RaInDROPs Keep Falling on My Head: Embodying Long-Term Flood Resilience

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Dr. Jared Bowden, Interim Director
State Climate Office of NC

- Expertise in atmospheric/regional climate modeling (creating data to support decisions about climate and extreme weather)
- Expertise in extreme rainfall in a warmer climate
- Passion for climate services – informing decisions related to weather and climate

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North Carolina State Climate Office

A UNC System Public Service Center dedicated to serving the needs of North Carolinians by translating climate information into useful and usable knowledge and bridging the gap between scientists, decision makers, and community members.

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Learning Outcomes

1. Explain rainfall intensity, duration, and frequency of rainfall events.
2. Describe methods and data sets that support RaInDROP.
3. Provide examples of how RaInDROP and atmospheric model experiments are being used to inform long-term flood resilience.

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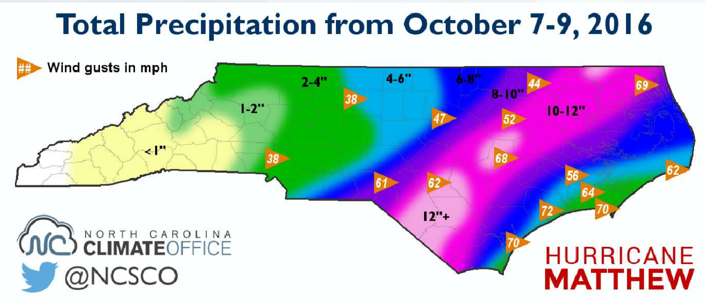
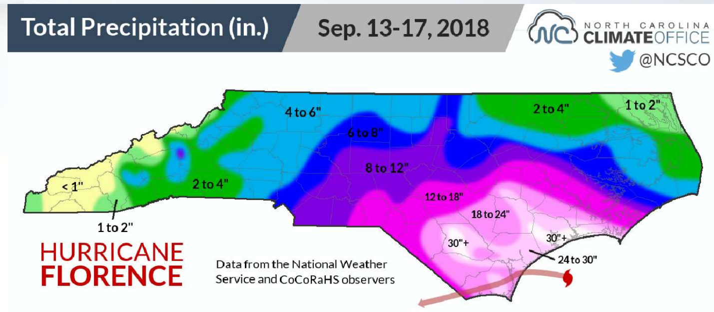
Event-driven applied climate research





State of North Carolina

ROY COOPER

GOVERNOR

October 29, 2018

EXECUTIVE ORDER NO. 80

NORTH CAROLINA'S COMMITMENT TO ADDRESS CLIMATE CHANGE AND TRANSITION TO A CLEAN ENERGY ECONOMY

2. Cabinet agencies shall evaluate the impacts of climate change on their programs and operations and integrate climate change mitigation and adaptation practices into their programs and operations. Council of State members, higher education institutions, local governments, private businesses, and other North Carolina entities are encouraged to address climate change and provide input on climate change mitigation and adaptation measures developed through the implementation of this Executive Order. Consistent with applicable law, cabinet agencies shall actively support such actions.

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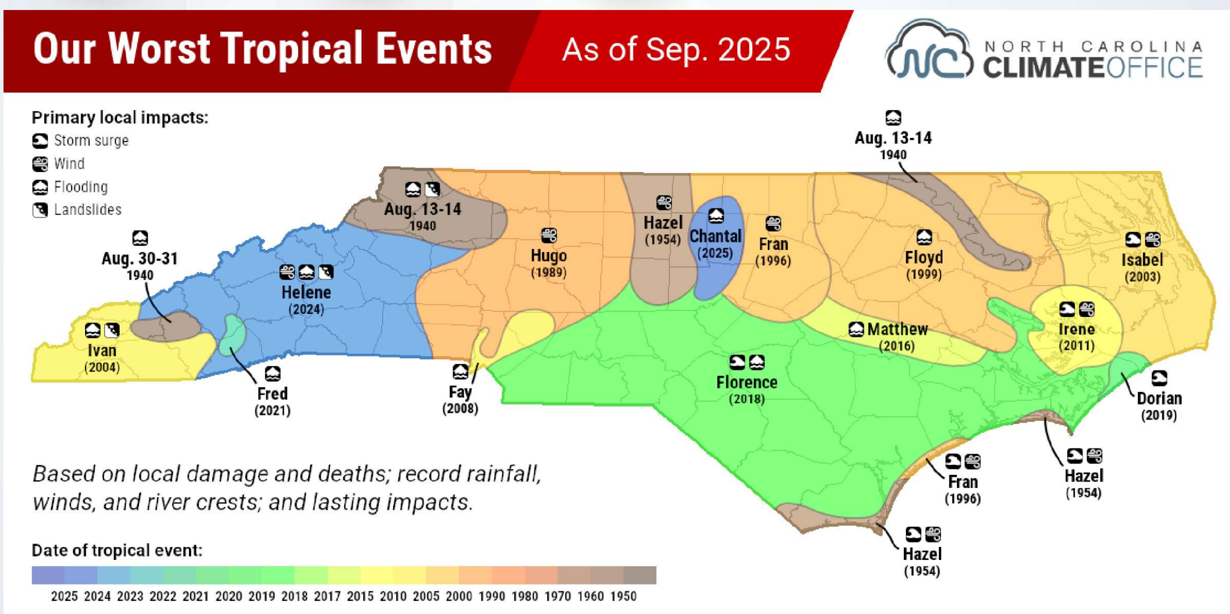
Flooding, especially from Tropical Cyclones, continues to be a big problem for NC communities



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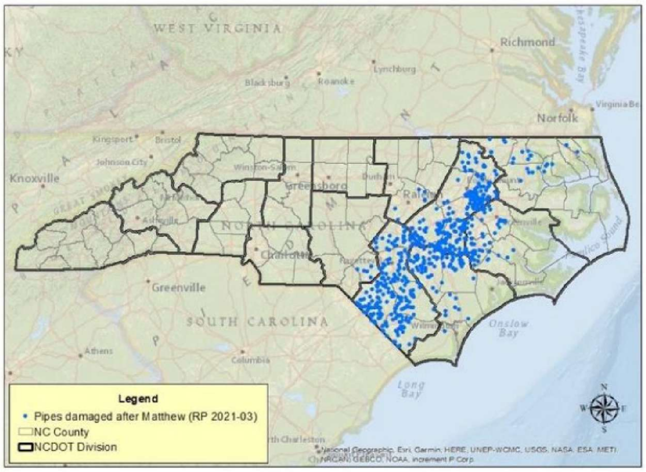
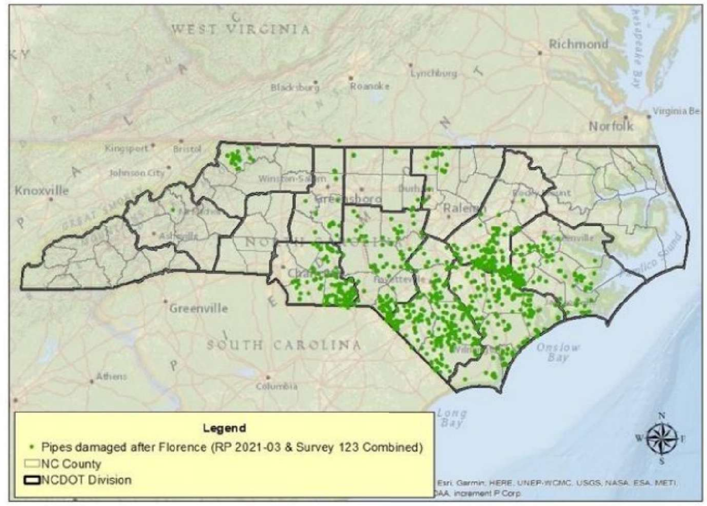
NCDOT recognized rainfall frequency and intensity changes And cost - pipes damaged after Matthew and Florence





Pipes Washed Away
(Figure from NCDOT Project 2021-08)

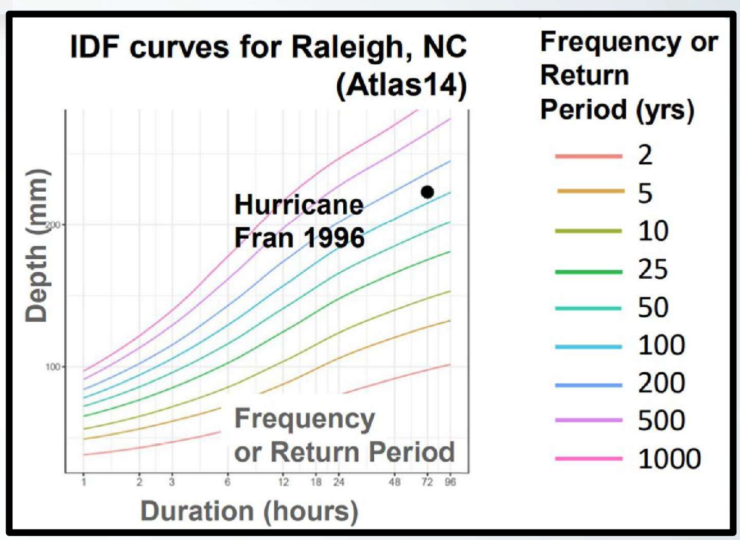
Intensity-Duration-Frequency (IDF) Curves

Rainfall Data
(Observations needed for a long record (e.g., 30 years) for different durations e.g., 24 hour)

Annual Maximum Series
(max. rainfall for that duration in a year)

Distribution Fitting
(Generalized Extreme Value)

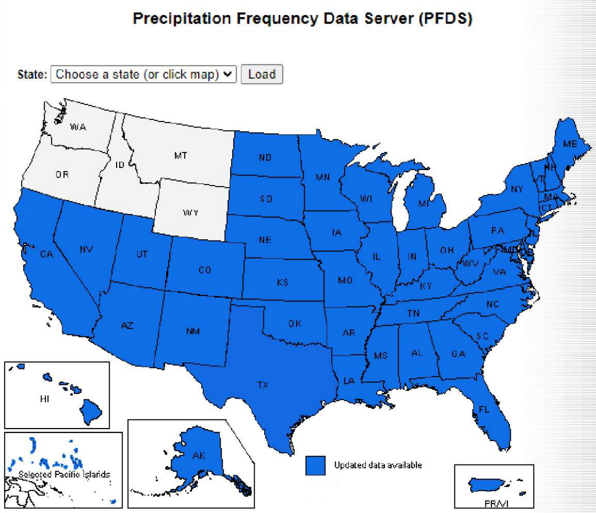
IDF Curves
(find desired cumulative probability to the fit curve; e.g., 1-in-100 yr event = 0.99)



NOAA Atlas 14 – U.S. Standard Reference

- Assembled and updated asynchronously in geopolitical regions ("volumes")
  - Missing Pacific Northwest
  - Discontinuities across states
  - Different lengths of obs records
  - Some updated for recent extremes
  - Static: doesn't consider changes in rainfall (historical trends / plausible future changes)
- ***Need -*** address these issues

(NC efforts w/ RaInDROP ; future Atlas 15)



https://hdsc.nws.noaa.gov/pfds/

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sub-hourly

sub-daily

multi-day

Duration

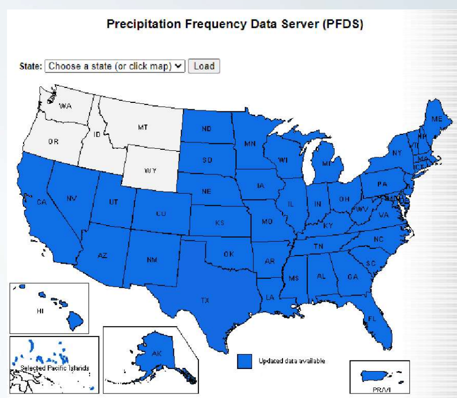
PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.394** (0.362-0.429)	**0.461** (0.423-0.503)	**0.529** (0.487-0.577)	**0.587** (0.538-0.639)	**0.646** (0.590-0.703)	**0.689** (0.626-0.748)	**0.726** (0.657-0.789)	**0.758** (0.682-0.825)	**0.792** (0.707-0.862)	**0.819** (0.724-0.892)
10-min	**0.629** (0.578-0.686)	**0.737** (0.677-0.804)	**0.848** (0.779-0.924)	**0.939** (0.861-1.02)	**1.03** (0.940-1.12)	**1.10** (0.997-1.19)	**1.15** (1.04-1.25)	**1.20** (1.08-1.31)	**1.25** (1.12-1.36)	**1.29** (1.14-1.40)
15-min	**0.787** (0.722-0.857)	**0.927** (0.850-1.01)	**1.07** (0.986-1.17)	**1.19** (1.09-1.29)	**1.30** (1.19-1.42)	**1.39** (1.26-1.51)	**1.46** (1.32-1.59)	**1.52** (1.36-1.65)	**1.58** (1.41-1.72)	**1.62** (1.43-1.76)
30-min	**1.08** (0.990-1.18)	**1.28** (1.18-1.40)	**1.52** (1.40-1.66)	**1.72** (1.58-1.87)	**1.93** (1.77-2.10)	**2.09** (1.90-2.27)	**2.24** (2.02-2.43)	**2.36** (2.12-2.57)	**2.51** (2.24-2.73)	**2.62** (2.32-2.86)
60-min	**1.34** (1.24-1.46)	**1.61** (1.47-1.75)	**1.95** (1.80-2.13)	**2.24** (2.05-2.44)	**2.57** (2.35-2.80)	**2.83** (2.58-3.08)	**3.08** (2.78-3.34)	**3.31** (2.98-3.60)	**3.60** (3.21-3.92)	**3.82** (3.38-4.17)
2-hr	**1.56** (1.42-1.71)	**1.86** (1.71-2.04)	**2.29** (2.09-2.51)	**2.65** (2.40-2.90)	**3.08** (2.78-3.36)	**3.43** (3.09-3.74)	**3.76** (3.37-4.11)	**4.09** (3.64-4.46)	**4.51** (3.98-4.92)	**4.84** (4.24-5.29)
3-hr	**1.65** (1.52-1.81)	**1.98** (1.82-2.17)	**2.44** (2.23-2.68)	**2.84** (2.59-3.10)	**3.34** (3.02-3.64)	**3.75** (3.38-4.09)	**4.15** (3.72-4.53)	**4.56** (4.06-4.97)	**5.11** (4.49-5.57)	**5.56** (4.84-6.07)
6-hr	**2.00** (1.84-2.18)	**2.40** (2.20-2.62)	**2.95** (2.72-3.22)	**3.44** (3.15-3.74)	**4.06** (3.70-4.40)	**4.58** (4.15-4.96)	**5.10** (4.58-5.51)	**5.63** (5.01-6.09)	**6.34** (5.57-6.85)	**6.93** (6.02-7.51)
12-hr	**2.37** (2.20-2.58)	**2.84** (2.63-3.09)	**3.52** (3.25-3.82)	**4.12** (3.78-4.47)	**4.90** (4.47-5.30)	**5.56** (5.04-5.99)	**6.23** (5.59-6.71)	**6.94** (6.15-7.46)	**7.90** (6.89-8.48)	**8.72** (7.49-9.37)
24-hr	**2.83** (2.65-3.04)	**3.42** (3.20-3.67)	**4.27** (4.00-4.57)	**4.93** (4.61-5.28)	**5.83** (5.43-6.24)	**6.54** (6.08-7.00)	**7.26** (6.72-7.78)	**7.99** (7.38-8.58)	**8.98** (8.26-9.66)	**9.76** (8.94-10.5)
2-day	**3.26** (3.04-3.51)	**3.93** (3.67-4.22)	**4.86** (4.54-5.23)	**5.59** (5.20-6.00)	**6.55** (6.08-7.05)	[illegible] (6.76-7.86)	**8.07** (7.45-8.69)	**8.84** (8.13-9.53)	**9.88** (9.05-10.7)	**10.7** (9.75-11.5)
3-day	**3.45** (3.23-3.71)	**4.14** (3.87-4.45)	**5.11** (4.77-5.49)	**5.86** (5.47-6.29)	**6.88** (6.39-7.38)	**7.67** (7.11-8.24)	**8.47** (7.83-9.11)	**9.29** (8.55-10.0)	**10.4** (9.52-11.2)	**11.2** (10.3-12.1)
4-day	**3.64** (3.41-3.90)	**4.36** (4.08-4.68)	**5.36** (5.01-5.74)	**6.14** (5.74-6.58)	**7.20** (6.70-7.72)	**8.03** (7.46-8.62)	**8.88** (8.21-9.54)	**9.73** (8.97-10.5)	**10.9** (9.99-11.7)	**11.8** (10.8-12.7)
7-day	**4.22** (3.96-4.50)	**5.03** (4.73-5.37)	**6.10** (5.73-6.52)	**6.95** (6.52-7.42)	**8.10** (7.58-8.65)	**9.01** (8.40-9.63)	**9.94** (9.24-10.6)	**10.9** (10.1-11.7)	**12.2** (11.2-13.1)	**13.1** (12.1-14.1)
10-day	**4.79** (4.51-5.11)	**5.69** (5.35-6.07)	**6.83** (6.42-7.28)	**7.72** (7.24-8.23)	**8.92** (8.35-9.52)	**9.86** (9.21-10.5)	**10.8** (10.1-11.6)	**11.8** (10.9-12.6)	**13.1** (12.1-14.0)	**14.1** (12.9-15.1)
20-day	**6.39** (6.02-6.82)	**7.54** (7.10-8.04)	**8.90** (8.37-9.50)	**9.99** (9.37-10.7)	**11.5** (10.7-12.2)	**12.6** (11.8-13.5)	**13.8** (12.8-14.8)	**15.0** (13.9-16.1)	**16.6** (15.3-17.8)	**17.8** (16.4-19.2)
30-day	**7.93** (7.48-8.45)	**9.33** (8.79-9.92)	**10.8** (10.2-11.5)	**12.0** (11.3-12.8)	**13.5** (12.7-14.4)	**14.7** (13.8-15.7)	**15.9** (14.8-17.0)	**17.1** (15.9-18.3)	**18.6** (17.3-20.0)	**19.8** (18.3-21.3)
45-day	**10.1** (9.62-10.7)	**11.8** (11.3-12.5)	**13.6** (12.9-14.3)	**14.9** (14.1-15.7)	**16.6** (15.7-17.5)	**17.9** (16.9-19.0)	**19.2** (18.1-20.4)	**20.5** (19.2-21.7)	**22.2** (20.7-23.6)	**23.4** (21.8-24.9)
60-day	**12.2** (11.6-12.8)	**14.2** (13.5-14.9)	**16.0** (15.2-16.8)	**17.4** (16.5-18.3)	**19.2** (18.2-20.2)	**20.5** (19.4-21.7)	**21.8** (20.6-23.1)	**23.1** (21.8-24.4)	**24.7** (23.2-26.2)	**25.9** (24.3-27.5)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.



Designing infrastructure to a standard duration and return period, depending on its function and lifecycle.

For example, a 24-hour, 25-year storm at Raleigh, NC is 5.83", with a 90% confidence interval of 5.43"-6.24".

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Insufficient U.S. Hydrologic Design Standards
The problem is larger than NC

Geophysical Research Letters

RESEARCH LETTER
10.1029/2019GL083235

Key Points:
- Conventional analyses neglect trends in extreme rainfall events such as the 100-year storm, which are critical for engineering design
- A regional aggregation approach reveals significant trends in very extreme rainfall in the United States, mainly due to climate warming
- Existing hydrologic infrastructure and analyses in much of the United States may be underperforming due to increases in storm activity

Supporting Information:
- Supporting Information S1

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U.S. Hydrologic Design Standards Insufficient Due to Large Increases in Frequency of Rainfall Extremes

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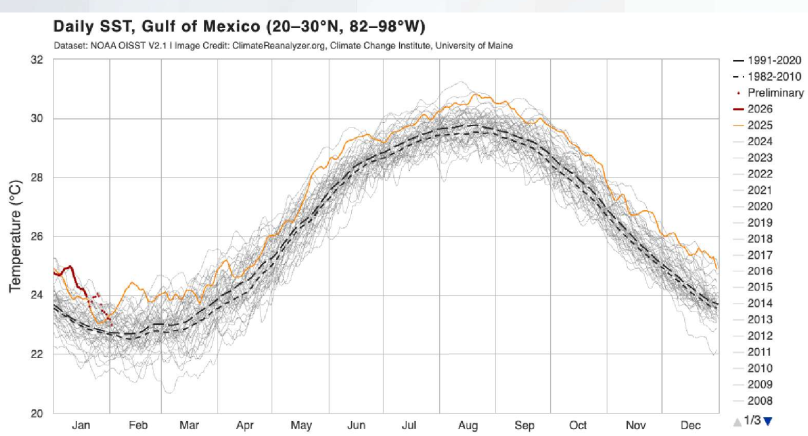
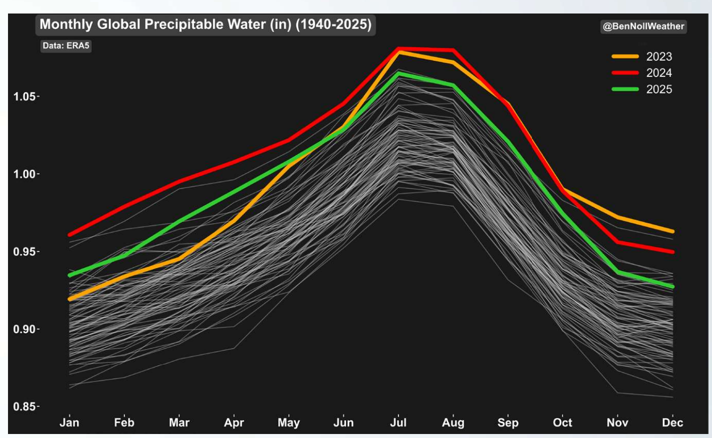
[2]Department of Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA, USA

Abstract Evidence for intensifying rainfall extremes has not translated into "actionable" information needed by engineers and risk analysts, who are often concerned with very rare events such as "100-year storms." Low signal-to-noise associated with such events makes trend detection nearly impossible using conventional methods. We use a regional aggregation approach to boost this signal-to-noise, showing that such storms have increased in frequency over much of the conterminous United States since 1950, a period characterized by widespread hydrologic infrastructure development. Most of these increases can be attributed to secular climate change rather than climate variability, and we demonstrate potentially serious implications for the reliability of existing and planned hydrologic infrastructure and analyses. Though trends in rainfall extremes have not yet translated into observable increases in flood risks, these results nonetheless point to the need for prompt updating of hydrologic design standards, taking into consideration recent changes in extreme rainfall properties.

The Concern – Increasing Weather Fuel
nearby oceans are warming = inc. atmospheric moisture

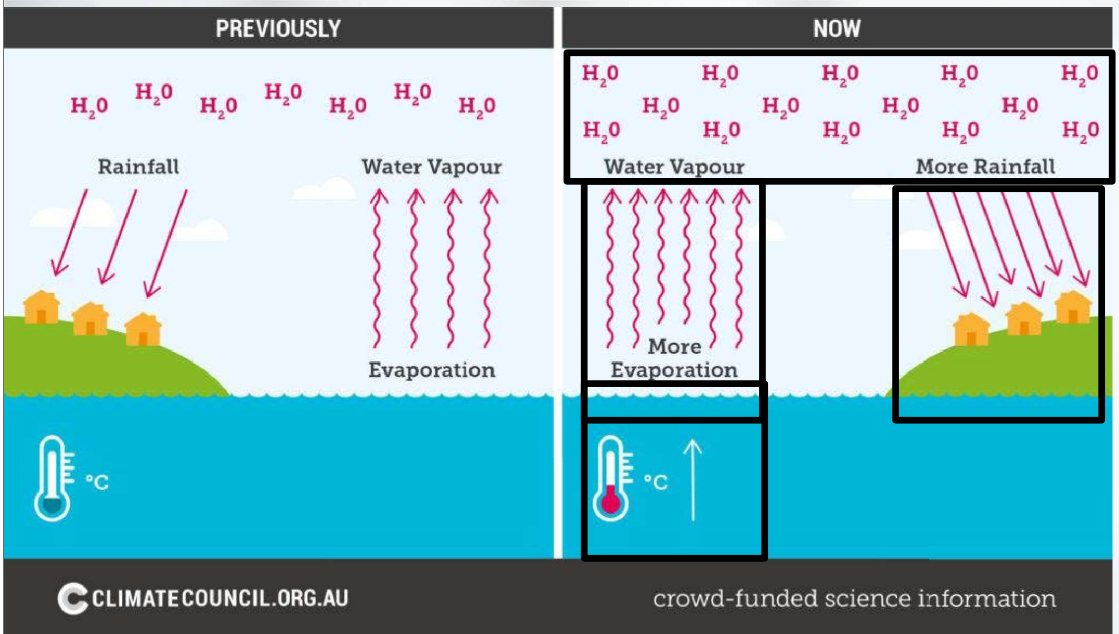


Daily Gulf Of Mexico SST
Source: https://climatereanalyzer.org



Monthly global precipitable water: ERA5, 1940-2025. BenNollWeather, via Albany "MAP" list

These changes result in a future intensification of the water cycle



Warmer air temps → increased water vapor capacity

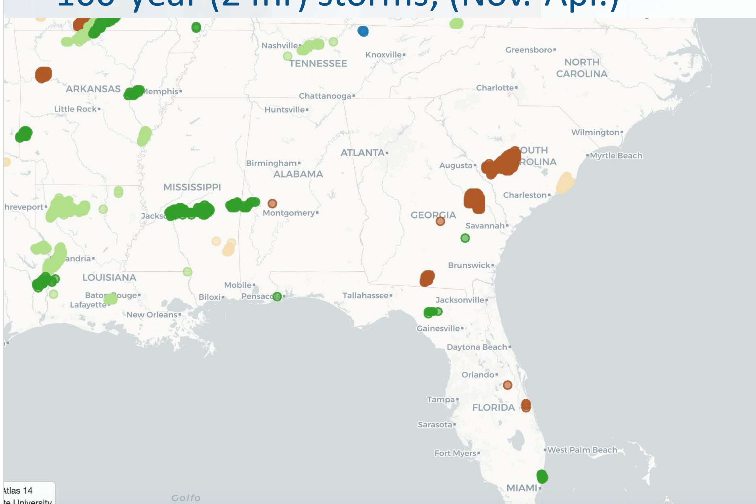
Warmer SSTs → more evaporation

More evaporation → more water vapor

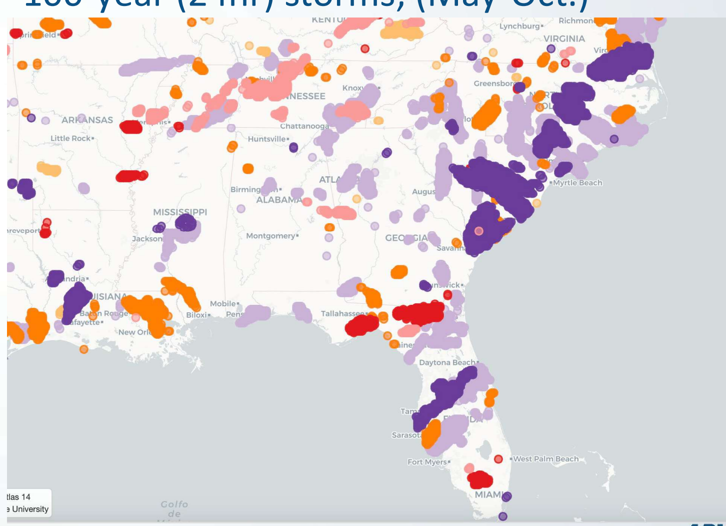
More water vapor → potential for more rain

Rainfall extremes within the SE US during the summer and fall seasons (when oceans are the warmest)

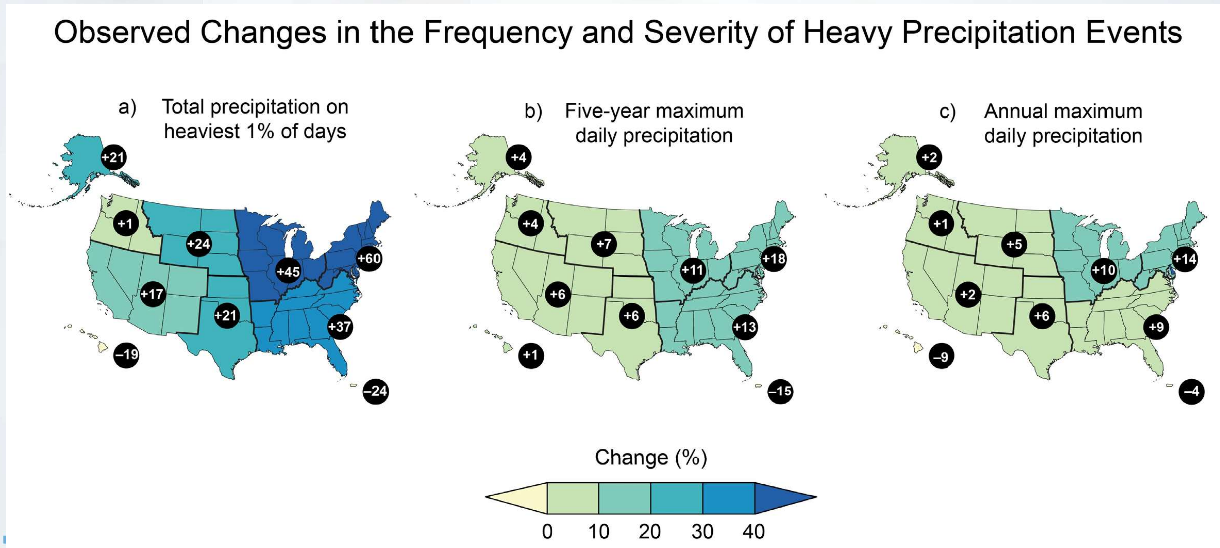
100-year (24hr) storms; (Nov.-Apr.)



100-year (24hr) storms; (May-Oct.)



Rainfall characteristics are changing and projected to intensify



Source: 5th National Climate Assessment

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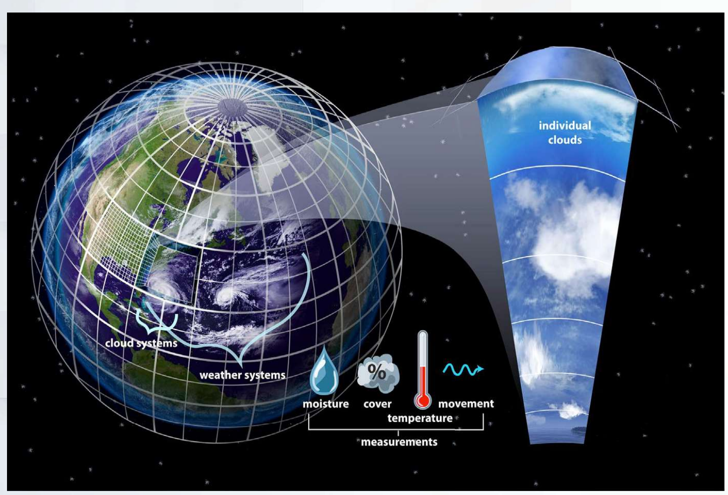
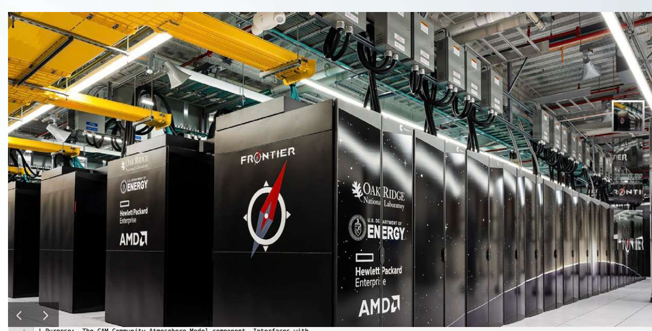
To quantify the growing risk of precipitation extremes requires using climate model data






```
! Purpose:  The CAM Community Atmosphere Model component. Interfaces with
!           a merged surface field that is provided outside of this module.
!           This is the atmosphere only component. It can interface with a
!           host of surface components.
!
!-----------------------------------------------------------------------
   use shr_kind_mod,      only: r8 => SHR_KIND_R8, cl=>SHR_KIND_CL, cs=>SHR_KIND_CS
   use pmgrid,            only: plat, plev
   use spmd_utils,        only: masterproc
   use abortutils,        only: endrun
   use camsrfexch_types,  only: surface_state, srfflx_state
   use shr_sys_mod,       only: shr_sys_flush
   use infnan,            only: nan
   use physics_types,     only: physics_state, physics_tend
   use cam_control_mod,   only: nsrest, print_step_cost, obliqr, lambm0, mvelpp, eccen
   use dyn_comp,          only: dyn_import_t, dyn_export_t
   use ppgrid,            only: begchunk, endchunk
   use perf_mod
   use cam_logfile,       only: iulog

   implicit none
   private
   save
   !
   ! Public access methods
   !
   public cam_init      ! First phase of CAM initialization
   public cam_run1      ! CAM run method phase 1
   public cam_run2      ! CAM run method phase 2
   public cam_run3      ! CAM run method phase 3
   public cam_run4      ! CAM run method phase 4
   public cam_final     ! CAM Finalization
   !
   ! Private module data
   !
#if ( defined SPMD )
   real(r8) :: cam_time_beg              ! Cam init begin timestamp
   real(r8) :: cam_time_end              ! Cam finalize end timestamp
   real(r8) :: stepon_time_beg = -1.0_r8 ! Stepon (run1) begin timestamp
   real(r8) :: stepon_time_end = -1.0_r8 ! Stepon (run4) end timestamp
   integer  :: nstep_beg = -1            ! nstep at beginning of run
#else
```

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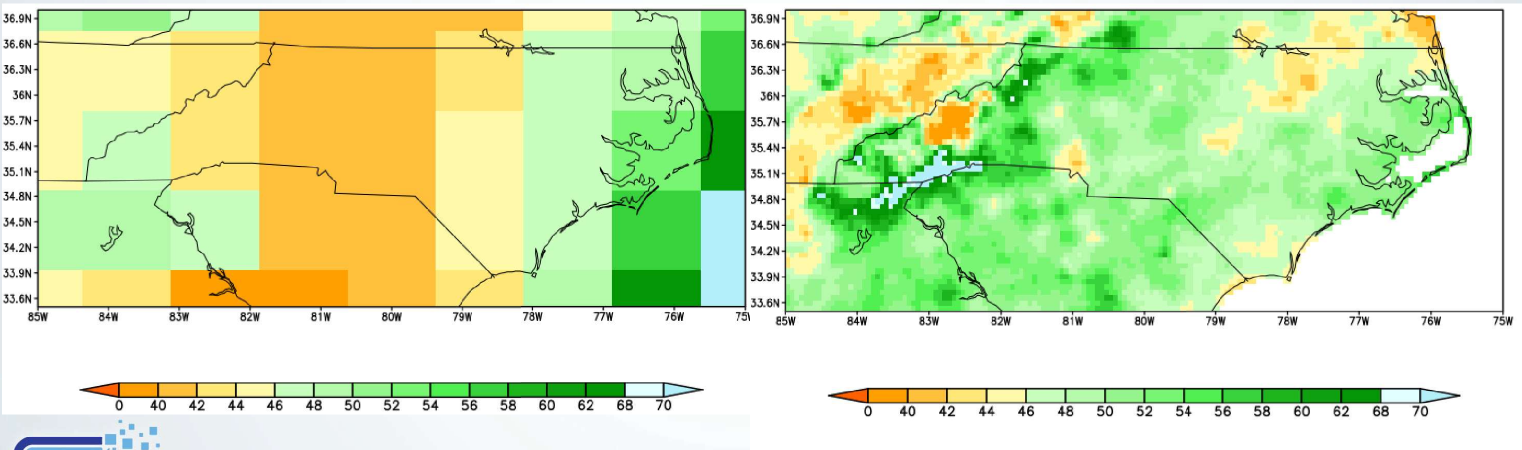
Global Climate Models (GCMs)

Model resolution typically hinders the ability to simulate extreme rainfall events and requires downscaling methods

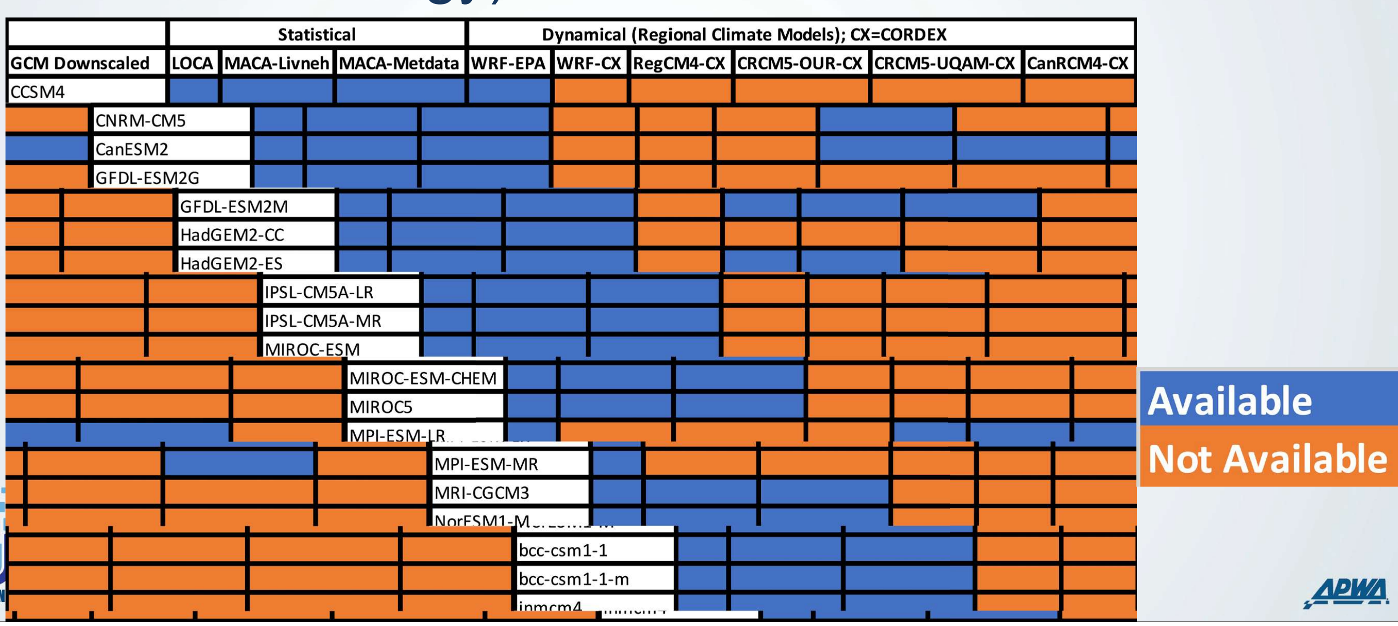
GCM Rainfall

Downscaled GCM rainfall
"Fit for purpose"



Considered many different model inputs

(LOCA selected; 17 different GCMs downscaled using a statistical methodology)



Use downscaled climate model data to create future Intensity-Duration-Frequency (IDF) Curves

Data
(Downscaled Model Projections For Baseline Historical And Future Scenario)

→

Annual Maximum Series
(daily rainfall)

→

Distribution Fitting
(Generalized Extreme Value)

→

IDF Curves
(find desired cumulative probability to the fit curve; e.g., 1-in-100 yr event = 0.99)

→

Develop Scale Factor Future/ Historical IDF

→

Apply to Observed Rainfall Depths Atlas14 (24hr)

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Plausible scenarios for future IDF curves

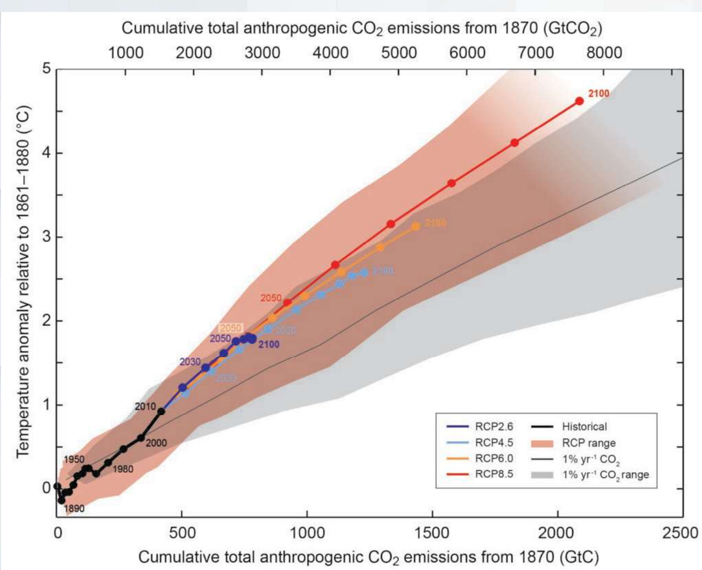

Figure source: IPCC Summary for Policymakers

RCP4.5 **(middle of the road) ;**

limit global warming to 3°C (5.4°F) by end-century

RCP8.5 **(high emission scenario)**

global warming exceeds 4°C (7°F) by end-century

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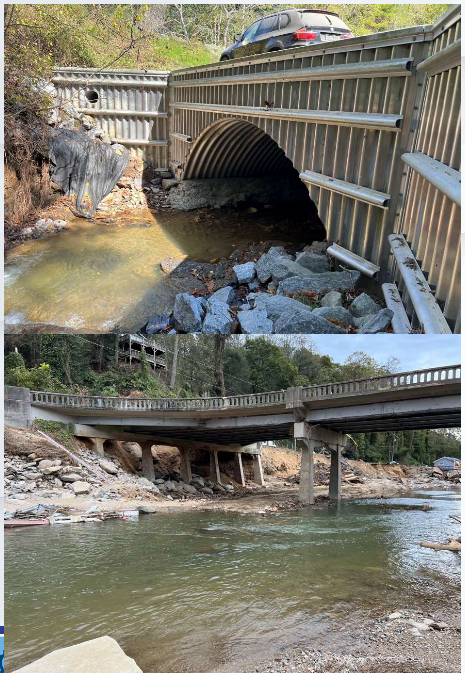
Future time horizons for IDF curves



Figures Courtesy: NCDOT

We provide future estimates for two 30 year future periods relative to a historical period

Historical: (1976-2005) – overlaps with Atlas14

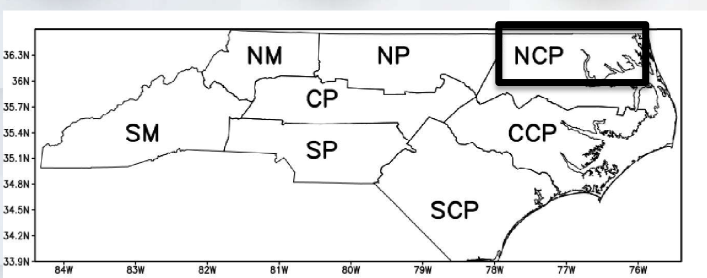
Mid-Century (2040-2069)

End-Century (2070-2099)

End-Century RCP8.5 = high impact low probability event

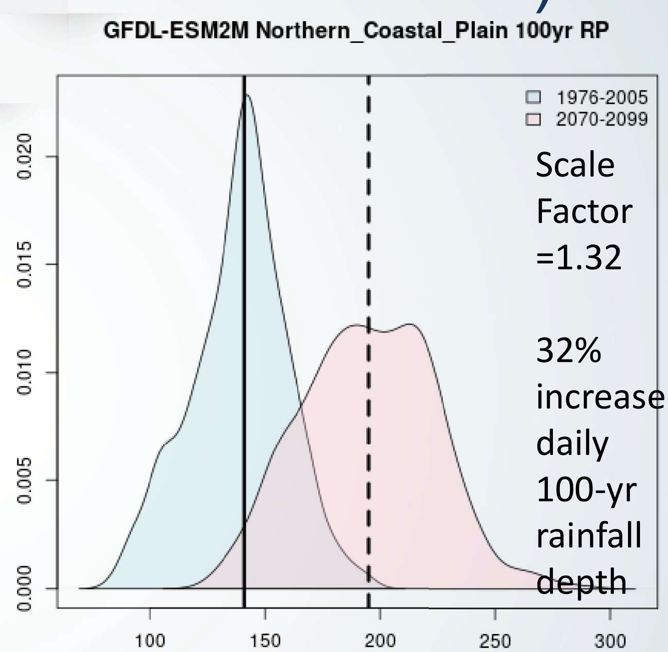
Mid-Century RCP4.5 = increasing probable event but with smaller impacts

Example Scale Factor (downscaled model)



Historical median (1976-2005) of grids within climate division

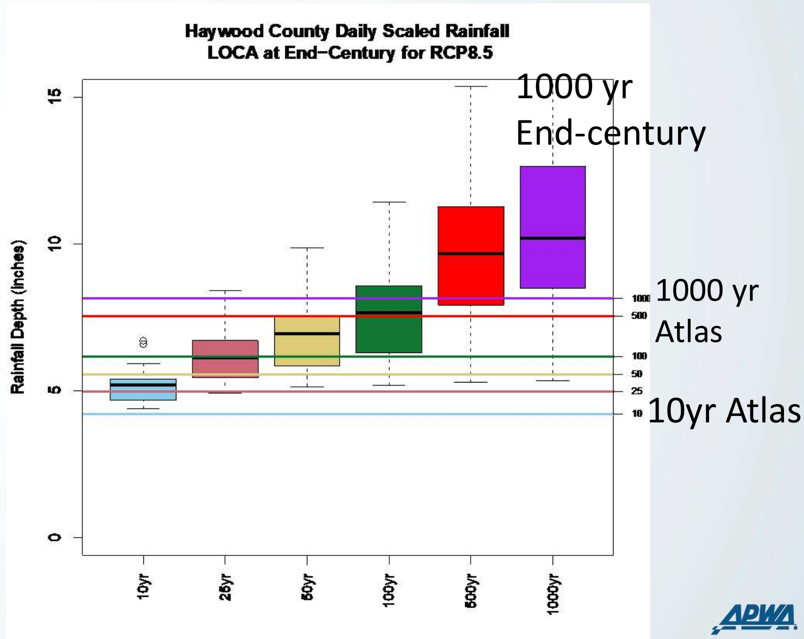
Future median (2070-2099) of grids within climate division



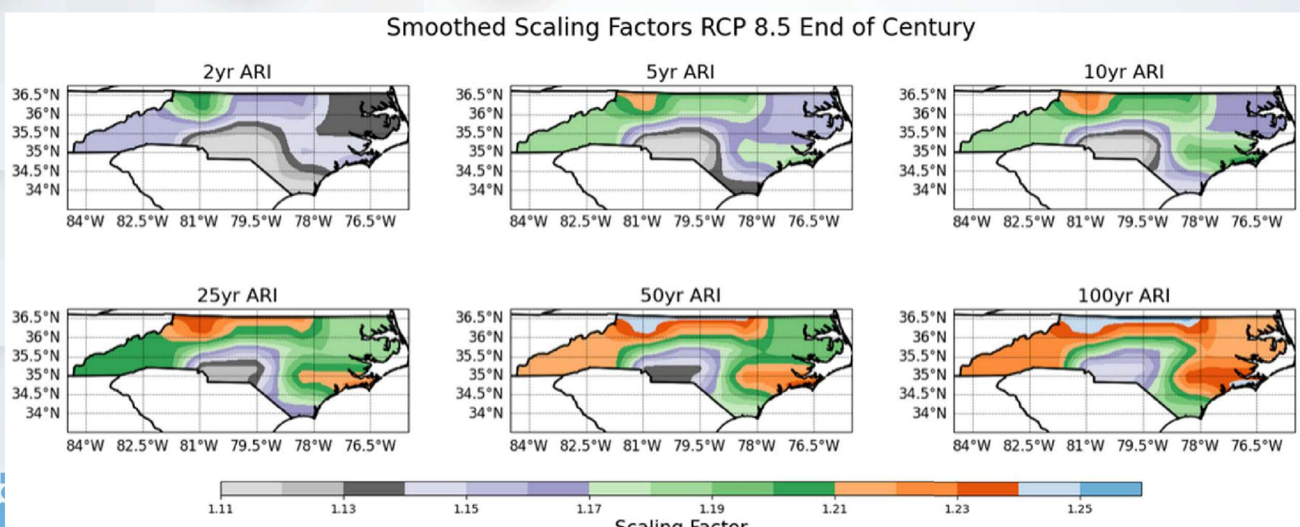
Example (scaling Atlas14 point observation) Haywood County – Helene region

High emission scenario shown

Future (end-century)	Now
10 year	25 year
25 year	50 year
50 year	100 year
100 year	500 year



Scale factors generated using downscaled climate data are applied to NOAA Atlas 14 point estimates; average of all 17 models



Rainfall Intensity, Duration and Return for Observations and Projections (RaInDROP) Tool

A way for engineers, planners, and policy makers to quantity and visualize future rainfall projections to aid in resilient design of infrastructure

https://products.climate.ncsu.edu/climate/raindrop-tool/

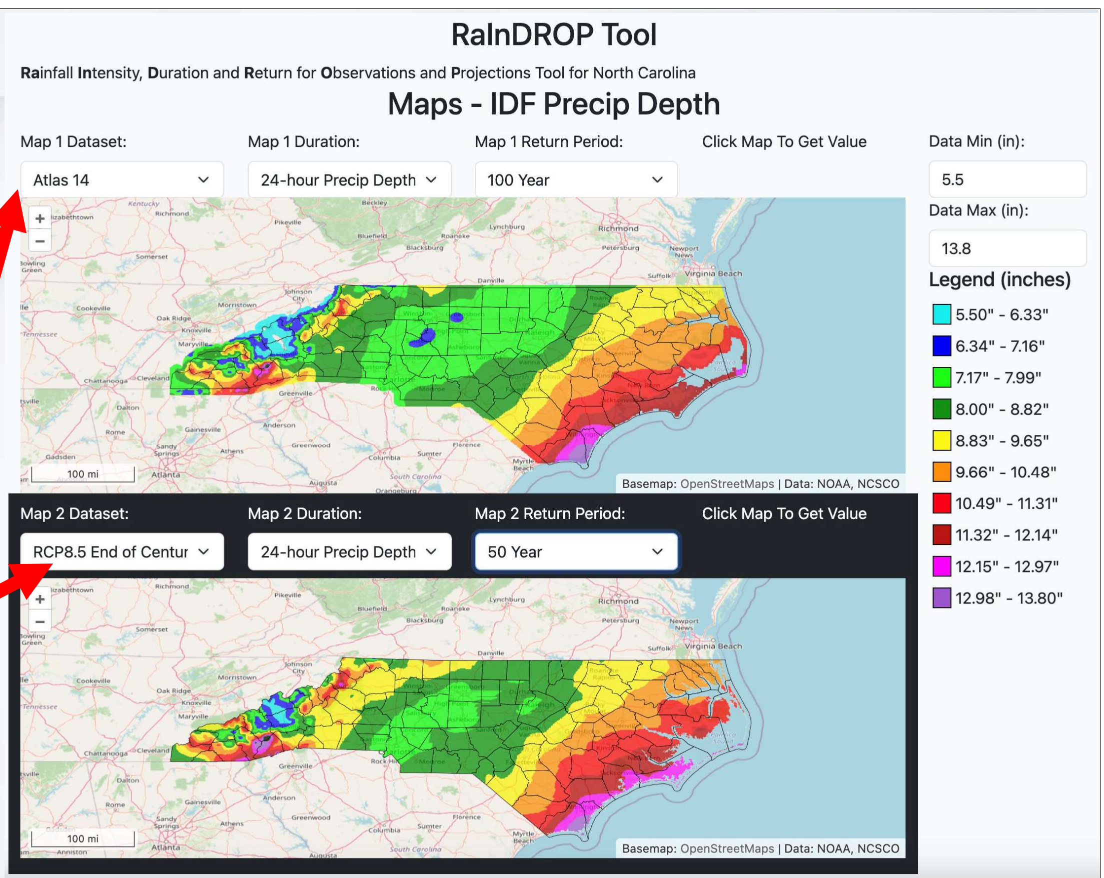
Select maps to compare

Example for 24-hour rainfall depth:

Atlas 14 – 100 year (top)

RCP8.5 – 50 year (bottom)

1-in-100yr could occur at a 1-in-50yr frequency



Pick a point and get estimate

Example for
24-hour rainfall depth:

Atlas 14 – 100 year (top = 7.66")

RCP8.5 – 50 year (bottom = 8.130 in)

Future 50yr exceeds current 100yr

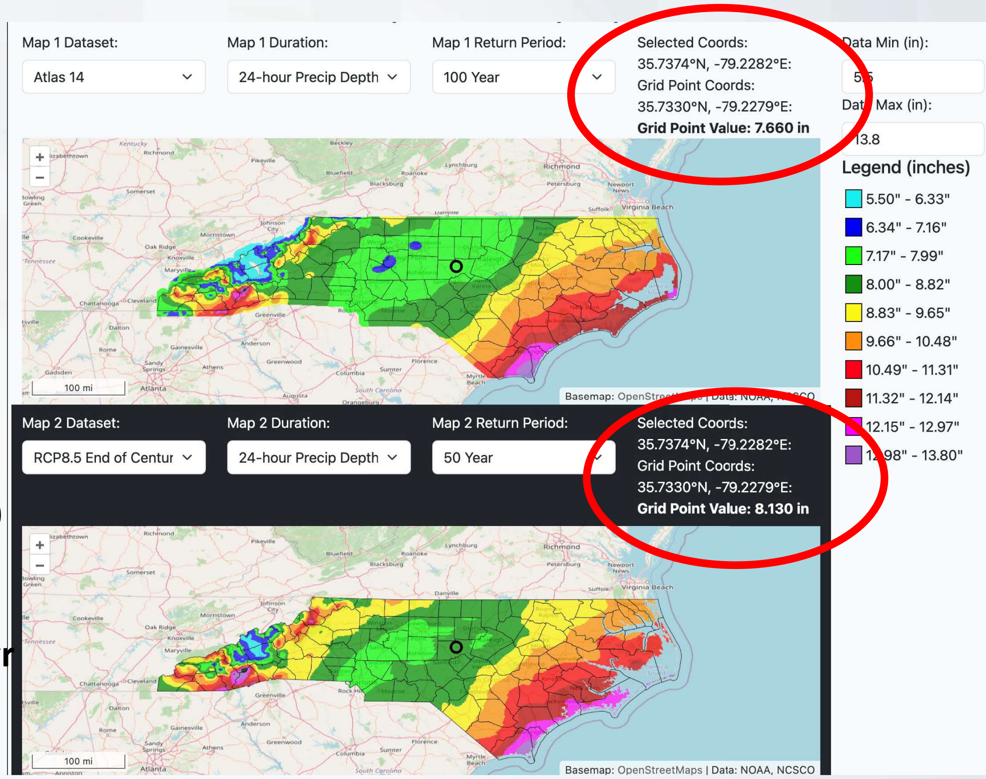


Table - IDF by Dataset

Lat (°N): Use the map or enter below — 35.7046

Lon (°E): Use the map or enter below — -79.2136

Update the table below by clicking on 'Update Table Location'

Update Table Location

Datasets

- [x] Atlas 14
- [ ] RCP4.5 Mid Century (Mean)
- [ ] RCP4.5 Mid Century (90 Percentile)
- [ ] RCP4.5 End of Century (Mean)
- [ ] RCP4.5 End of Century (90 Percentile)
- [ ] RCP8.5 Mid Century (Mean)
- [ ] RCP8.5 Mid Century (90 Percentile)
- [x] RCP8.5 End of Century (Mean)
- [x] RCP8.5 End of Century (90 Percentile)

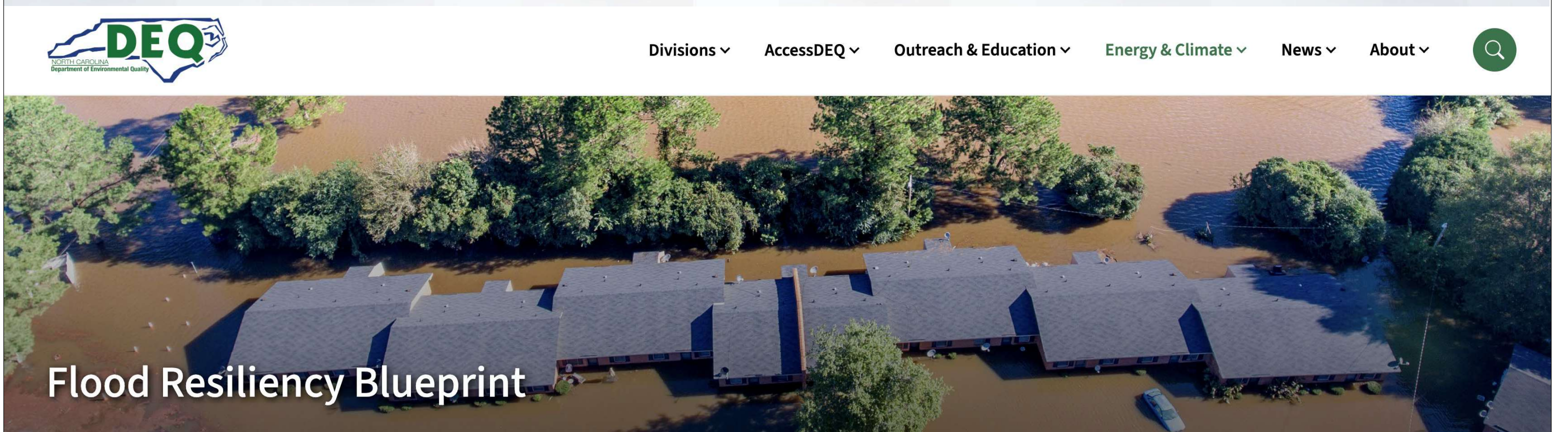
Durations

- [ ] 1-hour Precip Depth (in)
- [ ] 2-hour Precip Depth (in)
- [ ] 3-hour Precip Depth (in)
- [ ] 6-hour Precip Depth (in)
- [ ] 12-hour Precip Depth (in)
- [x] 24-hour Precip Depth (in)
- [ ] 1-hour Precip Intensity (in/hr)
- [ ] 2-hour Precip Intensity (in/hr)
- [ ] 3-hour Precip Intensity (in/hr)
- [ ] 6-hour Precip Intensity (in/hr)
- [ ] 12-hour Precip Intensity (in/hr)
- [x] 24-hour Precip Intensity (in/hr)

Precip Depth (in) and Intensity (in/hr) estimates for 35.70833°N, -79.21668°E:
(This is the nearest grid point to your selected location of 35.7046°N, -79.2136°E)
Note: Intensity is calculated by precip depth (inches) divided by duration (hours)

Dataset	Duration	ARI 2 yr	ARI 5 yr	ARI 10 yr	ARI 25 yr	ARI 50 yr	ARI 100 yr	ARI 500 yr	ARI 1000 yr
Atlas 14	24-hour Depth (in)	3.58	4.48	5.19	6.14	6.9	7.68	9.57	10.44
Atlas 14	24-hour Intensity (in/hr)	0.15	0.19	0.22	0.26	0.29	0.32	0.4	0.44
RCP8.5 End of Century (Mean)	24-hour Depth (in)	4.08	5.2	6.02	7.18	8.07	9.06	11.48	12.63
RCP8.5 End of Century (Mean)	24-hour Intensity (in/hr)	0.17	0.22	0.25	0.3	0.34	0.38	0.48	0.53
RCP8.5 End of Century (90 Percentile)	24-hour Depth (in)	4.65	5.96	7.27	8.78	10.01	11.37	14.93	17.33
RCP8.5 End of Century (90 Percentile)	24-hour Intensity (in/hr)	0.19	0.25	0.3	0.37	0.42	0.47	0.62	0.72

RaInDROP (data) supporting state resilience NC Flood Resiliency Blueprint



Increasing community resilience to flooding throughout NC

https://www.deq.nc.gov/energy-climate/flood-resiliency-blueprint

Communities able to see plausible future flooding extent within the NC Flood Resiliency Blueprint

Regulatory
1% Annual Chance
(100-Year Floodplain)

NEW Advisory (2D hydrology modeling)
1% Annual Chance
(100-Year Floodplain)

NEW Future (Example using RaInDROP)
1% Annual Chance
(100-Year Floodplain)

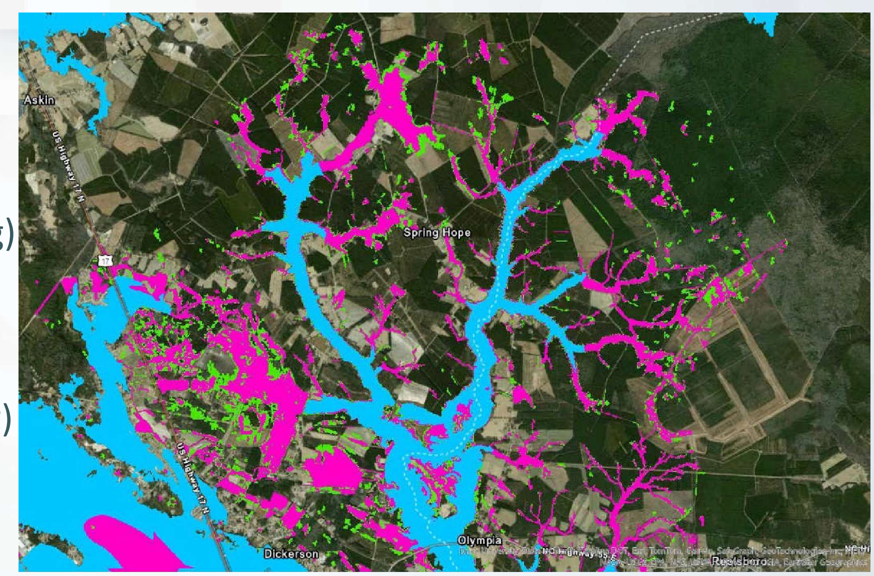
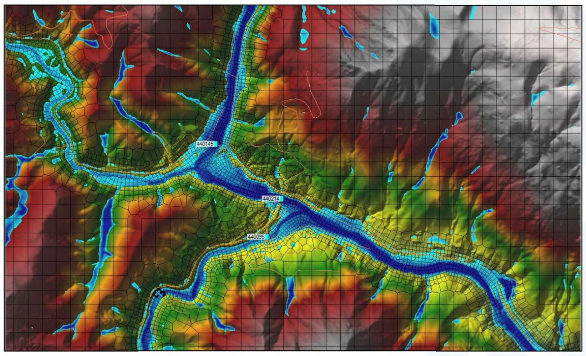


Figure Credit: Stuart Brown (DEQ)

Using RaInDROP to support Helene rebuilding Future design flows – Primary routes

Design Discharge Development for US 74A Rebuild, Gerton to Bat Cave to Chimney Rock, NC

Broad River, Hickory Creek, Reedy Patch Creek



Flooding Source	FEMA Effective 1D River Stations[1]	HEC-RAS 2D Reference Line / FEMA 1D RS[2]	HEC-RAS Rain-on-Grid										
			25-Year	25-Year EoC	50-Year	50-Year EoC	100-Year	100-Year EoC	500-Year	500-Year EoC	1000-Year	1000-Year EoC	Helene
Hickory Creek	RS 25624 to 23441	HickoryCk_23441	500	842	706	1,170	940	1,560	1,690	2,820	2,100	3,420	2,310
	RS 23145 to 20230	HickoryCk_20230	636	1,100	915	1,530	1,240	2,060	2,190	3,600	2,670	4,400	3,070
	RS 20038 to 16920	HickoryCk_16920	781	1,400	1,160	1,980	1,600	2,670	2,890	4,870	3,590	5,970	4,220
	RS 16373 to 12800	HickoryCk_13217	861	1,590	1,310	2,290	1,830	3,120	3,390	5,690	4,220	6,940	5,020
	RS 12257 to 7444	HickoryCk_7444	1,080	2,000	1,650	2,850	2,290	3,850	4,160	6,960	5,150	8,550	6,200
	RS 7037 to 5648	HickoryCk_5648	1,460	2,940	2,340	4,390	3,420	6,100	6,630	11,500	8,400	14,100	10,600
	RS 5358 to 0	HickoryCk_112	1,660	3,250	2,590	4,850	3,770	6,690	7,270	12,600	9,170	15,400	11,500
Broad River LDS	RS 344921 to 340563	BroadRv_UpStrm	3,880	7,650	6,110	11,500	8,750	16,000	17,200	30,600	21,600	38,800	33,800
	RS 340121 to 338916	BroadRv_339664	4,560	8,870	7,140	13,200	10,100	18,400	19,800	35,200	24,800	44,500	40,100
	RS 338471 to 335672	BroadRv_335672	5,890	11,200	9,100	16,400	12,700	23,000	24,700	44,700	31,200	57,000	53,900
Broad River DTL	RS 335672 to 329566	BroadRv_329566	5,970	11,300	9,210	16,600	12,800	23,200	24,800	45,200	31,600	57,700	55,100
	RS 329065 to 327997	BroadRv_328346	5,980	11,400	9,240	16,600	12,900	23,200	24,800	45,300	31,700	57,800	55,300
	RS 327674 to 327409	BroadRv_327409	6,020	11,400	9,300	16,700	12,900	23,400	25,000	45,600	31,800	58,100	55,800
	RS 326905	BroadRv_326905	6,120	11,600	9,430	17,000	13,100	23,700	25,300	46,200	32,200	59,000	57,000
	RS 326493 to 321151	BroadRv_321729	6,180	11,700	9,520	17,100	13,200	23,900	25,500	46,500	32,500	59,500	57,600
Reedy Patch Creek	RS 10000 to 8486	ReedyPatchCk_9600	2,010	3,110	2,600	4,230	3,440	5,520	5,900	9,570	7,130	11,400	7,440
	RS 8019 to 0	ReedyPatchCk_1200	2,550	4,530	3,730	6,350	5,090	8,570	9,230	15,600	11,500	19,100	13,500

Credit: David Markwood (SUMMIT Engineering)

APWA

State agencies' adoption of climate data/tools + contractors = increasing use with municipalities

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

- Data used to help justify higher stormwater design standards
- RaInDROP was used in the design phase of a large capital improvement project to evaluate the level of service to the project

APWA

City of Fayetteville – Russell/Person Street Bridges

- City used RaInDROP to review precipitation data and after discussions with NCSU, requested further analysis
- Sensitivity analysis using 15% increase rather than 6% increase from watershed studies
- Outcome was Railroad requested higher freeboard criteria that resulted in a more conservative design

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

APWA

Knightdale, NC – Mingo Creek 2D Analysis

- Currently, working with ESP Associates to use future rainfall from RaInDROP data for a watershed assessment

KNIGHTDALE
start something

APWA

Potential Uses

- RaInDROP tool provides information in a way that engineers and consultants are comfortable with for planning and design
- Sensitivity testing for the level of service
- Hydrologic modeling (2D rain on grid) with RaInDROP (gridded) rainfall values
- Education/awareness of future extreme rainfall risks in a warmer climate
- NC is a good test case for applications of Atlas 15 Volume 2 via RaInDROP

NOAA Atlas 15

- Stationary assumption to nonstationary assumption
- Volume 1 (updated metods + recent data)
- Volume 2 (Similar to RaInDROP – future risks associated with extreme rainfall for hydrologic design)
- Potential challenges
  - Different sources of information, differences, & the implications

NOAA ATLAS 15:

Update to the National Precipitation Frequency Standard

RaInDROP Tool…

…is a resource to assist with flood resilience, especially stormwater design.

…allows users to compare two maps with different precipitation frequency estimates to help plan and design for future environmental uncertainties.

Learning Outcomes

1. Explain rainfall intensity, duration, and frequency of rainfall events.
2. Describe methods and data sets that support RaInDROP.
3. Provide examples of how RaInDROP and atmospheric model experiments are being used to inform long-term flood resilience.

Supporting Long-Term Flood Resilience with Climate Data and Tools

Jared Bowden, PhD; Haven Cashwell, PhD; Alicia Lanier, PE, CFM

CLICK, LISTEN & LEARN

APWA

Questions?

Contact:
Jared Bowden
jhbowden@ncsu.edu

https://products.climate.ncsu.edu/climate/raindrop-tool/

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DEQ North Carolina Department of Environmental Quality

State of North Carolina Department of Transportation

North Carolina Climate Office

NCORR

NOAA