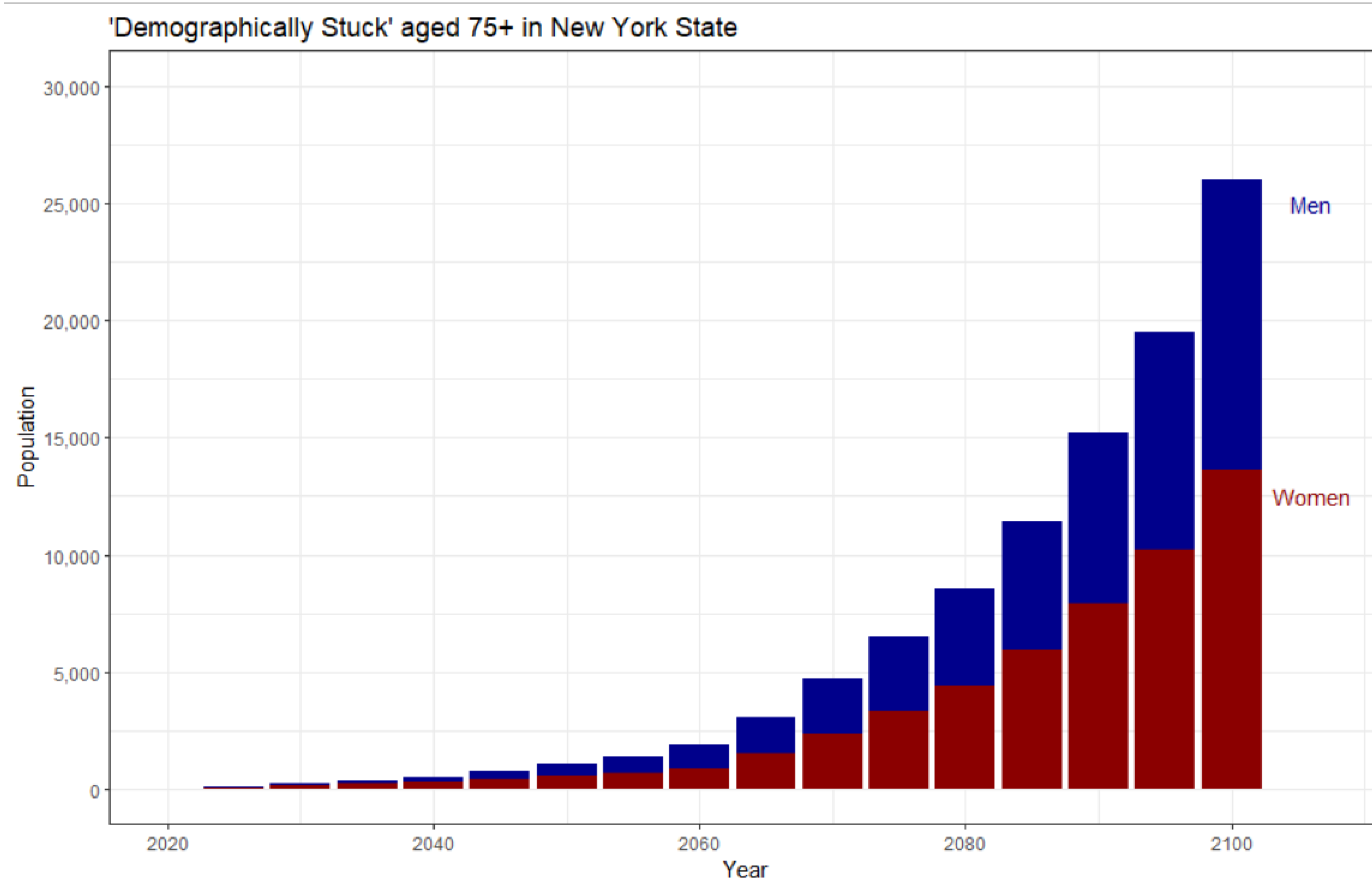
- NY: Displacement = +24K [+6K - +233K]
- NY: Amplification = -13K [-17K - +124K]

Major Changes include:

• New York	(+116K)	Nassau	(-112K)
• Kings	(+35K)	Suffolk	(-44K)
• Rockland	(+9K)	Richmond	(-11K)
• Saratoga	(+1.6K)	Westchester	(-5.4K)
• Orange	(+1.5K)	Ulster	(-1.2K)

New York Specific Results

~25K [13K – 70K] who could be ‘Demographically Stuck’ in NY by 2100.



Conclusion

- The amplification of demographic change (further fertility, mortality, and migration) is MUCH larger than just the migration effect ~ 26x larger!
  - We're calling this the "population amplification." (Sort of like a combined population momentum and gravity effect.)
- Population aging in vulnerable communities is particularly important and unveiled with our integrated demographic model.
  - Concentrated effects among populations with some of the least resources.
- "Demographically stuck" people receive no attention in the climate migration discussion but could occur in heavily impacted areas.
  - Not just the population itself that's aging and vulnerable but the communities that support the population too.
- Who is left behind? <- Older populations, mostly women.

GLISA Project: Why

Catalyze additional investment and research into the topic of in-migration and regional preparedness for climate change.

Introduce a new narrative around potential benefits and opportunities, rather than negative impacts and risks, to climate change.

Ensure the Great Lakes region is poised for sustainable and just economic growth into the next century. Inform business leaders and municipal/state governments to influence climate sensitive industries.

GLISA Project: How

- The idea is to produce a simple, replicable methodology for understanding climate migration.

- We started with a historical analysis to the relationship between migration into the Great Lakes region from places outside of the region and the role temperature might play in mediating this relationship.

- "Plug and Play" with the climate migration model.

Future Steps…

- We used IRS county-to-county migration data for the period 1990-2010.
  - Covers ~ 87% of US households and 95%-98% of the tax-filing universe and their dependents.

- We used gridMET climate dataset with downscaled historical temperature data from 1979-2020.
  - We started with average annual daily minimum, mean, and maximum temperatures for counties.
  - Eventually moved to # of days at different hot/cold temperature thresholds.

Future Steps…

- We then built a simple gravity model where the number of migrants moving between counties is a function of the distance (d), the population size (p), and the difference in mean temperatures between counties (ΔT).
    - If ΔT is positive, it suggests the origin county is colder than the destination county (ie, 25 at origin and 28 at destination; ΔT = 3).

- Sample includes ~122k county-year pairs. (ie, Cook IL -> Suffolk MA 1999) ΔT

Preliminary Results – In Migration

- We find a statistically significant, positive relationship between temperature differentials and the number of migrants moving into the Great Lakes region.
  - As temperature differentials increase, the number of migrants also tends to increase.
- Migrants into the Great Lakes region tend to come from colder areas.

	Estimate	z-value
(Intercept)	4.03	7316.6
Distance (d)	-0.000356	-472.7
Pop Total (p)	0.00000024	828.8
Mean Temperature Difference (ΔT)	0.024	303.2
N	122,054	

Preliminary Results – Out Migration

- We find a statistically significant, negative relationship between temperature differentials and the number of migrants moving out of the Great Lakes region.
  - As temperature differentials increase, the number of migrants tends to decrease.
- Migrants out of the Great Lakes region tend to go to colder areas.

	Estimate	z-value
(Intercept)	4.03	6656
Distance (d)	-0.000125	-235.6
Pop Total (p)	0.00000031	1248.6
Mean Temperature Difference (ΔT)	-0.00637	-100
N	171,439	

Not the relationship I expected!

Future Steps…

- Easy to implement into the Demographic Climate Migration Model.
    - Differences between expected migrants and heat/cold migrants provides the needed displacement.

- Introduces a new narrative around climate change that focuses on potential benefits and opportunities, rather than negative impacts and risk.

- Provides baseline estimates but does not provide guidance on how to start planning for climate migrants.
    - Puts bounds on likely futures rather than speculation.