Temperature-Related Migration and the Great Lakes Region

American Society of Adaptation Professionals

Authors: Matt Hauer, BJ Baule, and Kim Channell

Intro

Most environmental events can be categorized as either pulse-events of press-events where pulse events tend to be rapid-onset environmental events (such as wildfires or tropical cyclones) and press events tend to be more slower-onset environmental events (such as drought or extreme heat). Climate migration literature often focuses on the pulse events likely to displace people. These events tend to have a significant and detectable cause-and-effect relationship migration making them ideal for study. Its hard to overstate the potential migration outcomes resulting from destructive wildfires or hurricanes. But focusing on such specific environmental events tends to obscure the potential linkages between more press-events. Scholarship examining the relationship between press events and climate migration tends to focus on the developing world and the effect of heat or drought and the mediating impact on agricultural yields. In the US, most people are no longer engaged in agricultural production and this mediating avenue (the impact of heat/drought on agricultural production and thus climate migration) is likely closed. This does not mean extreme heat is not related to climate migration.

In our analysis, we examine the relationship between migration into the Great Lakes region from places outside of the Great Lakes region and the potential role differences in temperature might play in mediating this relationship. It seems likely that heat/cold waves in different parts of the US could impact migration streams into and out of the Great Lakes region.

Methods

To examine this relationship, we use two primary data sources: I first use IRS county-to-county migration data. The IRS began publishing annual county-to-county migration data in 1990, using every Form 1040, 1040A, and 1040EZ in the IRS Individual Master File. These data cover 95% to 98% of the tax-filing universe and their dependents (approximately 87% of US households)[1]. The IRS matches individual tax returns between two years (ie, tax year 2019 and tax year 2020) to identify both migrants and nonmigrants. A migrant is identified when a current year tax return contains a different address from a matched previous year's return and a non-migrant is identified when no change in address occurs between two consecutive years. Despite the size and large coverage of the dataset, systematic exclusion from the tax-filing universe does occur among undocumented populations, the poor, the elderly, and college students, but the overwhelming majority of US householders file US tax returns. These data are among the most robust and complete county-to-county migration data available in the United States. I use the period 1990-2010, based on Hauer and Byars' compiled dataset which contains 3.2 million county-year observations[2].

The second data source comes from the gridMET gridded climate dataset (Abatzoglou, 2013). This dataset consists of 4 km statistically downscaled historical temperature data from 1979-2020 at a daily timestep. BJ derives annual data from daily minimum and maximum temperature data (~2m above ground surface). Derived variables include: average annual daily temperature, average annual daily maximum temperature, average annual daily minimum temperature, and annual counts of threshold

---

[1] Gross, Emily. 2005. "Internal Revenue Service Area-to-Area Migration Data: Strengths, Limitations, and Current Uses." *Statistics of Income. SOI Bulletin* 25(3):159–60.
[2] Hauer, Mathew E., and James Byars. 2019. "IRS County-to-County Migration Data, 1990–2010." *Demographic Research* 40:1153–66.

exceedance. Threshold exceedances calculated were: Days with maximum temperatures greater than or equal to 90F, 95F, and 100F and Days with low temperatures less than or equal to 32F, 30F, and 0F. The resulting 4 km grids were then aggregated to the mean value of each county in the contiguous United States of America. Additionally, threshold exceedance grids were aggregated to the county level with the maximum grid cell value within each county being the value for the entire county. Outputs were provided to user in annual csv files coded by state and county FIPS codes.

I define the Great Lakes Region as any county in the states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin – any state that directly borders the Great Lakes. I subset the combined IRS and temperature datasets with the following two primary rules: 1) migration between two pairs of counties must be greater than 0; 2) non-migrants must be excluded from the analysis (ie, origin != destination). Further analyses subset between the Great Lakes Region as an origin, destination, or both. The final analytical samples includes more than 122k county-year pairs (ie, Cook IL -> Suffolk MA 1999).

I then build a gravity-based migration model to examine the role temperature differentials play in mediating the migration relationship. Gravity migration models rely on the basic observation that two factors play a large role in determining the flow of people between two locations: the size of those locations and the distance between those locations. Thus, a basic gravity model simply uses population size and distance.

The final model uses the following variables:

Mig = the number of migrants moving between county i and county j

d = the distance between county i and county j in miles

p = the total number of migrants from county i

ΔT = the difference in annual mean temperatures between county i and county j in Celsius

$$\log log\,(E(Mig)) \;=\; \alpha \,+\, \beta_1(d) + \beta_2(p) + \beta_3(\Delta T) +\, \epsilon$$

When ΔT is positive, it suggests the origin county is colder than the destination county (ie, 25 at origin and 28 at destination, ΔT=3).

As climate change progresses and makes some regions of the United States potentially intolerable or undesirable, determining what these thresholds are, as well as how they will affect nationwide migration, is extremely important as cities and communities plan for long-term development. We further refined our model from differences in average temperature to the number of days above and below certain temperature thresholds in both the origins and destinations. We chose temperatures above 90-, 95-, and 100-degrees as thresholds for extreme heat and temperatures below 32-, 20-, and 0-degrees Fahrenheit for extreme cold.

Thus, our analysis examines the relationship between mean temperature and number of days above/below critical thresholds.

Results

I find a statistically significant, positive association between temperature differentials and the number of migrants moving into the Great Lakes region after controlling for population size and distance. Thus, as temperature increases, the number of migrants also increases. Since this relationship is positive, and in conjunction with distance being negative and population being slightly positive, it suggests people moving into the Great Lakes are more likely to originate from areas with larger populations that are relatively close to the Great Lakes region and from areas colder than their Great Lakes destination.

Table 1. Relationship between Migrants moving to the Great Lakes Region from non-Great Lakes states.

	Estimate	z-value	pr(>|z|)
(Intercept)	4.03	7316.6	<2e-16
Distance (d)	-0.000356	-472.7	<2e-16
Pop Total (p)	0.00000024	828.8	<2e-16
Mean Temperature Difference (ΔT)	0.024	303.2	<2e-16
N	122,054		

I also looked at the relationship between those originating in the Great Lakes Region but whose destinations are *outside* of the Great Lakes. Here, the opposite relationship between temperature occurs. As the temperature difference increases, migration actually decreases. It appears that most migrants out of the Great Lakes region are not heading to warmer climates but are, in fact, heading to cooler climates, after controlling for distance and population size.

Table 2. Relationship between Migrants moving to Non-Great Lakes states from Great Lakes states

	Estimate	z-value	pr(>|z|)
(Intercept)	4.03	6656	<2e-16
Distance (d)	-0.000125	-235.6	<2e-16
Pop Total (p)	0.00000031	1248.6	<2e-16
Mean Temperature Difference (ΔT)	-0.00637	-100	<2e-16
N	171,439		

Table 3 examines the number of days above/below critical temperature thresholds for the number of migrants moving out of the Great Lakes Region. In the origin county, the number of days under 32 degrees is negatively associated with the number of migrants out of the GL region, but the number of days under 20 degrees and under 0 degrees is more positively associated with the # of out migrants.

In the destination county, the number of days over 90 is positively associated with the number of migrants, but the number of days above 95 is negatively associated and the number of days above 100 is not significant. Cold days are generally negatively associated with the number of migrants.

If we were to make any predictions based on these findings, as the GL region warms, we would expect the number of out-migrants to decrease because there would be fewer days under 20 and 0 degrees. Additionally, those who do move out might move to more northerly latitudes (ie as places that are less warm become warmer) based on the number of days above 90.

Table 3. Out-migration from the Great Lakes Region and days above/below critical temperature thresholds.

		Estimate	St. Dev	z-value	pr(>|z|)
(Intercept)		147.10	3.09	47.55	< 2e-16
Pop Total (p)		0.00	0.00	58.11	< 2e-16
Distance (d)		-0.02	0.00	-34.90	< 2e-16
Origin	Days over 90	-32.12	28.84	-1.11	0.265441
	Days over 95	NA	NA	NA	NA
	Days over 100	NA	NA	NA	NA
	Days under 32	-0.68	0.03	-26.84	< 2e-16
	Days under 20	0.14	0.03	4.31	1.63E-05
	Days under 0	0.52	0.07	6.96	3.52E-12
	Under 70, night	0.74	0.05	15.04	< 2e-16
	Under 80, night	7.06	1.08	6.53	6.66E-11
Destination	Days over 90	4.60	0.28	16.27	< 2e-16
	Days over 95	-8.74	2.56	-3.41	0.000646
	Days over 100	0.79	9.94	0.08	0.93677
	Days under 32	-0.25	0.02	-12.13	< 2e-16
	Days under 20	0.28	0.04	6.82	9.46E-12
	Days under 0	-0.55	0.11	-4.81	1.54E-06
	Under 70, night	-0.03	0.01	-2.16	0.030428
	Under 80, night	-0.42	0.15	-2.84	0.004483
	N	167,798			

Table 4 reports the relationship between days above/below temperature thresholds and in-migration into the Great Lakes region. Here we find the number of days above 100 is positively associated with migration into the GL region, but not days above 95. This might suggest in-migrants tend to come from the hottest regions. We also find that the number of days below 0 and 32 degrees is negatively associated with in-migration into the GL region. Further suggesting migrants are coming from warmer places. The variables for number of days with nights below 70 degrees suggests that places with more days where the nights are under 70 is negatively associated with in-migration.

Migrants tend to go to places that are very cold, as the number of days under 0 is positively associated with the number of in-migrants while the number of days under 32 is negatively associated. This is further bolstered by the number of nights under 70 and 80 degrees.

If we could make any predictive statements, it would be that as places warm up, they might start sending in-migrants into the more northerly reaches of the GL region.

Table 4. In-migration to the Great Lakes region and number of days above/below temperature thresholds.

		Estimate	St. Dev	z-value	pr(>|z|)
(Intercept)		63.63	1.35	47.19	< 2e-16
Pop Total (p)		0.00	0.00	87.91	< 2e-16
Distance (d)		-0.02	0.00	-66.80	< 2e-16
Origin	Days over 90	0.24	0.13	1.81	0.07065

	Days over 95	-3.47	1.23	-2.81	0.00489
	Days over 100	16.24	4.39	3.70	0.000215
	Days under 32	-0.07	0.01	-7.77	7.84E-15
	Days under 20	0.09	0.02	5.10	3.49E-07
	Days under 0	-0.11	0.04	-2.46	0.013903
	Under 70, night	-0.07	0.01	-14.65	< 2e-16
	Under 80, night	-0.32	0.07	-4.96	7.10E-07
Destination	Days over 90	-32.82	11.04	-2.97	0.002959
	Days over 95	NA	NA	NA	NA
	Days over 100	NA	NA	NA	NA
	Days under 32	-0.29	0.01	-25.80	< 2e-16
	Days under 20	0.00	0.01	0.02	0.983656
	Days under 0	0.28	0.03	9.30	< 2e-16
	Under 70, night	0.54	0.02	25.40	< 2e-16
	Under 80, night	7.35	0.48	15.19	< 2e-16
	N	269,554			

Discussion

In our analysis we examined the association between temperature and migration into and out of the Great Lakes region. We find that temperature has a statistically significant association with in- and out-migration for the Great Lakes.

Many municipalities are looking to capitalize on the potential of climate change to drive population growth in their areas. Our analysis finds several important findings. First, regarding out-migration from the Great Lakes, extreme cold temperatures (days under 20 and under 0 degrees) are positively associated with out-migration from days under 32 degrees are negatively associated with out-migration. As the more northerly regions of the US warm, we could expect fewer days under 20 degrees and more days under 32 degrees. This shift in the distribution could provide a 'protective' migration effect that could be associated with more people *staying* in the Great Lakes region as opposed to migrating away.

Second, when people do move out of the Great Lakes Region, they tend to move to places that are warm, but not hot, as evidenced by the positive relationship between destination days over 90 but a negative relationship with days over 95. The common refrain that northern migrants are moving to sunbelt cities in Arizona and Florida might not necessarily be true. Rather, Great Lakes out-migrants are moving to more temperate climates rather than more hot climates.

Third, migration into the Great Lakes region tends to come from areas of extreme heat (days over 100 degrees). As the US continues to warm and heat-dome like effects are felt in a variety of regions, the Great Lakes might remain as an attractive destination for those looking to escape extreme heat. It's possible that a reverse sunbelt migration could occur, given the findings here, with the Great Lakes region poised to capture this potential northerly migration.