Climate Hazards - Summary of Projections for Charlottesville

According to the Fourth National Climate Assessment,[i] the primary climate-related hazards of the Southeast are sea-level rise, increasing temperatures, drought, extreme heat, heavy precipitation, flooding, and changing seasonal patterns. To understand which of these hazards will affect Charlottesville and to what extent, ICLEI reviewed the best available local climate data and summarized the findings below.

Overview of Climate Data

Temperate.io[ii] was the primary tool used to generate climate data specific to Charlottesville. Temperate.io averages over 30 models for 22 different climate indicators (see Appendix for more details on methodology) and under low and high emissions scenarios. The "low" emissions scenario, or "RCP 4.5" assumes that aggressive action is taken on a global scale to reduce annual emissions. The high emissions scenario, or RCP 8.5, is the business-as-usual or no-action scenario. For planning purposes, the RCP 8.5 climate models are used for this risk assessment.

Because all the latest evidence points toward the world on track to exceed 3 degrees Celsius of warming (5.4 degrees Fahrenheit), it is important for Charlottesville to plan for the high emissions scenario. For this reason, the climate data relayed here is presented for a warmer and more variable climate. Table 1 categorizes the most relevant climate indicators for the City by their amount of change between the current year (2020) and 2100, as compared to 1970 averages. See Appendix for definitions, calculations, and graphical projections for each climate indicator.

Table 1 indicates a significant change in most of the temperature-related indicators, and moderate change in some precipitation-related indicators. These climate models do not indicate any clear trend in drought conditions (dry spells and dry days), although extended periods of extreme heat may deplete soil moisture and intensify naturally occurring drought conditions.[iii]

Table 1 Overview of Climate Indicators in Charlottesville (degree* and direction of change)**

Significant change	Moderate Change	Some change	No/Negligible change
Extreme heat events ↑ Heat wave duration ↑ Heat wave incidents ↑ Heating degree days ↓ Freezing degree days ↓ Avg. low temperature ↑ Frost days ↓ Extreme cold events ↓	Extreme precipitation events ↑ Cooling degree days ↑ Days w/ precipitation above 2 inches ↑	Avg high temperature ↑ Total precipitation ↑	Dry spells Maximum consecutive dry days Diurnal temperature range

* Change from 2020 to projected 2100 values (+/-)

Significant: > 50% Moderate: 20-50% Some: 5-20%

No/negligible: <5% and/or the overall trend is somewhat stable. See Appendix for graphical projections.

** The arrows represent the direction of change, i.e. ↑ indicates an upwards trend and ↓ indicates a downward trend.

Because Temperate.io is limited to precipitation and temperature models, more data analysis was needed to understand evolving flood risks in Charlottesville. Specifically, it is necessary to consider flood risk models that combine climate-informed precipitation models with on-the-ground conditions. Using the First Street Foundation's probabilistic flood models, Flood Factor is a free tool that allows users to see current and projected flood risks in specific locations.[iv] Flood Factor overlays the flood models with national property data to determine the number of properties that are at risk of flooding now and projected to be at risk in the future, as well as the extent of that risk. Table 2 breaks down the number of properties potentially impacted at different flood probability levels in Charlottesville.[v] The table indicates an upward trend in the potential impact of flood events at all probability levels. Most notably, a "5% chance flood event" in 2051 may impact almost 12% more properties than that of 2021.

Table 2: Summary of Flood Factor Data for Charlottesville

Flood Likelihood	Number of Properties Potentially Impacted			
	Today (2021)	In 15 years (2036)	In 30 years (2051)	% change between 2021-2051
20%	332	339	345	3.92%
5%	587	621	655	11.58%
1%	1,180	1,202	1,224	3.73%
0.2%	1,495	1,530	1,565	4.68%

Primary Climate Threats in Charlottesville

The climate projections summarized in the previous sections indicate that Charlottesville's greatest threats from climate change are the following:

1. **Significant increase in the frequency, duration, and intensity of extreme heat**

   The climate models show that by 2050, Charlottesville may experience more than twice as many extreme heat events (when the daily maximum temperature reaches dangerous levels) annually as there were in 2020. By 2100, there may be almost seven times as many. This equates to a change from approximately 10 events in 2020, to 25 events in 2050 and 77 events in 2100.

   Additionally, both the frequency and duration of heat waves (5+ days of extreme heat) will increase significantly over time. By 2050, Charlottesville may experience almost twice as many heat waves as there were in 2020, and they may be slightly longer. By 2100, there may be more than three times as many heat waves, and they may also be three times as long. This equates to approximately 3 heat wave events in 2020 of up to 9 days each, 7 heat waves in 2050 of up to 12 days long, and 14 heat wave events in 2100 for up 30 days long.

2. **Changing seasonal patterns**

   Increasing average low temperatures and cooling degree days, along with decreasing frost days, extreme cold days, heating degree days, and freezing degree days, weather is changing in Charlottesville. Winters may become more mild overall, and the growing season may shift or become more unpredictable. Warmer overall temperatures may also intensify naturally occurring drought conditions through the evaporation of soil moisture.

3. **Increasingly intense storms and flooding in Charlottesville**

   Precipitation patterns are not projected to change substantially, but there may be a moderate increase in occurrences of heavy (>2 inches) and extreme (> 95th percentile) precipitation. Additionally, a statistically significant flood event (<20% chance) will likely be of higher intensity in 2051 than an event with the same probability in 2021. Flood events may not increase significantly in terms of frequency, but they may become more intense.

   Finally, although Charlottesville will not be directly exposed to sea-level rise, the City may be exposed to a greater frequency and intensity of storms originating in the coastal areas due to a combination of sea-level rise and other changing weather patterns.[vi] It is also worth noting that the City may experience in-migration from the coastal areas as they become less desirable or even habitable, in some cases.

The aforementioned threats will be the focus of Charlottesville's vulnerability assessment, in which we will identify specific aspects of the community that are most vulnerable to these hazards and should be prioritized for adaptation.

Appendix: Detailed Climate Data

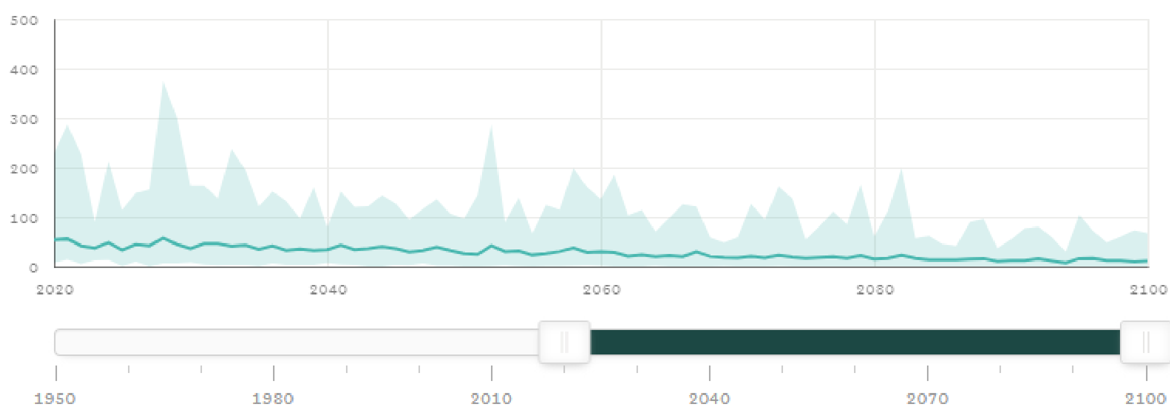
Temperate.io

Accumulated Freezing Degree Days

Maximum cumulative total of differences in average daily temperature and freezing for consecutive days across the aggregation period.

Freezing degree days (fdd) are "a measure of how cold it has been and how long it has been cold; the cumulative fdd is usually calculated as a sum of average daily degrees below freezing for a specified time period (10 days, month, season, etc.)" (Cryosphere Glossary, National Snow and Ice Data Center) Temperate provides annual degree days (accumulated over the course of a year).

Year	Total Diff.	% Change (from 2020)
2020	54.26	--
2050	26.13	-51.84%
2100	10.93	-79.86%

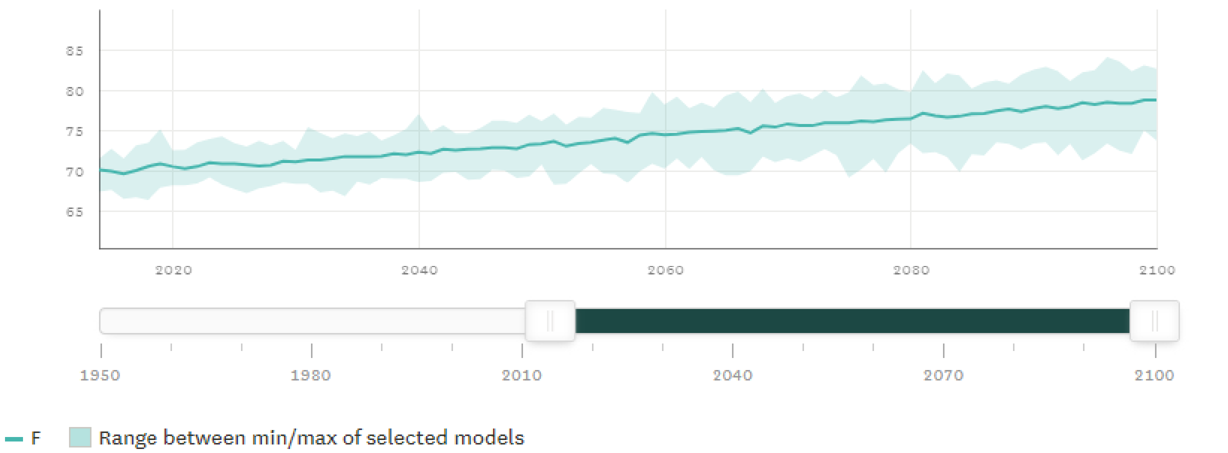


— F Range between min/max of selected models

Maximum cumulative total of differences in average daily temperature and freezing for consecutive days across the aggregation period.

Average High Temperature

Year	Average High Temperature (F)	% Change
2020	70.5	--
2050	73.3	3.97%
2100	78.7	11.63%



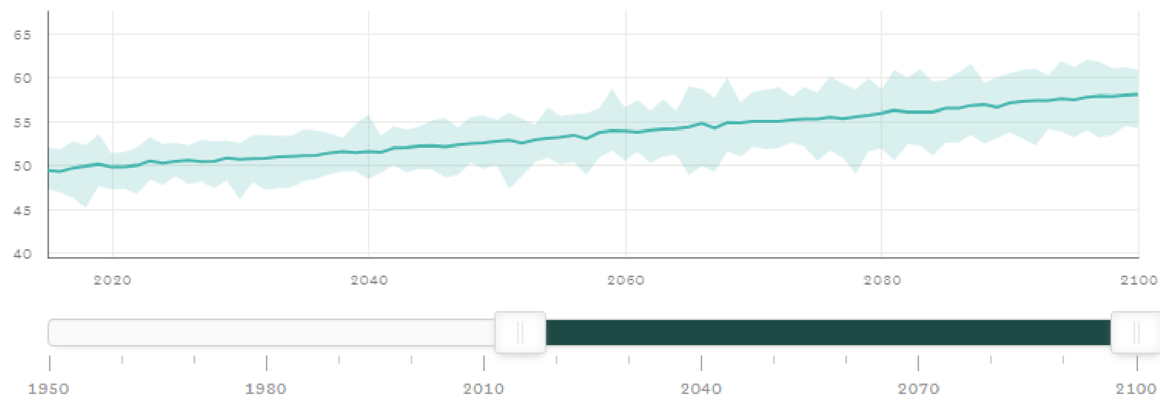
Aggregated average high temperature, generated from daily data using all requested models

Downscaled from CMIP5, using the Localized Constructed Analogs (LOCA) statistical technique. Data available at loca.ucsd.edu.

Average Low Temperature

Aggregated average low temperature.

Year	Average Low Temperature (F)	% Change
2020	49.8	--
2050	52.7	5.82%
2100	78.7	58.03%



F   Range between min/max of selected models

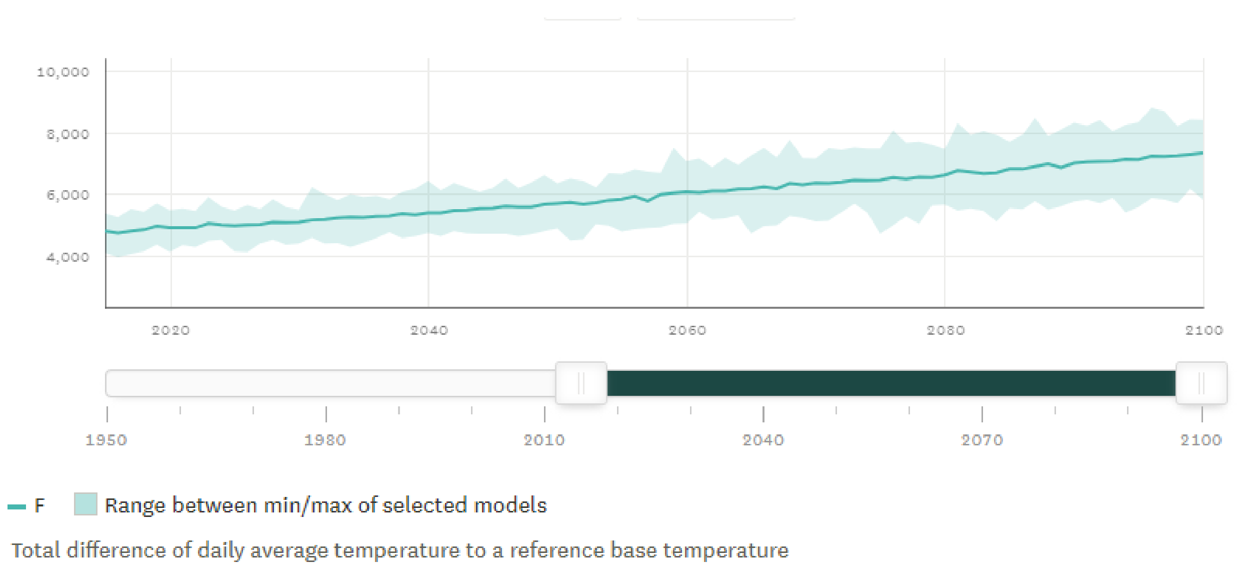
Aggregated average low temperature, generated from daily data using all requested models

Cooling Degree Days

Total difference of daily average temperature to a reference base temperature of 50°F.

"Cooling degree days (CDD) are a measure of how hot the temperature was on a given day or during a period of days. A day with a mean temperature of 80°F has 15 CDD. If the next day has a mean temperature of 83°F, it has 18 CDD. The total CDD for the two days is 33 CDD." (Units and Calculators Explained, U.S. Energy Information Administration). Temperate provides annual degree days (accumulated over the course of a year).

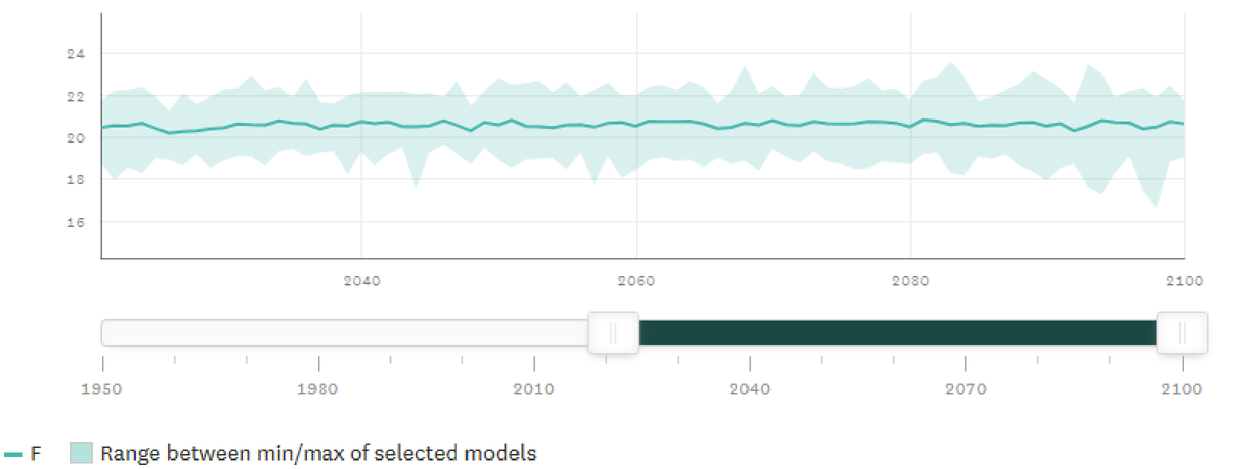
Year	Total Diff.	% Change (from 2020)
2020	4911.82	--
2050	5697.91	16.00%
2100	7331.12	49.25%



Diurnal Range in Temperature

Average difference between daily max and daily min temperature.

Year	Avg Dif. Btwn Daily Max and Min Temp	% Change (from 2020)
2020	20.75	--
2050	20.56	-0.92%
2100	20.62	-0.63%

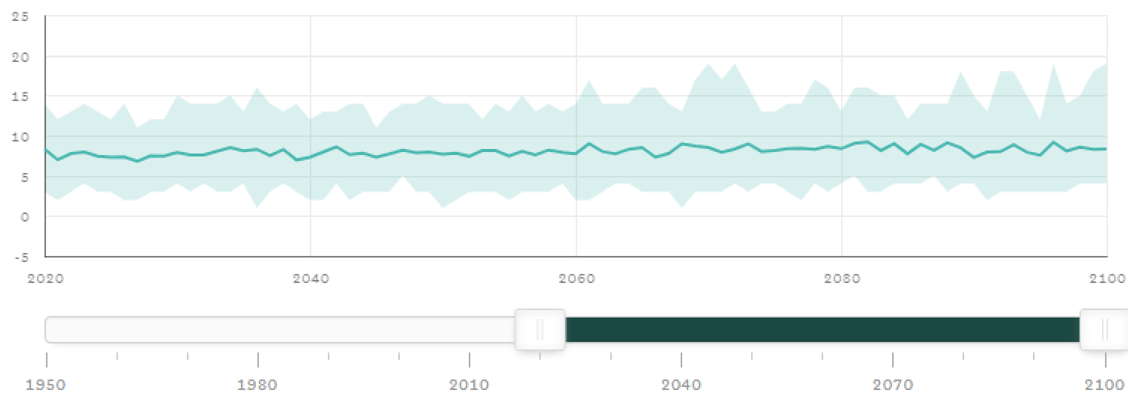


Average difference between daily max and daily min temperature

Dry Spells

Total number of times per period that there are 5 or more consecutive days without precipitation.

Year	Avg Dif. Btwn Daily Max and Min Temp	% Change (from 2020)
2020	8.31	--
2050	7.66	-7.82%
2100	8.31	0.00%



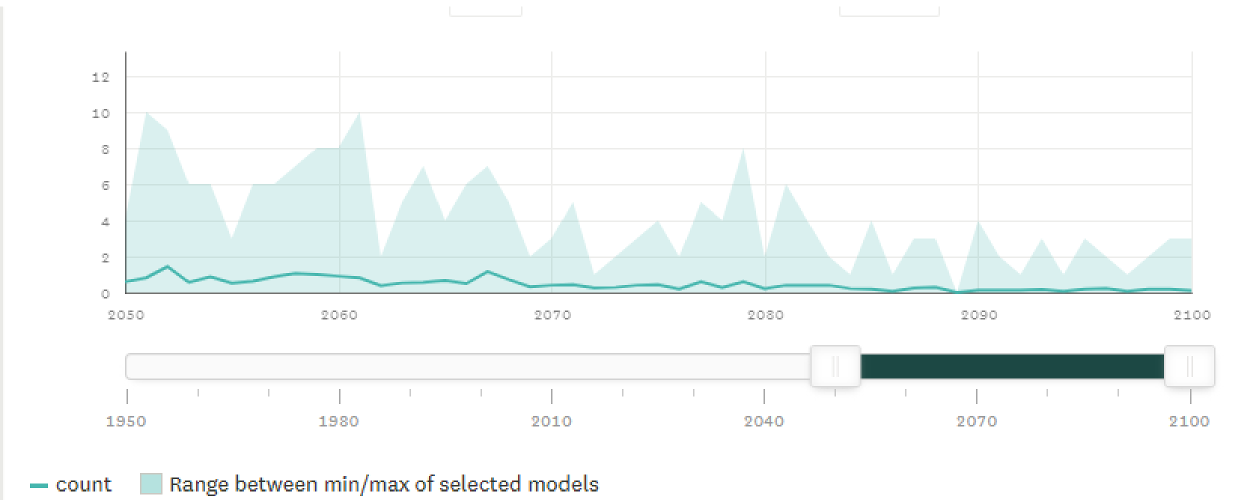
count   Range between min/max of selected models

Total number of times per period that there are 5 or more consecutive days without precipitation

Extreme Cold Events

Total number of times per period daily minimum temperature is below the 1st percentile of historic observations

Year	Number of events	% Change (from 2020)
2020	1.78	--
2050	0.59	-66.85%
2100	0.1	-94.38%

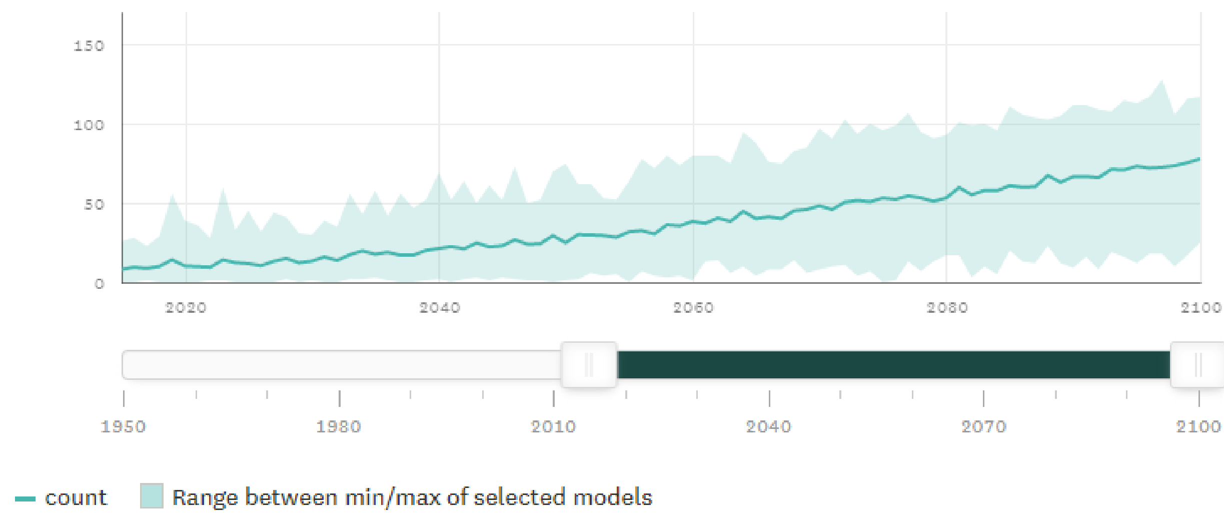


Total number of times per period daily minimum temperature is below the specified percentile of historic observations

Extreme Heat Events

Number of times per year that the daily maximum temperature exceeds the 99th percentile of historic observations, using 1971 as the base range year.

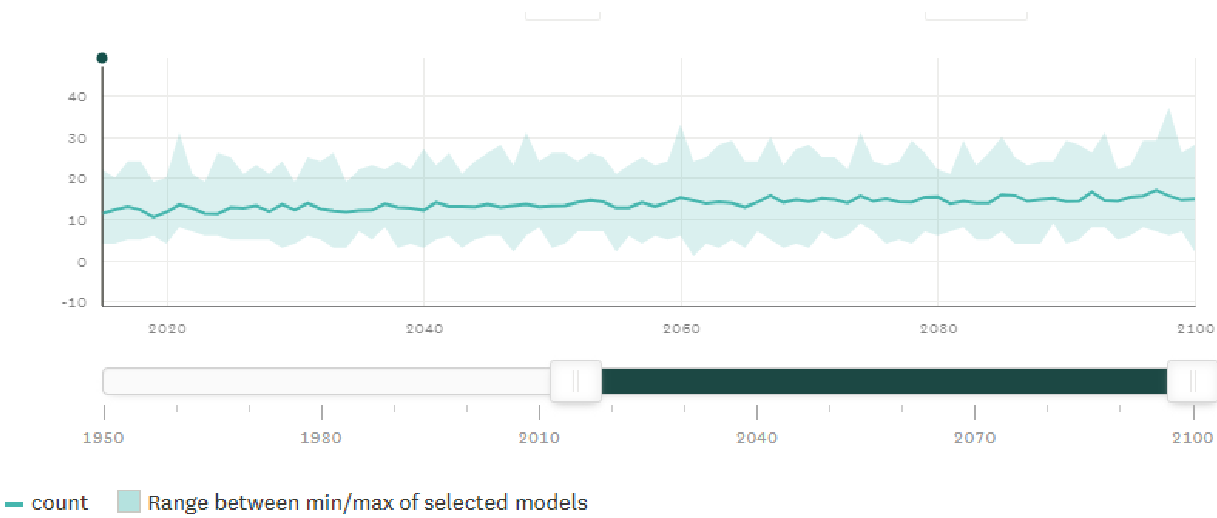
Year	Number of Events	% Change
2020	10	--
2050	25	150% (more than twice as many events)
2100	78	680% (almost 7x as many events)



Extreme Precipitation Events

Number of times per year that the daily average precipitation rate exceeds the 95th percentile of historic observations, using 1971 as the base range year.

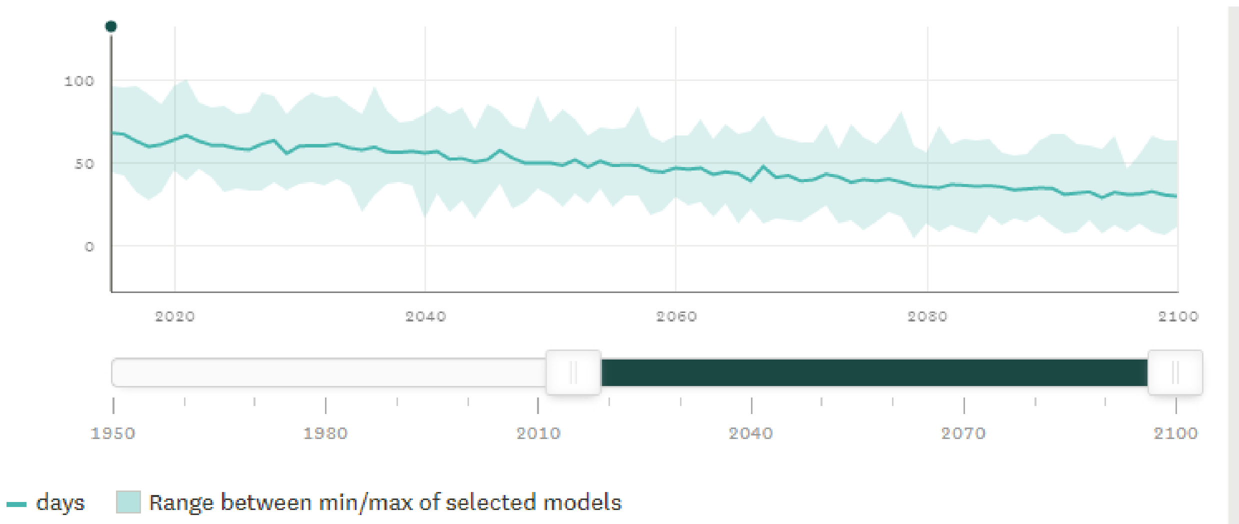
Year	Number of Events	% Change
2020	12	--
2050	13	8.33%
2100	15	25%



Frost Days

Number of times per year in which daily low temperature is below the freezing point of water.

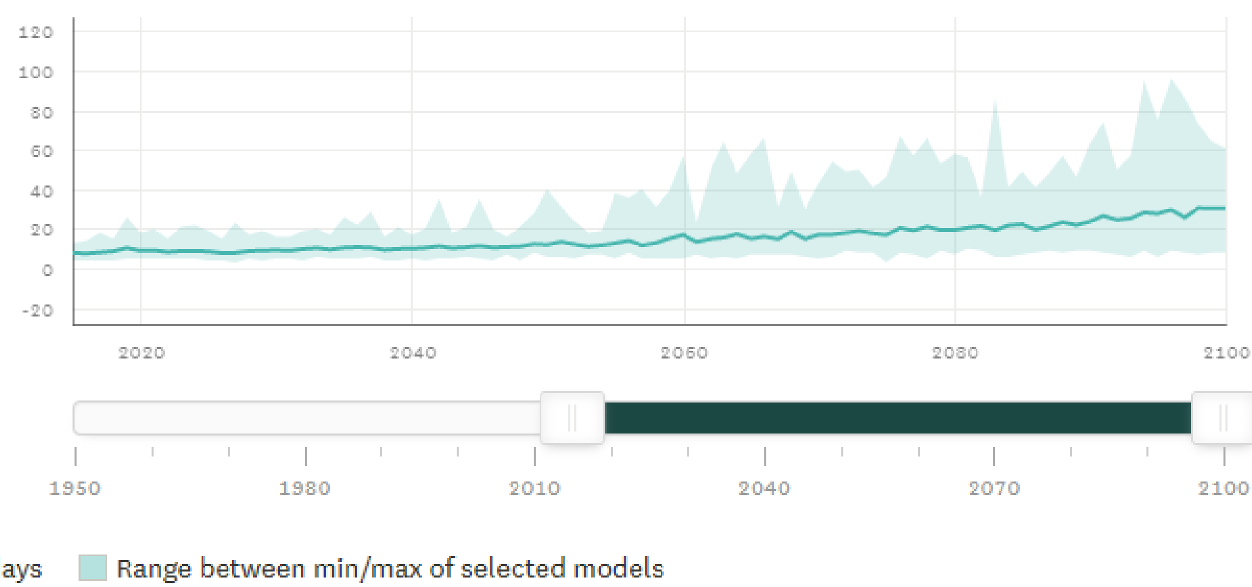
Year	Number of Events	% Change
2020	63	--
2050	50	-20.63%
2100	29	-53.97%



Heat Wave Duration Index

Maximum period of consecutive days with daily high temperature greater than 5C above historic norm

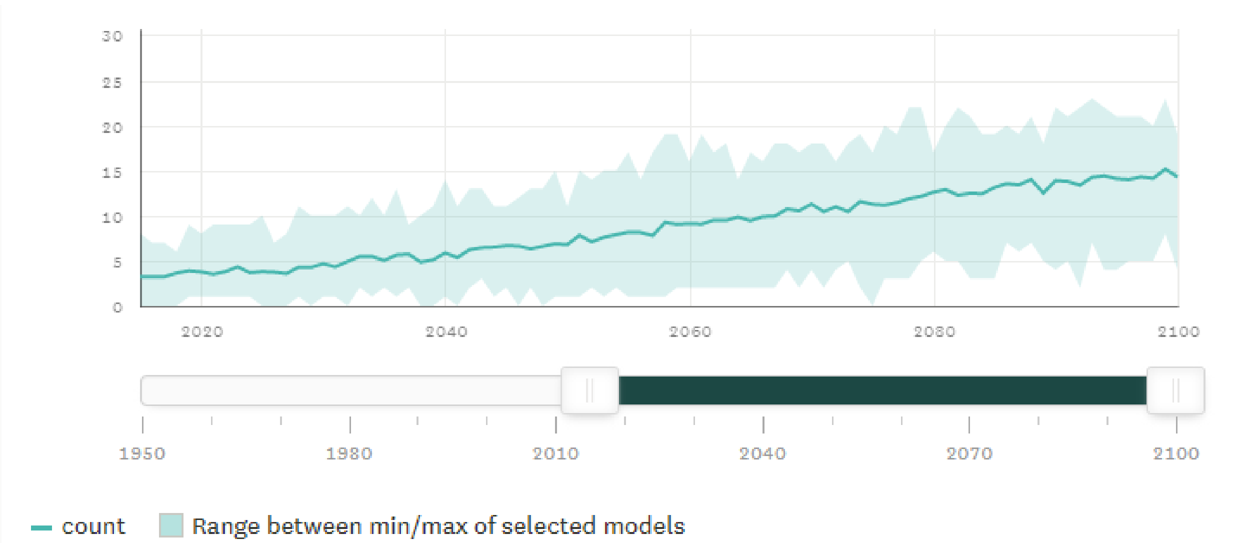
Year	Max. Heat Wave Duration (# Days)	% Change
2020	9	--
2050	12	33.33%
2100	30	233.33% (more than 3x as long)



Heat Wave Incidents

Number of times daily high temperature exceeds 5C above historic norm for at least five consecutive days, using 1971 as the historic base range year.

Year	Number of Incidents	% Change
2020	4	--
2050	7	75%
2100	14	250% (more than 3x as many events)

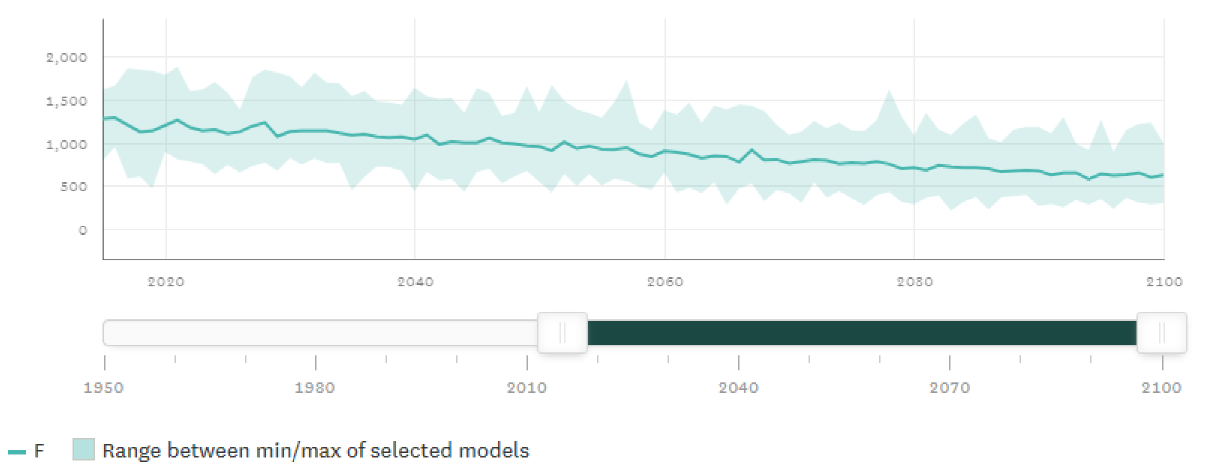


Heating Degree Days

Total difference of daily average temperature to a reference base temperature of 50F.

“Heating degree days (HDD) are a measure of how cold the temperature was on a given day or during a period of days. For example, a day with a mean temperature of 40°F has 25 HDD. Two such cold days in a row have a total of 50 HDD for the two-day period” (Units and Calculators Explained, U.S. Energy Information Administration). Temperate provides annual degree days (accumulated over the course of a year).

Year	Total diff.	% Change
2020	1276	--
2050	952.47	-25.36%
2100	623.09	-51.17%

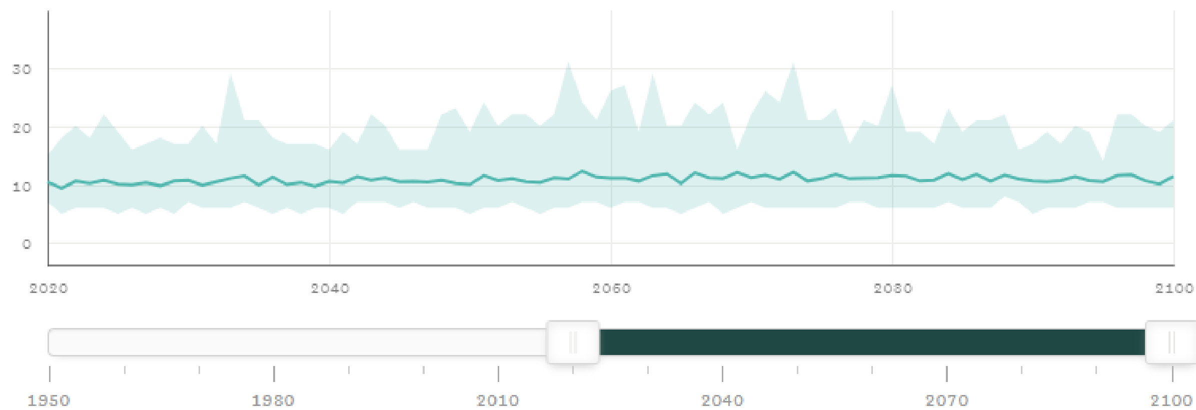


Total difference of daily average temperature to a reference base temperature

Max Consecutive Dry Days

Maximum number of consecutive days with no precipitation

Year	# days	% Change
2020	10.44	--
2050	10	-4.21%
2100	11.41	9.29%



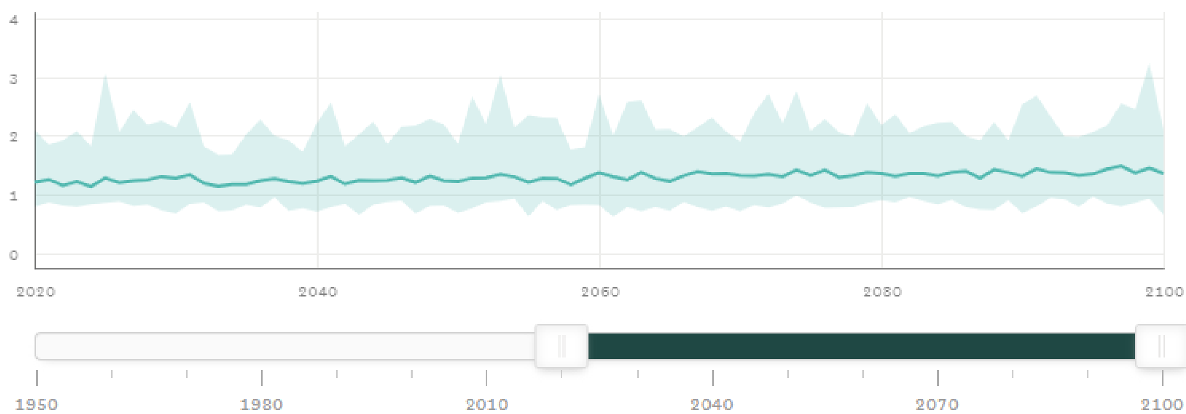
days   Range between min/max of selected models

Maximum number of consecutive days with no precipitation

Percentile Precipitation

The 99th percentile of precipitation rate for each timespan.

Year	in/day	% Change
2020	1.21	--
2050	1.22	0.83%
2100	1.36	12.40%



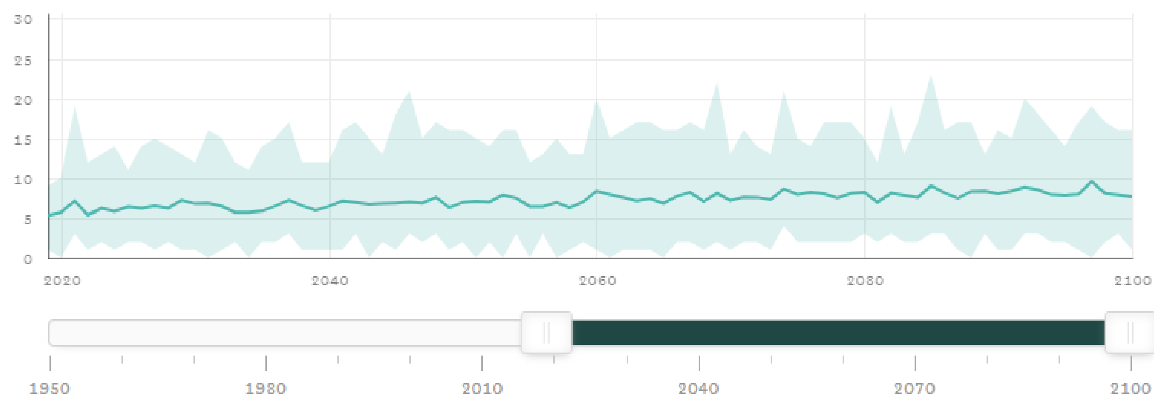
in/day Range between min/max of selected models

The specified percentile of precipitation rate for each timespan. Defaults to 50th percentile (Median)

Precipitation Threshold

Number of days where precipitation rate, generated from daily data averaging all available models, is greater than or equal to 2 inches.

Year	# days	% Change
2020	5.31	--
2050	6.97	31.26%
2100	7.66	44.26%



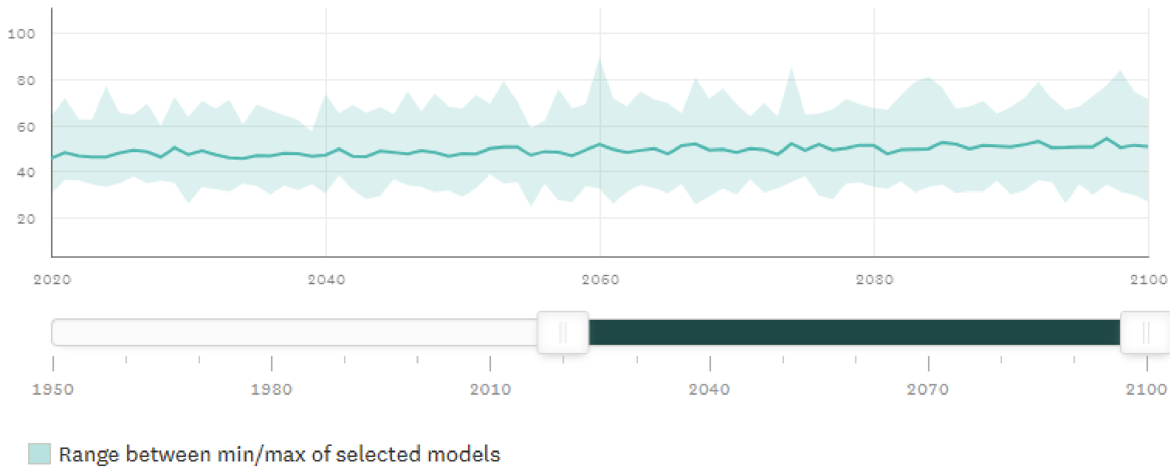
days   Range between min/max of selected models

Number of days where precipitation rate, generated from daily data using all requested models, fulfils the comparison

Total Precipitation

Total annual precipitation (inches)

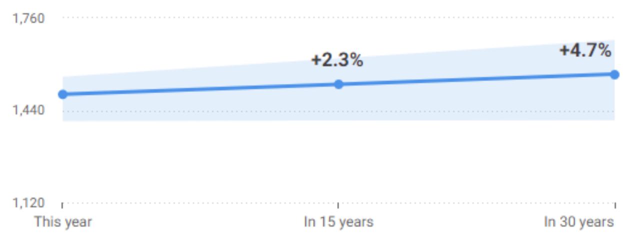
Year	Inches	% Change
2020	45.46	--
2050	47.52	4.53%
2100	50.64	11.39%



Total precipitation

Flood Factor

Change in number of properties at risk



Total annual flood damages in Charlottesville

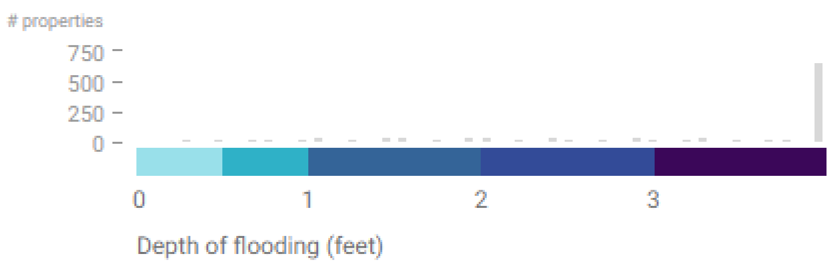
$2.8M This year

$2.9M +4% In 30 years

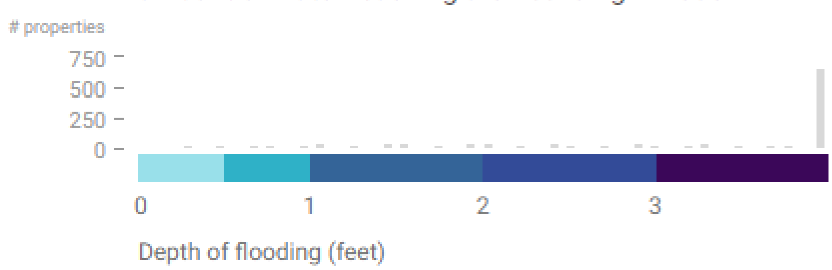
Damage breakdown by Flood Factor

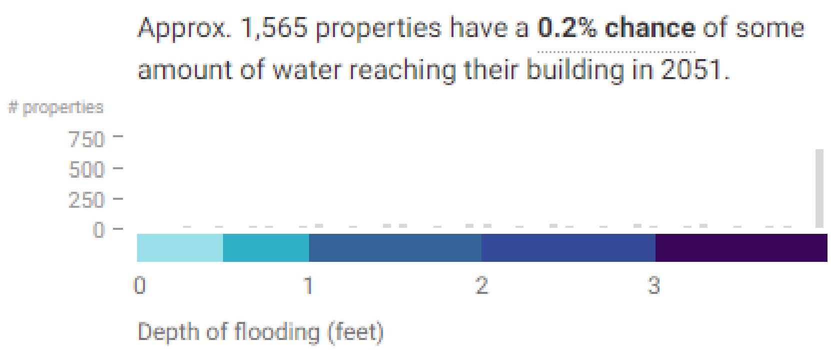
	This year ($)	In 30y ($)	Change
Minor (2)	0	200	–
Moderate (3-4)	5,100	6,000	+18%
Major (5-6)	117.6K	148.6K	+26%
Severe (7-8)	91.1K	98.3K	+8%
Extreme (9-10)	2.6M	2.7M	+2%

Approx. 1,495 properties have a **0.2% chance** of some amount of water reaching their building in 2021.



Approx. 1,530 properties have a **0.2% chance** of some amount of water reaching their building in 2036.





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i [Fourth National Climate Assessment]

ii [Temperate: Your Climate Adaptation Planning Companion]

iii [NCIS State Summaries: Virginia]

iv [Flood Factor Methodology]

v [Flood Factor: Charlottesville, VA.]

vi [National Climate Assessment, Chapter 19: Southeast.]