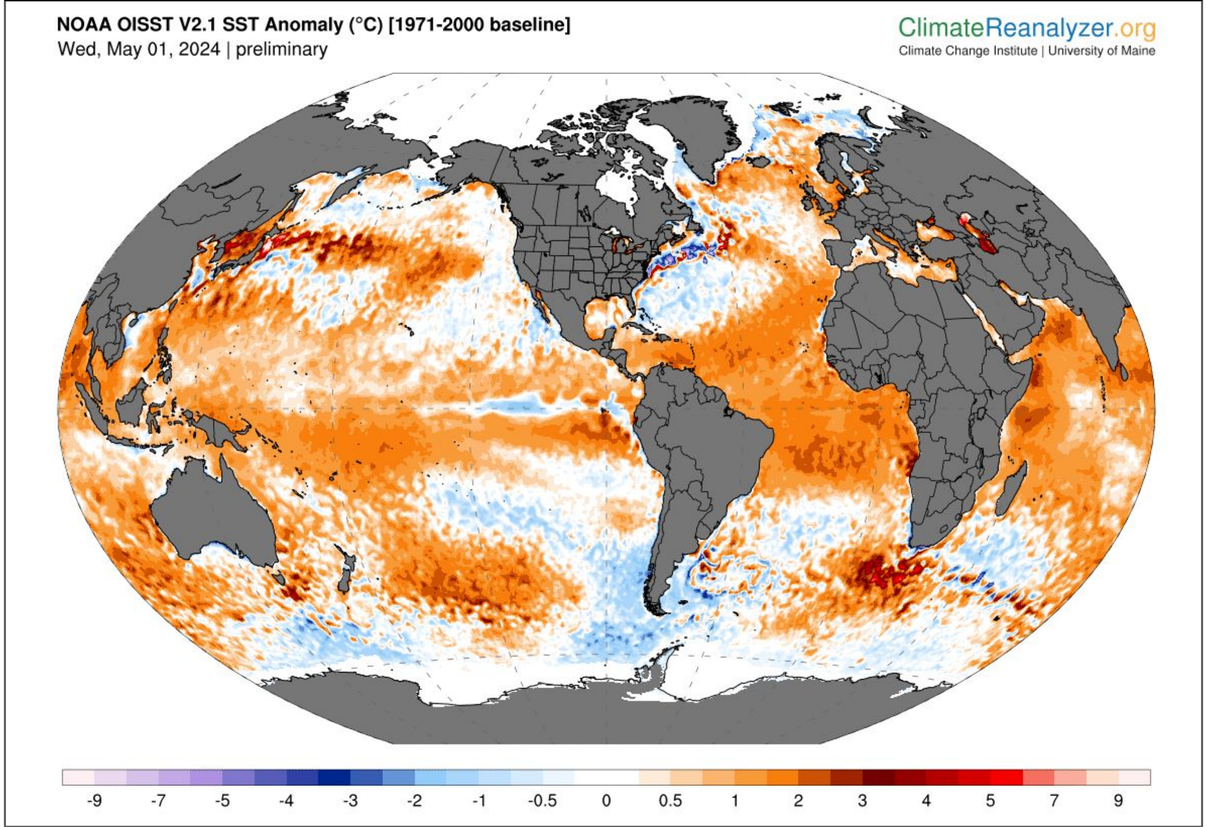
Shifting Vulnerability - Extreme Weather Hazards and the Climate Future

Perspectives on Vermont’s Future for the Rural Resilience and Adaptation Committee

May 10, 2024

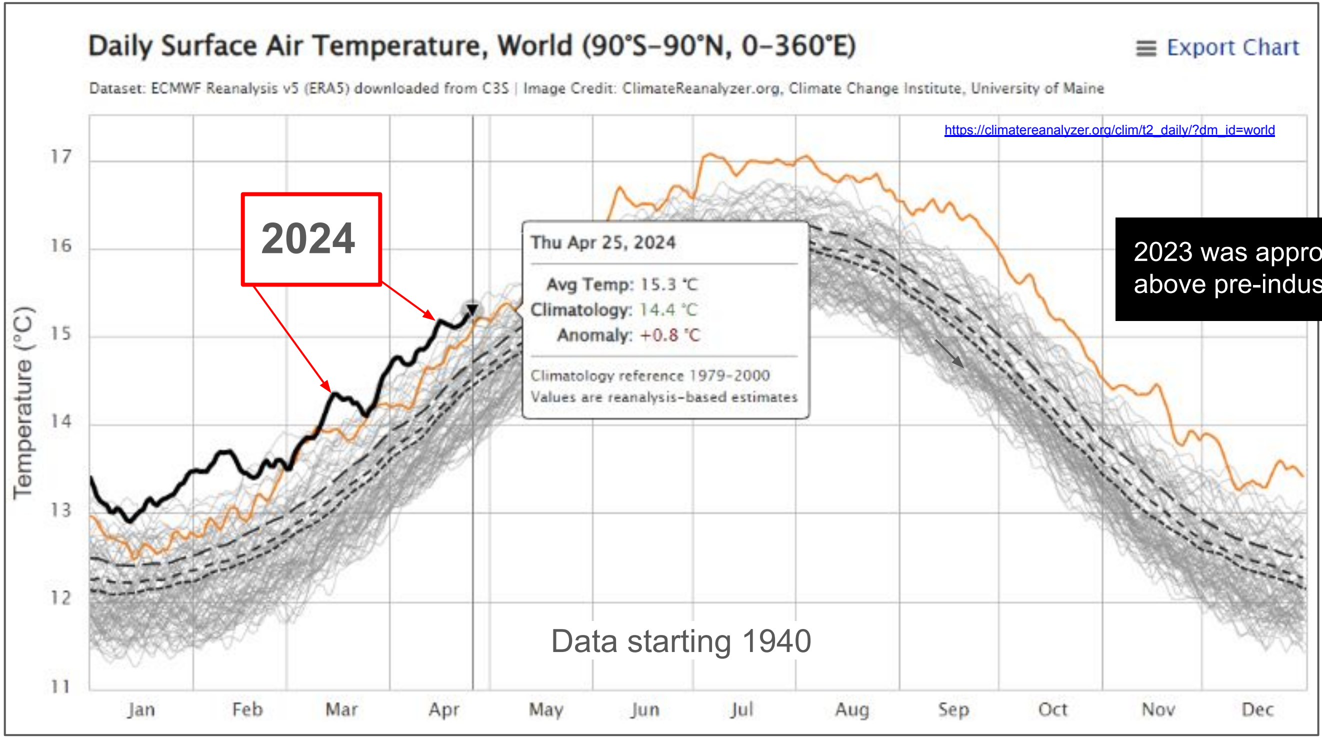
Drs. Jay Shafer and Lesley-Ann Dupigny-Giroux

May 1 Ocean Temperature Anomaly



Fact: 90% excess energy from greenhouse gas forcing/climate change are going back into oceans. Oceans strongly regulate weather.

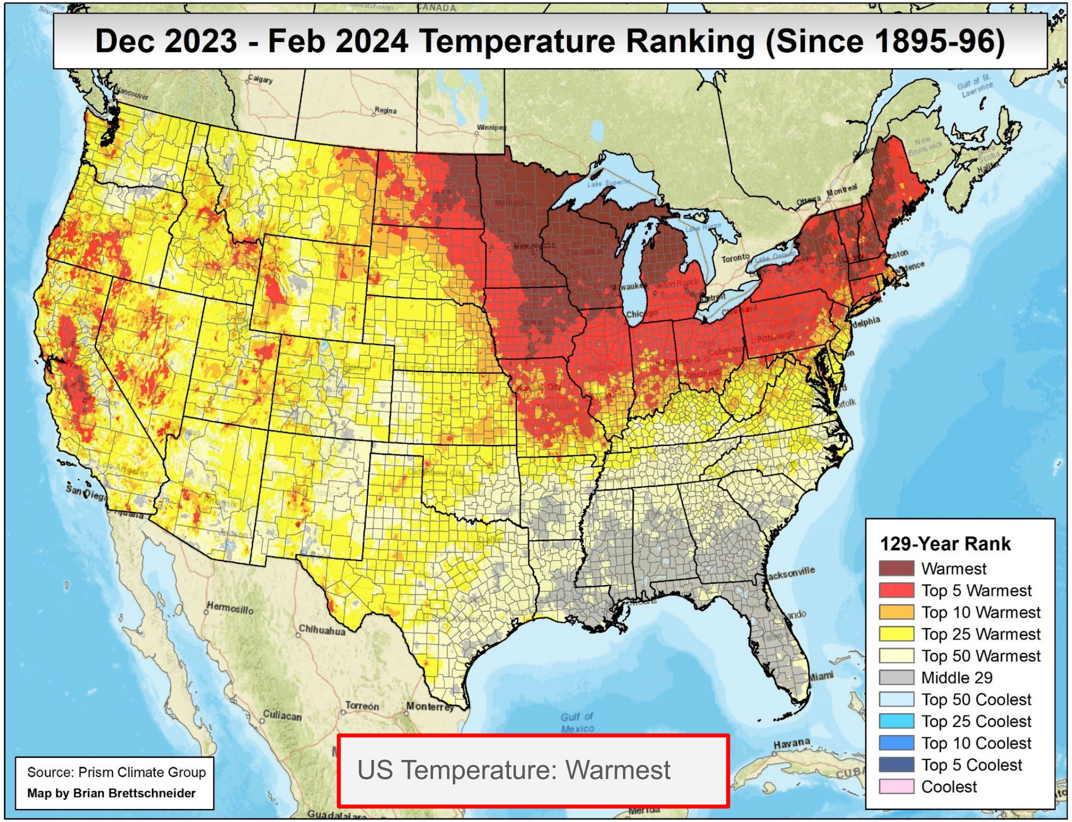
Surface Air Temperature: “The Oven is Preheating”



2023 was approximately +1.5 °C above pre-industrial levels

Fact: Fastest input of atmospheric carbon from carbon-intensive economy in 3-4 million years. Corresponding temperature increase will continue to accelerate without mitigation. Adaptation is critical.

Winter temperature check: Our strongest changing season



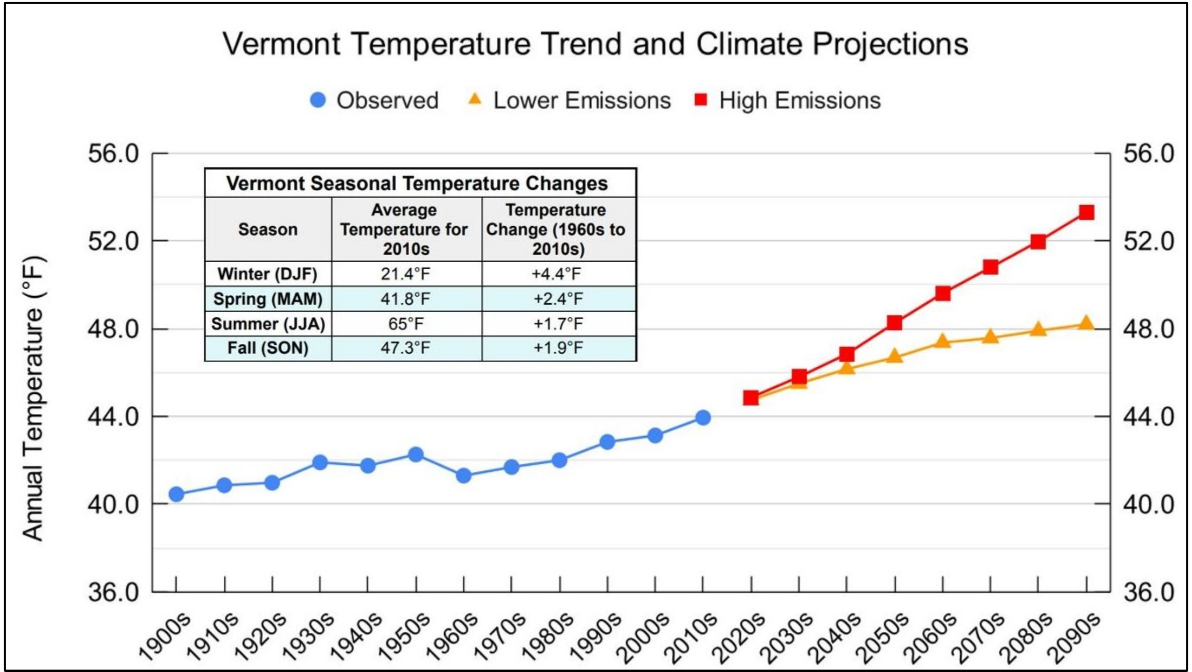
Top 10 Warmest Winters at Burlington (1941-2024)

Rank	Season	Mean Avg Temperature
1	2023-2024	30.7
2	2015-2016	30.1
3	2016-2017	29.5
4	2022-2023	29.0
5	2001-2002	28.7
6	2011-2012	27.8
7	2019-2020	26.1
8	1948-1949	25.8
9	1996-1997	25.6
-	1952-1953	25.6

2023-2024 was also the second wettest

Warmer and Wetter Winters: More thaws, less reliable snow cover, heavier precipitation events, more wet snow

Vermont Temperature Projection



Vermont Seasonal Temperature Changes

Season	Average Temperature for 2010s	Temperature Change (1960s to 2010s)
Winter (DJF)	21.4°F	+4.4°F
Spring (MAM)	41.8°F	+2.4°F
Summer (JJA)	65°F	+1.7°F
Fall (SON)	47.3°F	+1.9°F

Vermont's warming is consistent with global climate warming. Mean annual temperature is projected to increase another 2°F to 3°F by 2050. Winter will continue to warm about two times faster than other seasons.

Projection data: https://crt-climate-explorer.nemac.org/ , Observation data: https://www.ncdc.noaa.gov/cag/divisional/mapping/43/pcp/202009/12/value

Changing Vulnerability/Risk - “Seasonal Shenanigans”

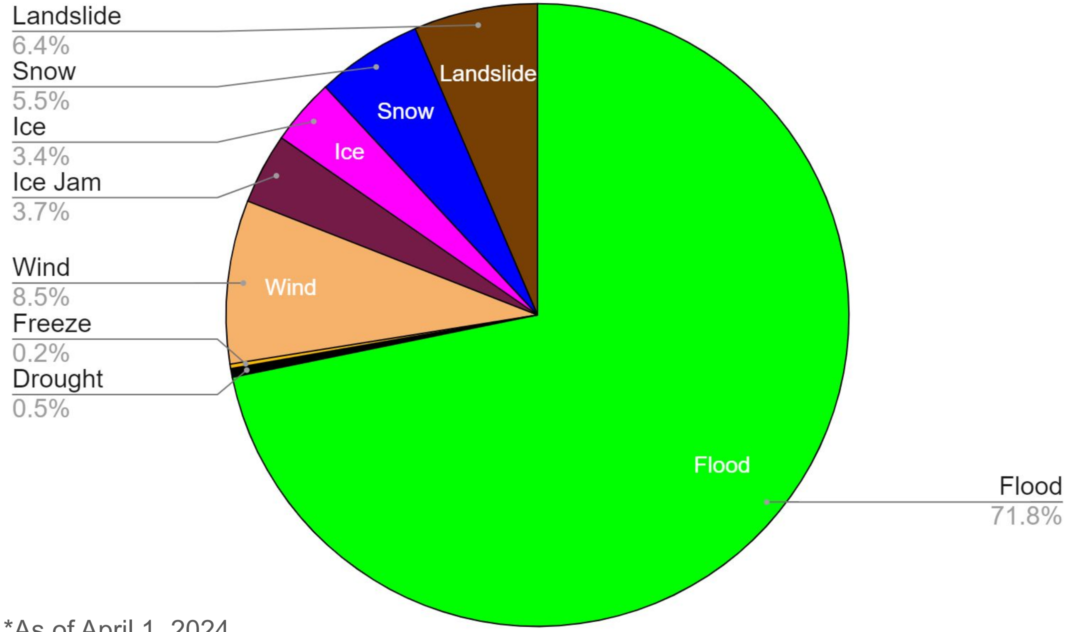
- **High Confidence Seasonal Change**
  - Retreating cold: Shorter winters with more precipitation
  - Expanding warmth: Elongated periods of heat earlier and later in the season
  - Combination creates more intra-seasonal variability
- **Frequency change:** Expansion of extreme weather impacts with hazards emerging at different times of the year
- **Intensity change:** Heavier precipitation potential increases hydrology (flooding) risks
- **Compounding risk:** More complex multi-hazard storms with blurry seasons - “October in December storm events”

Vermont FEMA Disaster Declarations (1963 to *2024)

FEMA Disaster Declarations	
County	**Total Declarations**
Lamoille	33
Orange	30
Washington	29
Chittenden	28
Orleans	28
Franklin	27
Addison	26
Caledonia	26
Essex	25
Windsor	24
Windham	21
Rutland	19
Bennington	18
Grand Isle	15

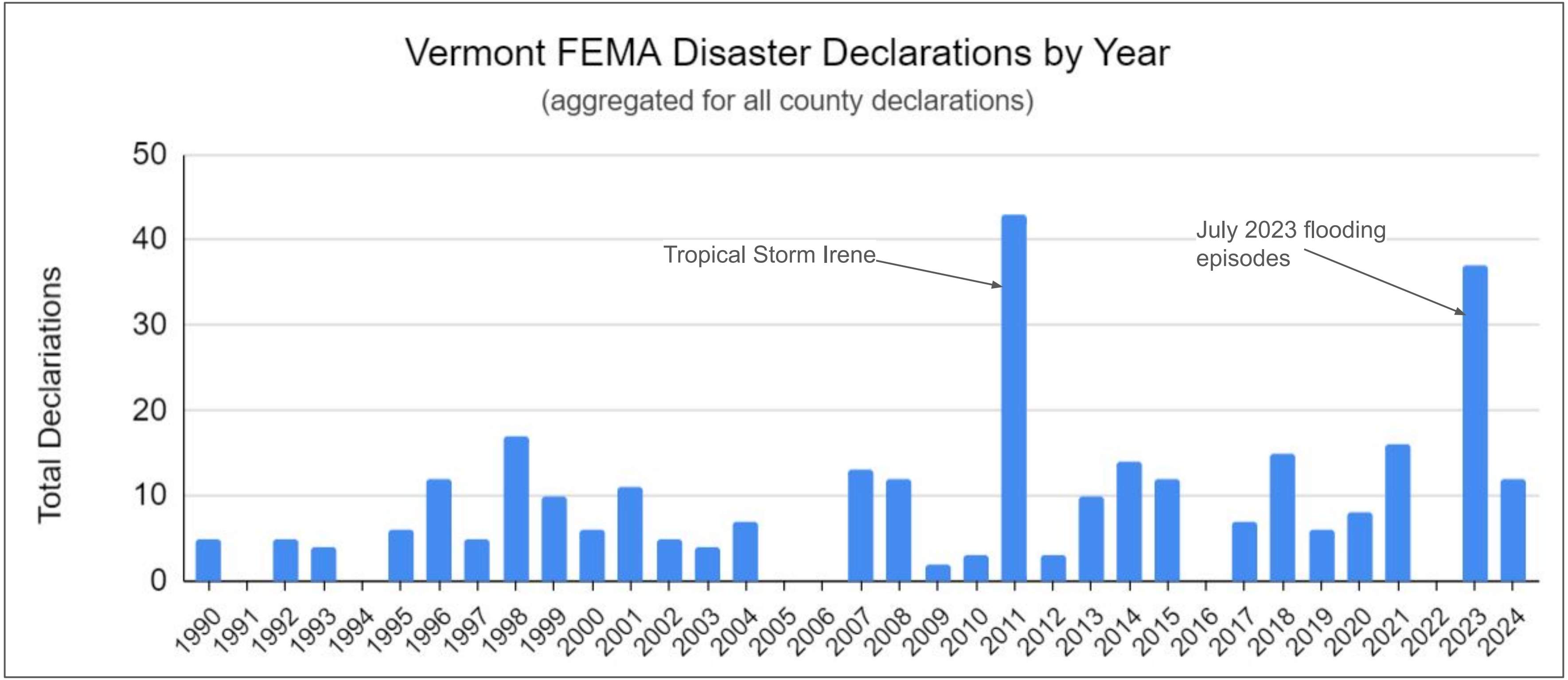
Data: https://www.fema.gov/openfema-data-page/disaster-declarations-summaries-v2

Hazard Type Classification

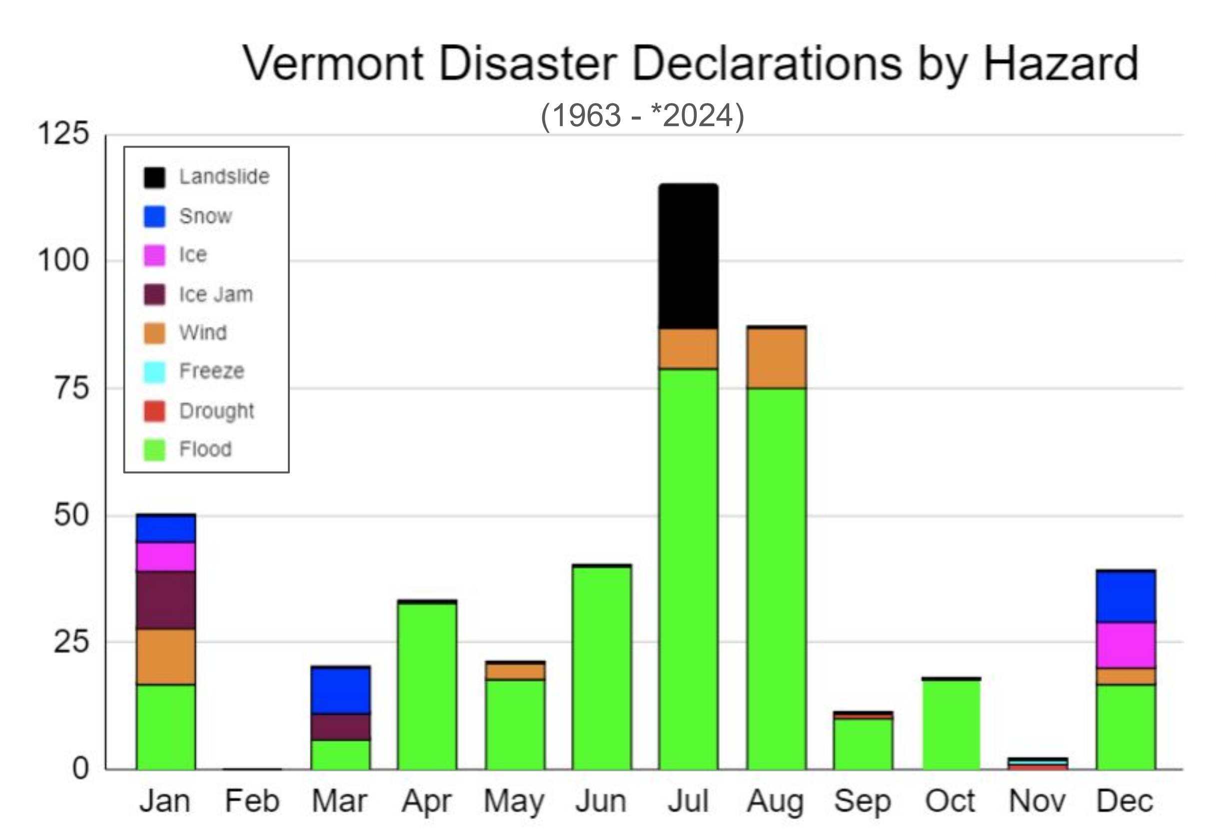


*As of April 1, 2024

Vulnerability = frequency * intensity ; heavy rainfall/flooding will remain the hazard causing the greatest vulnerabilities into the future.



Data: https://www.fema.gov/openfema-data-page/disaster-declarations-summaries-v2



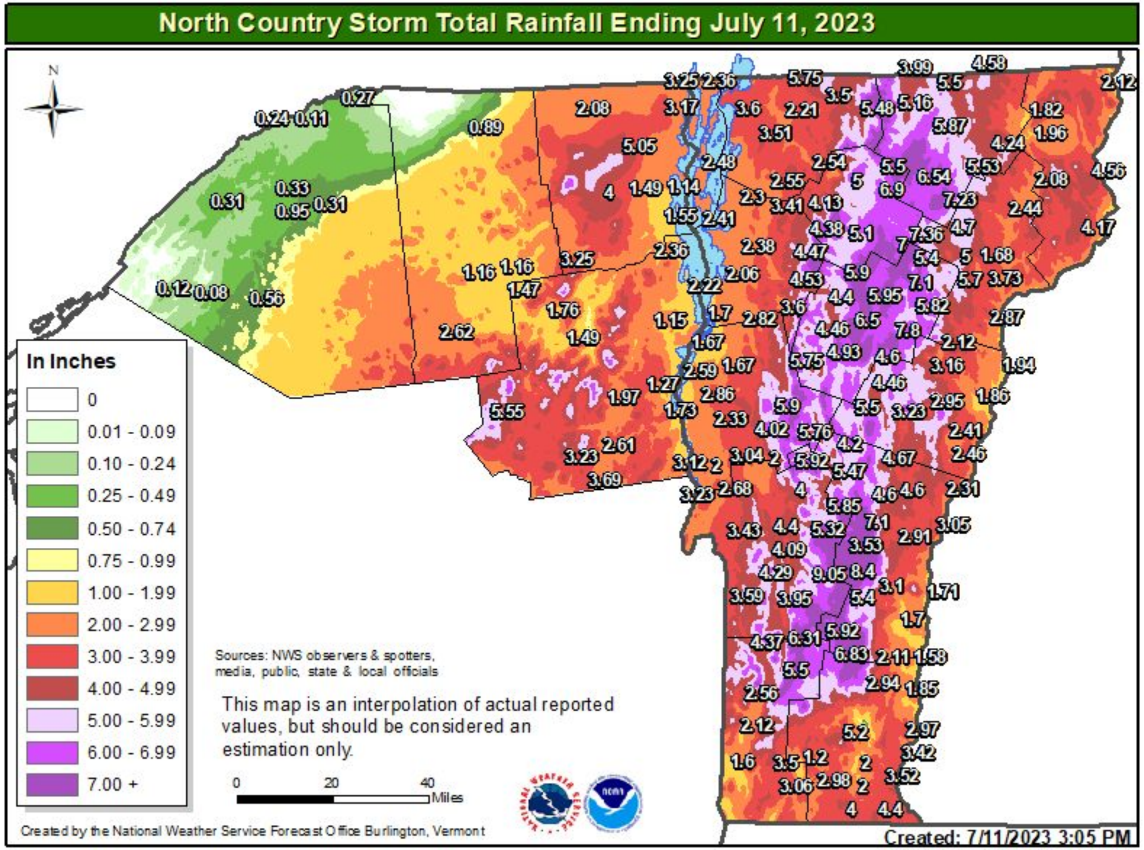
Increasing vulnerability with shifting seasonal risk exposure. Warmer winters create more multi-hazard storm exposure through increasing wet snow, more rain on snow (snowmelt), and greater vulnerability from high wind events.

*As of April 1, 2024

Data: https://www.fema.gov/openfema-data-page/disaster-declarations-summaries-v2

Future Risk: Modeling the frequency change of future black-swan type extreme events (e.g., Irene, July 2023) is currently beyond the capabilities of the science. However, regarding the intensity change, the future climate favors increased potential for heavier rainfall from warmer oceans (more evaporation) and slower moving storm systems.

July 2023 Heavy Rainfall and Flooding



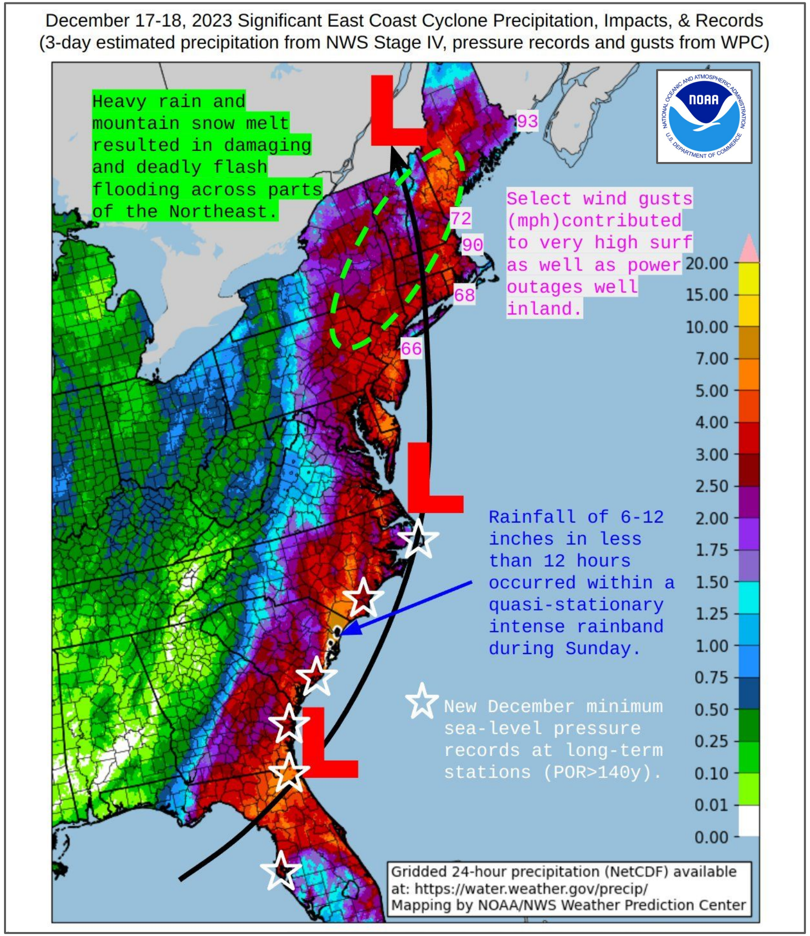
July 2023 v. Irene (Aug 2011)

48-hr Rainfall Accumulation Comparison (inches)				
Number	Name	Irene Rainfall	July 10-11, 2023 Rainfall	Difference
VT-WS-7	Middlesex 3.1 ENE	4.66	8.03	3.37
VT-WS-5	Berlin 4.3 WNW	5.15	7.54	2.39
VT-WS-13	Middlesex 6.9 NE	4.87	7.21	2.34
VT-WR-6	Ludlow 3.4 S	7.15	6.28	-0.87
VT-WS-15	East Calais 1.5 SW	4.39	5.95	1.56
VT-WS-12	Cabot 3.9 ENE	5.81	5.70	-0.11
VT-LM-1	Stowe 0.2 SW	5.43	5.56	0.13
VT-OL-1	Westfield 0.7 WNW	5.27	5.16	-0.11
VT-WS-11	Waitsfield 1.8 SE	6.45	4.93	-1.52
VT-WR-2	Pomfret 2.6 N	6.83	4.81	-2.02
VT-WS-19	Waterbury 3.0 NW	4.42	4.53	0.11
VT-CH-13	Richmond 3.4 SSE	4.87	4.46	-0.41
VT-RT-1	West Rutland 1.2 N	5.25	4.40	-0.85
VT-WR-4	Norwich 1.6 NNE	3.91	4.03	0.12
VT-CL-6	Danville 2.0 E	5.04	3.73	-1.31
VT-CH-4	Underhill 4.4 NNE	4.86	3.41	-1.45
VT-AD-5	Orwell 1.2 WNW	4.78	3.12	-1.66
VT-CH-3	Charlotte 2.9 NNE	3.99	2.22	-1.77

Above table is data is from the citizen science program where observers experienced both storms, CoCoRaHS https://www.cocorahs.org/.

Dec 18, 2023 Storm: Heavy Rainfall/Flooding and Wind

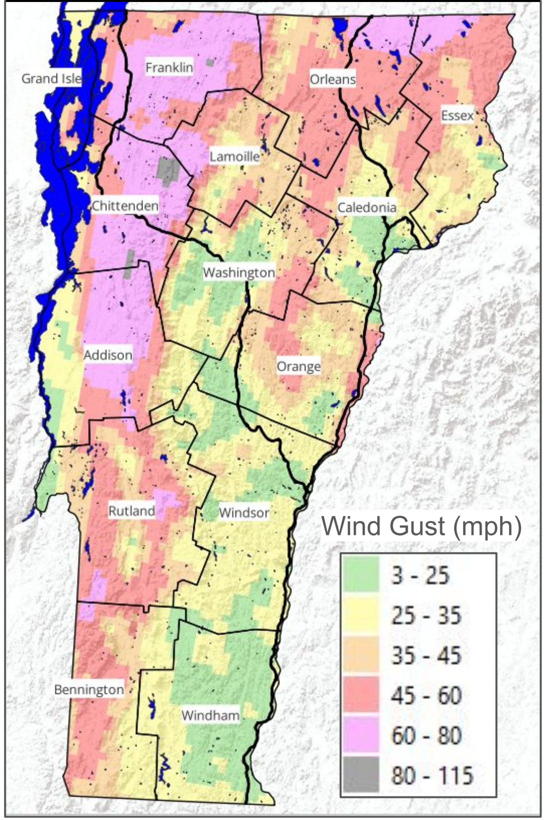
VT County Disaster Declarations
Essex
Lamoille
Orange
Orleans
Rutland
Windham
Windsor



“October in December” storm morphology

Jan 9-10, 2024 Storm: Wet Snow and High Wind

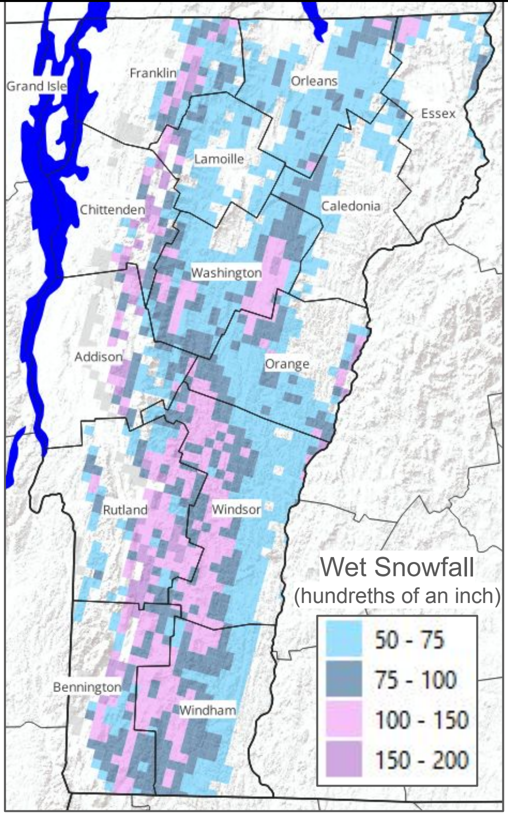
Peak Wind Gusts

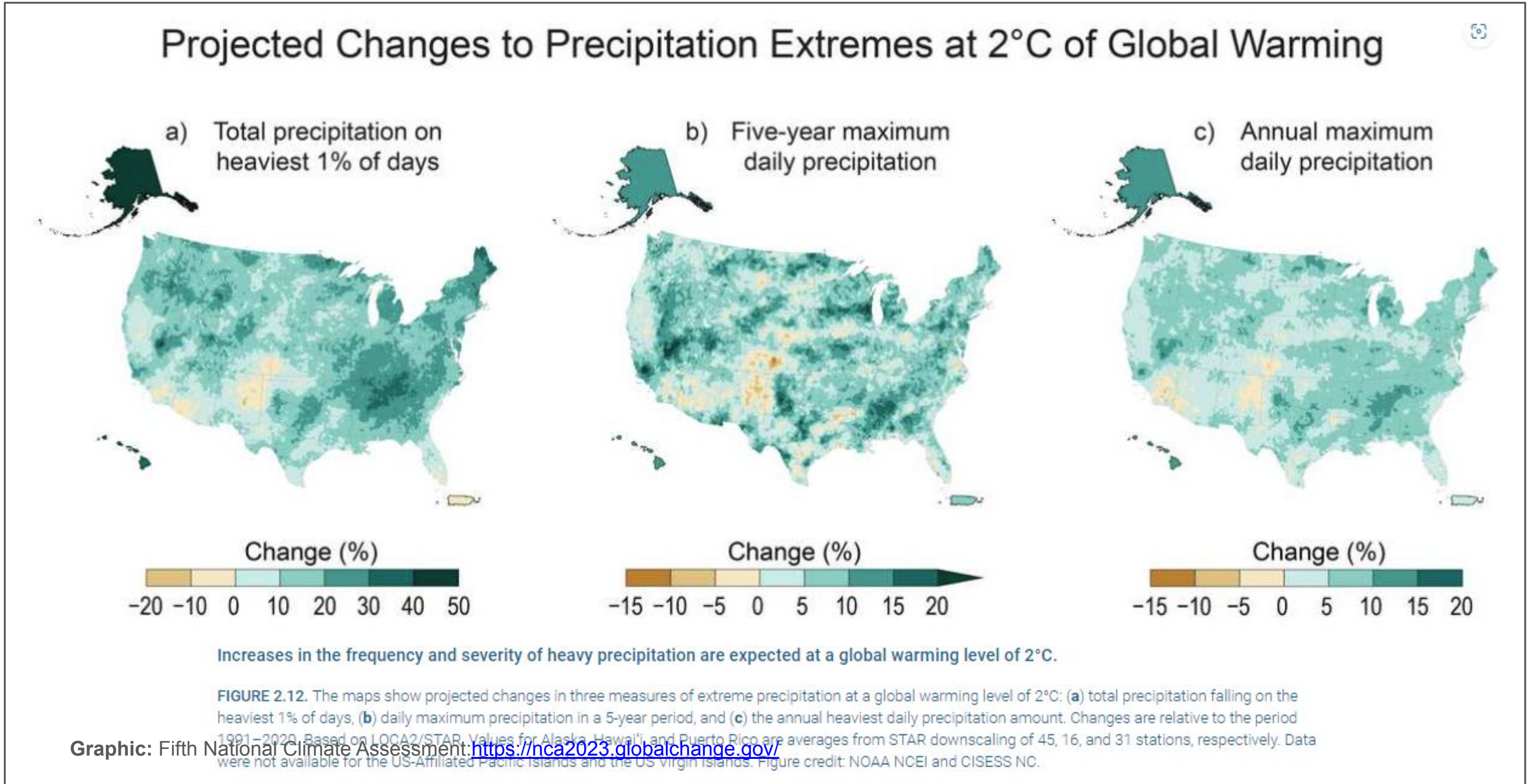


VT County Disaster Declarations
Chittenden
Essex
Franklin
Lamoille
Orleans

Fact: Wet snowfall has caused more power outage impacts in the last 10 years than any other hazard.

Wet Snowfall Liquid Content



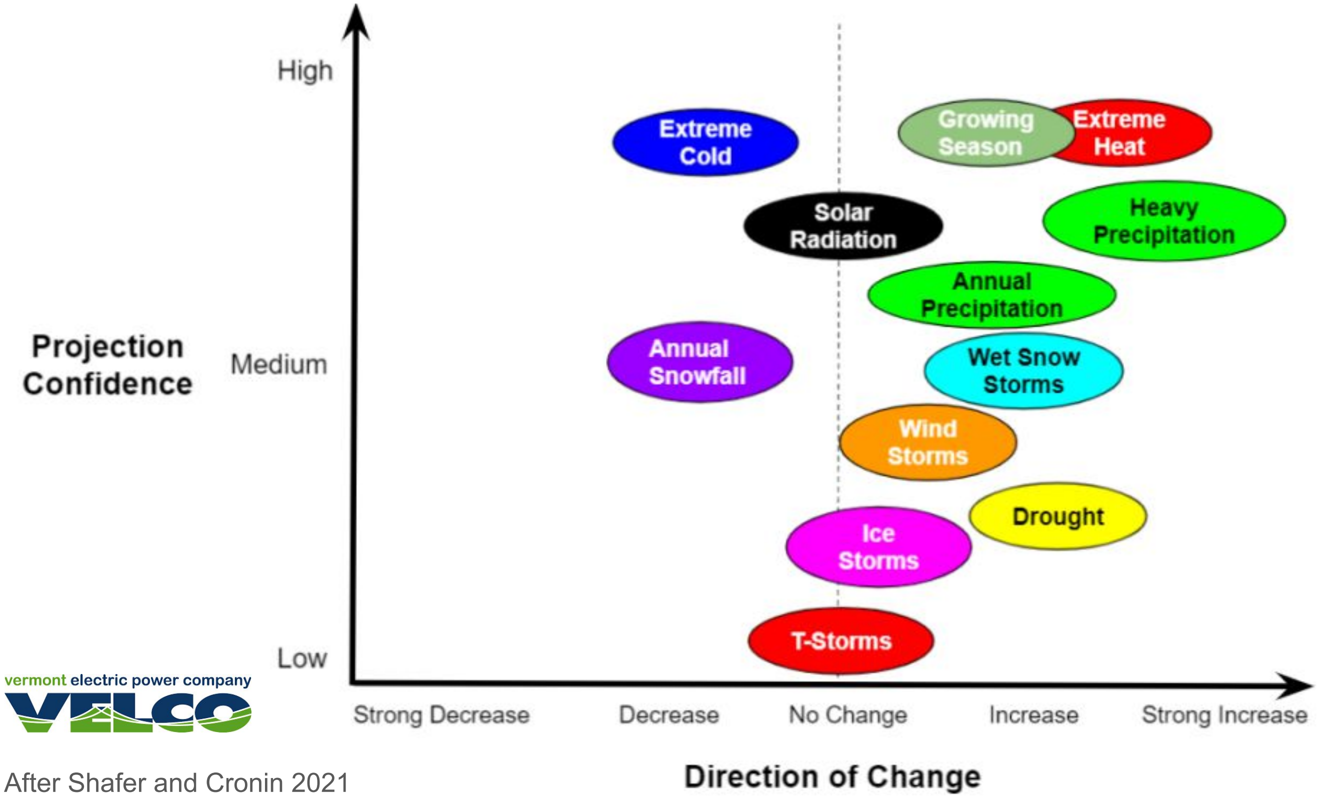


Graphic: Fifth National Climate Assessment: https://nca2023.globalchange.gov/

Timing of 2°C of warming depends on atmospheric carbon concentration and SSP scenarios. Generally reached between 2042 and 2053 with most SSP scenarios. Thirty-year ahead increases suggest an increase of 10 to 20% frequency of heavy precipitation events, as defined in three above ways.This does not necessarily correlated to flooding impacts, as additional hydrologic factors such as precursor soil moisture and time of year are important.

Above figure source: Fifth National Climate Assessment:https://nca2023.globalchange.gov/

Vermont Hazard Prediction Changes through 2050



After Shafer and Cronin 2021