Heat Waves & Droughts in Northeast US

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Quick outline:

I. Heat wave circulation patterns for the Northeast US

II. Seasonal drought circulation patterns for the Northeast US

III. Connecting heat waves and droughts

IV. Where does summer 2022 fit in?

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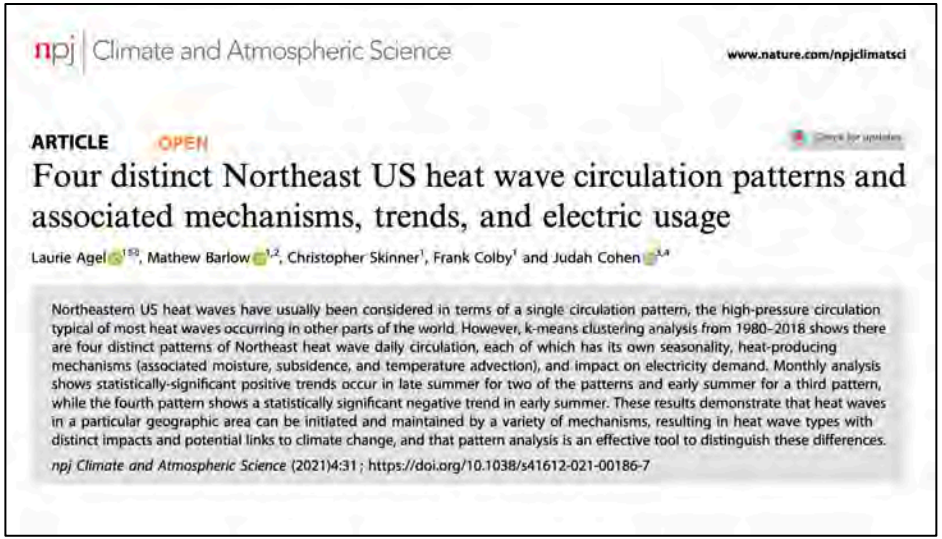
Part I: Heat wave Circulation in Northeast US



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ARTICLE OPEN

Four distinct Northeast US heat wave circulation patterns and associated mechanisms, trends, and electric usage

Laurie Agel[1✉], Mathew Barlow[1,2], Christopher Skinner[1], Frank Colby[1] and Judah Cohen[3,4]

Northeastern US heat waves have usually been considered in terms of a single circulation pattern, the high-pressure circulation typical of most heat waves occurring in other parts of the world. However, k-means clustering analysis from 1980–2018 shows there are four distinct patterns of Northeast heat wave daily circulation, each of which has its own seasonality, heat-producing mechanisms (associated moisture, subsidence, and temperature advection), and impact on electricity demand. Monthly analysis shows statistically-significant positive trends occur in late summer for two of the patterns and early summer for a third pattern, while the fourth pattern shows a statistically significant negative trend in early summer. These results demonstrate that heat waves in a particular geographic area can be initiated and maintained by a variety of mechanisms, resulting in heat wave types with distinct impacts and potential links to climate change, and that pattern analysis is an effective tool to distinguish these differences.

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Part 1. Heat wave circulation patterns: **Identifying heat wave days for the Northeast US**

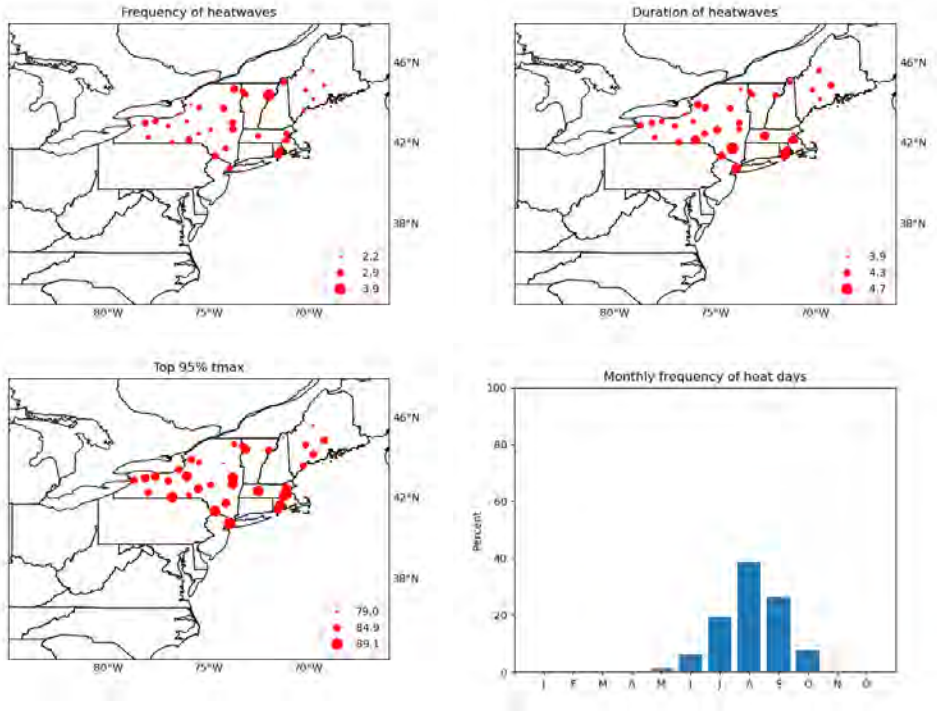
35 GHCN stations, 1980–2018 T_{MAX}

Defn: **Station heat wave**:

- 95th-percentile T_{MAX} for at least 3 days

Defn: **Regional heat wave day**:

- Any day when at least one station is experiencing a heat wave
- 1693 regional heat wave days



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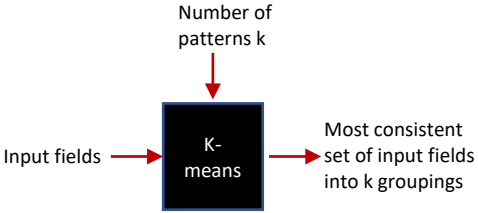
Part 1. Heat wave circulation patterns: **Identifying patterns**

Non-hierarchical k-means clustering on 1693 regional heat wave days

- 500-hPa geopotential height anomalies
- 900-hPa wind anomalies
- 4 patterns optimal in this case



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Part 1. Heat wave circulation patterns: **Identifying patterns**

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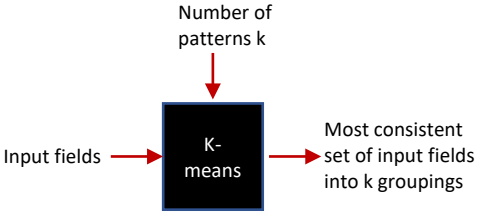

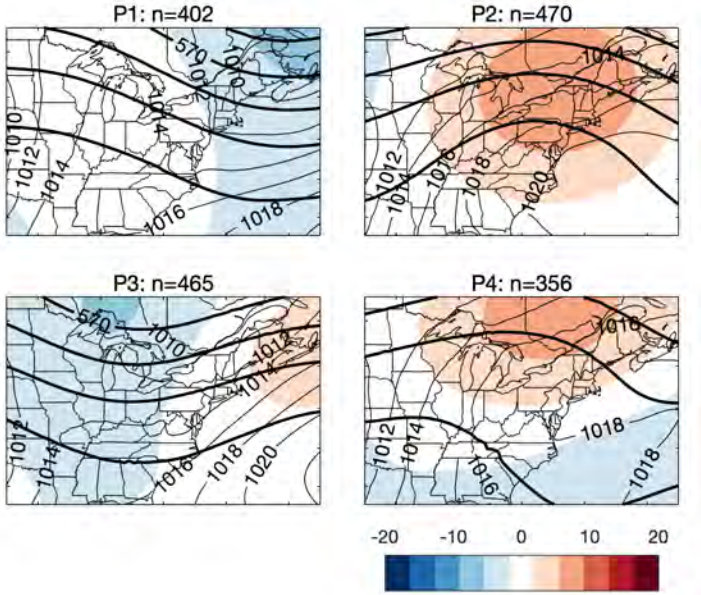

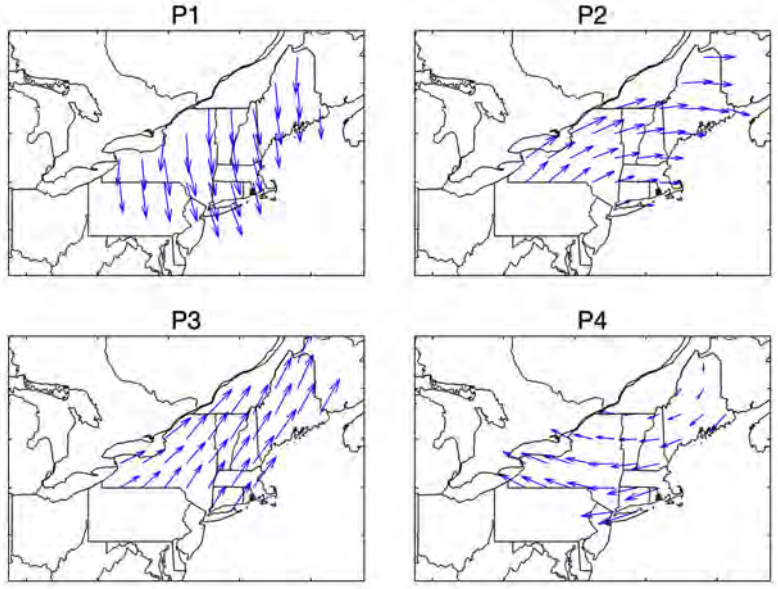

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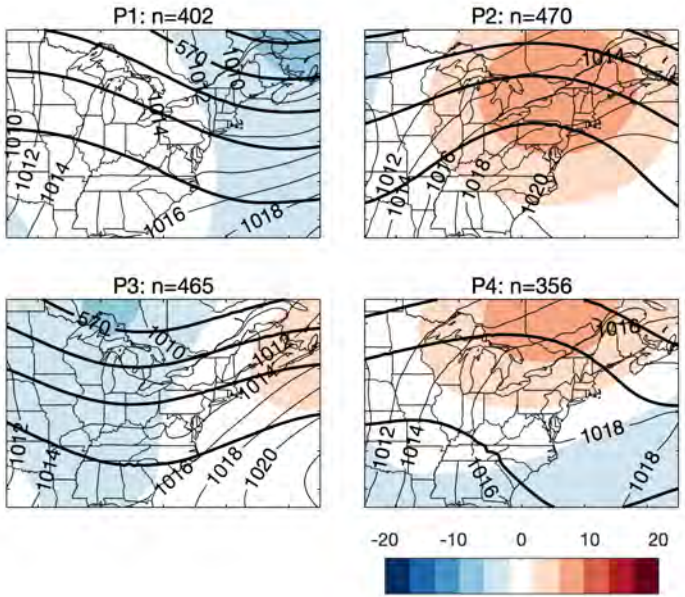
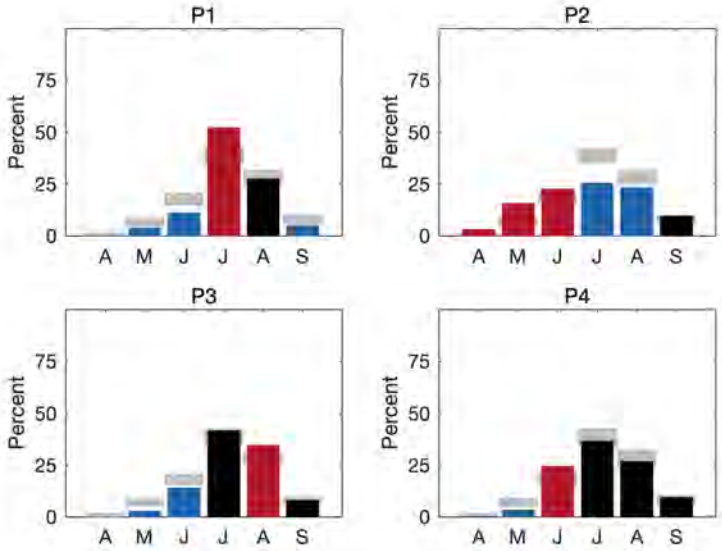
Part 1. Heat wave circulation patterns: **Seasonality of the patterns**



Monthly frequency of heat wave pattern days



= less frequent than you would expect

= more frequent than you would expect

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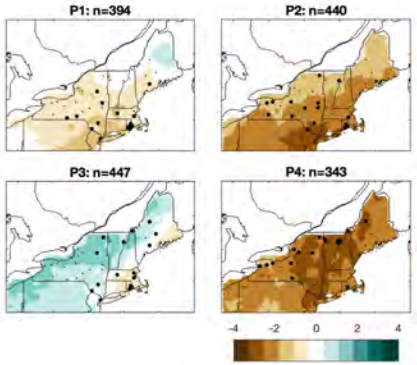
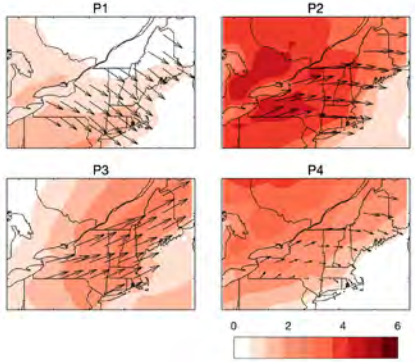
Part 1. Heat wave circulation patterns: **Each pattern tells a story…**

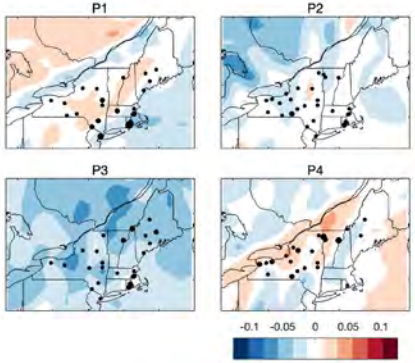
Precipitation anomalies



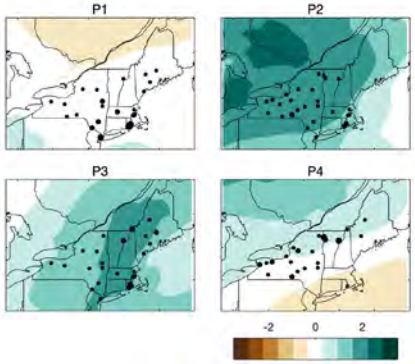
Surface temp anomalies



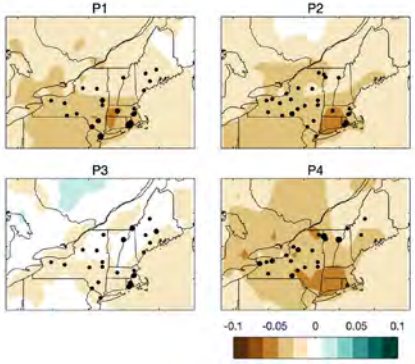
Subsidence anomalies



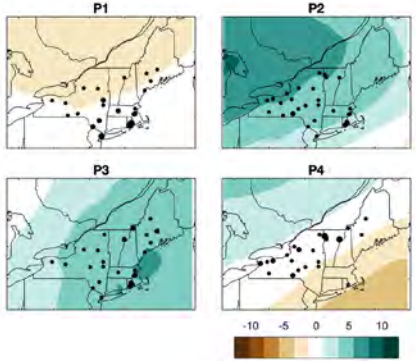
2-m specific humidity anomalies



Soil moisture anomalies



PWAT anomalies



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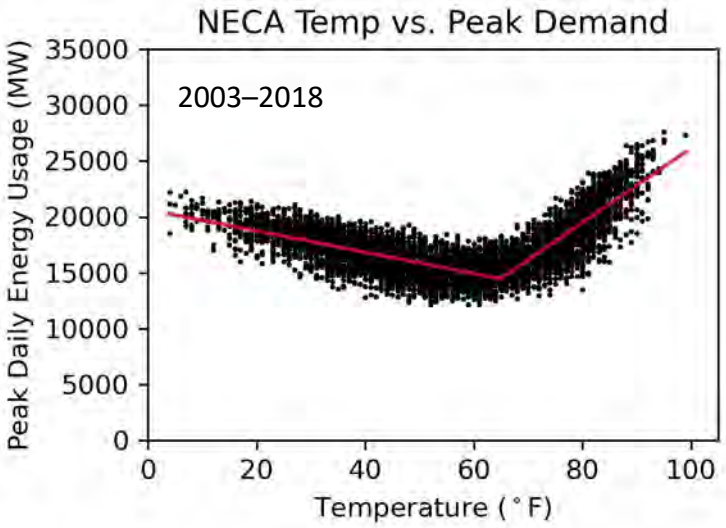
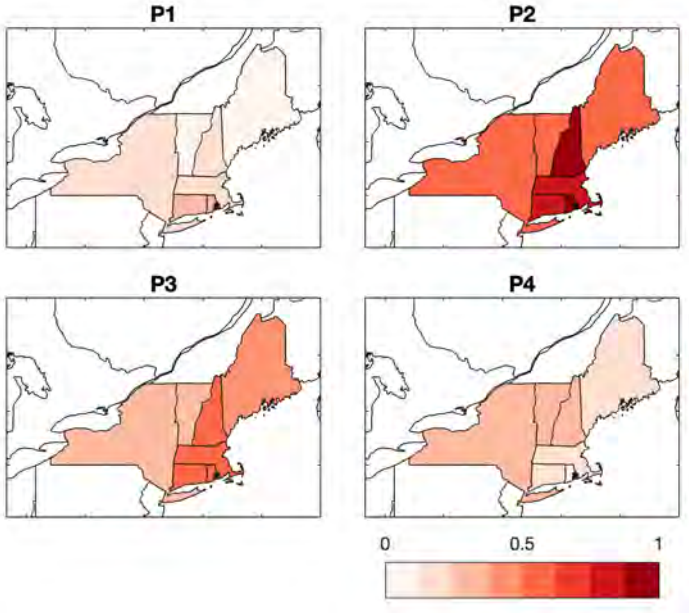
Part 1. Heat wave circulation patterns: **the connection to energy usage**



Data from ISO New England, NY-ISO

Relative energy usage during heat waves



P2 stands out for anomalous energy usage (remember this often occurs in Apr–June)

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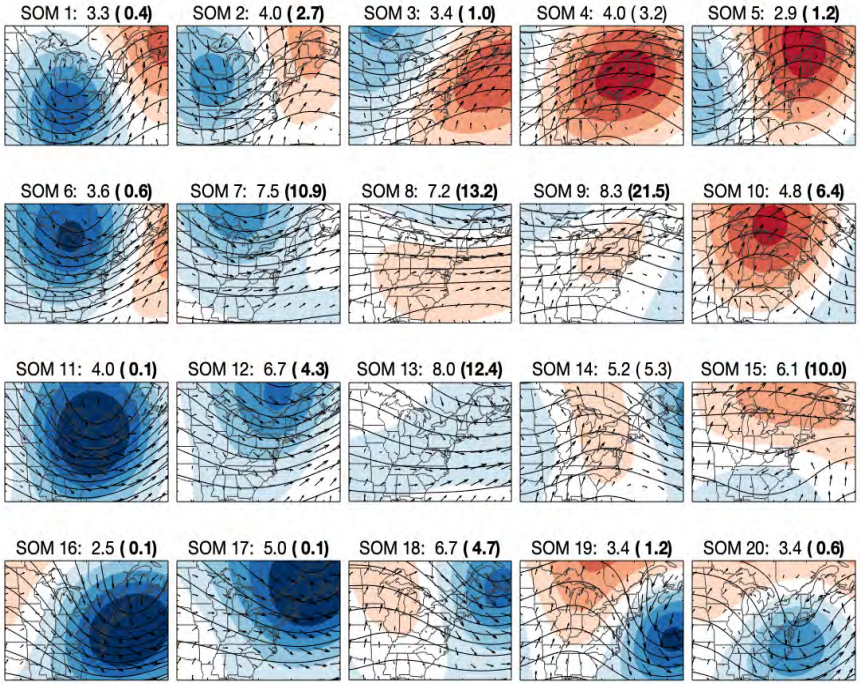
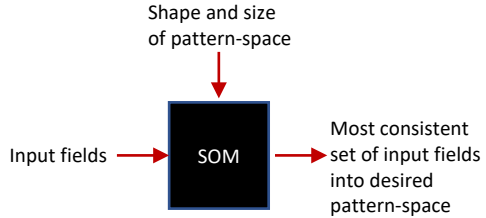
Part 1. Heat wave circulation patterns: **How do these fit into all-days circulation?**

1980–2018 circulation patterns





- Self-organizing maps (SOMs)
- Same input fields as for heat waves
- All days 1980–2018
- 4x5 rectangular space
- Similar patterns located near each other in pattern-space

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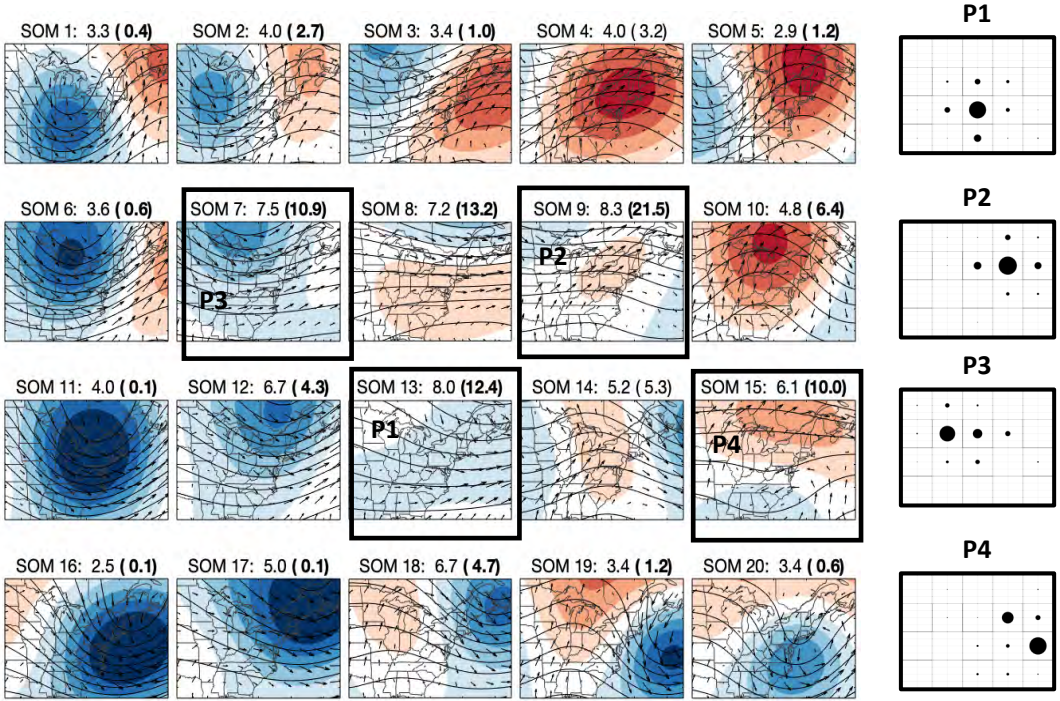
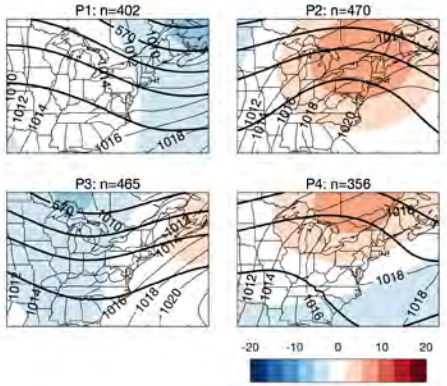
Part 1. Heat wave circulation patterns: **How do these fit into all-days circulation?**

1980–2018 circulation patterns



Heat wave patterns



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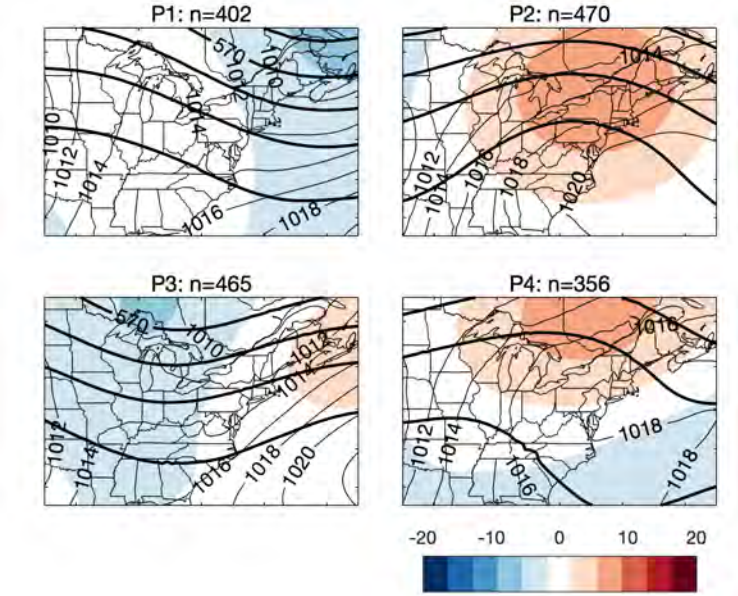
Part 1. Heat wave circulation patterns: **Four flavors, a summary**



P1
- July/Aug
- NW winds
- Dry air
- Subsidence

P2
- Favored in spring
- Heat dome
- High temps, low prec
- Highest energy use

P3
- July/Aug
- SW winds
- Warm, humid airmass
- Precipitation common

P4
- Summer pattern
- Troughing over Atlantic
- Driest soil moisture
- Moist air NW, dry air SE

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Part II: Drought Circulation in Northeast US

…a peek into some of our current research

Supported by NOAA MAPP NA20OAR4310424

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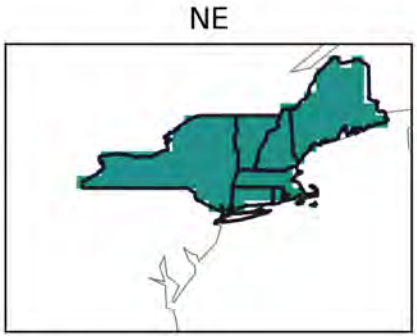
Part 2. Seasonal Drought circulation patterns: **Identifying drought days for the Northeast US**

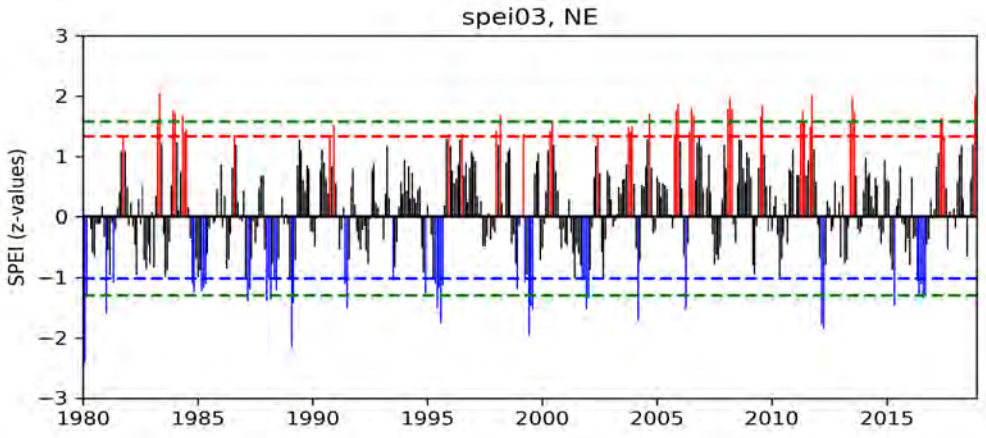


Standardized Precipitation-Evapotranspiration Index (SPEI)

Takes into account both precipitation and potential evapotranspiration (PET)

Gridded dataset, 0.5 degrees, global

Value for each month assessing relative wet vs dry conditions for the previous *n* months where n is 1,2,…,12,24 etc.



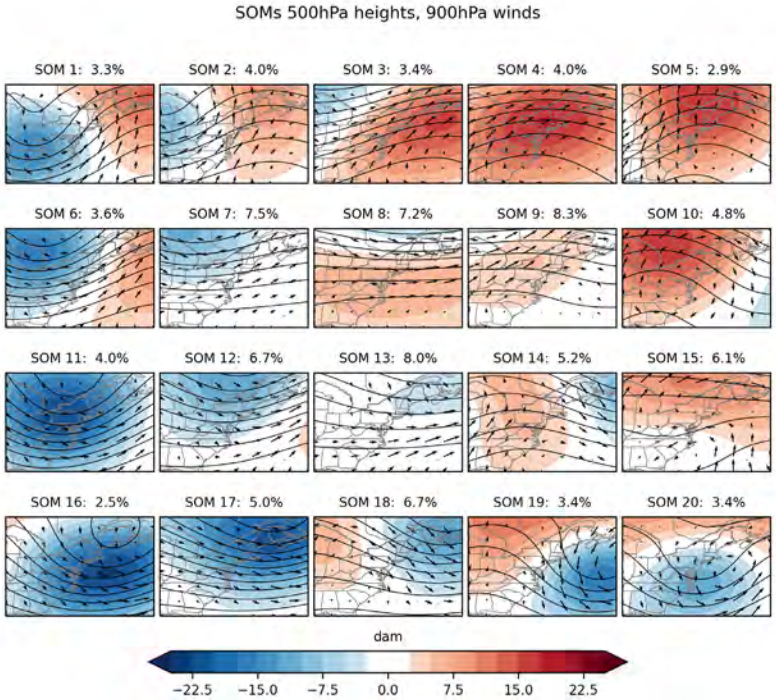
We have chosen to work with **3-month SPEI**, using a top **10% threshold (blue dashed line)** for driest periods, 1980–2020

For driest 3-month periods in NE,

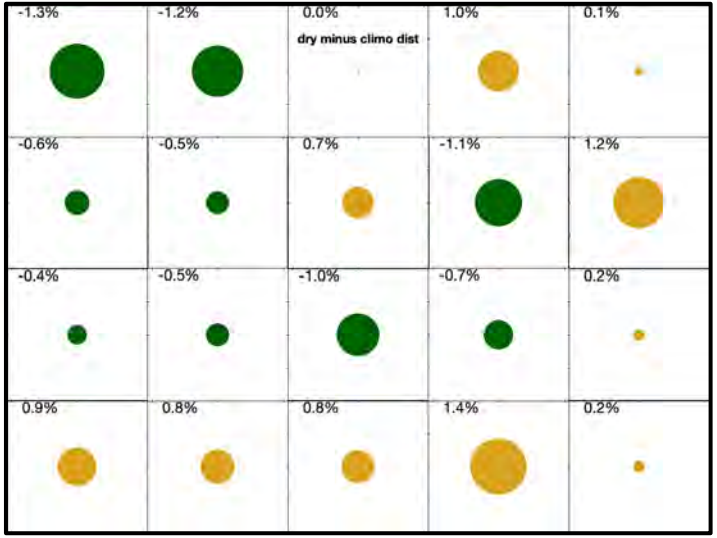
- **Mean SPE**I for top 10% dry periods is **-1.369**
- **Mean duration** of top 10% dry periods is **2.1** months (this means the dry event itself can be 5 months or more in duration)
- Total of **22 dry events**, ranging from 1-5 months in duration

For more info, Laurie_Agel@uml.edu

Part 2. Seasonal drought circulation patterns: **Where do drought days fit into overall circulation?**



Dry event day frequency minus all-day frequency per SOM



= less dry days than you would expect

= more dry days than you would expect

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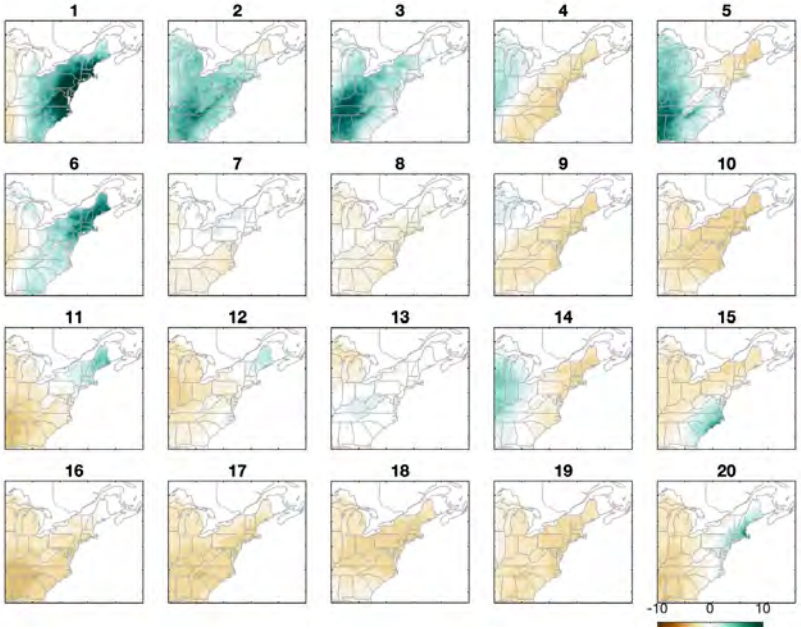
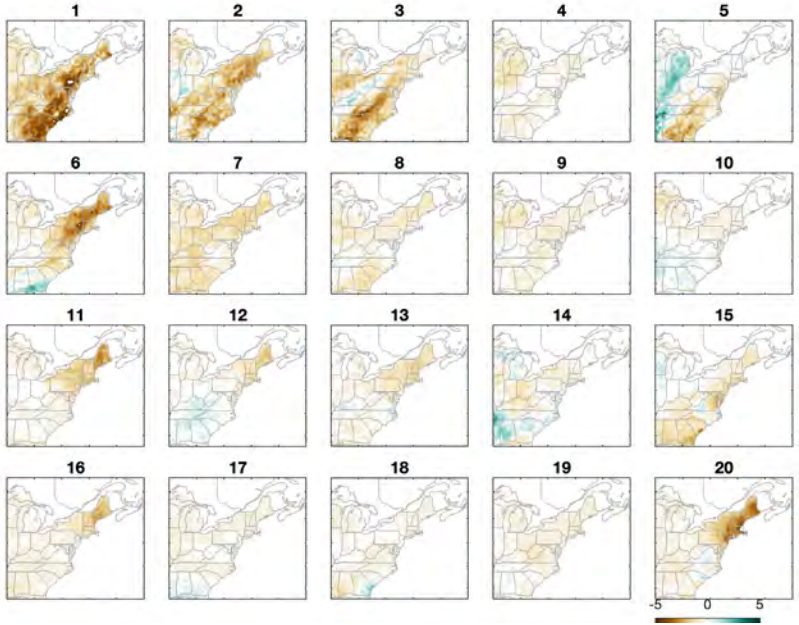
Part 2. Seasonal drought circulation patterns: **Precipitation during drought periods**

Climatological precipitation anomalies



Drought day difference from climatology



- Biggest difference for normally wet patterns
- Driest patterns slightly more dry for drought days (esp SOM20)

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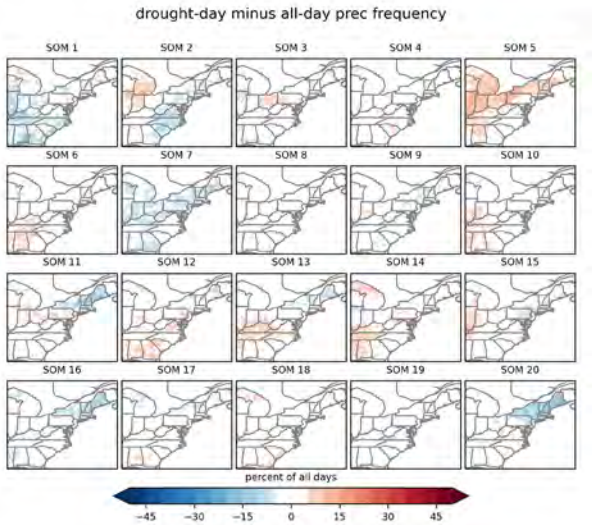
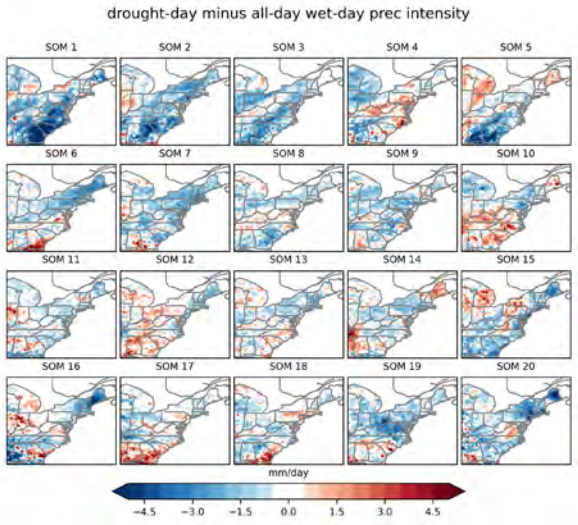
Part 2. Seasonal drought circulation patterns: **A closer look at precipitation (>1mm/day) during drought periods**

FREQ



INTENSITY



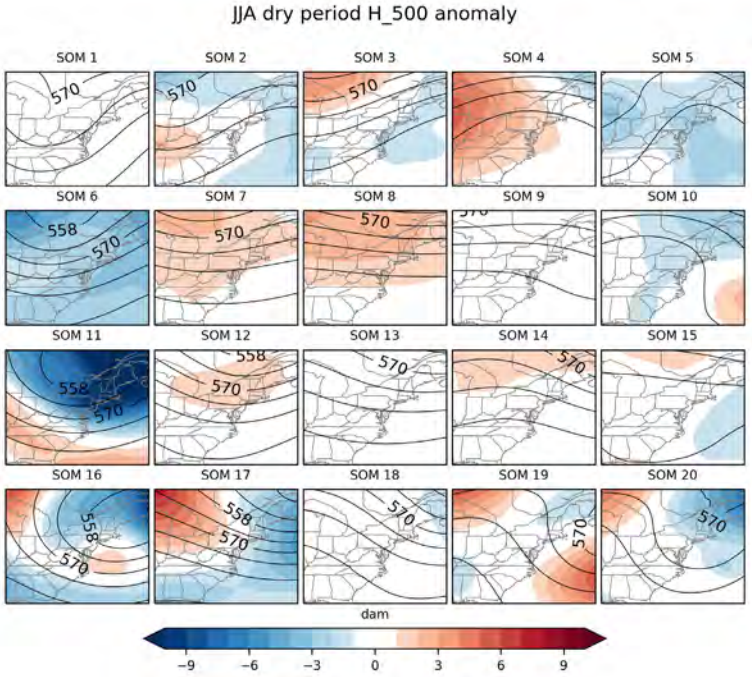
Ongoing research…

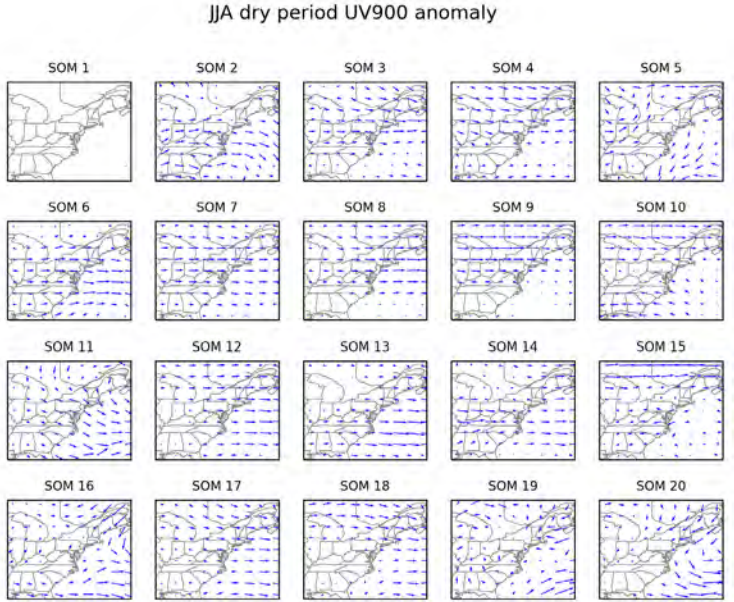
Is precipitation less freq or less intense (or a combination of both) during drought periods in the NE within these SOMs?

How does this change seasonally?

For more info, Laurie_Agel@uml.edu

Part 2. Seasonal drought circulation patterns: **Circulation differences from climatology**



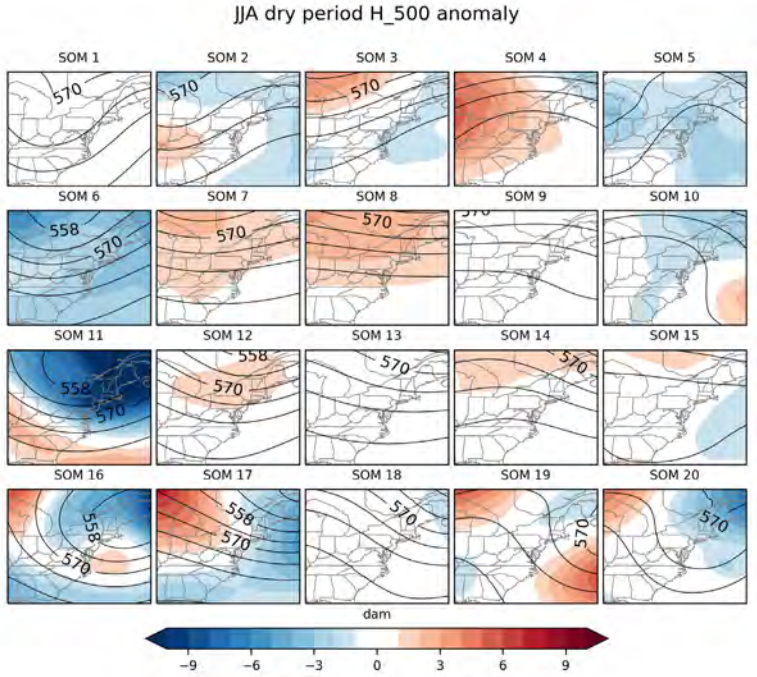


= more troughing

= more ridging

For more info, Laurie_Agel@uml.edu

Part 2. Seasonal drought circulation patterns: **Putting it all together**



= more troughing

= more ridging

Ongoing research…..

Do these circulation changes favor

- Advection of dry air?
- More evaporation?
- Suppression of precipitation?

To what level is NE drought driven by

- Changes between circulation patterns?
- Changes within circulation patterns?

Do trends in pattern frequency play a role?

For more info, Laurie_Agel@uml.edu

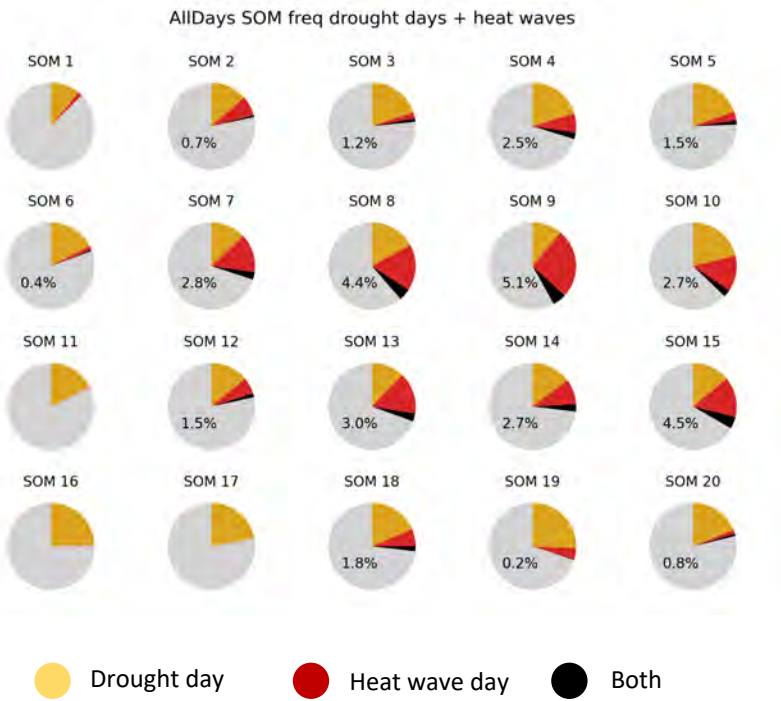
Part III: Connecting heat waves and droughts

Does favored circulation for drought == favored circulation for heat waves?
(Spoiler: No!)

For more info, Laurie_Agel@uml.edu

Part 3. Connecting heat waves and droughts: **How often do heat waves occur during drought periods?**

- Some SOMs support both drought and heat wave days (SOMs 8,9,15)
- Some SOMs rarely support heat waves (wettest and driest SOMs)
- Favored drought SOMs are not the most common favored heat wave SOMs



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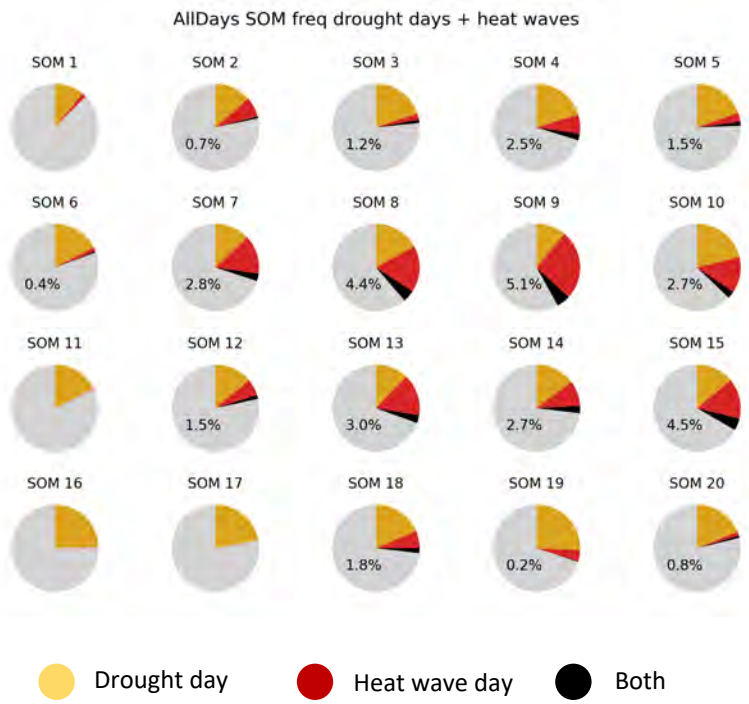
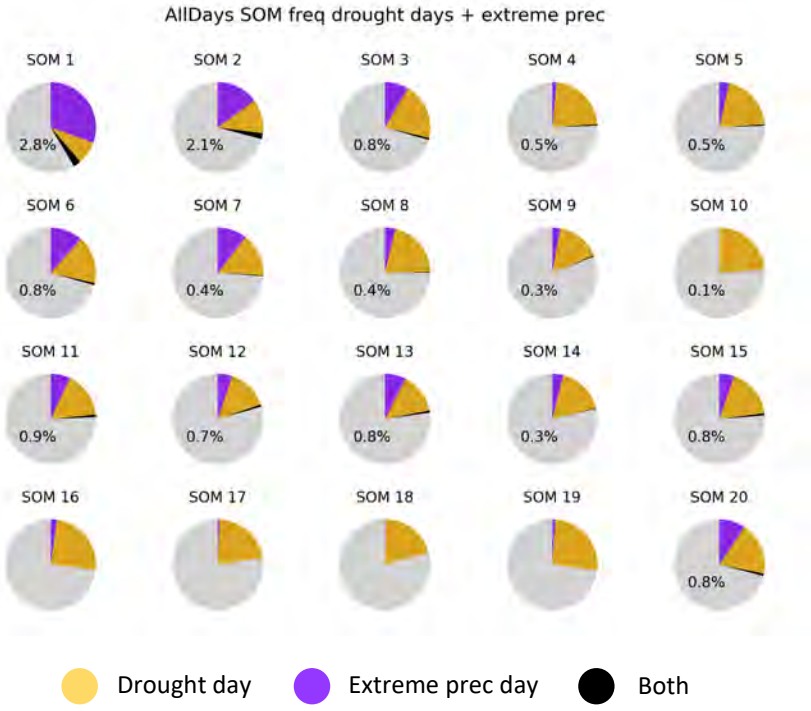
- Favored drought SOMs are not the most common favored heat wave SOMs
- Extreme precipitation can occur during drought periods too!





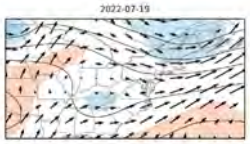
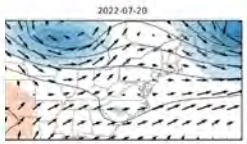
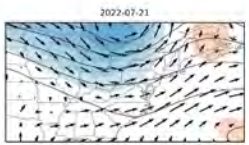
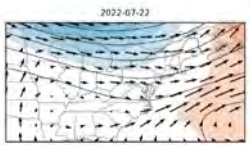
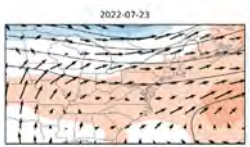
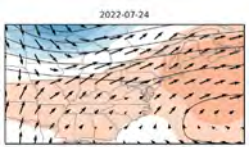
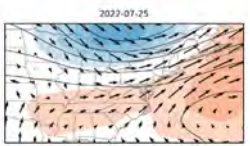
For more info, Laurie_Agel@uml.edu

Part IV: Where does summer 2022 fit in?

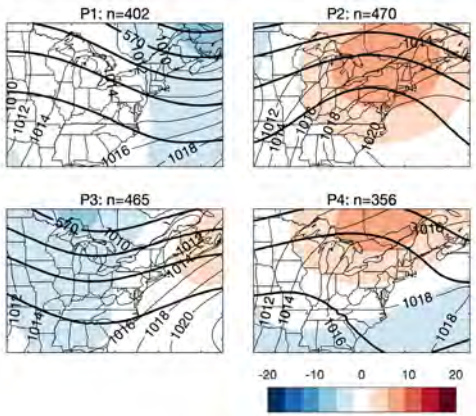
Image from Boston Globe

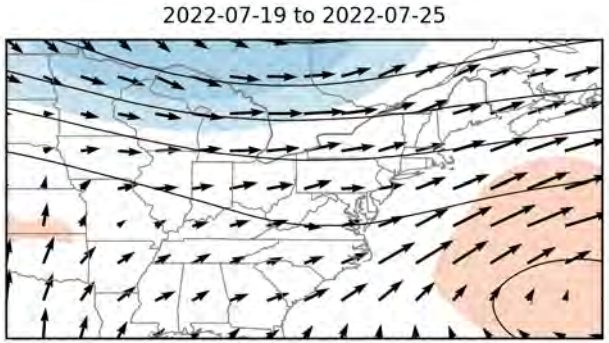
For more info, Laurie_Agel@uml.edu

Part 4. Summer 2022: **Which heat wave patterns best describe the Boston July 19–25 heatwave?**

T_{MAX} 93F	T_{MAX} 92F	T_{MAX} 94F	T_{MAX} 94F	T_{MAX} 94F	T_{MAX} 100F	T_{MAX} 90F
						
P1	P3	P3	P3	P3	P2	P2

Heat wave patterns





Composite: best match to P3

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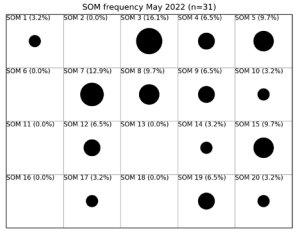
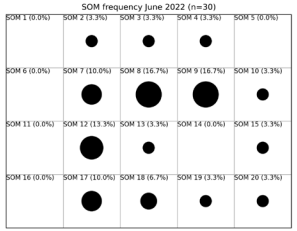
Part 4. Summer 2022: **Which SOMs do May–July 2022 fit best to?**

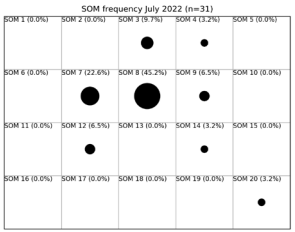
May: ridge patterns, some dry patterns



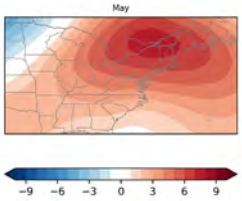
June: shifting to driest patterns



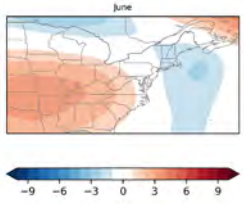
July: shifting away from driest patterns to heat wave patterns



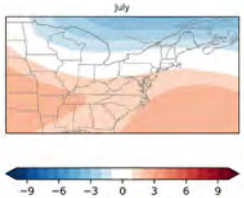
May circ anoms

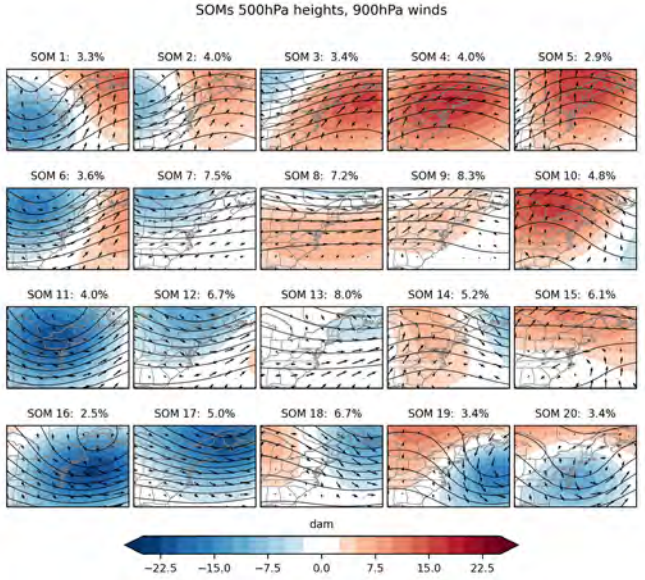


June circ anoms



July circ anoms





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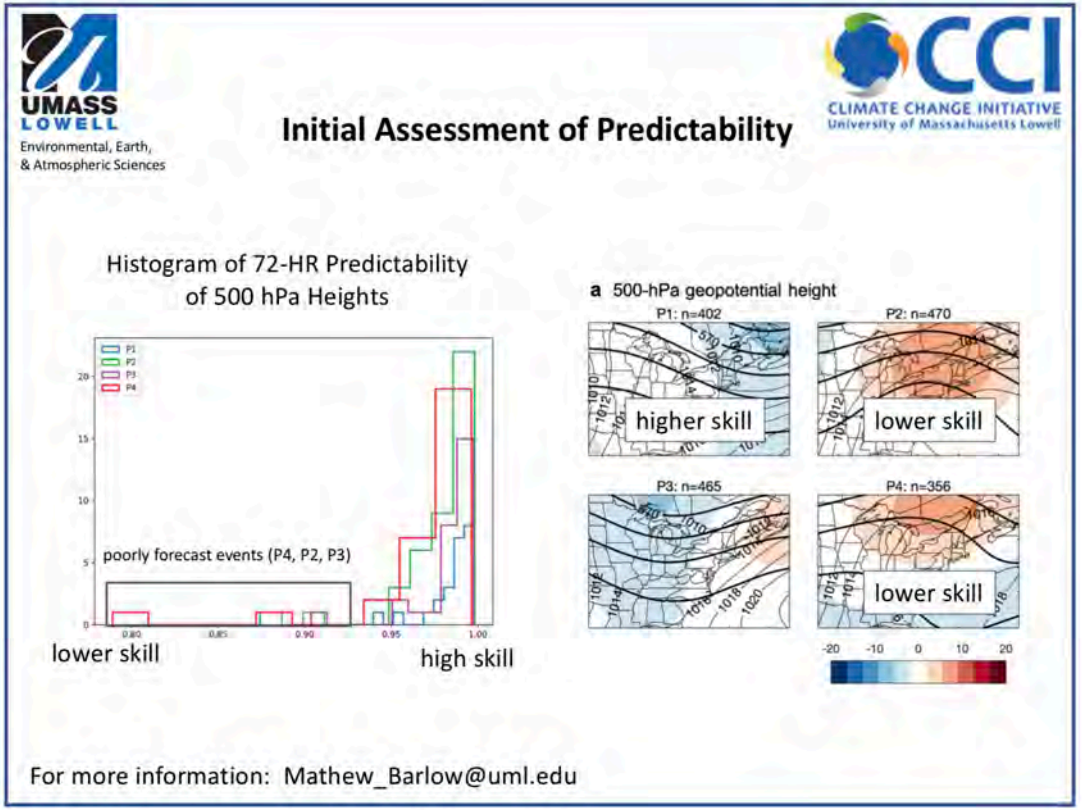
Part 4. Summer 2022: **Can we we use this knowledge to better predict heat waves or drought?**

In addition to retrospective pattern matching……

Which heat wave patterns are most predictable?

Are circulation patterns more predictable than surface temperatures?

Can we make better 3-10 day predictions of heat waves by considering circulation patterns?



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Quick outline:

I. Heat wave circulation patterns for the Northeast US

II. Seasonal drought circulation patterns for the Northeast US

III. Connecting heat waves and droughts

IV. Where does summer 2022 fit in?

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