8. Vulnerability to Extreme Heat

Methods

Future heat hazard risks for Florida were derived using an ArcGIS plugin named SimCLIM.[26] The SimCLIM tool for ArcGIS provides spatial representations of climate data for both the current climate baseline (1960-1991) and projected future climate out to the year 2100. State-specific data for Florida represents downscaled global climate data derived for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). SimCLIM data related to temperature includes projections of minimum, maximum, and departure from current baseline temperature. This project utilizes the maximum and temperature change from baseline to identify different risk levels and areas across the state of Florida. A detailed discussion of the approach used to downscale the Florida-specific data is provided below followed by an explanation of the methods used to create the tract-level future heat risk.

Downscaling Global Climate Data

Monthly projections of monthly-mean daily maximum temperature calculated by the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset are used in the downscaling represented in this report (Maurer et al., 2007). CMIP3 compares different climate models and downscaling techniques and was used for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). While climate projections that will be used in the Fifth Assessment Report (AR5) are currently available for analysis, they are not utilized here because the IPCC Synthesis Report has not yet been released.

CMIP3 includes 21 different global climate models (GCMs). These models are combined to make ensembles. Models and ensembles are run with many different settings. The settings used to create the projections presented here were selected to represent the low end, high end, and middle of the range of projections (Figure 42). The 50th percentile ensembles are used for this assessment.

[26] SimCLIM is an integrated modeling system for assessing climate change impacts and adaptation. Amongst a range of applications, it can be used to assist in climate proofing across various sectors including: water, agriculture, health, ecosystems, coastal zone issues (sea level rise and coastal erosion). More information from www.climsystems.com/simclim/.

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a] Best estimate	*Likely* range	Sea Level Rise) (m at 2090-2099 relative to 1980-1999) Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Figure 42: The six illustrative cases of carbon dioxide, methane, nitrous oxide, and sulfur dioxide emissions used in AR4.

Most climate models cover the entire globe, but this requires the use of a relatively coarse spatial resolution. In order to provide more detail, climate scientists use a process called downscaling. There are two ways to downscale data: statistical downscaling and dynamical downscaling. Dynamical downscaling involves increasing the modeled detail of physical processes. However, statistical downscaling requires less computing power than dynamical downscaling or running a regional climate model, and these other approaches are not necessarily more accurate (Brekke et al., 2013). The downscaling method used by CMIP3 that is shown here is a type of statistical downscaling known as bias corrected spatial disaggregation (BCSD) (Wood et al., 2004). BCSD is one of the most robust statistical downscaling methods (Brekke et al., 2013), and it yields results that are sufficiently comparable to other techniques (Maurer et al., 2010; Abatzoglou and Brown, 2011; Wood et al., 2004).

The fact that Florida is a peninsula creates some unique challenges. Global climate models do not have an ideal spatial resolution for representing the effects of the coast on Florida's climate (Misra et al., 2011). This also makes the use of statistical downscaling more challenging (Barsugli and Anderson, 2009). In addition, some models have difficulty representing certain climate cycles, such as the El Niño Southern Oscillation (ENSO), that affect Florida's climate (Misra et al., 2011; Joseph and Nigam, 2006).

Downscaled data for Florida representing one-km by one-km grids was utilized to create a spatial representation of annual heat hazard areas in 2100 (Figure 43) and temperature change from the 1960-1991 baseline (Figure 44) for the A1B scenario. These were compared to 2100 heat hazard areas during the warmest months of the year (June-August) (Figure 46) and temperature change during these months as compared to the 1960-1991 baseline (Figure 46) to identify areas where both temperature extremes and more rapid temperature changes will likely occur. While the monthly-mean maximum temperature (annualized high temperatures) will be highest across central Florida and into south and southwest Florida (Figure 43), the temperatures during the warmest months of the year will be highest throughout the entire state with the exception of the eastern seaboard (Figure 45). This analysis will focus on the months of June to August given the enhanced hazard risk present during that time frame. However, note that in neither instance will the modeled monthly-mean daily maximum temperatures

exceed 100°F. What is perhaps more important to consider is the fact that the panhandle will experience a disproportionate increase in maximum temperatures compared to the current baseline temperature (Figure 46). It is in these places, from Panama City through Apalachicola to Jacksonville, that temperature change will likely require more adaptation, mitigation, and protective action.

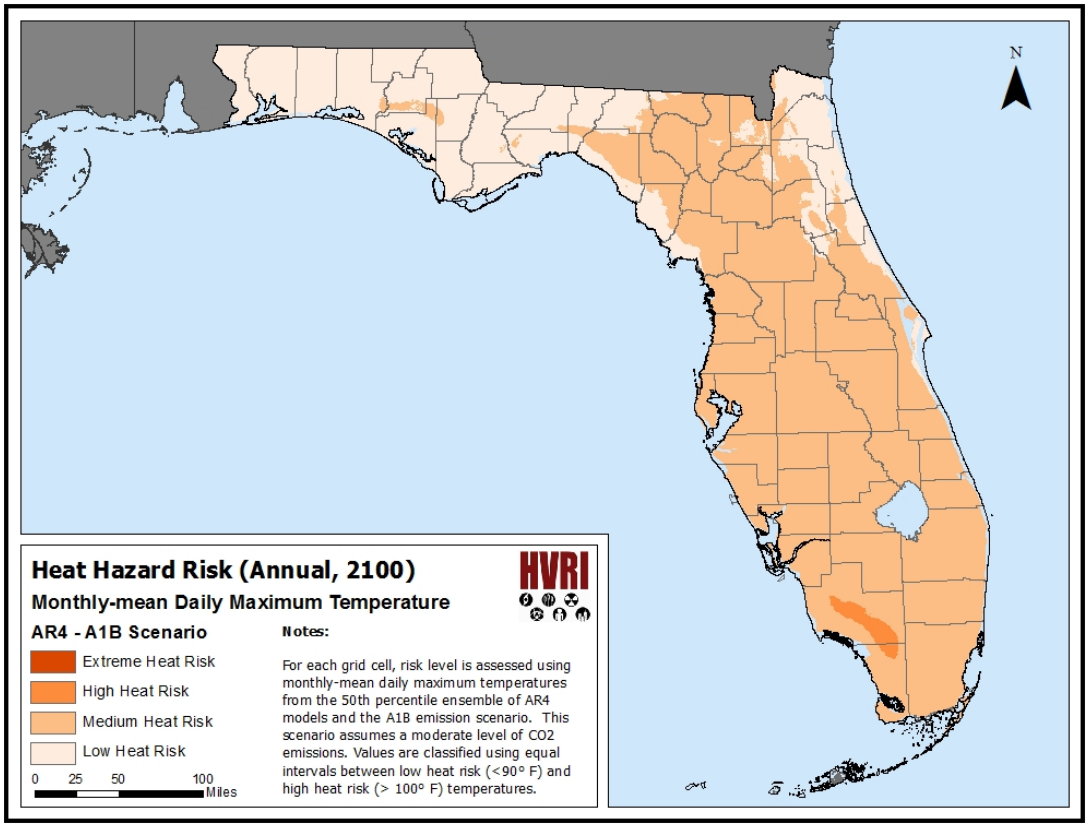

Figure 43: Monthly-mean daily maximum temperature for the A1B scenario in Florida, 2100.

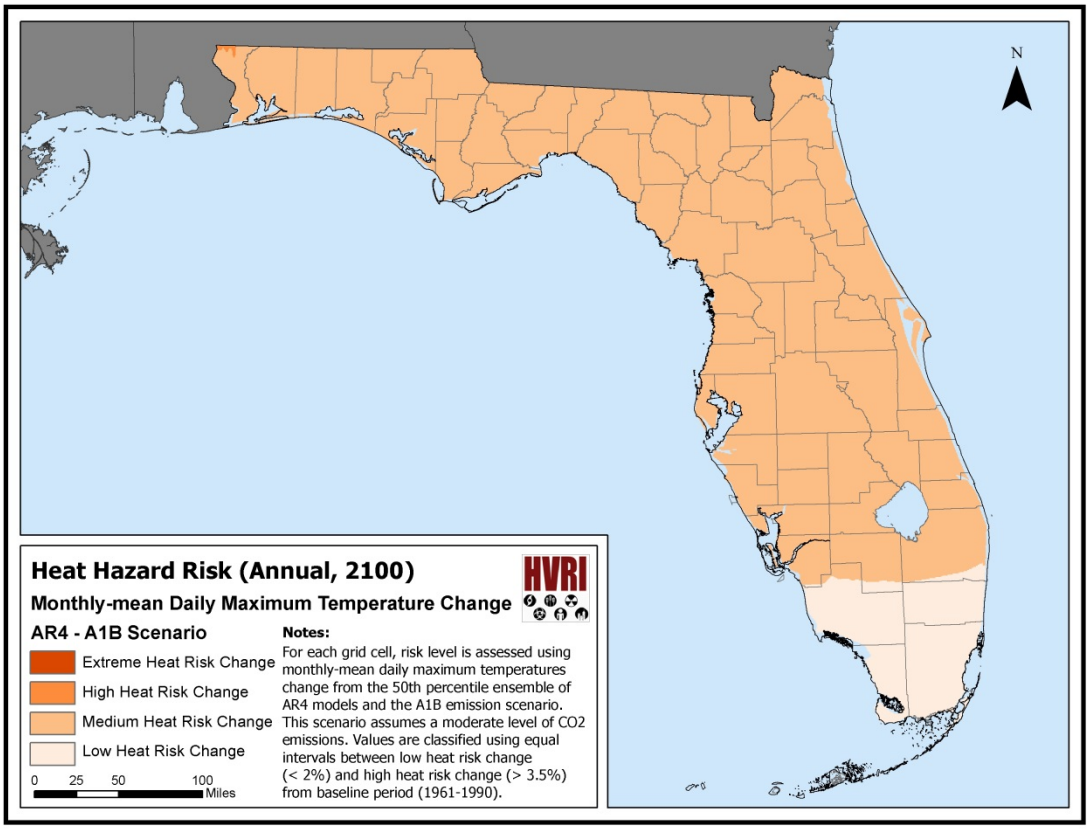

Figure 44: Annual change in monthly-mean daily maximum temperature for the A1B scenario in Florida from 1990 baseline to 2100.

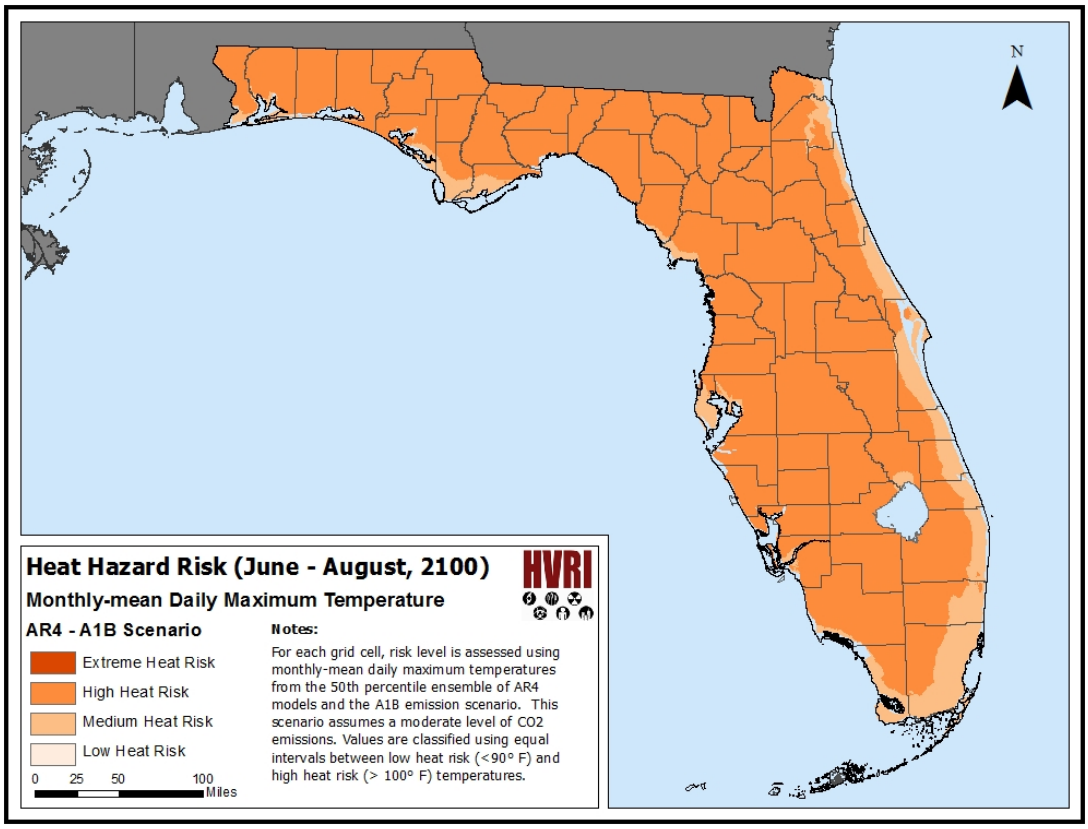

Figure 45: Monthly-mean daily maximum temperature for the A1B scenario in Florida - June-August, 2100.

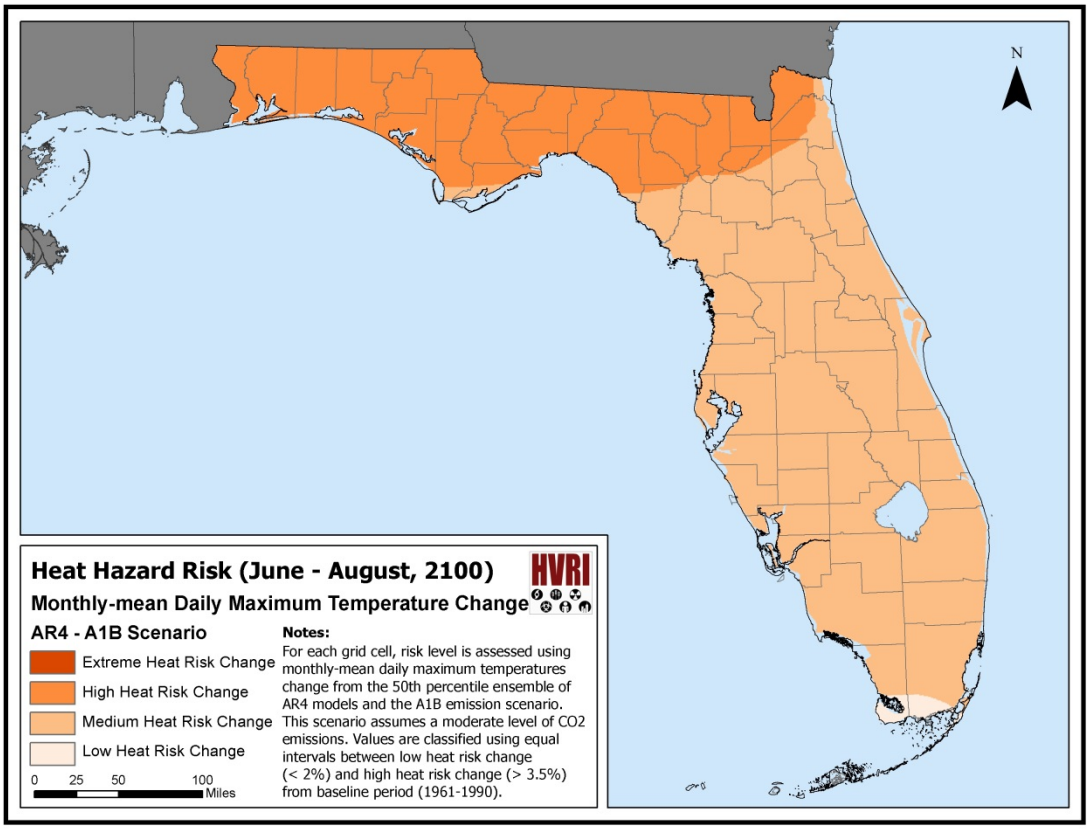

Figure 46: June-August change in monthly-mean daily maximum temperature for the A1B scenario in Florida from 1990 baseline to 2100.

Zonal statistics (min, max, average, standard deviation) utilizing known geographies – in this case census tracts - enable a transition from downscaled climate data on heat hazards to enumeration units more readily understood and analyzed. In this case, each census tract was categorized into one of five classes based on the average monthly-mean daily maximum temperature from June – August, coinciding (spatially) with it. Using the following equal interval classification scheme, future changes in risk at the tract- level can be easily seen in comparison to the current risk level:

- Low = Less than 90°F average monthly-mean daily maximum temperature from June – August
- Medium = Between 90°F - 95°F average monthly-mean daily maximum temperature from June – August
- High = Between 95°F - 100°F average monthly-mean daily maximum temperature from June – August
- Extreme = Greater than 100°F average monthly-mean daily maximum temperature from June – August

State Summary

The AR4-B1 scenario shows the vast majority of the state (97% as shown in Table 57) in the medium heat risk category (90°F - 95°F daily maximum temperatures) during the warmest months of the year (Figure 47), with over 18 million people at a medium level of risk (Table 58). In this scenario, there are no areas of the state within the low or extreme risk categories.

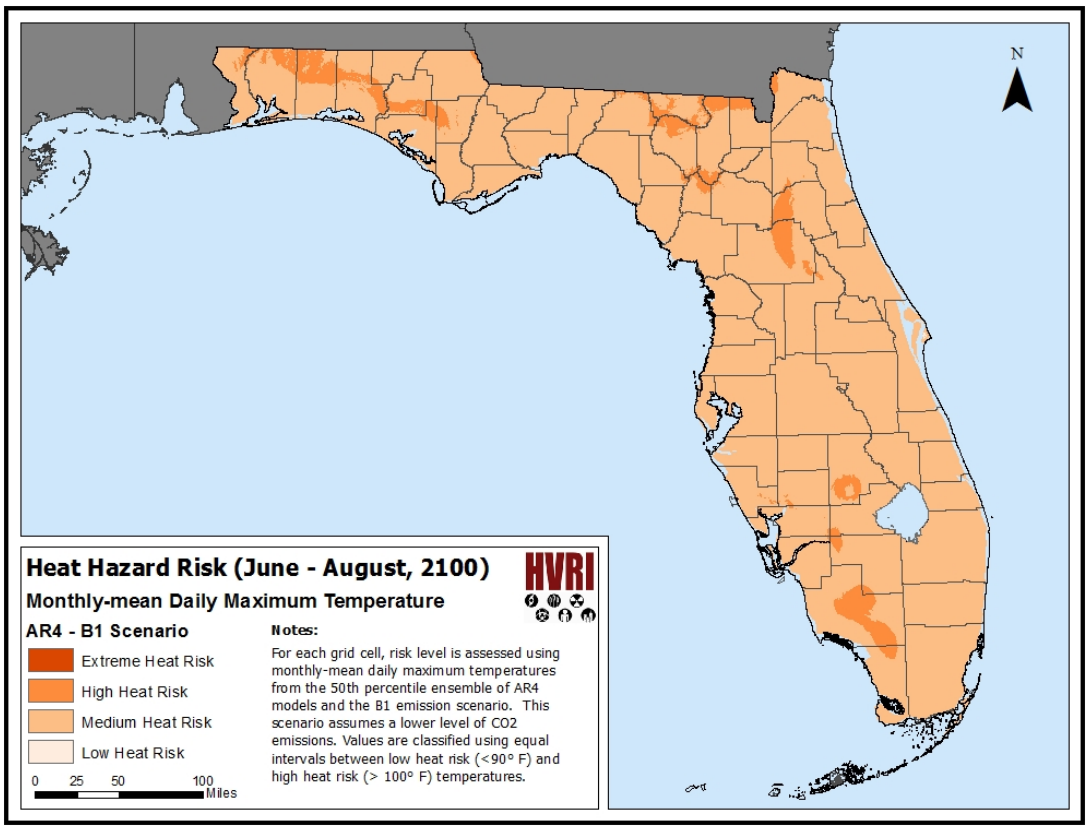

Figure 47: Heat hazard risk for B1 scenario in Florida - June-August, 2100.

Table 57: Census tract summary for heat hazard risk using the B1 scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario				
	Extreme (>100°)	High (95°-100°)	Medium (90°- 95°)	Low (<90°)	Out		Extreme (>100°)	High (95°-100°)	Medium (90°- 95°)	Low (<90°)	Out
Alachua	-	5.36%	94.64%	-	-	Lee	-	0.60%	99.40%	-	-
Baker	-	25.00%	75.00%	-	-	Leon	-	-	100.00%	-	-
Bay	-	2.27%	97.73%	-	-	Lewy	-	-	100.00%	-	-
Bradford	-	-	100.00%	-	-	Liberty	-	-	100.00%	-	-
Brevard	-	-	100.00%	-	-	Madison	-	60.00%	40.00%	-	-
Broward	-	-	100.00%	-	-	Manatee	-	-	100.00%	-	-
Calhoun	-	66.67%	33.33%	-	-	Marion	-	17.46%	82.54%	-	-
Charlotte	-	2.56%	97.44%	-	-	Martin	-	-	100.00%	-	-
Citrus	-	-	100.00%	-	-	Miami-Dade	-	-	100.00%	-	-
Clay	-	10.00%	90.00%	-	-	Monroe	-	74.19%	25.81%	-	-
Collier	-	5.41%	94.59%	-	-	Nassau	-	16.67%	83.33%	-	-
Columbia	-	50.00%	50.00%	-	-	Okaloosa	-	24.39%	75.61%	-	-
DeSoto	-	33.33%	66.67%	-	-	Okeechobee	-	-	100.00%	-	-
Dixie	-	-	100.00%	-	-	Orange	-	-	100.00%	-	-
Duval	-	-	100.00%	-	-	Osceola	-	-	100.00%	-	-
Escambia	-	2.82%	97.18%	-	-	Palm Beach	-	-	100.00%	-	-
Flagler	-	-	100.00%	-	-	Pasco	-	-	100.00%	-	-
Franklin	-	-	100.00%	-	-	Pinellas	-	-	100.00%	-	-
Gadsden	-	-	100.00%	-	-	Polk	-	-	100.00%	-	-
Gilchrist	-	40.00%	60.00%	-	-	Putnam	-	29.41%	70.59%	-	-
Glades	-	75.00%	25.00%	-	-	Santa Rosa	-	8.00%	92.00%	-	-
Gulf	-	-	100.00%	-	-	Sarasota	-	2.13%	97.87%	-	-
Hamilton	-	100.00%	-	-	-	Seminole	-	-	100.00%	-	-
Hardee	-	-	100.00%	-	-	St. Johns	-	-	100.00%	-	-
Hendry	-	66.67%	33.33%	-	-	St. Lucie	-	-	100.00%	-	-
Hernando	-	-	100.00%	-	-	Sumter	-	-	100.00%	-	-
Highlands	-	14.81%	85.19%	-	-	Suwannee	-	85.71%	14.29%	-	-
Hillsborough	-	-	100.00%	-	-	Taylor	-	-	100.00%	-	-
Holmes	-	25.00%	75.00%	-	-	Union	-	-	100.00%	-	-
Indian River	-	-	100.00%	-	-	Volusia	-	-	100.00%	-	-
Jackson	-	18.18%	81.82%	-	-	Wakulla	-	25.00%	75.00%	-	-
Jefferson	-	33.33%	66.67%	-	-	Walton	-	63.64%	36.36%	-	-
Lafayette	-	50.00%	50.00%	-	-	Washington	-	57.14%	42.86%	-	-
Lake	-	3.57%	96.43%	-	-	**State Total**	-	2.99%	97.01%	-	-

Table 58: Census tract population summary for heat hazard risk using the B1 scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario				
	Extreme (>100°)	High (95°-100°)	Medium (90° - 95°)	Low (<90°)	Out		Extreme (>100°)	High (95°-100°)	Medium (90° - 95°)	Low (<90°)	Out
Alachua	-	21,821	225,515	-	-	Lee	-	2,800	615,954	-	-
Baker	-	7,519	19,596	-	-	Leon	-	-	275,487	-	-
Bay	-	8,552	160,300	-	-	Levy	-	-	40,801	-	-
Bradford	-	-	28,520	-	-	Liberty	-	-	8,365	-	-
Brevard	-	-	543,369	-	-	Madison	-	10,553	8,671	-	-
Broward	-	-	1,748,066	-	-	Manatee	-	-	322,833	-	-
Calhoun	-	12,192	2,433	-	-	Marion	-	38,293	293,005	-	-
Charlotte	-	3,837	156,141	-	-	Martin	-	-	146,318	-	-
Citrus	-	-	141,236	-	-	Miami-Dade	-	-	2,493,127	-	-
Clay	-	12,461	178,404	-	-	Monroe	-	54,862	18,228	-	-
Collier	-	32,680	288,840	-	-	Nassau	-	14,983	58,331	-	-
Columbia	-	33,918	33,613	-	-	Okaloosa	-	66,486	114,336	-	-
DeSoto	-	8,341	26,521	-	-	Okeechobee	-	-	39,996	-	-
Dixie	-	-	16,422	-	-	Orange	-	-	1,145,956	-	-
Duval	-	-	864,263	-	-	Osceola	-	-	268,685	-	-
Escambia	-	9,859	287,760	-	-	Palm Beach	-	-	1,319,462	-	-
Flagler	-	-	95,696	-	-	Pasco	-	-	464,697	-	-
Franklin	-	-	11,549	-	-	Pinellas	-	-	916,542	-	-
Gadsden	-	-	46,389	-	-	Polk	-	-	602,095	-	-
Gilchrist	-	7,470	9,469	-	-	Putnam	-	25,540	48,824	-	-
Glades	-	10,618	2,266	-	-	Santa Rosa	-	8,185	143,187	-	-
Gulf	-	-	15,863	-	-	Sarasota	-	41,193	338,255	-	-
Hamilton	-	14,799	-	-	-	Seminole	-	-	422,718	-	-
Hardee	-	-	27,731	-	-	St. Johns	-	-	190,039	-	-
Hendry	-	24,824	14,316	-	-	St. Lucie	-	-	277,789	-	-
Hernando	-	-	172,778	-	-	Sumter	-	-	87,023	-	-
Highlands	-	14,709	84,077	-	-	Suwannee	-	39,748	1,803	-	-
Hillsborough	-	-	1,229,226	-	-	Taylor	-	-	22,570	-	-
Holmes	-	5,544	14,383	-	-	Union	-	-	15,535	-	-
Indian River	-	-	138,028	-	-	Volusia	-	-	494,593	-	-
Jackson	-	9,293	40,453	-	-	Wakulla	-	5,276	25,500	-	-
Jefferson	-	4,496	10,265	-	-	Walton	-	32,866	22,177	-	-
Lafayette	-	5,706	3,164	-	-	Washington	-	16,682	8,214	-	-
Lake	-	5,077	291,975	-	-	**State Total**	-	611,183	18,179,743	-	-

Looking at the A1B scenario tells a different story, with most census tracts within the state falling into a high heat risk category (95°F - 100°F daily maximum temperatures). The exception can be seen (Figure 48) along the entire eastern seaboard where daily maximum temperatures will be slightly cooler. As with the B1 scenario, no populations in Florida will fall into the extreme risk category in the A1B scenario (Table 60). However, the converse is also true in that no place in Florida will be in the low heat risk category (<85°F) using this scenario. Additionally, the A1B scenario places a much higher percentage of census tracts in the high risk zone (Table 59) than did the B1 scenario.

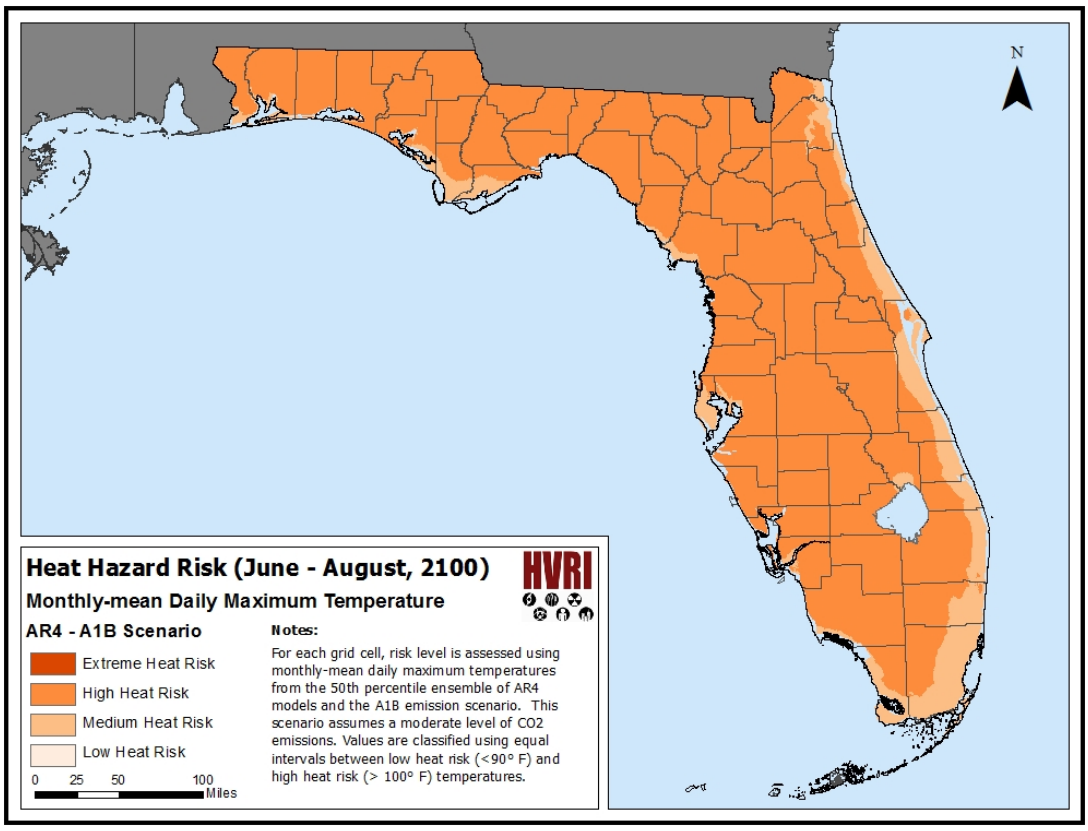

Figure 48: Heat hazard risk for A1B scenario in Florida - June-August, 2100.

Table 59: Census tract summary for heat hazard risk using the A1B scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario				
	Extreme (>100°)	High (95° - 100°)	Medium (90° - 95°)	Low (<90°)	Out		Extreme (>100°)	High (95° - 100°)	Medium (90° - 95°)	Low (<90°)	Out
Alachua	-	100.00%	-	-	-	Lee	-	89.22%	10.78%	-	-
Baker	-	100.00%	-	-	-	Leon	-	100.00%	-	-	-
Bay	-	77.27%	22.73%	-	-	Levy	-	100.00%	-	-	-
Bradford	-	100.00%	-	-	-	Liberty	-	100.00%	-	-	-
Brevard	-	18.58%	81.42%	-	-	Madison	-	100.00%	-	-	-
Broward	-	8.59%	91.41%	-	-	Manatee	-	100.00%	-	-	-
Calhoun	-	100.00%	-	-	-	Marion	-	100.00%	-	-	-
Charlotte	-	100.00%	-	-	-	Martin	-	8.82%	91.18%	-	-
Citrus	-	100.00%	-	-	-	Miami-Dade	-	0.58%	99.42%	-	-
Clay	-	100.00%	-	-	-	Monroe	-	74.19%	25.81%	-	-
Collier	-	91.89%	8.11%	-	-	Nassau	-	50.00%	50.00%	-	-
Columbia	-	100.00%	-	-	-	Okaloosa	-	85.37%	14.63%	-	-
DeSoto	-	100.00%	-	-	-	Okeechobee	-	63.64%	36.36%	-	-
Dixie	-	100.00%	-	-	-	Orange	-	100.00%	-	-	-
Duval	-	78.61%	21.39%	-	-	Osceola	-	100.00%	-	-	-
Escambia	-	80.28%	19.72%	-	-	Palm Beach	-	16.37%	83.63%	-	-
Flagler	-	50.00%	50.00%	-	-	Pasco	-	100.00%	-	-	-
Franklin	-	50.00%	50.00%	-	-	Pinellas	-	13.88%	86.12%	-	-
Gadsden	-	100.00%	-	-	-	Polk	-	100.00%	-	-	-
Gilchrist	-	100.00%	-	-	-	Putnam	-	100.00%	-	-	-
Glades	-	100.00%	-	-	-	Santa Rosa	-	80.00%	20.00%	-	-
Gulf	-	66.67%	33.33%	-	-	Sarasota	-	100.00%	-	-	-
Hamilton	-	100.00%	-	-	-	Seminole	-	100.00%	-	-	-
Hardee	-	100.00%	-	-	-	St. Johns	-	43.59%	56.41%	-	-
Hendry	-	100.00%	-	-	-	St. Lucie	-	4.55%	95.45%	-	-
Hernando	-	100.00%	-	-	-	Sumter	-	100.00%	-	-	-
Highlands	-	100.00%	-	-	-	Suwannee	-	100.00%	-	-	-
Hillsborough	-	86.92%	13.08%	-	-	Taylor	-	100.00%	-	-	-
Holmes	-	100.00%	-	-	-	Union	-	100.00%	-	-	-
Indian River	-	6.67%	93.33%	-	-	Volusia	-	38.60%	61.40%	-	-
Jackson	-	100.00%	-	-	-	Wakulla	-	100.00%	-	-	-
Jefferson	-	100.00%	-	-	-	Walton	-	100.00%	-	-	-
Lafayette	-	100.00%	-	-	-	Washington	-	100.00%	-	-	-
Lake	-	100.00%	-	-	-	**State Total**	-	57.49%	42.51%	-	-

Table 60: Census tract population summary for heat hazard risk using the A1B scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario				
	Extreme (>100°)	High (95° - 100°)	Medium (90° - 95°)	Low (<90°)	Out		Extreme (>100°)	High (95° - 100°)	Medium (90° - 95°)	Low (<90°)	Out
Alachua	-	247,336	-	-	-	Lee	-	553,882	64,872	-	-
Baker	-	27,115	-	-	-	Leon	-	275,487	-	-	-
Bay	-	138,206	30,646	-	-	Levy	-	40,801	-	-	-
Bradford	-	28,520	-	-	-	Liberty	-	8,365	-	-	-
Brevard	-	119,319	424,050	-	-	Madison	-	19,224	-	-	-
Broward	-	176,747	1,571,319	-	-	Manatee	-	322,833	-	-	-
Calhoun	-	14,625	-	-	-	Marion	-	331,298	-	-	-
Charlotte	-	159,978	-	-	-	Martin	-	20,302	126,016	-	-
Citrus	-	141,236	-	-	-	Miami-Dade	-	12,923	2,480,204	-	-
Clay	-	190,865	-	-	-	Monroe	-	54,862	18,228	-	-
Collier	-	304,840	16,680	-	-	Nassau	-	40,551	32,763	-	-
Columbia	-	67,531	-	-	-	Okaloosa	-	165,257	15,565	-	-
DeSoto	-	34,862	-	-	-	Okeechobee	-	25,456	14,540	-	-
Dixie	-	16,422	-	-	-	Orange	-	1,145,956	-	-	-
Duval	-	669,106	195,157	-	-	Osceola	-	268,685	-	-	-
Escambia	-	241,653	55,966	-	-	Palm Beach	-	252,699	1,066,763	-	-
Flagler	-	59,397	36,299	-	-	Pasco	-	464,697	-	-	-
Franklin	-	7,055	4,494	-	-	Pinellas	-	143,008	773,534	-	-
Gadsden	-	46,389	-	-	-	Polk	-	602,095	-	-	-
Gilchrist	-	16,939	-	-	-	Putnam	-	74,364	-	-	-
Glades	-	12,884	-	-	-	Santa Rosa	-	123,191	28,181	-	-
Gulf	-	12,787	3,076	-	-	Sarasota	-	379,448	-	-	-
Hamilton	-	14,799	-	-	-	Seminole	-	422,718	-	-	-
Hardee	-	27,731	-	-	-	St. Johns	-	106,445	83,594	-	-
Hendry	-	39,140	-	-	-	St. Lucie	-	14,523	263,266	-	-
Hernando	-	172,778	-	-	-	Sumter	-	87,023	-	-	-
Highlands	-	98,786	-	-	-	Suwannee	-	41,551	-	-	-
Hillsborough	-	1,082,424	146,802	-	-	Taylor	-	22,570	-	-	-
Holmes	-	19,927	-	-	-	Union	-	15,535	-	-	-
Indian River	-	14,368	123,660	-	-	Volusia	-	228,217	266,376	-	-
Jackson	-	49,746	-	-	-	Wakulla	-	30,776	-	-	-
Jefferson	-	14,761	-	-	-	Walton	-	55,043	-	-	-
Lafayette	-	8,870	-	-	-	Washington	-	24,896	-	-	-
Lake	-	297,052	-	-	-	**State Total**	-	10,948,875	7,842,051	-	-

The A1FI scenario plays out the most extreme projection for the state of Florida, with almost 96% of the census tracts in the state in the high risk category (Table 61) corresponding to over 18 million people (Table 62). This scenario also includes some extreme risk areas in northern Florida and in the panhandle (Figure 49), with a small portion of Miami-Dade County being the only part of the state in the medium risk category.

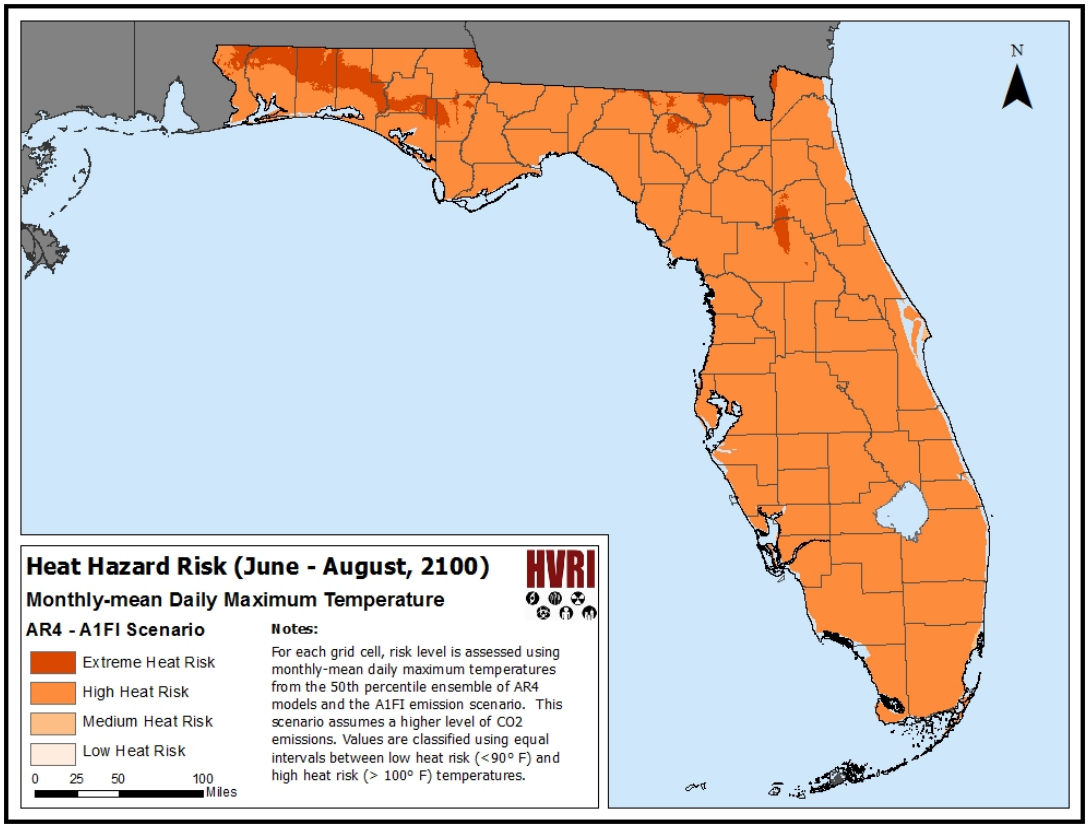

Figure 49: Heat hazard risk for A1FI scenario in Florida - June-August, 2100.

Table 61: Census tract summary for heat hazard risk using the A1FI scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario				
	Extreme (>100°)	High (95°-100°)	Medium (90°-95°)	Low (<90°)	Out		Extreme (>100°)	High (95°-100°)	Medium (90°-95°)	Low (<90°)	Out
Alachua	-	100.00%	-	-	-	Lee	-	100.00%	-	-	-
Baker	25.00%	75.00%	-	-	-	Leon	-	100.00%	-	-	-
Bay	2.27%	97.73%	-	-	-	Levy	-	100.00%	-	-	-
Bradford	-	100.00%	-	-	-	Liberty	100.00%	-	-	-	-
Brevard	-	100.00%	-	-	-	Madison	40.00%	60.00%	-	-	-
Broward	-	100.00%	-	-	-	Manatee	-	100.00%	-	-	-
Calhoun	100.00%	-	-	-	-	Marion	11.11%	88.89%	-	-	-
Charlotte	-	100.00%	-	-	-	Martin	-	100.00%	-	-	-
Citrus	-	100.00%	-	-	-	Miami-Dade	-	79.77%	20.23%	-	-
Clay	-	100.00%	-	-	-	Monroe	-	100.00%	-	-	-
Collier	-	100.00%	-	-	-	Nassau	16.67%	83.33%	-	-	-
Columbia	16.67%	83.33%	-	-	-	Okaloosa	24.39%	75.61%	-	-	-
DeSoto	-	100.00%	-	-	-	Okeechobee	-	100.00%	-	-	-
Dixie	-	100.00%	-	-	-	Orange	-	100.00%	-	-	-
Duval	-	100.00%	-	-	-	Osceola	-	100.00%	-	-	-
Escambia	4.23%	95.77%	-	-	-	Palm Beach	-	100.00%	-	-	-
Flagler	-	100.00%	-	-	-	Pasco	-	100.00%	-	-	-
Franklin	-	100.00%	-	-	-	Pinellas	-	100.00%	-	-	-
Gadsden	11.11%	88.89%	-	-	-	Polk	-	100.00%	-	-	-
Gilchrist	-	100.00%	-	-	-	Putnam	23.53%	76.47%	-	-	-
Glades	-	100.00%	-	-	-	Santa Rosa	12.00%	88.00%	-	-	-
Gulf	-	100.00%	-	-	-	Sarasota	-	100.00%	-	-	-
Hamilton	100.00%	-	-	-	-	Seminole	-	100.00%	-	-	-
Hardee	-	100.00%	-	-	-	St. Johns	-	100.00%	-	-	-
Hendry	-	100.00%	-	-	-	St. Lucie	-	100.00%	-	-	-
Hernando	-	100.00%	-	-	-	Sumter	-	100.00%	-	-	-
Highlands	-	100.00%	-	-	-	Suwannee	71.43%	28.57%	-	-	-
Hillsborough	-	100.00%	-	-	-	Taylor	-	100.00%	-	-	-
Holmes	25.00%	75.00%	-	-	-	Union	-	100.00%	-	-	-
Indian River	-	100.00%	-	-	-	Volusia	-	100.00%	-	-	-
Jackson	27.27%	72.73%	-	-	-	Wakulla	-	100.00%	-	-	-
Jefferson	33.33%	66.67%	-	-	-	Walton	63.64%	36.36%	-	-	-
Lafayette	-	100.00%	-	-	-	Washington	57.14%	42.86%	-	-	-
Lake	-	100.00%	-	-	-	**State Total**	1.54%	95.97%	2.49%	-	-

Table 62: Census tract population summary for heat hazard risk using the A1FI scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario				
	Extreme (>100°)	High (95°-100°)	Medium (90°-95°)	Low (<90°)	Out		Extreme (>100°)	High (95°-100°)	Medium (90°-95°)	Low (<90°)	Out
Alachua	-	247,336	-	-	-	Lee	-	618,754	-	-	-
Baker	7,519	19,596	-	-	-	Leon	-	275,487	-	-	-
Bay	8,552	160,300	-	-	-	Levy	-	40,801	-	-	-
Bradford	-	28,520	-	-	-	Liberty	8,365	-	-	-	-
Brevard	-	543,369	-	-	-	Madison	6,834	12,390	-	-	-
Broward	-	1,748,066	-	-	-	Manatee	-	322,833	-	-	-
Calhoun	14,625	-	-	-	-	Marion	20,909	310,389	-	-	-
Charlotte	-	159,978	-	-	-	Martin	-	146,318	-	-	-
Citrus	-	141,236	-	-	-	Miami-Dade	-	2,115,040	378,087	-	-
Clay	-	190,865	-	-	-	Monroe	-	73,090	-	-	-
Collier	-	321,520	-	-	-	Nassau	14,983	58,331	-	-	-
Columbia	14,284	53,247	-	-	-	Okaloosa	66,486	114,336	-	-	-
DeSoto	-	34,862	-	-	-	Okeechobee	-	39,996	-	-	-
Dixie	-	16,422	-	-	-	Orange	-	1,145,956	-	-	-
Duval	-	864,263	-	-	-	Osceola	-	268,685	-	-	-
Escambia	14,225	283,394	-	-	-	Palm Beach	-	1,319,462	-	-	-
Flagler	-	95,696	-	-	-	Pasco	-	464,697	-	-	-
Franklin	-	11,549	-	-	-	Pinellas	-	916,542	-	-	-
Gadsden	4,769	41,620	-	-	-	Polk	-	602,095	-	-	-
Gilchrist	-	16,939	-	-	-	Putnam	21,941	52,423	-	-	-
Glades	-	12,884	-	-	-	Santa Rosa	10,819	140,553	-	-	-
Gulf	-	15,863	-	-	-	Sarasota	-	379,448	-	-	-
Hamilton	14,799	-	-	-	-	Seminole	-	422,718	-	-	-
Hardee	-	27,731	-	-	-	St. Johns	-	190,039	-	-	-
Hendry	-	39,140	-	-	-	St. Lucie	-	277,789	-	-	-
Hernando	-	172,778	-	-	-	Sumter	-	87,023	-	-	-
Highlands	-	98,786	-	-	-	Suwannee	32,889	8,662	-	-	-
Hillsborough	-	1,229,226	-	-	-	Taylor	-	22,570	-	-	-
Holmes	5,544	14,383	-	-	-	Union	-	15,535	-	-	-
Indian River	-	138,028	-	-	-	Volusia	-	494,593	-	-	-
Jackson	13,618	36,128	-	-	-	Wakulla	-	30,776	-	-	-
Jefferson	4,496	10,265	-	-	-	Walton	32,866	22,177	-	-	-
Lafayette	-	8,870	-	-	-	Washington	16,682	8,214	-	-	-
Lake	-	297,052	-	-	-	**State Total**	335,205	18,077,634	378,087	-	-

Analyzing Heat Hazard in Combination with SoVI and MedVI

About Bivariate Classifications

Here, we keep the exposure constant by using the same hazard threat surface but use different vulnerability perspectives (Social and Medical) in bivariate representations to create an easily understood depiction of not only increased threat but also a limited ability to adequately prepare for and respond to these threats. In doing so, we are able to quickly identify three specific geographic areas of interest:

1. Areas where the hazard itself should be the focus of planning and mitigation,
2. Areas where understanding the underlying socioeconomics and demographics would prove to be the most advantageous input point to create positive change, and
3. Areas where a combination of classic hazard mitigation techniques and social mitigation practices should be utilized in order to maximize optimal outcomes.

The following maps utilize a three by three bivariate representation in which one can easily identify areas of limited to elevated SoVI in relation to areas with low to extreme hazard classifications. Places identified in item number one in the preceding list are shaded in the blue colors and can be understood as locations where hazard susceptibility is higher than SoVI or MedVI. Areas identified in item number two above, indicating where socioeconomics and demographics play an important role, are shaded in the pink/red colors and can be conceived as locations where SoVI or MedVI are greater than physical hazard threats. Places identified in item number three above are shaded either in gray-tones or in a dark burgundy color and can be understood as areas that have equal vulnerability and hazard classification scores.

Integrating B1 Scenario Extreme Heat with SoVI and MedVI

The pattern of social vulnerability comes through clearly when coupled with heat hazard because of the general lack of variation across Florida. Only three census tracts corresponding to just over 16,000 people are susceptible to high heat risk and high social vulnerability in the AR4-B1 scenario (Table 63), but census tracts throughout central and southern Florida display medium heat risk and high social vulnerability (Figure 50).

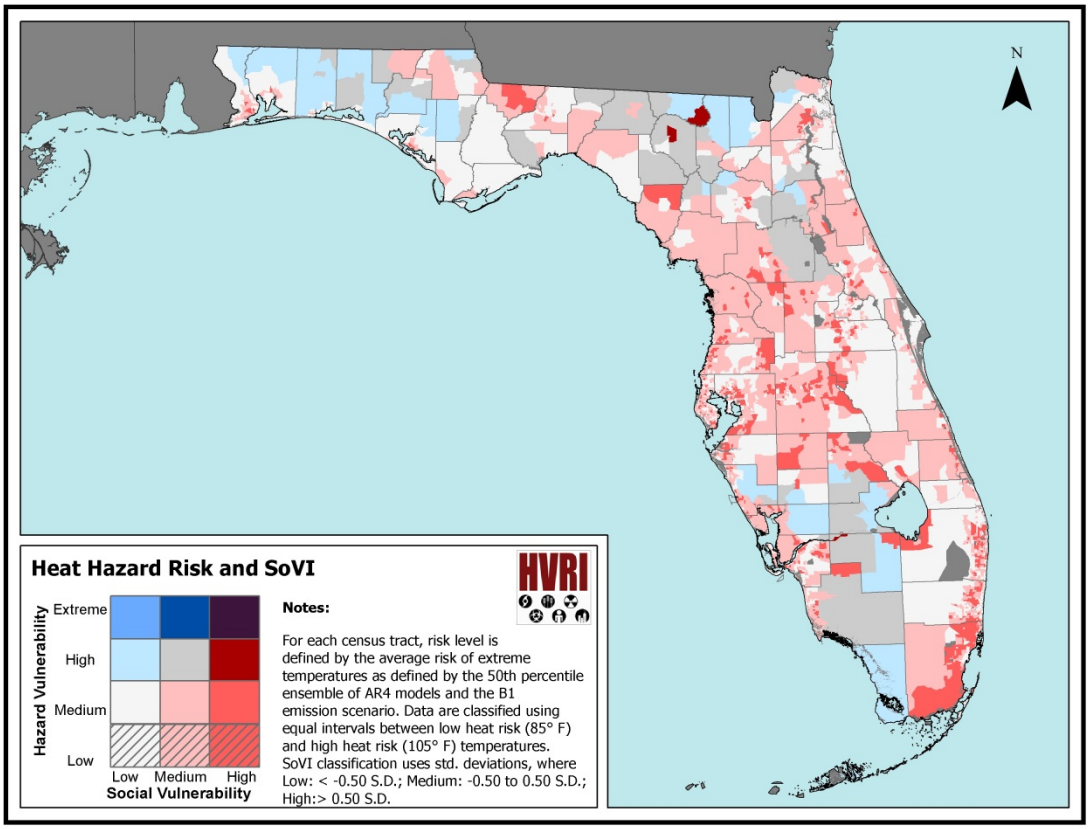

Figure 50: Bivariate representation of SoVI and heat hazard risk for B1 scenario in Florida.

Table 63: Tract and population summary for counties with high SoVI and medium or greater heat hazard risk using the B1 scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Heat Hazard Risk								
Hamilton	1	1,760	Hendry	1	7,530	Suwannee	1	7,016
State Total	**3**	**16,306**		-	-		-	-
Medium Heat Hazard Risk								
Alachua	4	19,406	Bay	3	8,846	Brevard	6	20,847
Broward	111	549,548	Charlotte	5	17,905	Citrus	5	23,598
Clay	1	5,311	Collier	15	76,682	Columbia	1	2,872
DeSoto	3	13,900	Dixie	1	7,331	Duval	37	150,426
Escambia	12	39,923	Flagler	3	15,884	Gadsden	5	25,033
Hardee	2	10,630	Hendry	2	14,316	Hernando	15	62,301
Highlands	8	35,116	Hillsborough	73	279,785	Indian River	5	14,670
Lake	9	40,805	Lee	32	100,752	Leon	6	17,898
Manatee	19	84,453	Marion	15	102,216	Martin	2	4,091
Miami-Dade	359	1,900,621	Okeechobee	3	10,116	Orange	50	252,348
Osceola	14	103,651	Palm Beach	104	378,320	Pasco	28	87,242
Pinellas	37	132,662	Polk	52	219,460	Putnam	3	10,480
Santa Rosa	1	6,115	Sarasota	13	46,430	Seminole	7	25,901
St. Johns	1	4,155	St. Lucie	10	37,115	Sumter	6	52,106
Volusia	18	83,236		-	-		-	-
State Total	**1,106**	**5,094,503**		-	-		-	-

Integrating heat hazard risk in the B1 scenario with MedVI shows a much different picture for the state of Florida. Here, a much higher percentage of the state falls into the high medical vulnerability category coupled with medium or high hazard vulnerability (Figure 51). Twenty-three counties across the state have tracts with high heat hazard risk and high medical vulnerability (Table 64). Columbia, Marion, Suwannee, and Walton Counties each have more than 30,000 people at high hazard risk coupled with high medical vulnerability. Another 5 million people with high MedVI are at medium risk.

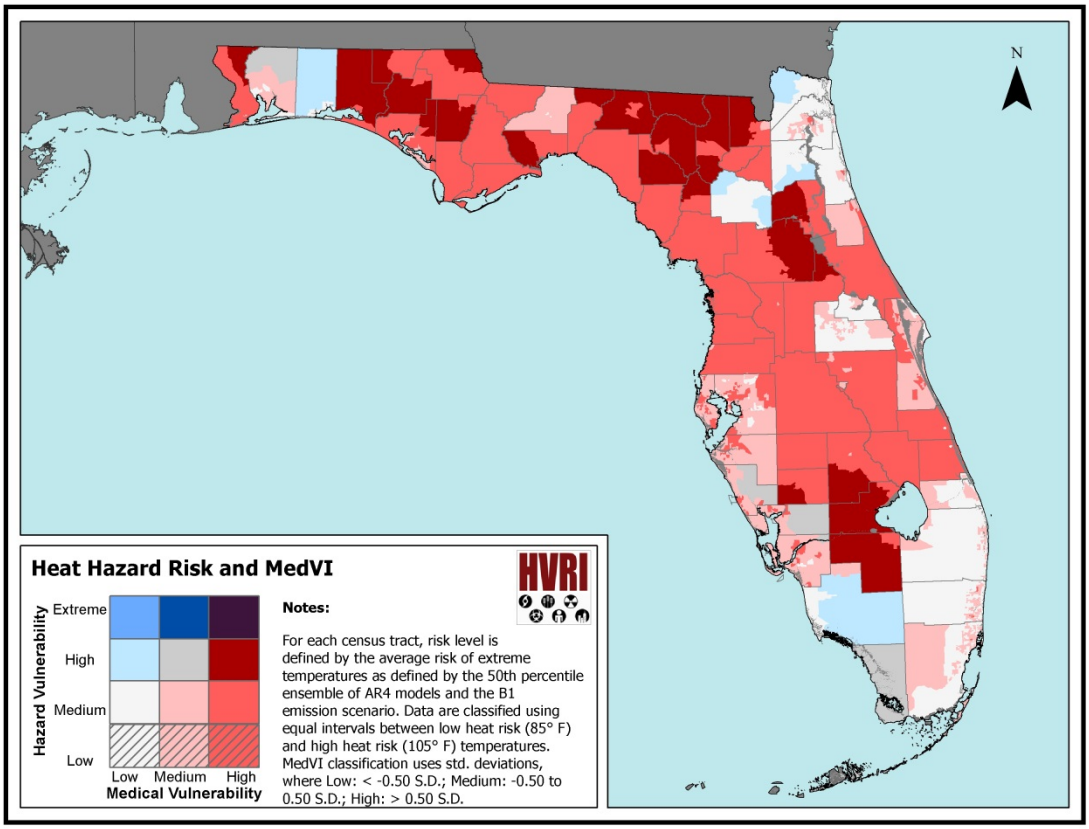

Figure 51: Bivariate representation of MedVI and heat hazard risk for B1 scenario in Florida.

Table 64: Tract and population summary for counties with high MedVI and medium or greater heat hazard risk using the B1 scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Heat Hazard Risk								
Baker	1	7,519	Bay	1	8,552	Calhoun	2	12,192
Columbia	6	33,918	DeSoto	3	8,341	Escambia	2	9,859
Gilchrist	2	7,470	Glades	2	10,618	Hamilton	3	14,799
Hendry	4	24,824	Highlands	4	14,709	Holmes	1	5,544
Jackson	2	9,293	Jefferson	1	4,496	Lafayette	1	5,706
Lake	2	5,077	Madison	3	10,553	Marion	11	38,293
Putnam	5	25,540	Suwannee	6	39,748	Wakulla	1	5,276
Walton	7	32,866	Washington	4	16,682		-	-
State Total	**74**	**351,875**		-	-		-	-
Medium Heat Hazard Risk								
Baker	2	12,912	Bay	31	119,244	Bradford	4	28,520
Brevard	27	158,238	Broward	4	27,116	Calhoun	1	2,433
Charlotte	7	32,234	Citrus	27	141,236	Columbia	6	33,613
DeSoto	6	26,521	Dixie	3	16,422	Duval	10	34,821
Escambia	68	284,537	Flagler	6	24,521	Franklin	4	11,549
Gadsden	9	46,389	Gilchrist	3	9,469	Glades	1	2,266
Gulf	3	15,863	Hardee	6	27,731	Hendry	2	14,316
Hernando	44	172,778	Highlands	22	84,076	Hillsborough	85	307,926
Holmes	3	14,383	Indian River	29	138,028	Jackson	9	40,453
Jefferson	2	10,265	Lafayette	1	3,164	Lake	54	291,975
Lee	32	136,588	Levy	9	40,801	Liberty	2	8,365
Madison	2	8,671	Manatee	17	73,525	Marion	51	293,005
Miami-Dade	4	12,514	Okeechobee	11	39,996	Osceola	39	264,577
Pasco	131	458,710	Pinellas	68	272,992	Polk	153	602,092
Putnam	12	48,824	Sarasota	16	63,596	St. Johns	2	7,673
St. Lucie	43	277,789	Sumter	18	87,023	Suwannee	1	1,803
Taylor	4	22,570	Union	3	15,535	Volusia	113	494,593
Wakulla	3	25,500	Walton	4	22,177	Washington	3	8,214
State Total	**1,220**	**5,420,132**		-	-		-	-

Integrating A1B Scenario Extreme Heat with SoVI and MedVI

When looking at the A1B scenario, census tracts characterized by high SoVI and high heat hazard risk span central and southern Florida, as well as the Gulf Coast (Figure 52). In particular, Collier, Duval, Hernando, Hillsborough, Lee, Manatee, Marion, Orange, Osceola, Pasco, Polk, Sumter, and Volusia Counties each have more than 50,000 people living in high SoVI and high heat hazard zones (Table 65). In total, almost 2 million people in the state of Florida are at high risk coupled with high SoVI, with 3 million people at medium risk.

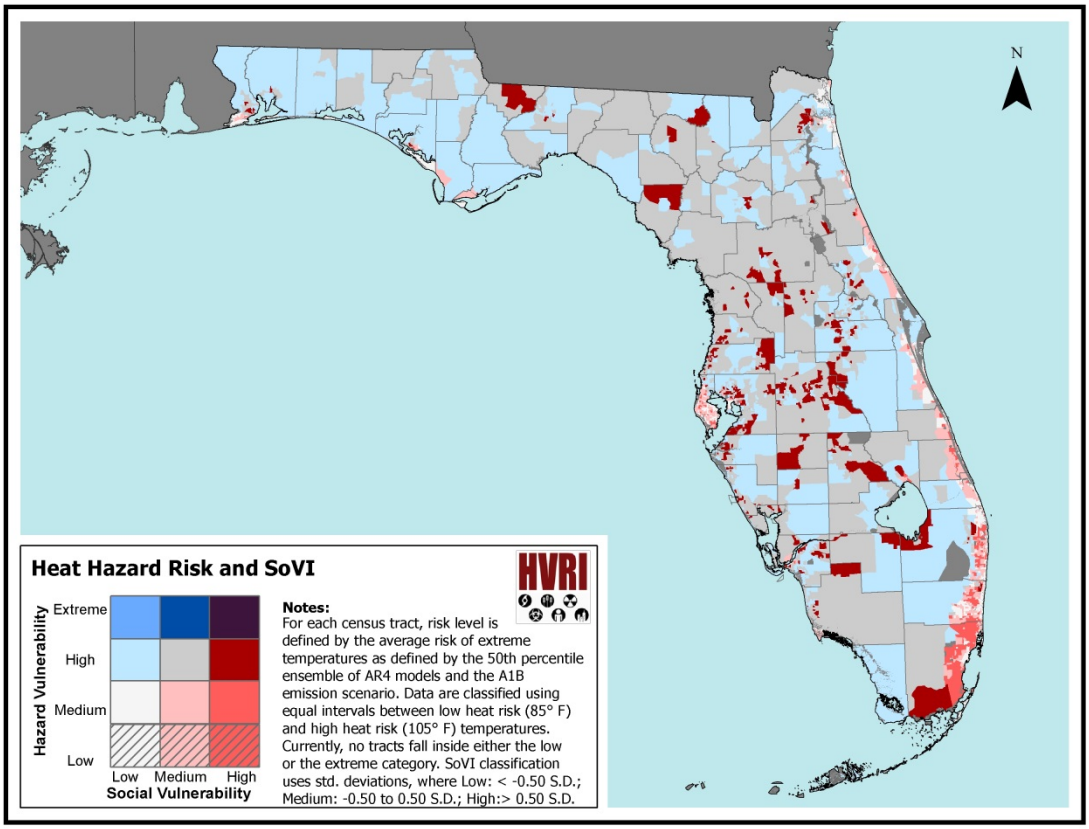

Figure 52: Bivariate representation of SoVI and heat hazard risk for A1B scenario in Florida.

Table 65: Tract and population summary for counties with high SoVI and medium or greater heat hazard risk using the A1B scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Heat Hazard Risk								
Alachua	4	19,406	Bay	2	6,725	Brevard	1	3,232
Broward	6	31,584	Charlotte	5	17,905	Citrus	5	23,598
Clay	1	5,311	Collier	15	76,682	Columbia	1	2,872
DeSoto	3	13,900	Dixie	1	7,331	Duval	35	142,066
Escambia	11	36,771	Flagler	1	6,321	Gadsden	5	25,033
Hamilton	1	1,760	Hardee	2	10,630	Hendry	3	21,846
Hernando	15	62,301	Highlands	8	35,116	Hillsborough	69	264,982
Lake	9	40,805	Lee	31	95,946	Leon	6	17,898
Manatee	19	84,453	Marion	15	102,216	Miami-Dade	1	6,218
Okeechobee	1	4,598	Orange	50	252,348	Osceola	14	103,651
Palm Beach	10	37,463	Pasco	28	87,242	Pinellas	2	10,973
Polk	52	87,242	Putnam	3	10,480	Santa Rosa	1	6,115
Sarasota	13	46,430	Seminole	7	25,901	Sumter	6	52,106
Suwannee	1	7,016	Volusia	10	53,636		-	-
State Total	**473**	**1,948,109**		-	-		-	-
Medium Heat Hazard Risk								
Bay	1	2,121	Brevard	5	17,615	Broward	105	517,964
Duval	2	8,360	Escambia	1	3,152	Flagler	2	9,563
Hillsborough	4	14,803	Indian River	5	14,670	Lee	1	4,806
Martin	2	4,091	Miami-Dade	358	1,894,403	Okeechobee	2	5,518
Palm Beach	94	340,857	Pinellas	35	121,689	St. Johns	1	4,155
St. Lucie	10	37,115	Volusia	8	29,600		-	-
State Total	**636**	**3,030,482**		-	-		-	-

The picture looks quite a bit different when medical vulnerability is considered in relation to heat hazard. A good portion of counties are nearly entirely comprised of tracts containing residents both highly at risk and highly vulnerable to heat hazards (Figure 53). These mainly rural tracts across south central to north Florida number more than 1,000 and contain 4.5 million people (Table 66). An additional 1.2 million people across nearly 300 tracts in 16 counties are characterized by a medium heat hazard risk and high medical vulnerability.

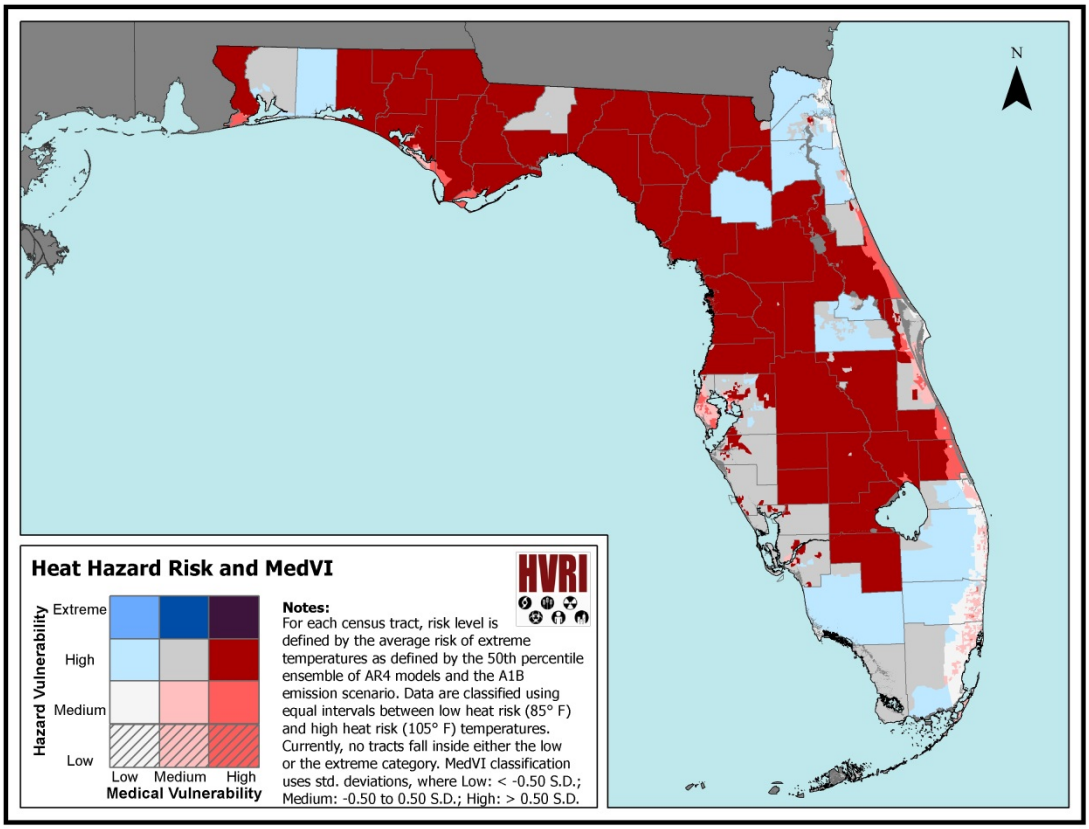

Figure 53: Bivariate representation of MedVI and heat hazard risk for A1B scenario in Florida.

Table 66: Tract and population summary for counties with high MedVI and medium or greater heat hazard risk using the A1B scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Heat Hazard Risk								
Baker	3	20,431	Bay	28	114,818	Bradford	4	28,520
Brevard	7	47,468	Calhoun	3	14,625	Charlotte	7	32,234
Citrus	27	141,236	Columbia	12	67,531	DeSoto	9	34,862
Dixie	3	16,422	Duval	8	23,254	Escambia	57	241,653
Flagler	1	7,924	Franklin	2	7,055	Gadsden	9	46,389
Gilchrist	5	16,939	Glades	3	12,884	Gulf	2	12,787
Hamilton	3	14,799	Hardee	6	27,731	Hendry	6	39,140
Hernando	44	172,778	Highlands	26	98,785	Hillsborough	72	261,611
Holmes	4	19,927	Indian River	2	14,368	Jackson	11	49,746
Jefferson	3	14,761	Lafayette	2	8,870	Lake	56	297,052
Lee	32	136,588	Lewy	9	40,801	Liberty	2	8,365
Madison	5	19,224	Manatee	17	73,525	Marion	62	331,298
Okeechobee	7	25,456	Osceola	39	264,577	Pasco	131	458,710
Pinellas	2	8,501	Polk	153	602,092	Putnam	17	74,364
Sarasota	16	63,596	St. Lucie	2	14,523	Sumter	18	87,023
Suwannee	7	41,551	Taylor	4	22,570	Union	3	15,535
Volusia	44	228,217	Wakulla	4	30,776	Walton	11	55,043
Washington	7	24,896		-	-		-	-
State Total	**1,017**	**4,533,831**		-	-		-	-
Medium Heat Hazard Risk								
Bay	4	12,978	Brevard	20	110,770	Broward	4	27,116
Duval	2	11,567	Escambia	13	52,743	Flagler	5	16,597
Franklin	2	4,494	Gulf	1	3,076	Hillsborough	13	46,315
Indian River	27	123,660	Miami-Dade	4	12,514	Okeechobee	4	14,540
Pinellas	66	264,491	St. Johns	2	7,673	St. Lucie	41	263,266
Volusia	69	266,376		-	-		-	-
State Total	**277**	**1,238,176**		-	-		-	-

Integrating A1FI Scenario Extreme Heat with SoVI and MedVI

The A1FI scenario shows areas with high heat hazard risk coupled with high social vulnerability in similar areas to what was depicted with the A1B scenario. The biggest difference between the two scenarios occurs in the panhandle, with the heat hazard risk reaching the extreme category (Figure 54). Here, Hamilton and Suwannee Counties each have one census tract displaying extreme heat hazard risk and high social vulnerability, totaling 8,700 people (Table 67). Another 43 counties with over 1,000 tracts cover almost 5 million people in the high heat hazard risk and high social vulnerability categories.

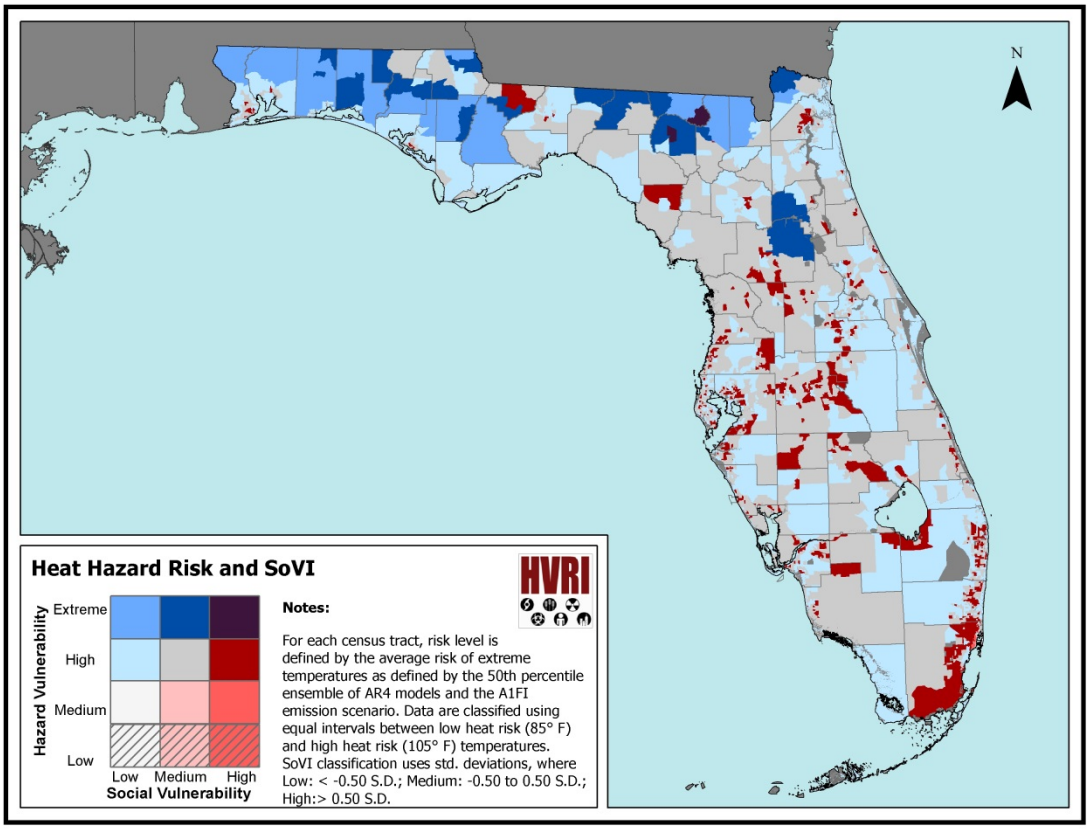

Figure 54: Bivariate representation of SoVI and heat hazard risk for A1FI scenario in Florida.

Table 67: Tract and population summary for counties with high SoVI and medium or greater heat hazard risk using the A1FI scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Heat Hazard Risk								
Hamilton	1	1,760	Suwannee	1	7,016		-	-
State Total	**2**	**8,776**		-	-		-	-
High Heat Hazard Risk								
Alachua	4	19,406	Bay	3	8,846	Brevard	6	20,847
Broward	111	549,548	Charlotte	5	17,905	Citrus	5	23,598
Clay	1	5,311	Collier	15	76,682	Columbia	1	2,872
DeSoto	3	13,900	Dixie	1	7,331	Duval	37	150,426
Escambia	12	39,923	Flagler	3	15,884	Gadsden	5	25,033
Hardee	2	10,630	Hendry	3	21,846	Hernando	15	62,301
Highlands	8	35,116	Hillsborough	73	279,785	Indian River	5	14,670
Lake	9	40,805	Lee	32	100,752	Leon	6	17,898
Manatee	19	84,453	Marion	15	102,216	Martin	2	4,091
Miami-Dade	319	1,727,866	Okeechobee	3	10,116	Orange	50	252,348
Osceola	14	103,651	Palm Beach	104	378,320	Pasco	28	87,242
Pinellas	37	132,662	Polk	52	219,460	Putnam	3	10,480
Santa Rosa	1	6,115	Sarasota	13	46,430	Seminole	7	25,901
St. Johns	1	4,155	St. Lucie	10	37,115	Sumter	6	52,106
Volusia	18	83,236		-	-		-	-
State Total	**1,067**	**4,929,278**		-	-		-	-
Medium Heat Hazard Risk								
Miami-Dade	40	172,755		-	-		-	-
State Total	**40**	**172,755**		-	-		-	-

When comparing the A1FI scenario of heat hazard risk to medical vulnerability, a large portion of the northern and central parts of the state display a high heat hazard risk and high MedVI (Figure 55). Conversely, much of south Florida, although in the high heat hazard risk category, falls into the low or medium category of medical vulnerability. There are 49 census tracts with both extreme heat hazard risk and high medical vulnerability (Table 68), mostly located in the panhandle and accounting for over 240,000 people. Additionally, 5.5 million people in 1,200 tracts across 52 counties are located in high heat hazard risk and high medical vulnerability tracts.

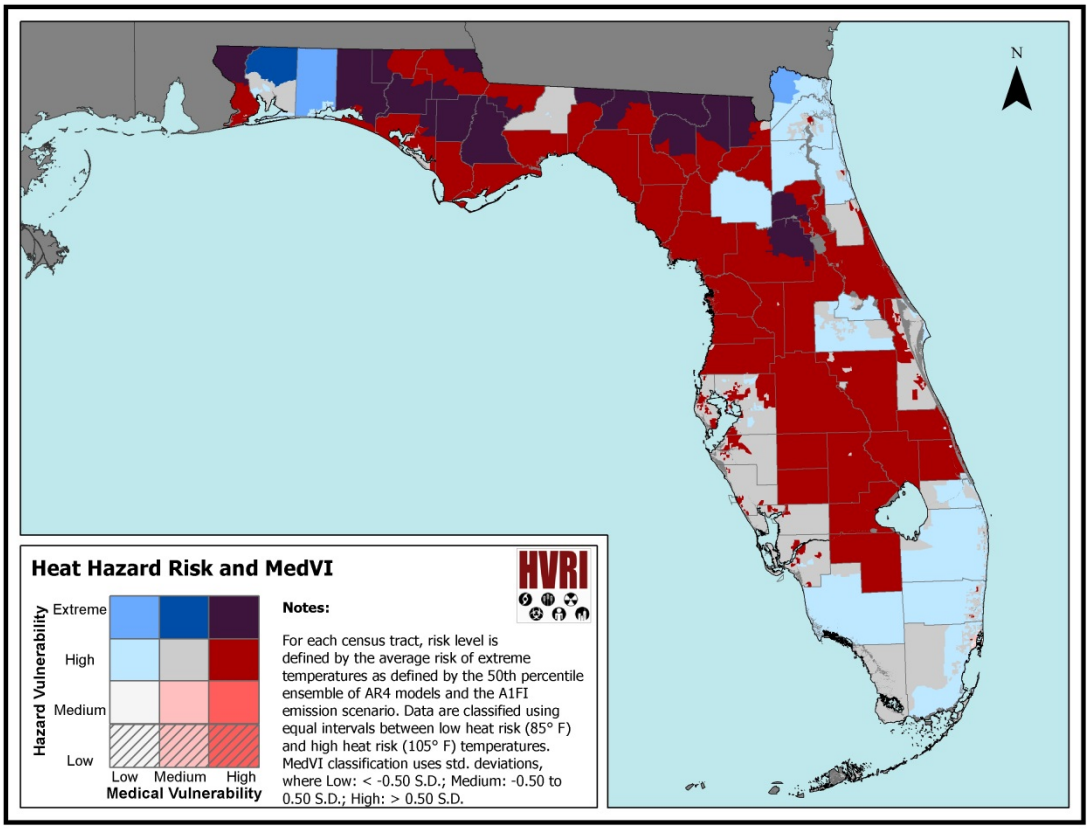

Figure 55: Bivariate representation of MedVI and heat hazard risk for A1FI scenario in Florida.

Table 68: Tract and population summary for counties with high MedVI and heat hazard risk using the A1FI scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Heat Hazard Risk								
Baker	1	7,519	Bay	1	8,552	Calhoun	3	14,625
Columbia	2	14,284	Escambia	2	14,225	Gadsden	1	4,769
Hamilton	3	14,799	Holmes	1	5,544	Jackson	3	13,618
Jefferson	1	4,496	Liberty	2	8,365	Madison	2	6,834
Marion	7	20,909	Putnam	4	21,941	Suwannee	5	32,889
Walton	7	32,866	Washington	4	16,682		-	-
State Total	**49**	**242,917**		-	-		-	-
High Heat Hazard Risk								
Baker	2	12,912	Bay	31	119,244	Bradford	4	28,520
Brevard	27	158,238	Broward	4	27,116	Charlotte	7	32,234
Citrus	27	141,236	Columbia	10	53,247	DeSoto	9	34,862
Dixie	3	16,422	Duval	10	34,821	Escambia	67	280,171
Flagler	6	24,521	Franklin	4	11,549	Gadsden	8	41,620
Gilchrist	5	16,939	Glades	3	12,884	Gulf	3	15,863
Hardee	6	27,731	Hendry	6	39,140	Hernando	44	172,778
Highlands	26	98,785	Hillsborough	85	307,926	Holmes	3	14,383
Indian River	29	138,028	Jackson	8	36,128	Jefferson	2	10,265
Lafayette	2	8,870	Lake	56	297,052	Lee	32	136,588
Levy	9	40,801	Madison	3	12,390	Manatee	17	73,525
Marion	55	310,389	Miami-Dade	3	10,061	Okeechobee	11	39,996
Osceola	39	264,577	Pasco	131	458,710	Pinellas	68	272,992
Polk	153	602,092	Putnam	13	52,423	Sarasota	16	63,596
St. Johns	2	7,673	St. Lucie	43	277,789	Sumter	18	87,023
Suwannee	2	8,662	Taylor	4	22,570	Union	3	15,535
Volusia	113	494,593	Wakulla	4	30,776	Walton	4	22,177
Washington	3	8,214		-	-		-	-
State Total	**1,243**	**5,526,637**		-	-		-	-
Medium Heat Hazard Risk								
Miami-Dade	1	2,453		-	-		-	-
State Total	**1**	**2,453**		-	-		-	-

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