From dust to drought: Evolving rainfall patterns in the U.S. Caribbean and lessons for South-Central CASC states

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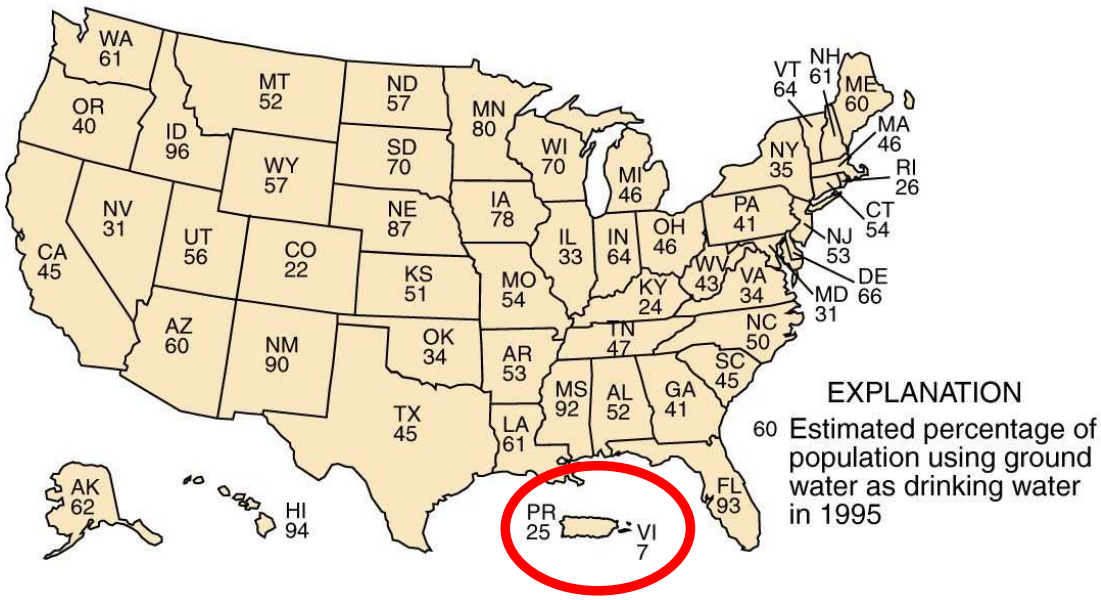
LSU

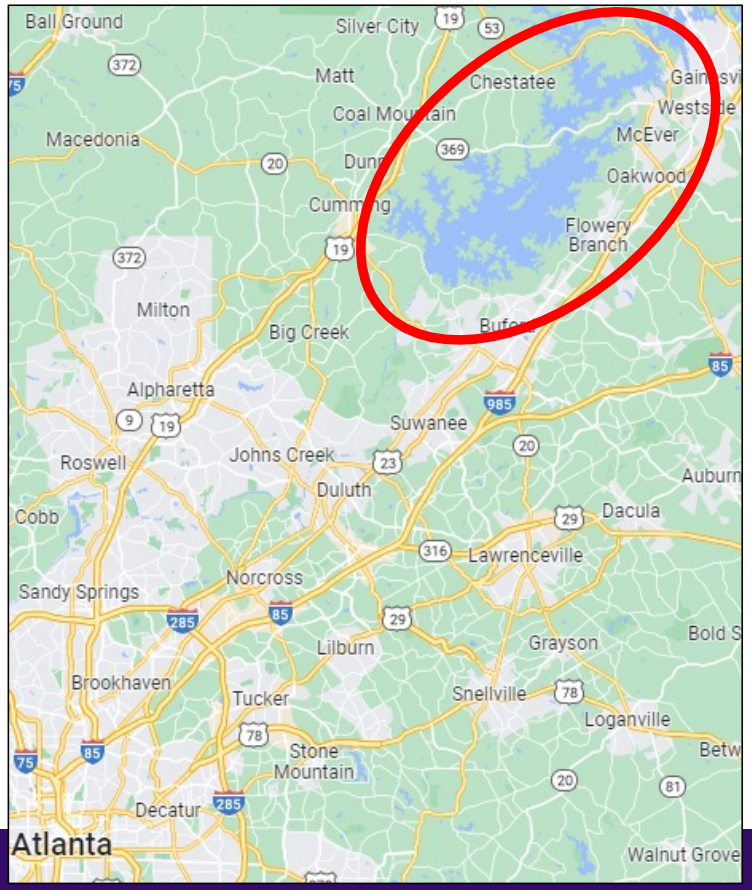
Water Resources in the Caribbean

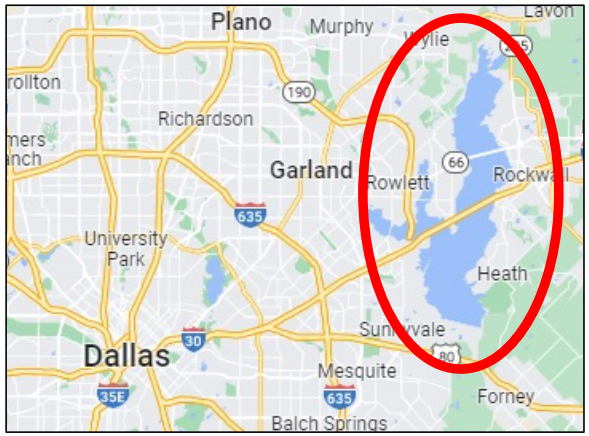
- Primary source of freshwater is regular rainfall
- Limited groundwater availability
- Few surface water resources



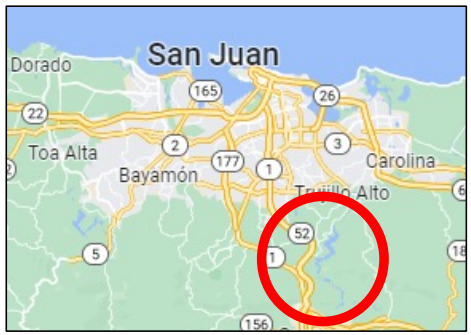
Credit: USGS

Water Resources in the Caribbean





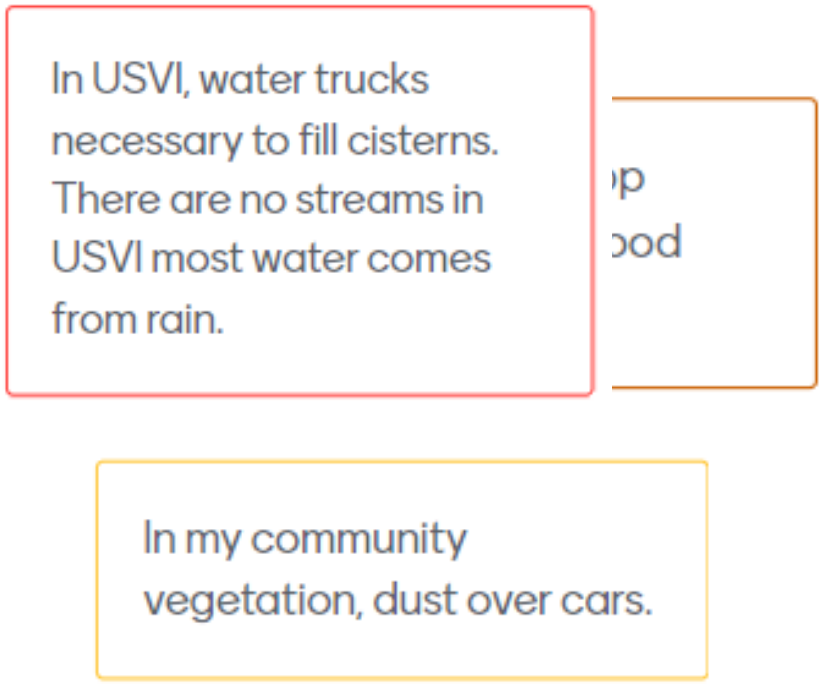
All scales the same!



- Lago Loíza, PR – 22,000 acre-feet
- Lake Ray Hubbard, TX – 490,000 acre-feet
- Lake Lanier, GA – 1,000,000 acre-feet

Water Resources in the Caribbean

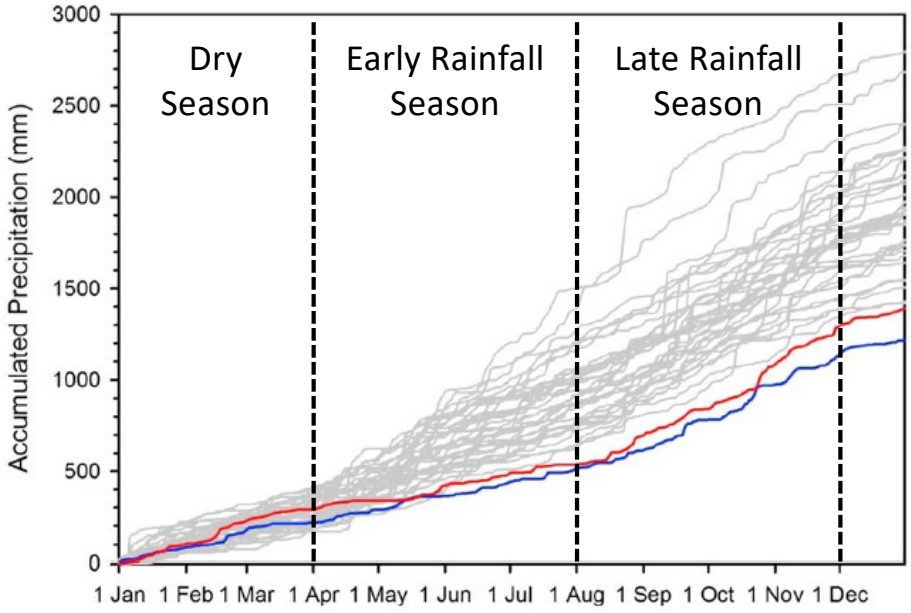
- From the 2022 Caribbean Drought Learning Network annual meeting:
- **Q:** How do you know drought is occurring in your community?



The 2015 Caribbean Drought

- First “extreme drought” recorded by U.S. Drought Monitor in PR
- Agricultural sector losses exceeded $12 million
- Water shortages cost La Autoridad de Acueductos y Alcantarillados as much as $15 million a month

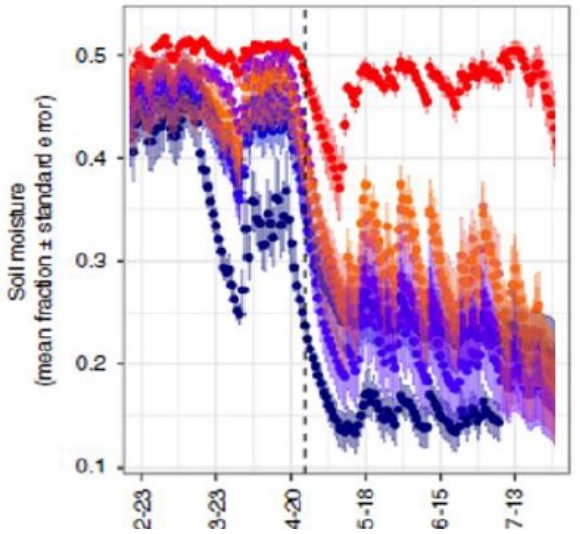
Mote et al. (2017)



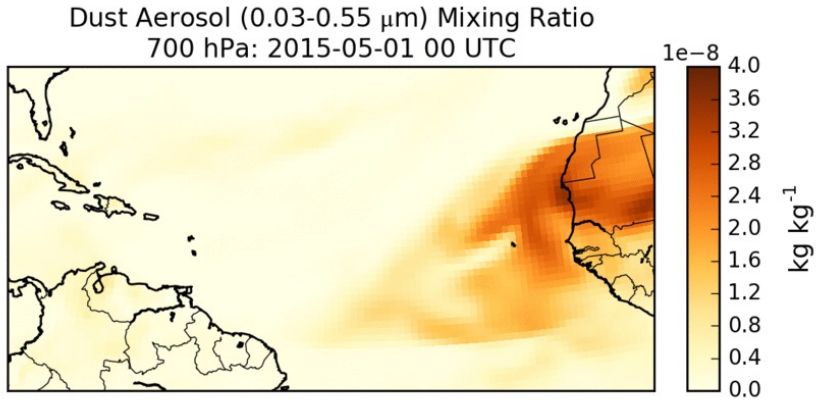
Red line - 2015 **Blue line - 1994**

The 2015 Caribbean Drought

- Soil moisture rapidly declined during late April and early May 2015
- Luquillo Mountains in eastern PR were hardest hit
- Coincided with large Saharan dust outbreak that continued through July



O'Connell et al. (2018)

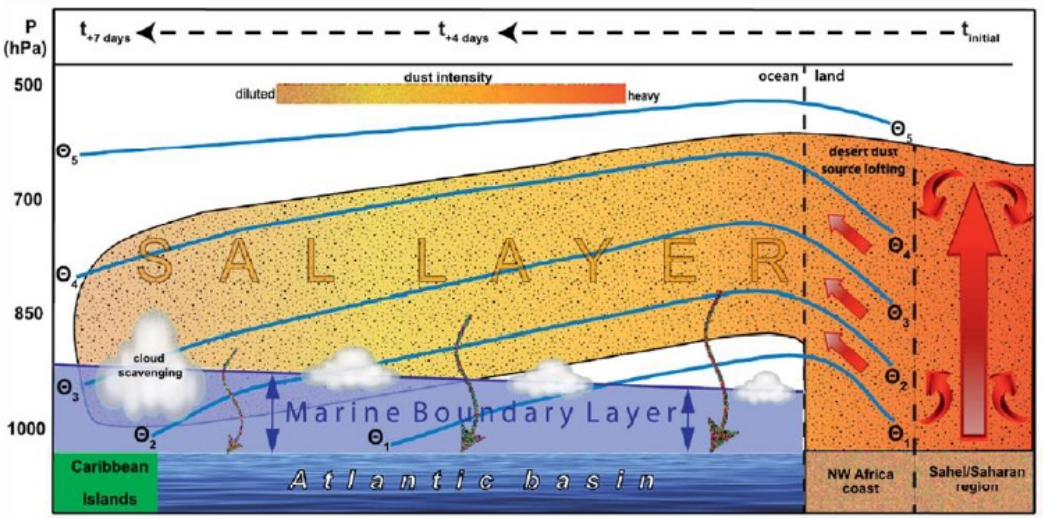


Key Questions

1. Does Saharan dust cause Caribbean droughts?
2. How anomalous was the rapid onset of the 2015 drought?
3. How will Caribbean rainfall (and dust) evolve in the future?

The Saharan Air Layer

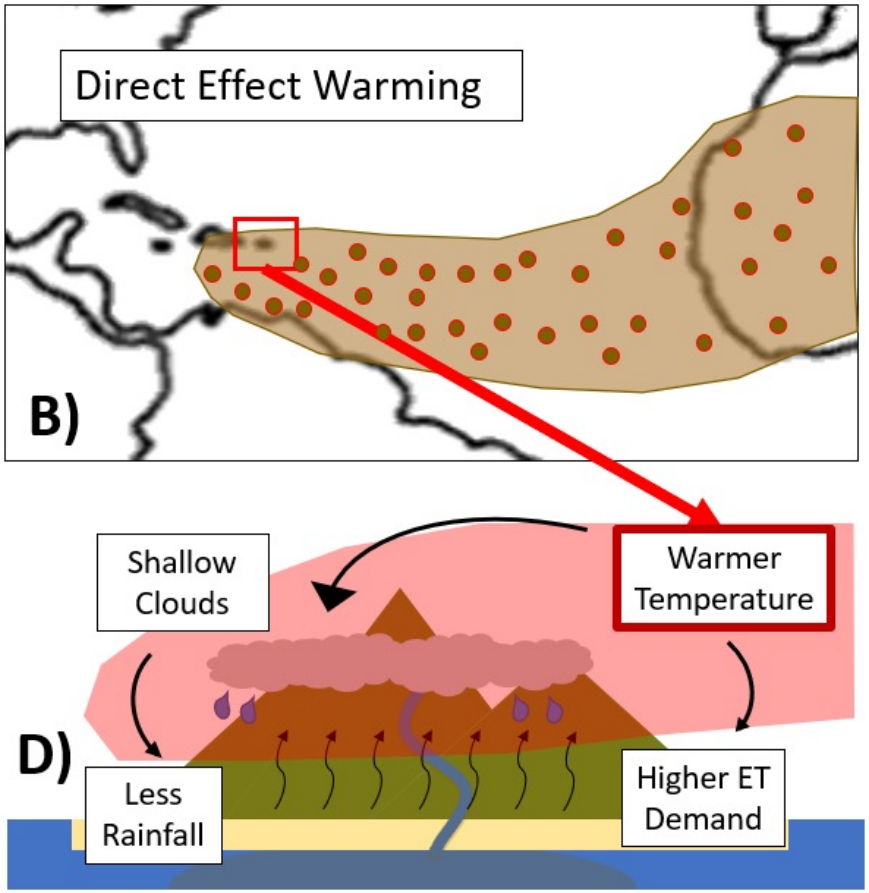
- The SAL transports westward 25–37 million tons of dust annually
- Journey to Barbados normally lasting 5–7 days
- SAL soundings are 50–60% drier than a typical moist tropical sounding between ~1.5–6 km



Kuciauskas et al. (2017)

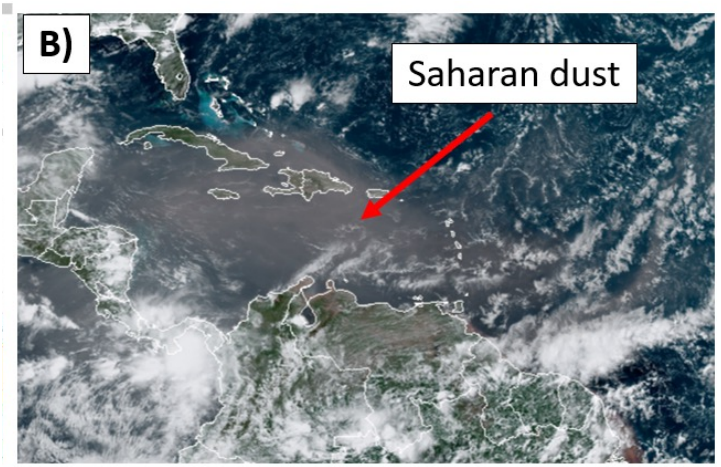
The Saharan Air Layer

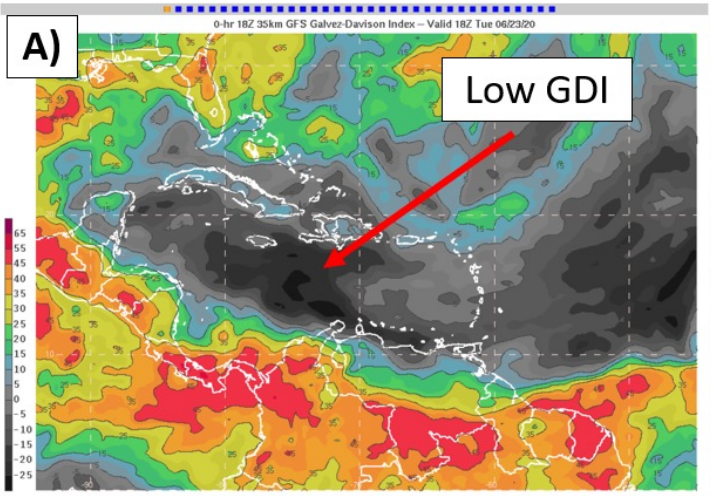
- The SAL is already hot and dry due to its desert origins
- Dust within the SAL interacts with incoming radiation to further warm the layer
  - Called “direct effect” warming



SAL-Rainfall Connections

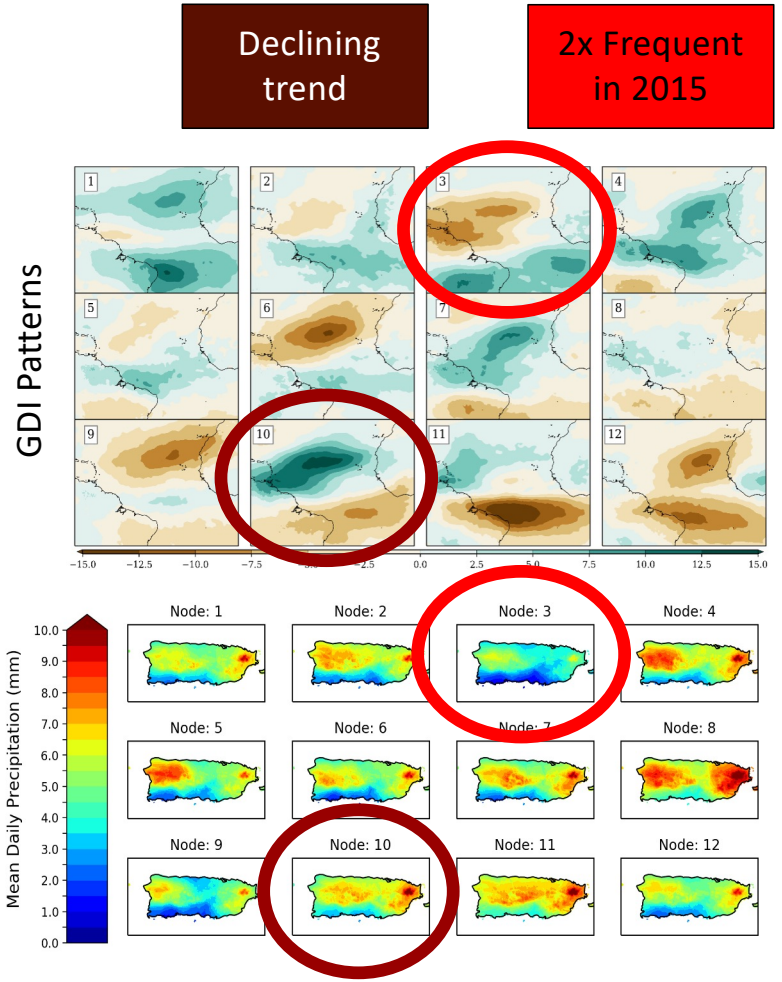
- The presence of an elevated warm layer suppresses thunderstorm development
- The SAL can be clearly discerned with the Galvéz-Davison Index (GDI)
  - Used by Caribbean forecasters to predict convective rainfall





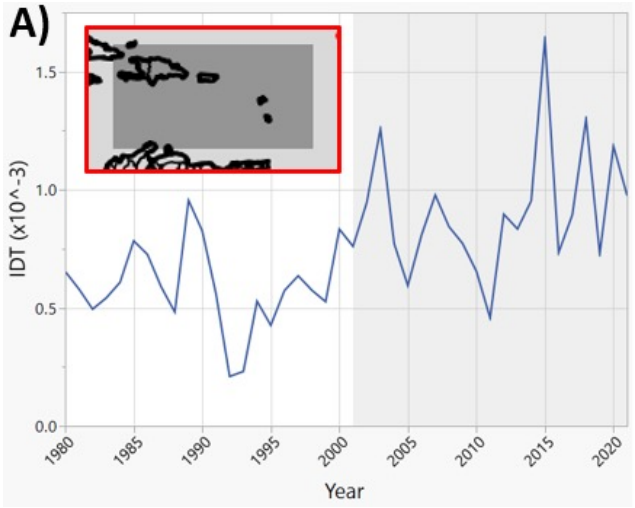
SAL-Drought Connections

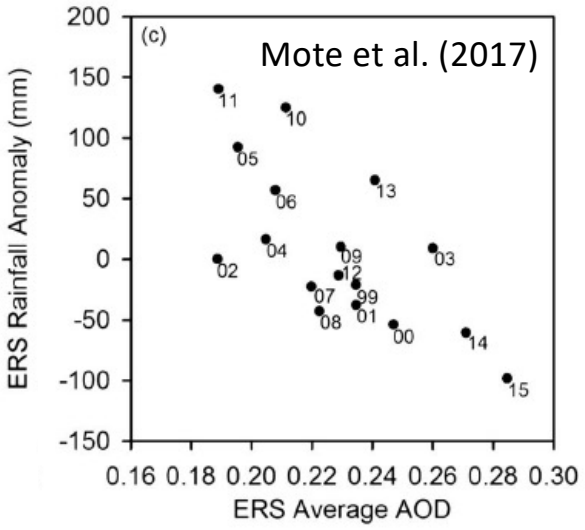
- We can use the GDI to infer the location of the SAL within numerical weather models, even if they don't resolve dust
- Historically, the SAL-type GDI patterns are more common during drought years
- The wettest GDI patterns are declining in frequency

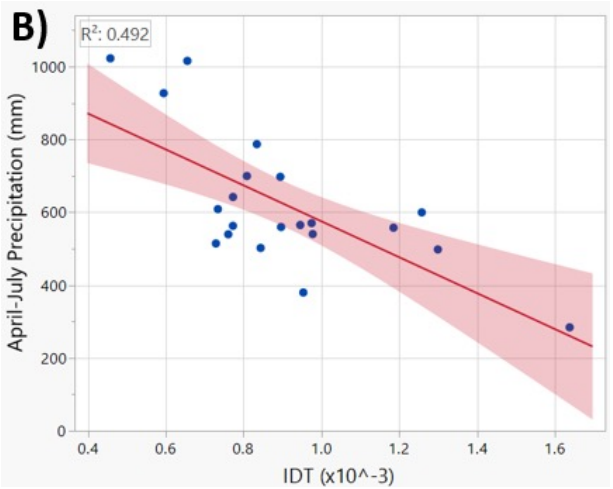


SAL-Drought Connections

- Last ~20 years have been an elevated Saharan dust period
- High dust years are associated with less rainfall in PR







Flash Drought in the Caribbean

- Drought impacts can accumulate quickly in wet tropical settings
- Rapid onset drought has received extensive attention recent under the guise of “flash drought”
- Flash drought is essentially unexplored in the global tropics

Comparison of dry spell frequencies (consecutive days of precipitation <0.25 mm) between 1991–2020 between five Great Plains locations and the Caribbean

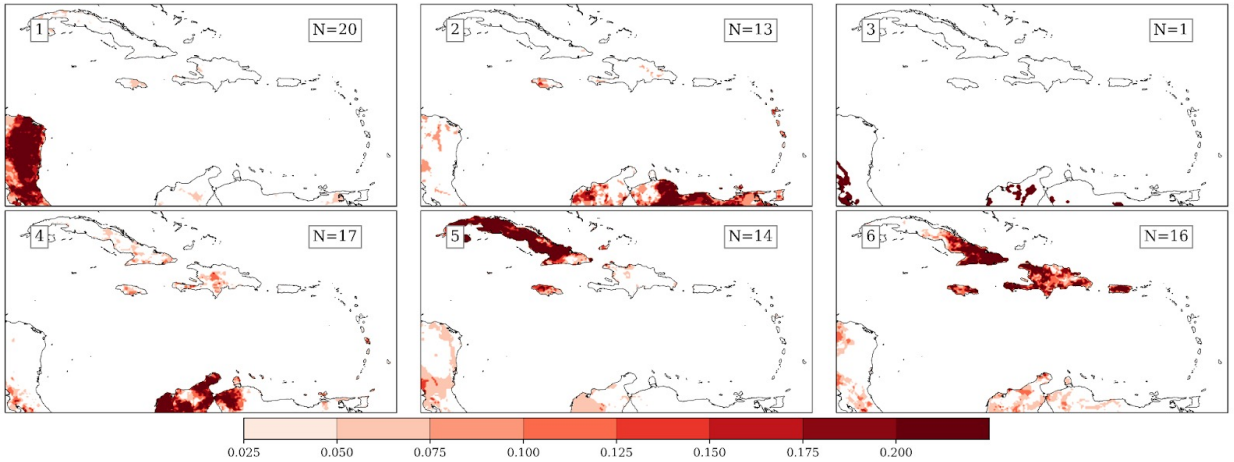
Location	14 days	7 days	3 days
Denver, CO	137	468	972
Omaha, NE	77	363	1039
Wichita, KS	117	445	967
Dallas, TX	133	451	944
San Juan, PR	8	108	600

Ramseyer and Miller (In review)

Flash Drought in the Caribbean

Ramseyer and Miller (In review)

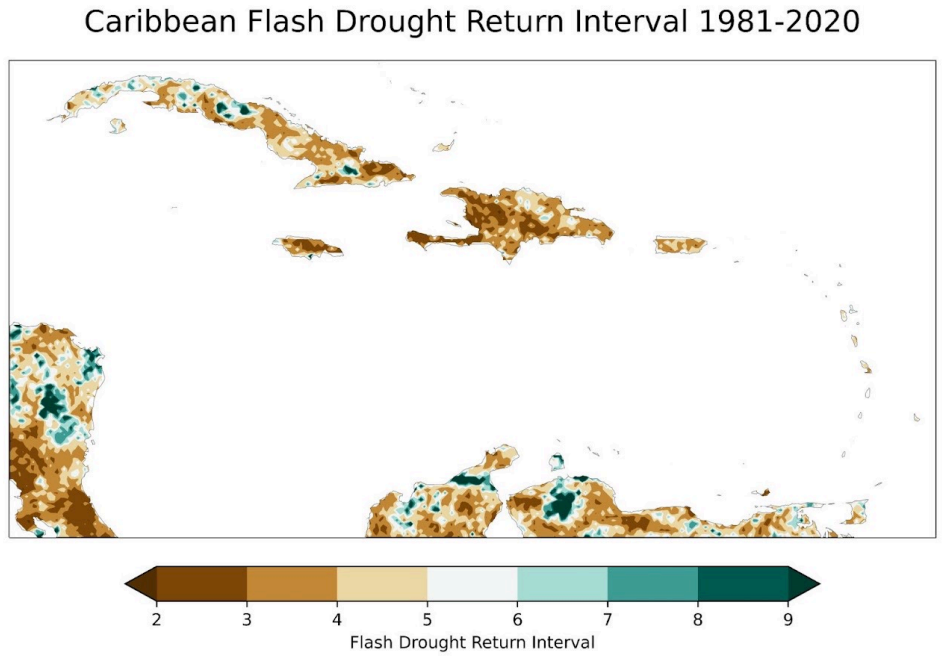
- The Evaporative Demand Drought Index (EDDI) is used to identify instance of high water draw from the atmosphere
- A self-organizing map (SOM) is used to group episodes of widespread, rapid increases in EDDI



- The SOM identified five different flash drought typologies for the Caribbean based on 88 flash drought outbreaks

Flash Drought in the Caribbean

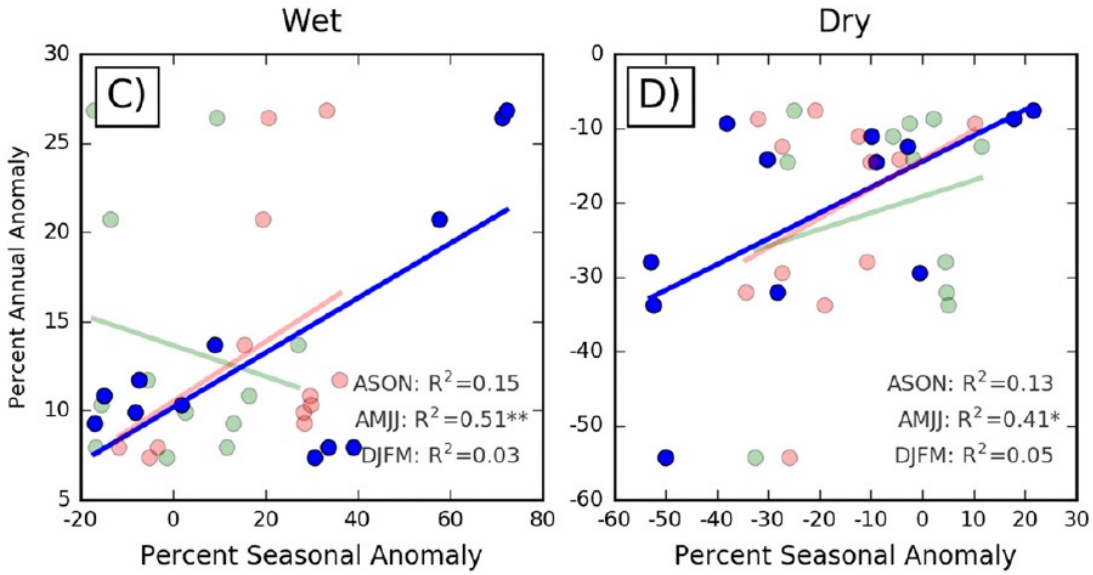
- “Caribbean drought” is a bit of a misnomer
- High within-basin variability
- Most locations across the Caribbean experience a flash drought every 5 years or sooner



Ramseyer and Miller (In review)

Future Precipitation Regimes

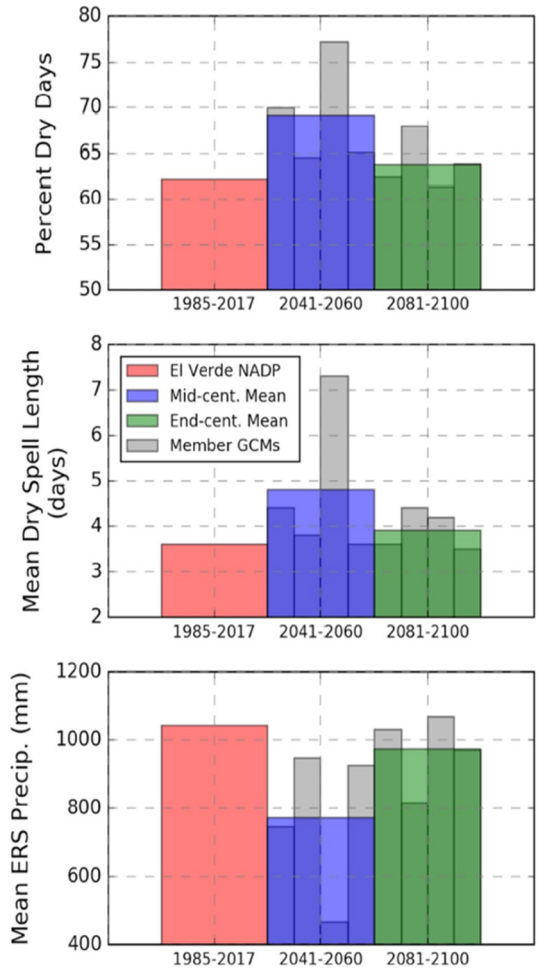
- The early rainfall season (ERS) (April-July) is the most critical period of the year for drought
- Future precipitation projections focus on this period



Miller et al. (2019)

Future Precipitation Regimes

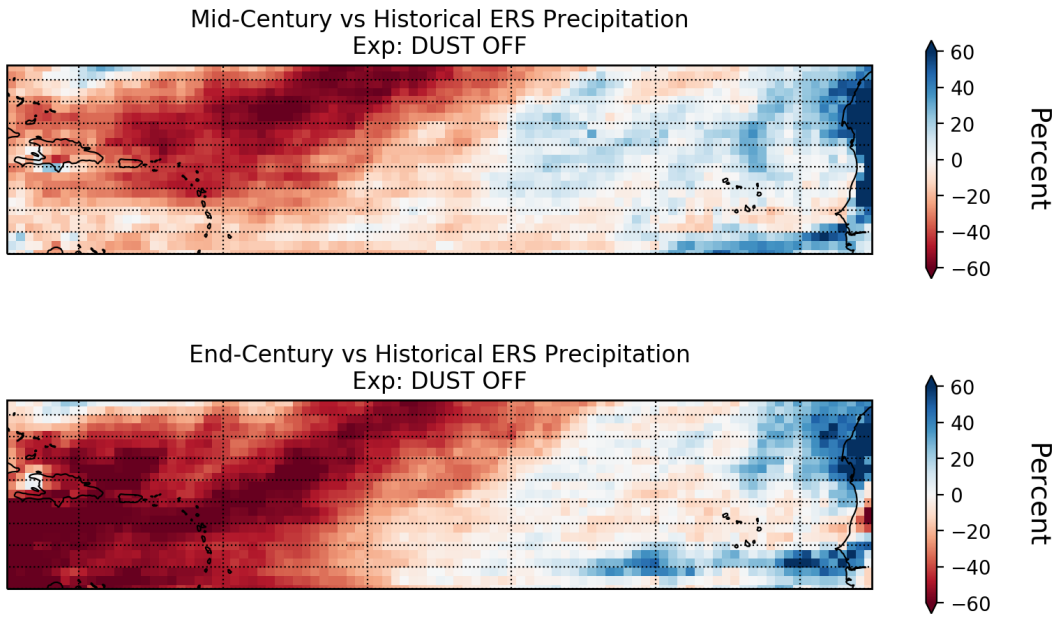
- A machine-learning technique used future GCM predictions of GDI to infer the dry-day frequency for mid- and end-21st century in the Luquillo Mountains
- Proportion of dry days likely to increase by mid-21st century and then rebound



Ramseyer et al. (2019)

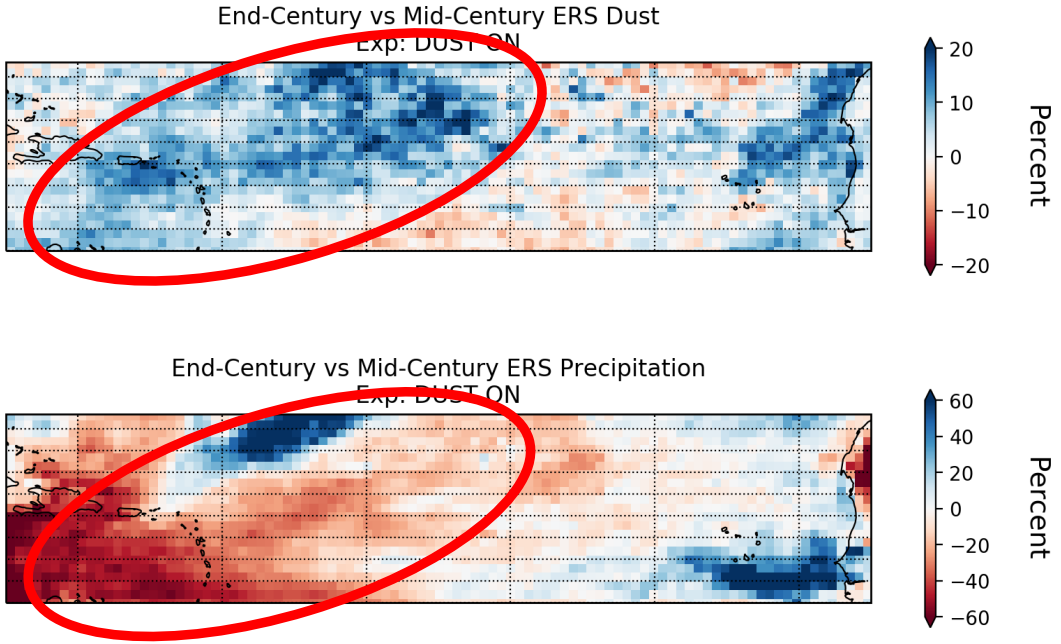
Future Precipitation Regimes

- Dynamically downscaled CMIP5 GCMs detect a slight larger decrease in ERS rainfall
- Mean ERS precipitation decreases from the 2014-2018 simulation by **39.5%** by mid-century
- Mean ERS precipitation decreases from the 2014-2018 simulation by **50.5%** by end-century



Future Precipitation Regimes

- Areas with increased ERS dust generally correspond to reduced precipitation
- Pockets of reduced dust also experience increased ERS rainfall between mid- and end-21st century



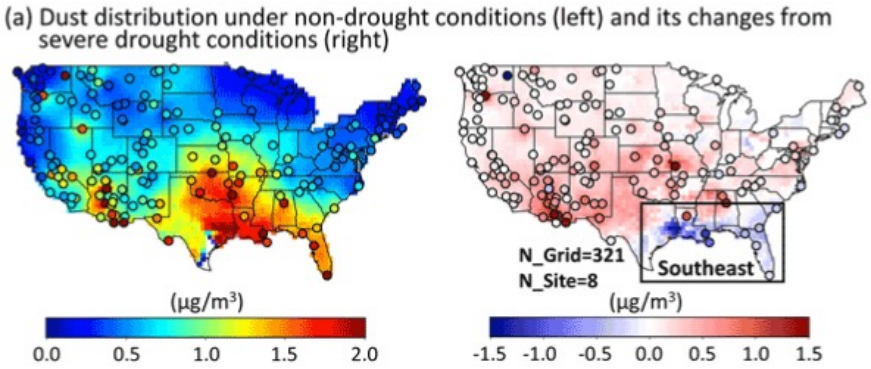
Relevance to the SC-CASC

1. Saharan dust outbreaks can reach the Gulf Coast

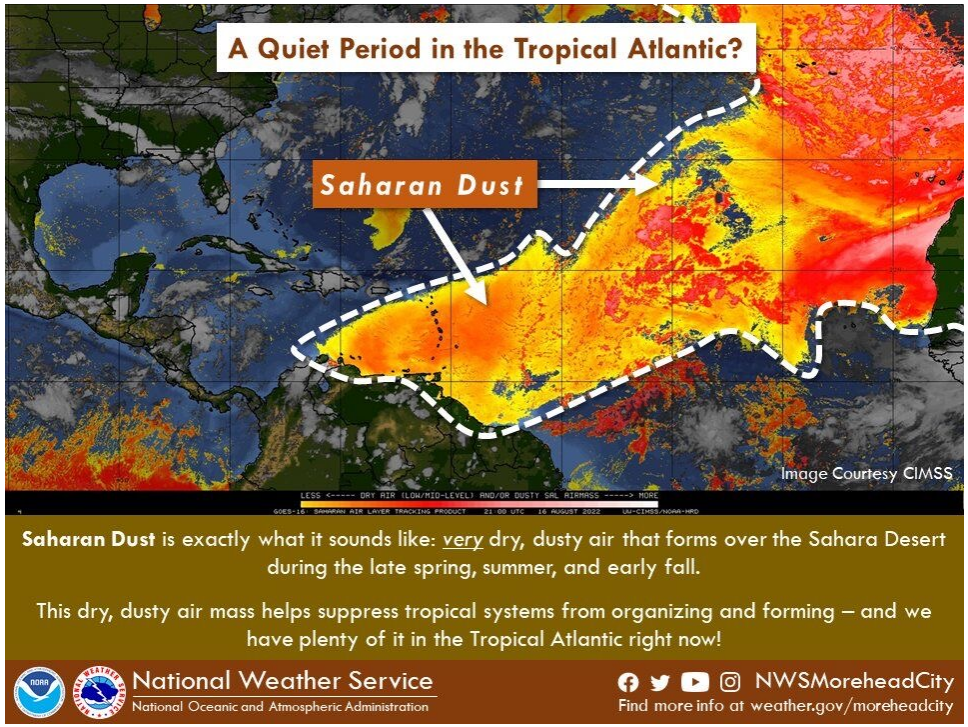
Credit: KBTX

Relevance to the SC-CASC

2. Not directly associated with drought, but can suppress tropical activity



Li and Wang (2022)



Credit: NWS Morehead City

How will Caribbean rainfall (and dust) evolve in the future?

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Relevance to the SC-CASC

3. Drought outreach to stakeholders in Spanish-speaking areas

SECA RIBE | Providing data and tools to better understand and predict droughts in the Caribbean Islands

CARIBBEAN DROUGHT LEARNING NETWORK

How will Caribbean rainfall (and dust) evolve in the future?

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Questions?

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