NORTH CAROLINA
Department of Transportation

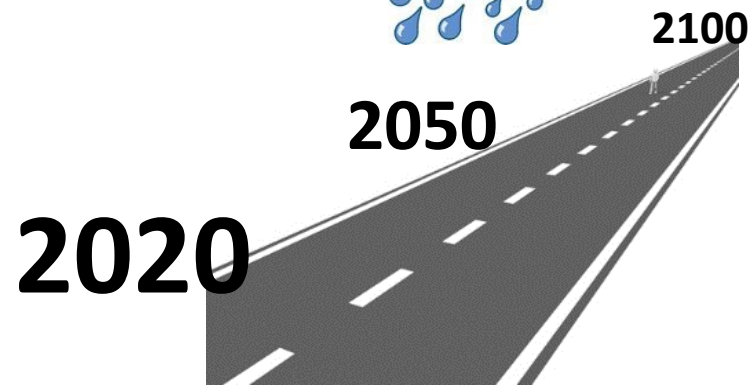
NC-NOAA Atlas-14 Volume 13 Update Status

Matthew (Matt) Lauffer, CPM, PE
NCDOT Hydraulics Unit

NC Erosion and Sediment Control Workshop – December 2, 2021

Agenda

- Existing NOAA Atlas 14
- Updated NOAA Atlas 14 – What is taking so long?
- Are there other Options?
- What about Non-Stationarity?
- NCDOT Precipitation Research
  - NCHRP 50-61
  - RP-2020-57
- Next Steps



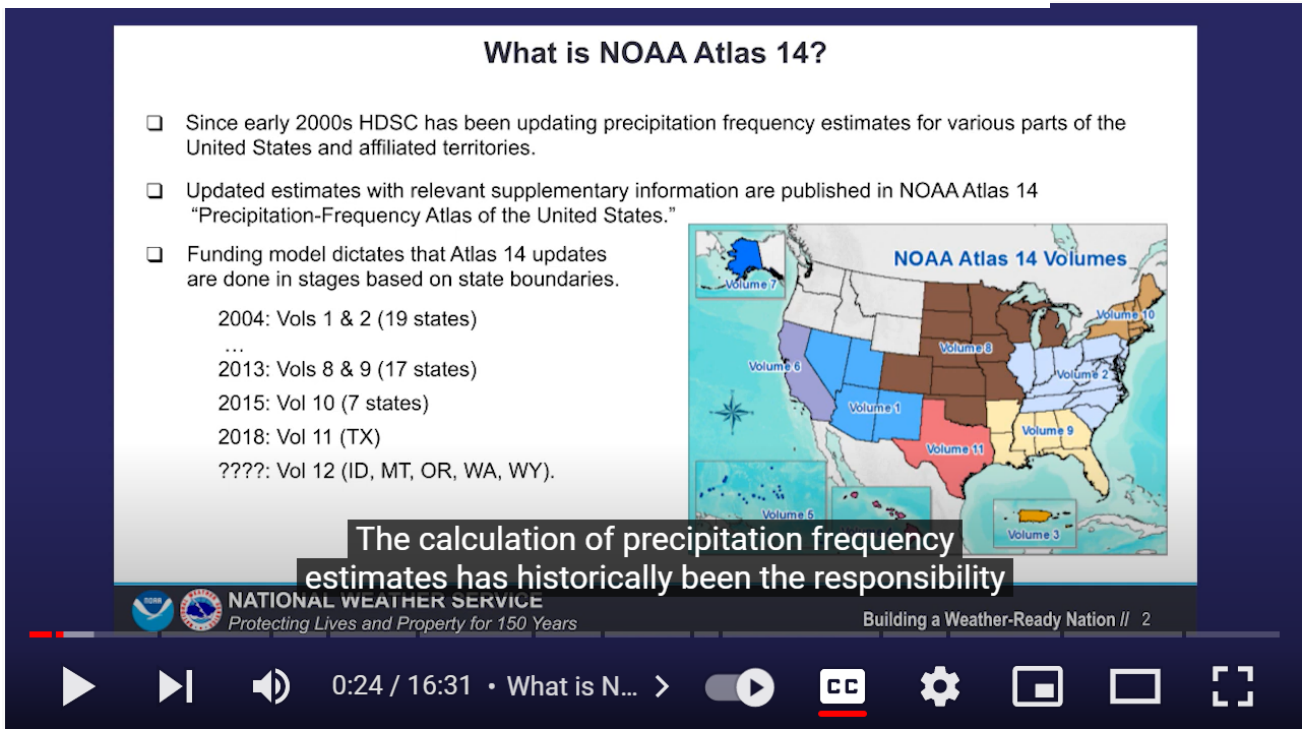
Background NOAA ATLAS-14

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HOME FORECAST PAST WEATHER SAFETY INFORMATION EDUCATION

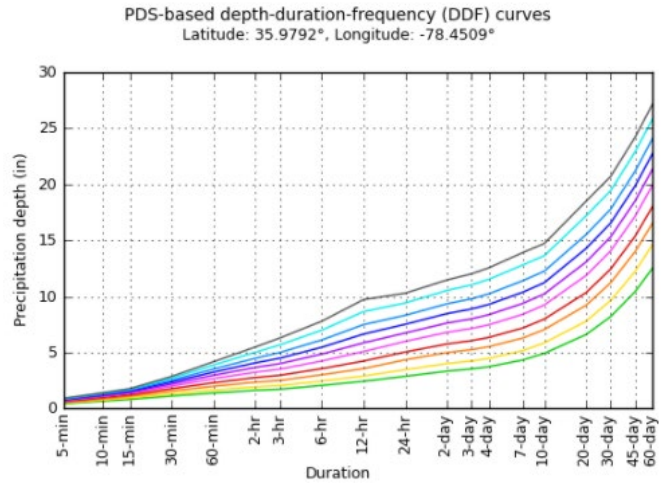
Hydrometeorological Design Studies Center

Weather.gov > Office of Water Prediction > Hydrometeorological Design Studies Center



https://www.youtube.com/watch?v=bD623aYVxeE&t=490s

Provides DDF and IDF data for locations around the US.

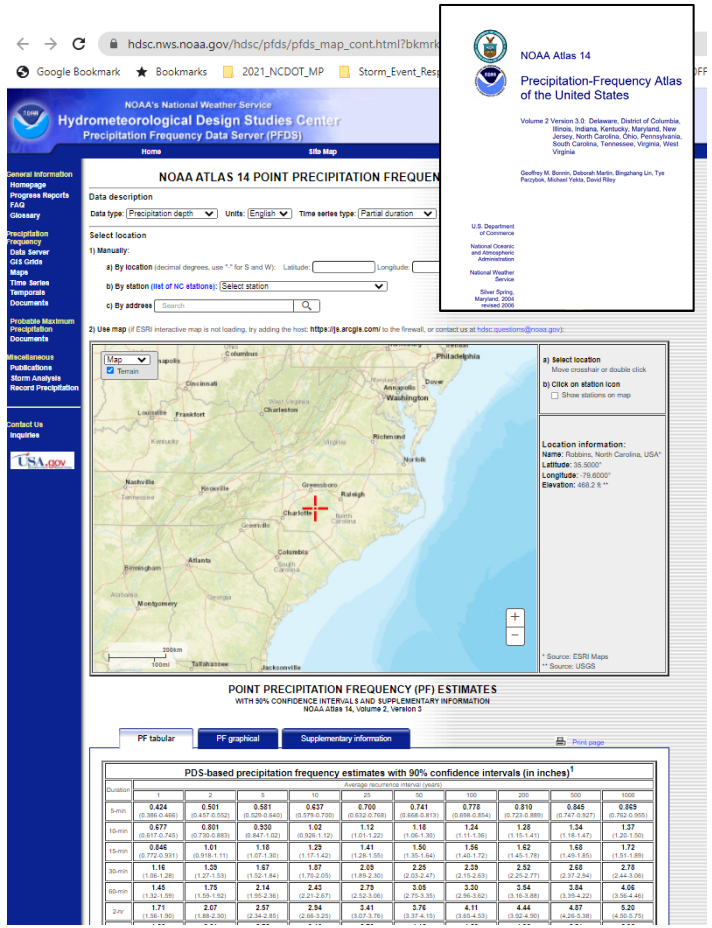


Existing NOAA Atlas 14 Volume 2

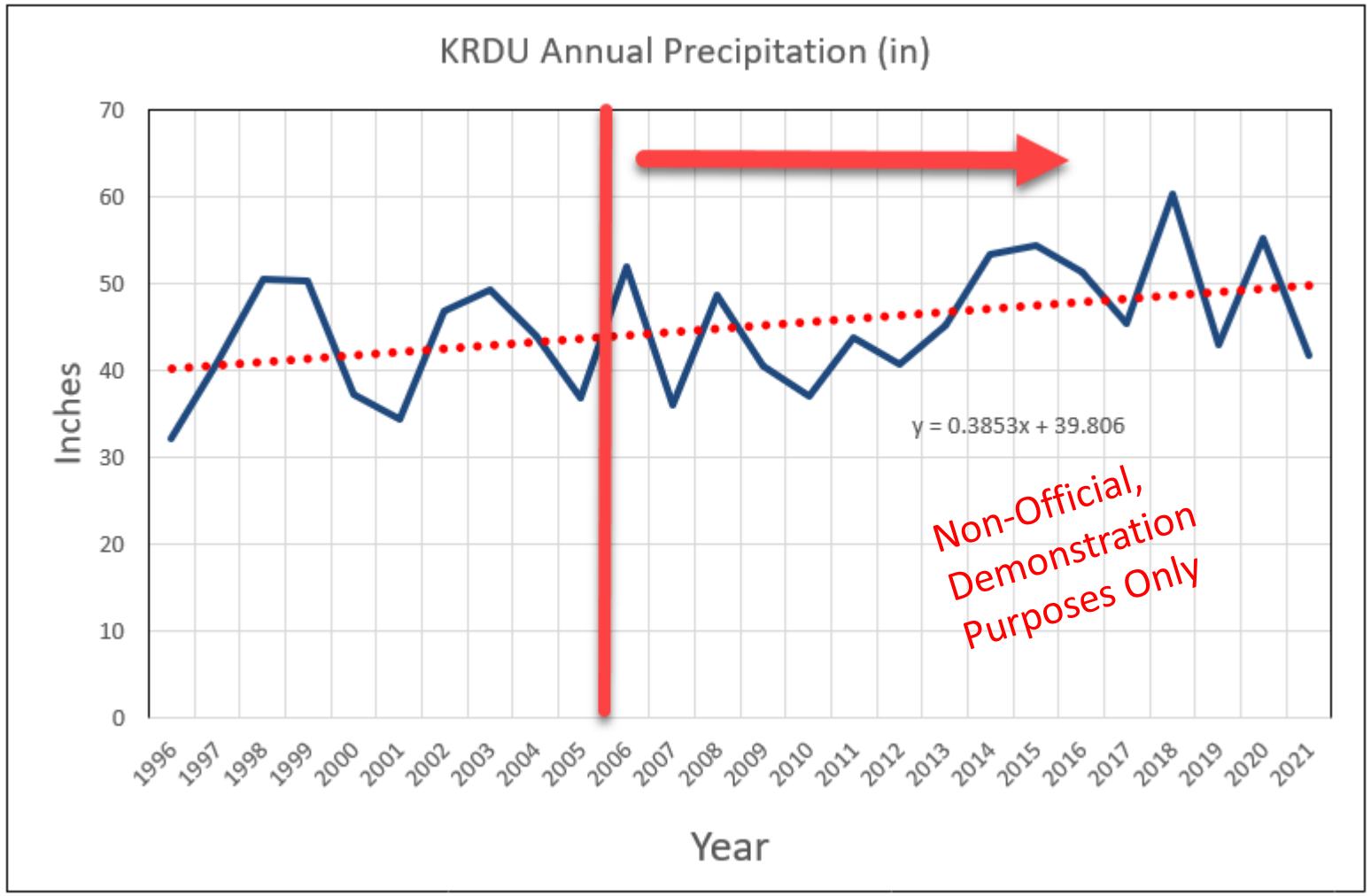
Current NWS Precipitation Frequency (PF) Documents

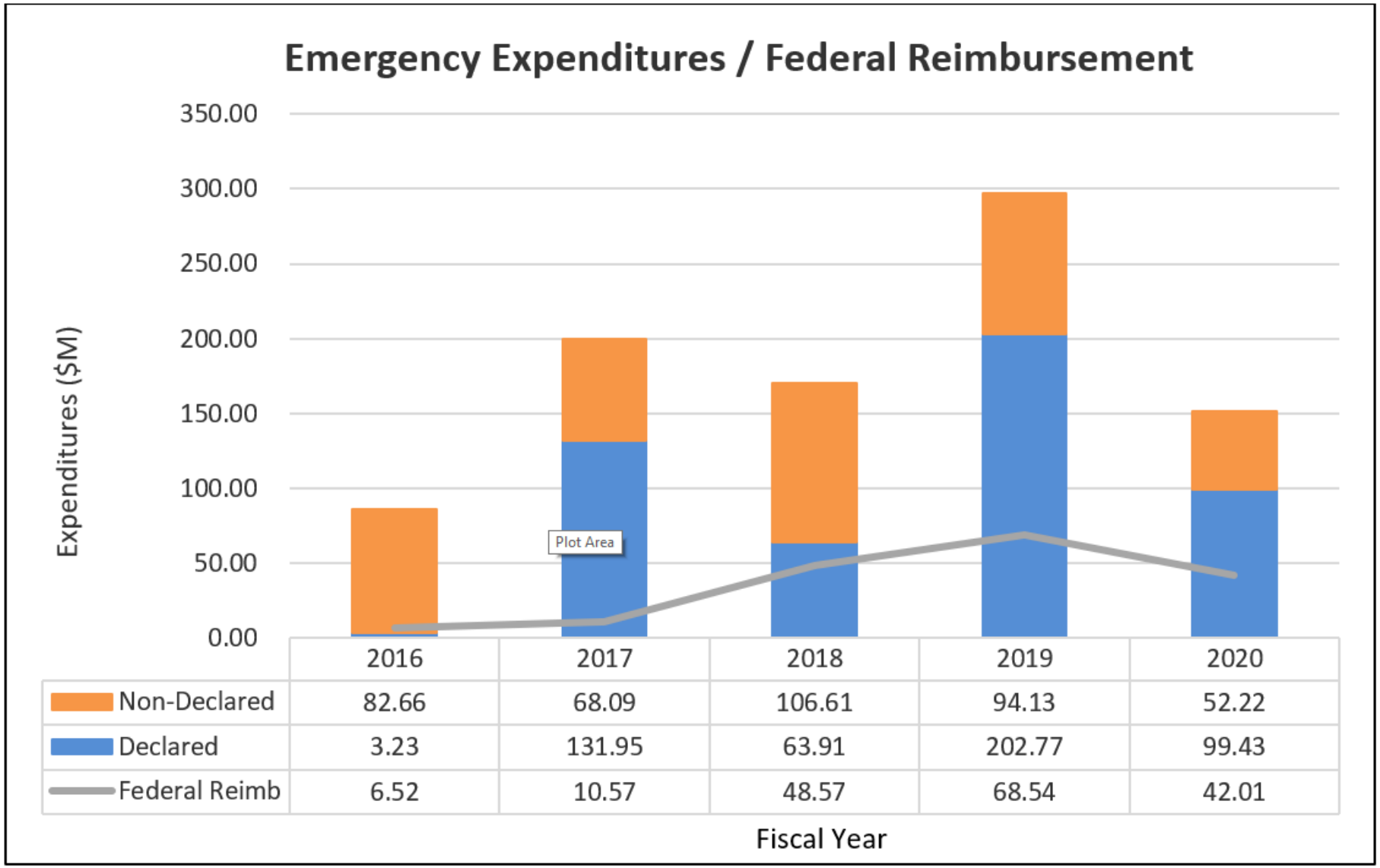
PF DOCUMENTS BY TITLE:

Document Link	Title	Release Year	Latest Revision
NOAA Atlas 2 Vol 1	Precipitation-Frequency Atlas of the Western United States, Montana	1973	1973
NOAA Atlas 2 Vol 2	Precipitation-Frequency Atlas of the Western United States, Wyoming	1973	2006
NOAA Atlas 2 Vol 5	Precipitation-Frequency Atlas of the Western United States, Idaho	1973	1973
NOAA Atlas 2 Vol 9	Precipitation-Frequency Atlas of the Western United States, Washington	1973	1973
NOAA Atlas 2 Vol 10	Precipitation-Frequency Atlas of the Western United States, Oregon	1973	1973
NOAA Atlas 14 Vol 1	Precipitation-Frequency Atlas of the United States, Semiarid Southwest	2006	2011
NOAA Atlas 14 Vol 2	Precipitation-Frequency Atlas of the United States, Ohio River Basin and Surrounding States	2004	2006
NOAA Atlas 14 Vol 3	Precipitation-Frequency Atlas of the United States, Puerto Rico and the U.S. Virgin Islands	2006	2008
NOAA Atlas 14 Vol 4	Precipitation-Frequency Atlas of the United States, Hawaiian Islands	2009	2011
NOAA Atlas 14 Vol 5	Precipitation-Frequency Atlas of the United States, Selected Pacific Islands	2009	2011
NOAA Atlas 14 Vol 6	Precipitation-Frequency Atlas of the United States, California	2011	2014
NOAA Atlas 14 Vol 7	Precipitation-Frequency Atlas of the United States, Alaska	2012	2012
NOAA Atlas 14 Vol 8	Precipitation-Frequency Atlas of the United States, Midwestern States	2013	2013
NOAA Atlas 14 Vol 9	Precipitation-Frequency Atlas of the United States, Southeastern States	2013	2013
NOAA Atlas 14 Vol 10	Precipitation-Frequency Atlas of the United States, Northeastern States	2015	2015
NOAA Atlas 14 Vol 11	Precipitation-Frequency Atlas of the United States, Texas	2018	2018
Technical Paper 40	Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years	1961	1961
Technical Paper 49	Two- to Ten-Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States	1964	1964
Arkell & Richards	Short Duration Rainfall Relations for the Western United States. Preprint Volume of the Conference on Climate and Water Management, AMS	1986	1986



Annual Precipitation from RDU





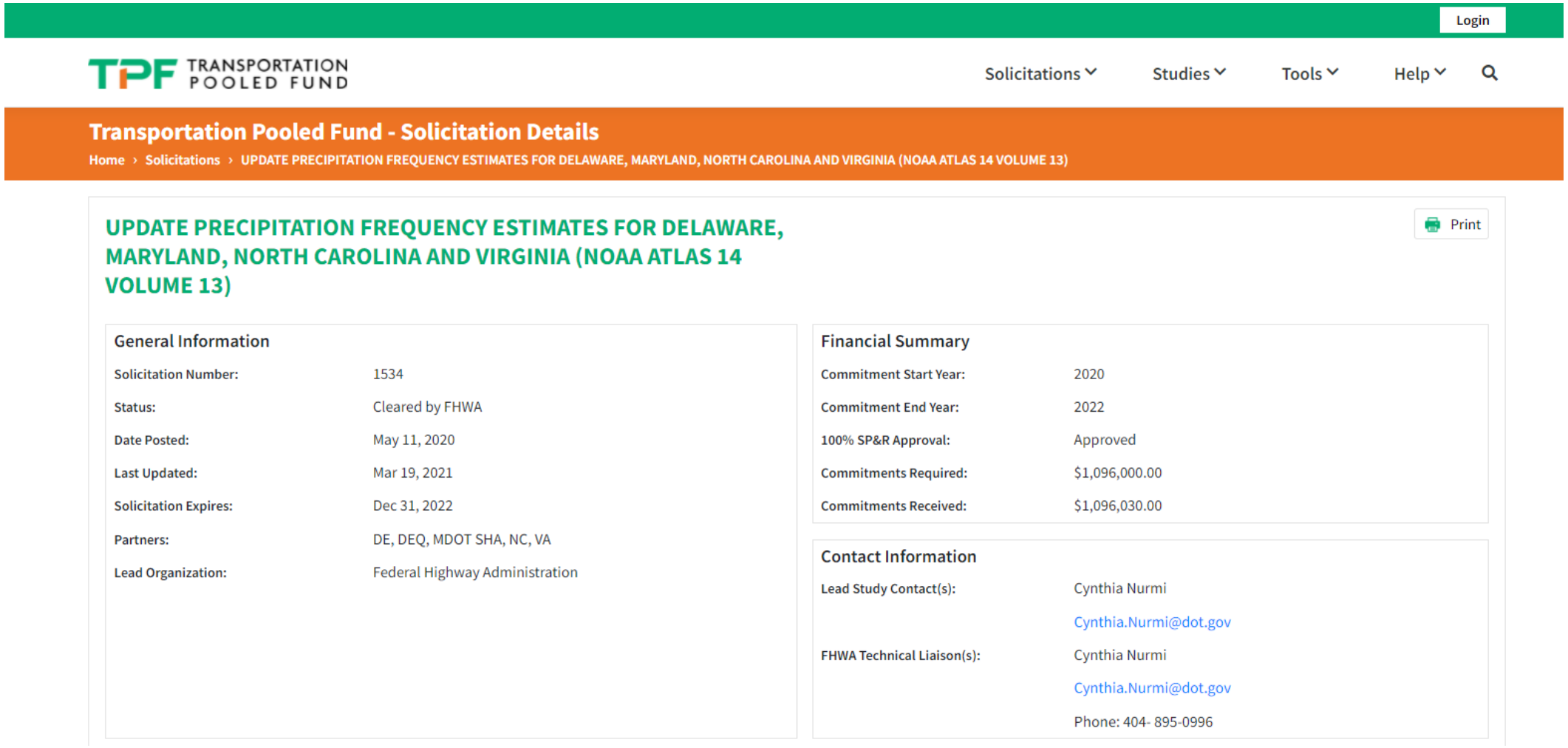
	2016	2017	2018	2019	2020
Non-Declared	82.66	68.09	106.61	94.13	52.22
Declared	3.23	131.95	63.91	202.77	99.43
Federal Reimb	6.52	10.57	48.57	68.54	42.01

Figure 1: *Emergency Expenditures and Federal Reimbursement*

Updated Atlas 14 for NC. What is taking so long?

- Atlas 14 is supported by external funding sources
- Require Memorandums of Agreement between NOAA and partnering Agency
- May 2020 – FHWA –Transportation Pooled Fund Study (TPF) - Solicitation for NOAA Atlas 14, Volume 13 Update (DE, MD, VA, NC)

FHWA- Transportation Pooled Fund Study



Login

TPF TRANSPORTATION POOLED FUND

Solicitations Studies Tools Help

Transportation Pooled Fund - Solicitation Details

Home › Solicitations › UPDATE PRECIPITATION FREQUENCY ESTIMATES FOR DELAWARE, MARYLAND, NORTH CAROLINA AND VIRGINIA (NOAA ATLAS 14 VOLUME 13)

Print

UPDATE PRECIPITATION FREQUENCY ESTIMATES FOR DELAWARE, MARYLAND, NORTH CAROLINA AND VIRGINIA (NOAA ATLAS 14 VOLUME 13)

General Information

Solicitation Number:	1534
Status:	Cleared by FHWA
Date Posted:	May 11, 2020
Last Updated:	Mar 19, 2021
Solicitation Expires:	Dec 31, 2022
Partners:	DE, DEQ, MDOT SHA, NC, VA
Lead Organization:	Federal Highway Administration

Financial Summary

Commitment Start Year:	2020
Commitment End Year:	2022
100% SP&R Approval:	Approved
Commitments Required:	$1,096,000.00
Commitments Received:	$1,096,030.00

Contact Information

Lead Study Contact(s):	Cynthia Nurmi
	Cynthia.Nurmi@dot.gov
FHWA Technical Liaison(s):	Cynthia Nurmi
	Cynthia.Nurmi@dot.gov
	Phone: 404- 895-0996

Budget NOAA Atlas XIV Vol 13

Cost Description	DE	MD	NC	VA	Project Total
Contract Labor	$30,920	$160,820	$402,240	$350,020	$946,000
PRISM	$4,000	$17,000	$44,000	$37,000	$100,000
Web Support	$600	$5,100	$13,200	$11,100	$30,000
IT Equipment	$300	$2,550	$6,600	$5,550	$15,000
Office Supply	$100	$850	$2,200	$1,850	$5,000
TOTAL COST:	**$35,920**	**$186,320**	**$468,240**	**$405,520**	**$1,096,000**

Budget NOAA Atlas XIV Vol 13

Organization	Year	Commitments	Technical Contact Name	Funding Contact Name	Contact Number
Delaware Department of Transportation	2021	$35,950.00	Michael DuRoss	Art Jenkins	(302)760-2092
Maryland Department of Transportation State Highway Administration	2021	$93,160.00	Sandy Hertz	Sharon Hawkins	410-545-2920
Maryland Department of Transportation State Highway Administration	2022	$93,160.00	Sandy Hertz	Sharon Hawkins	410-545-2920
North Carolina Department of Transportation	2021	$234,120.00	Matt Lauffer	Neil Mastin	919 707 6661
North Carolina Department of Transportation	2022	$234,120.00	Matt Lauffer	Neil Mastin	919 707 6661
Virginia Department of Environmental Quality	2021	$142,760.00	ANDREW HAMMOND	Carla Woods	(804)698-4056
Virginia Department of Environmental Quality	2022	$142,760.00	ANDREW HAMMOND	Carla Woods	(804)698-4056
Virginia Department of Transportation	2021	$60,000.00	Alex Foraste	Bill Kelsh	434-293-1934
Virginia Department of Transportation	2022	$60,000.00	Alex Foraste	Bill Kelsh	434-293-1934

NOAA Atlas XIV Vol 13 Benefits/ Objectives

Benefits:

- More Stations
- Two more decades of record
- Better Analysis Techniques

Objectives:

- update precipitation frequency estimates
- the estimates and associated bounds of 90% confidence intervals will be provided at 30arc-sec resolution for durations of 5-minute through 60-day at average recurrence intervals (ARIs)of 1-year through 1,000-year
- web based publication available at Precipitation Frequency Data Server (PFDS).

- Detailed Scope of Work available at: https://www.pooledfund.org/Document/Download?id=8985

NOAA Atlas XIV Vol 13 Schedule

- Interagency Agency Agreement – FHWA/NOAA - FFY22 Q2
- Study Begins – FFY22 Q2
- Study Concludes - FFY 24 Q2

WorkPlan Task Breakdown:

- Task 1 - Data collection and quality control
- Task 2 - Regionalization and calculation of regional statistics
- Task 3 - Frequency distribution selection and frequency calculations
- Task 4 - Estimates for 5-minute and 10-minute durations
- Task 5 - Internal consistency at observing locations
- Task 6 - Error estimates for DDF/IDF curves
- Task 7 - Rainfall frequency estimates with confidence limits
- Task 8 - Spatial interpolation and consistency
- Task 9 - Temporal distributions
- Task 10 - Peer review
- Task 11 - Documentation
- Task 12 - Final deliverables
- Task 13 - Status Reporting

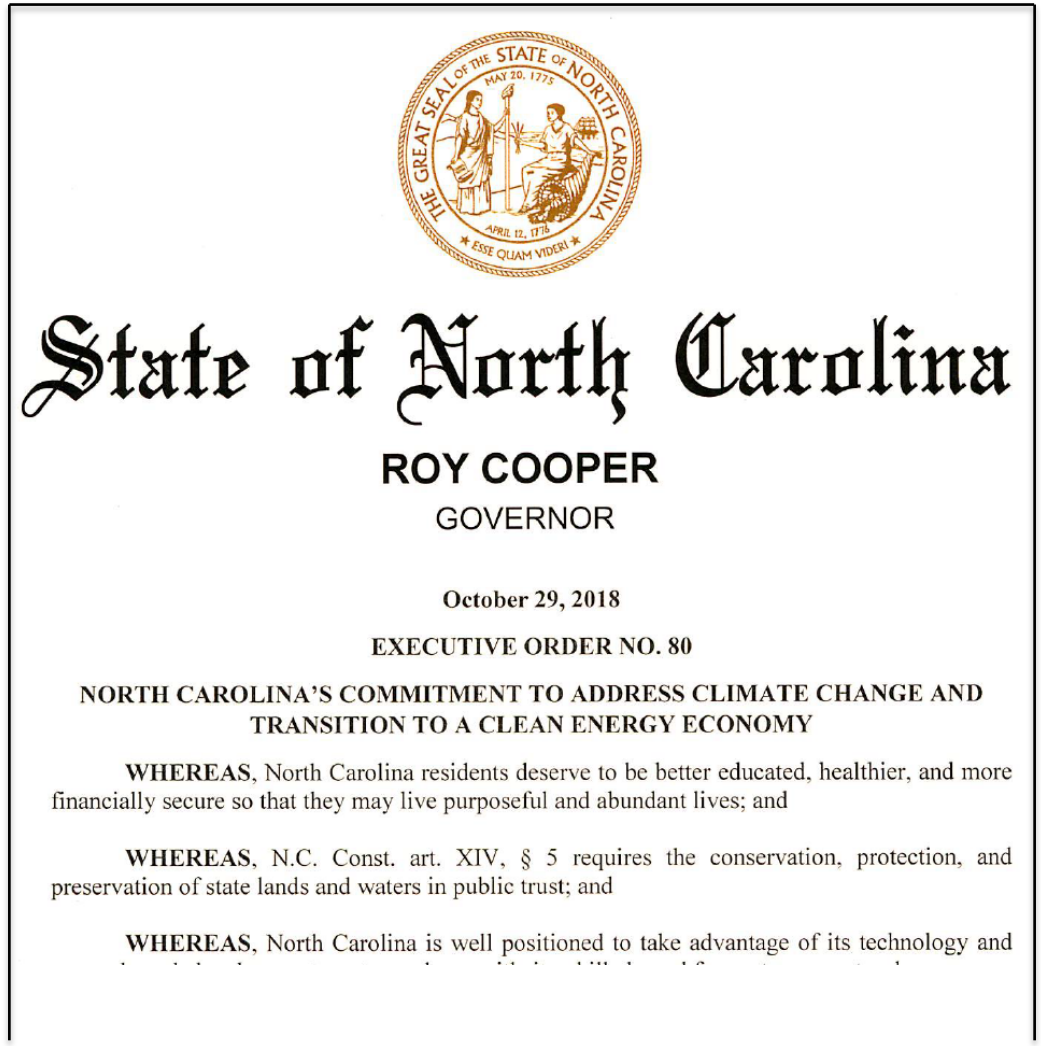
Other Options for Atlas 14 update? Infrastructure Investment and Jobs Act

$492M for **NOAA mapping, observations and modeling**. Investments in NOAA flood mapping and modeling programs can have significant benefits of protecting lives and property during extreme weather events. Specific programs funded include the Coastal Mapping Program, nextGen National Water Modeling framework, Atlas 14 & Probable Maximum Precipitation, and flood inundation maps (FIM) that depict the extent and depth of floods stemming from actual and forecasted events.

- Update precipitation frequency estimates for entire nation
- Would include climate adaptation/non-stationarity
- Later delivery date – FY25 or FY26

What about Non-Stationarity/Climate Adaptation?

Executive Order 80



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

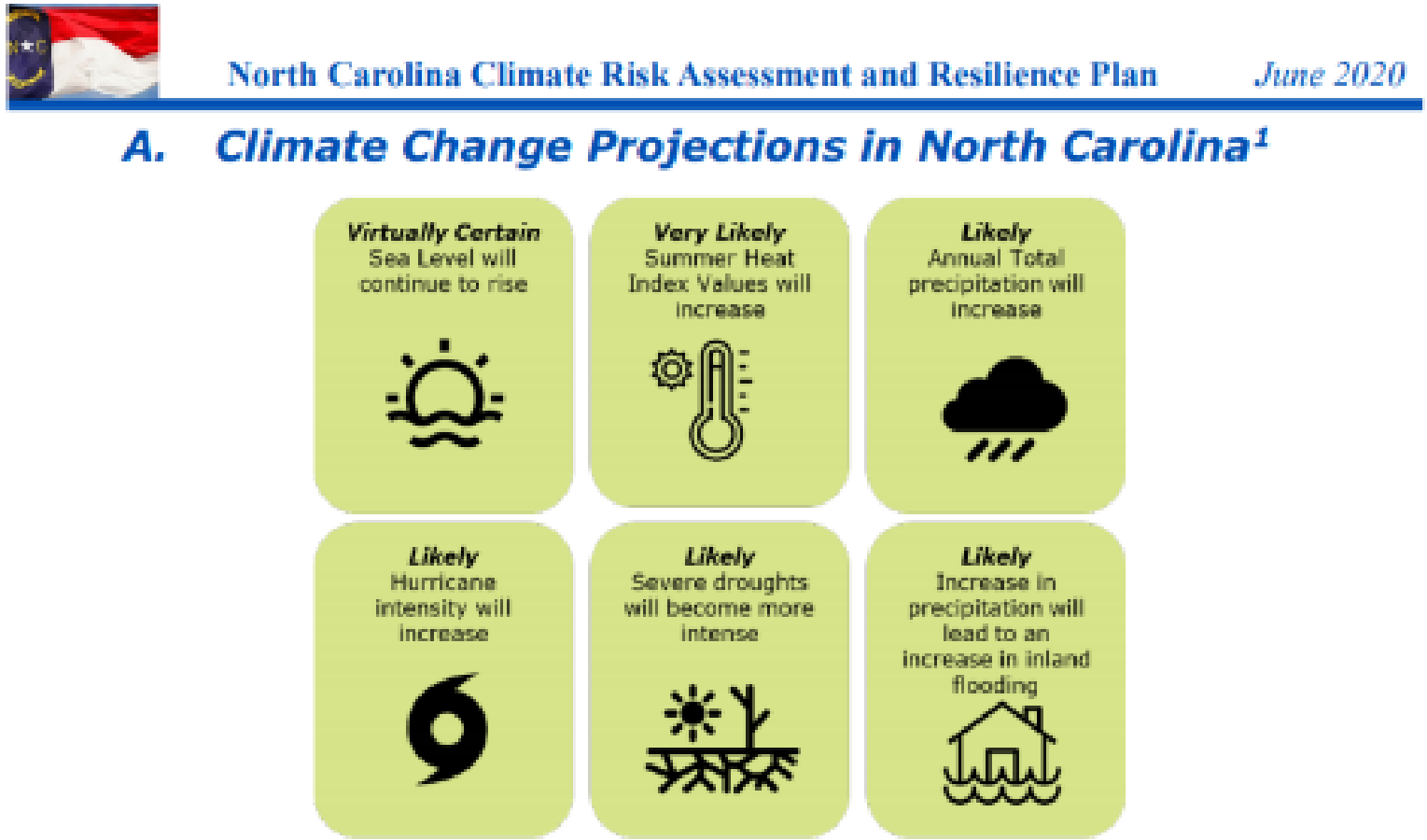
WHEREAS, North Carolina residents deserve to be better educated, healthier, and more financially secure so that they may live purposeful and abundant lives; and

WHEREAS, N.C. Const. art. XIV, § 5 requires the conservation, protection, and preservation of state lands and waters in public trust; and

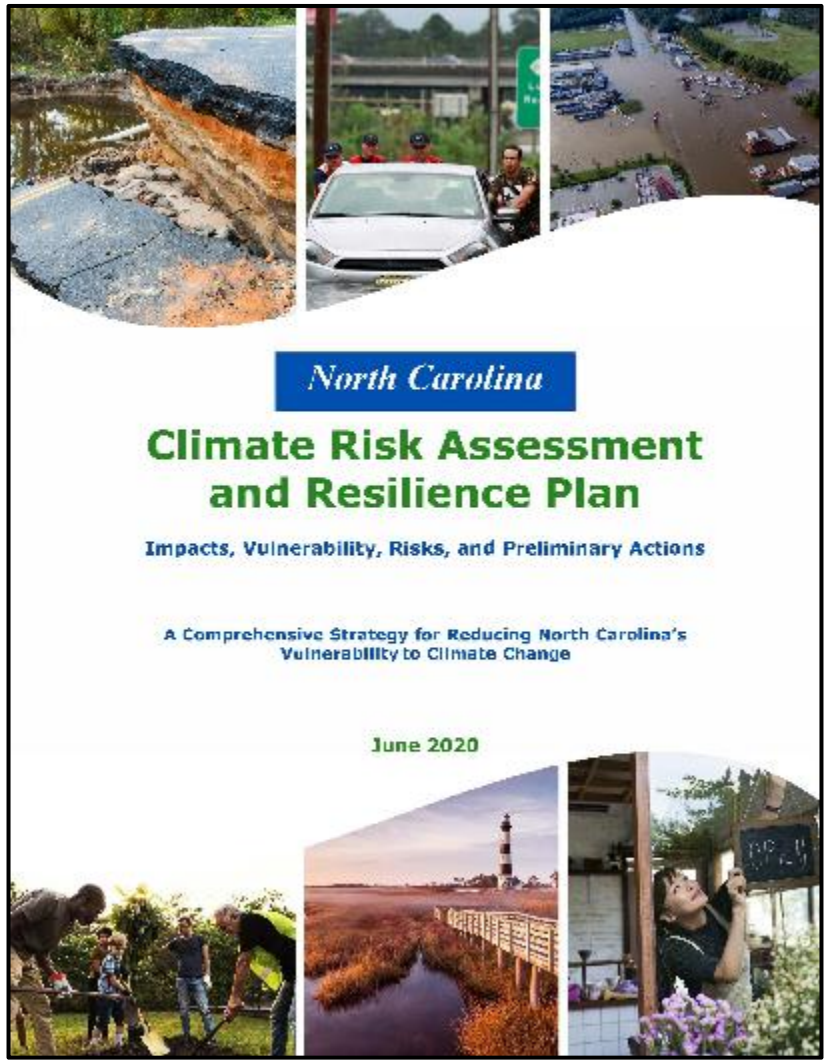
WHEREAS, North Carolina is well positioned to take advantage of its technology and

Report from the climate scientists

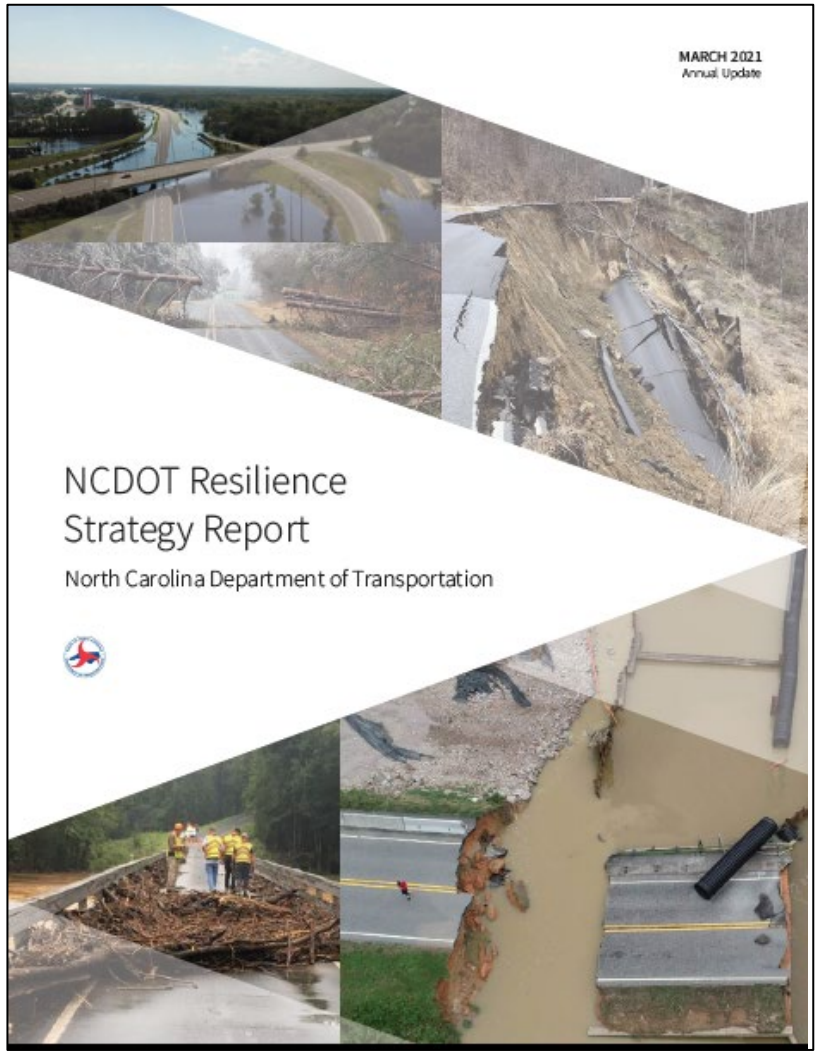
Report from the climate scientists



NC Climate RARP



Resilience Strategy Report

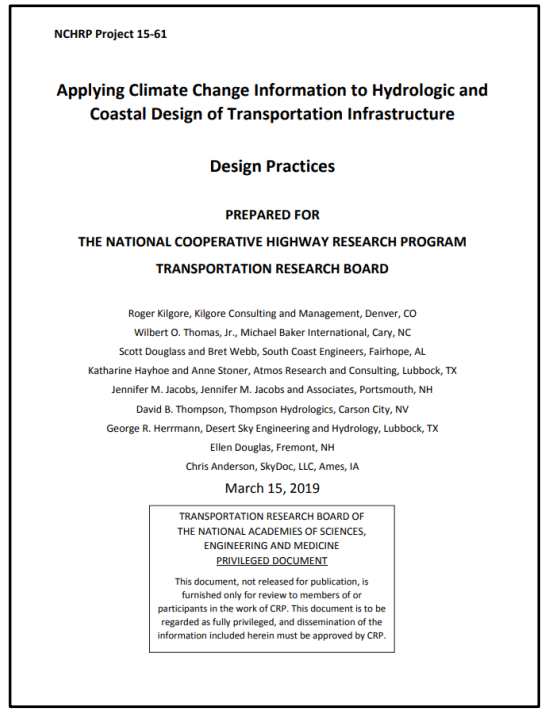


NCDOT Climate Precipitation Research

- National Cooperative Highway Research Program Project (NCHRP) 15-61 – Applying Climate Change Information to Hydrologic and Coastal Design of Transportation Infrastructure

- NCDOT Participated in an inland precipitation and coastal design project.

https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4046



NCHRP Project 15-61

Applying Climate Change Information to Hydrologic and Coastal Design of Transportation Infrastructure

Design Practices

PREPARED FOR

THE NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

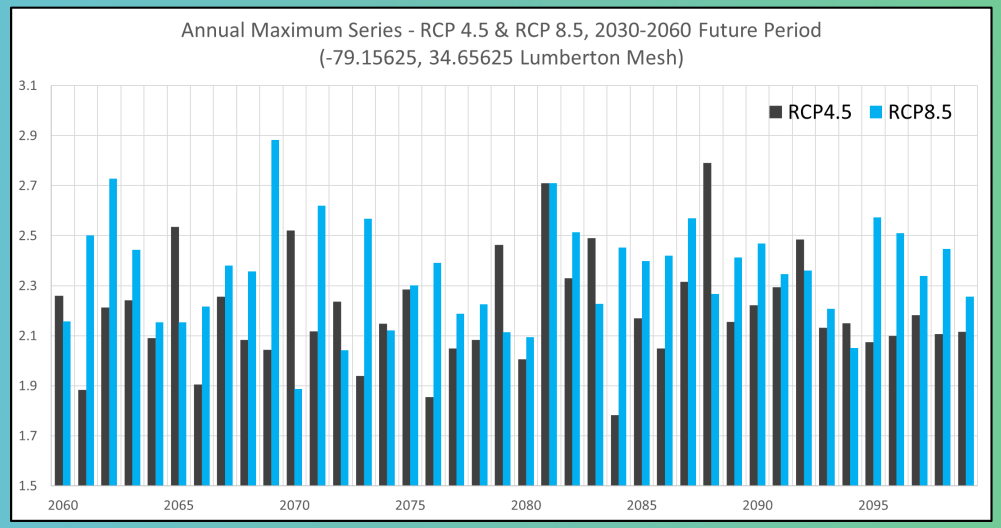
TRANSPORTATION RESEARCH BOARD

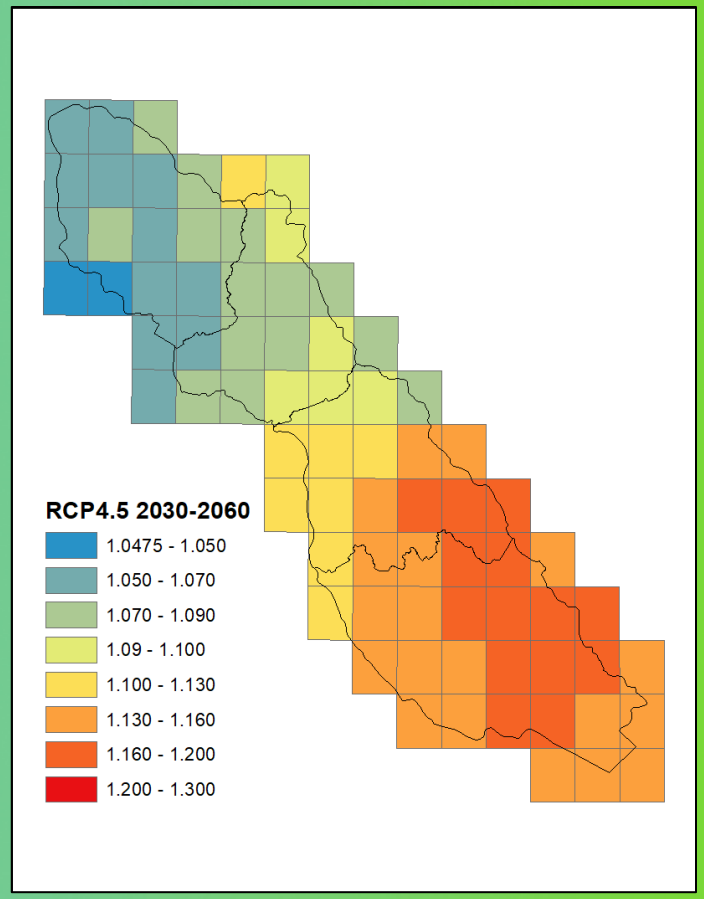
Roger Kilgore, Kilgore Consulting and Management, Denver, CO
Wilbert O. Thomas, Jr., Michael Baker International, Cary, NC
Scott Douglass and Bret Webb, South Coast Engineers, Fairhope, AL
Katharine Hayhoe and Anne Stoner, Atmos Research and Consulting, Lubbock, TX
Jennifer M. Jacobs, Jennifer M. Jacobs and Associates, Portsmouth, NH
David B. Thompson, Thompson Hydrologics, Carson City, NV
George R. Herrmann, Desert Sky Engineering and Hydrology, Lubbock, TX
Ellen Douglas, Fremont, NH
Chris Anderson, SkyDoc, LLC, Ames, IA

March 15, 2019

NCDOT — NCRHP Project 15-61 Inland Hydrology, Climate Change Guidelines Pilot

Lumber River Basin, North Carolina





NCRHP Project 15-61
Inland Hydrology

- Problem Statement
- Project Context
- Methods
- Results
- Conclusions

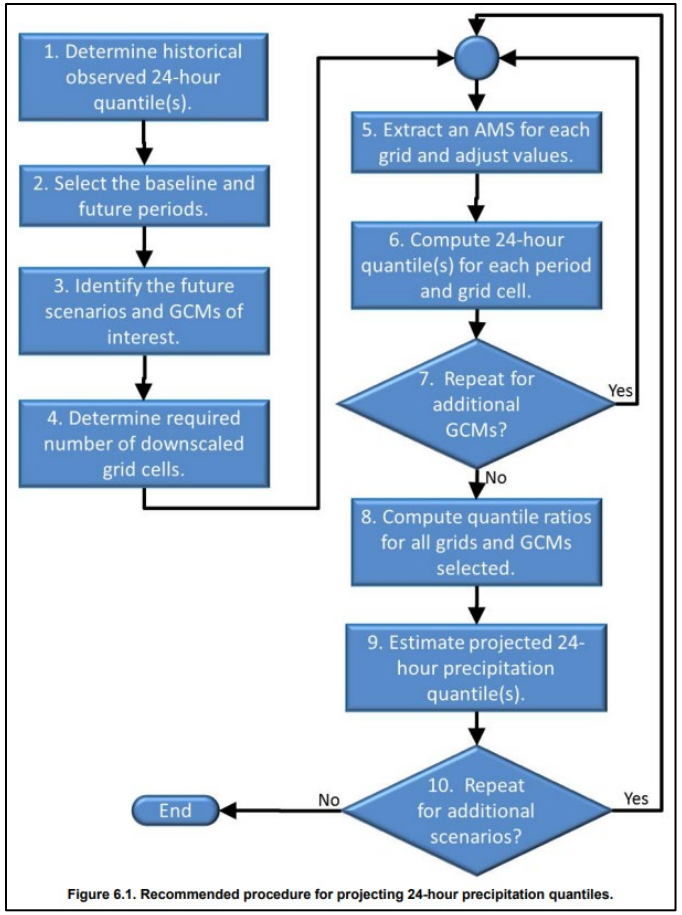


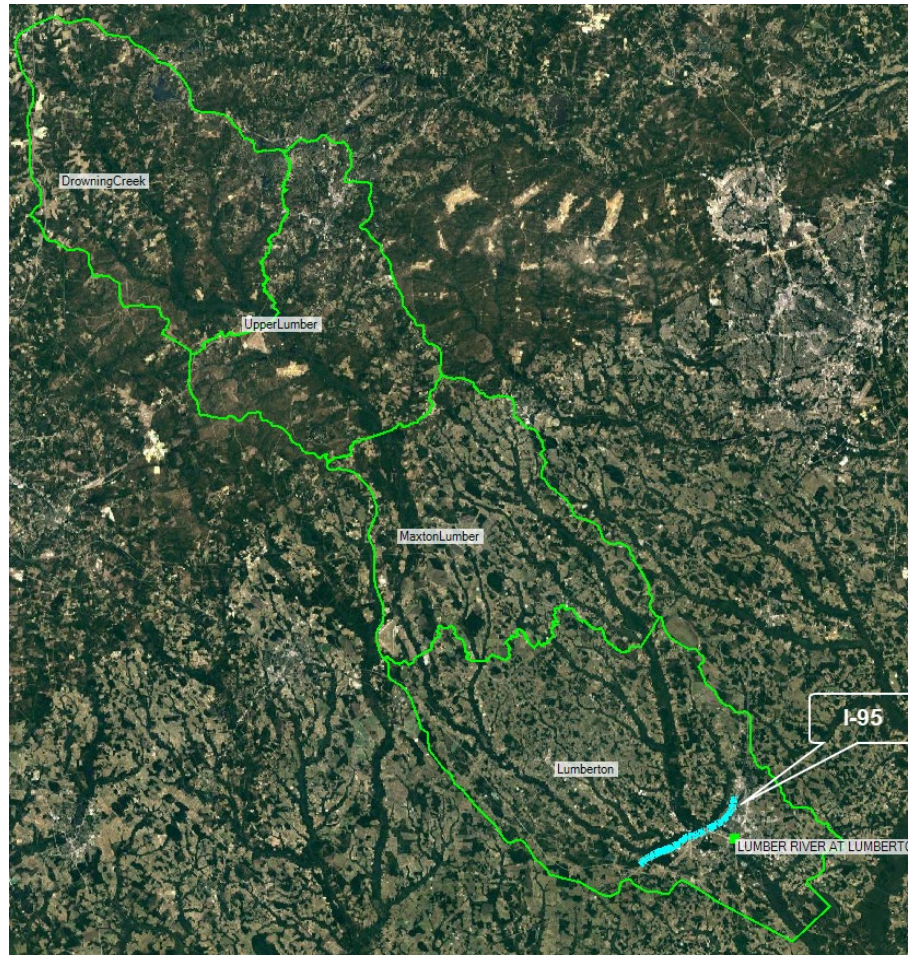
Figure 6.1. Recommended procedure for projecting 24-hour precipitation quantiles.

Problem Statement

- Project 24-Hour Precipitation Quantiles using the 10-Step Procedure
- "Guidelines" (hereto after known as)
  - NCHRP Project 15-61: *Applying Climate Change Information to Hydrologic and Coastal Design of Transportation Infrastructure, Design Practices*
- Project 24-Hour Event Flood Elevations along I-95 Corridor in Lumberton, NC

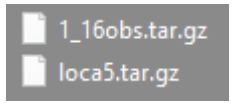
Project Context

- Interstate 95 widening Lumberton, NC
- Lumber River watershed
- NCHRP 15-61 Guidelines



Methods

- Atlas 14 AEP
  - Extract AEP rainfall depths from 24-hour spatial grids
- LOCA Downscaled CMIP5 Precipitation (1950-2099) (1/16th Degree)
  - RCP 4.5, RCP 8.5
- CMIP Tool



  - Load observed and loca5 data
  - Project 24-Hour Precipitation Quantiles using the 10-Step Procedure
- Simulate projected flood elevations

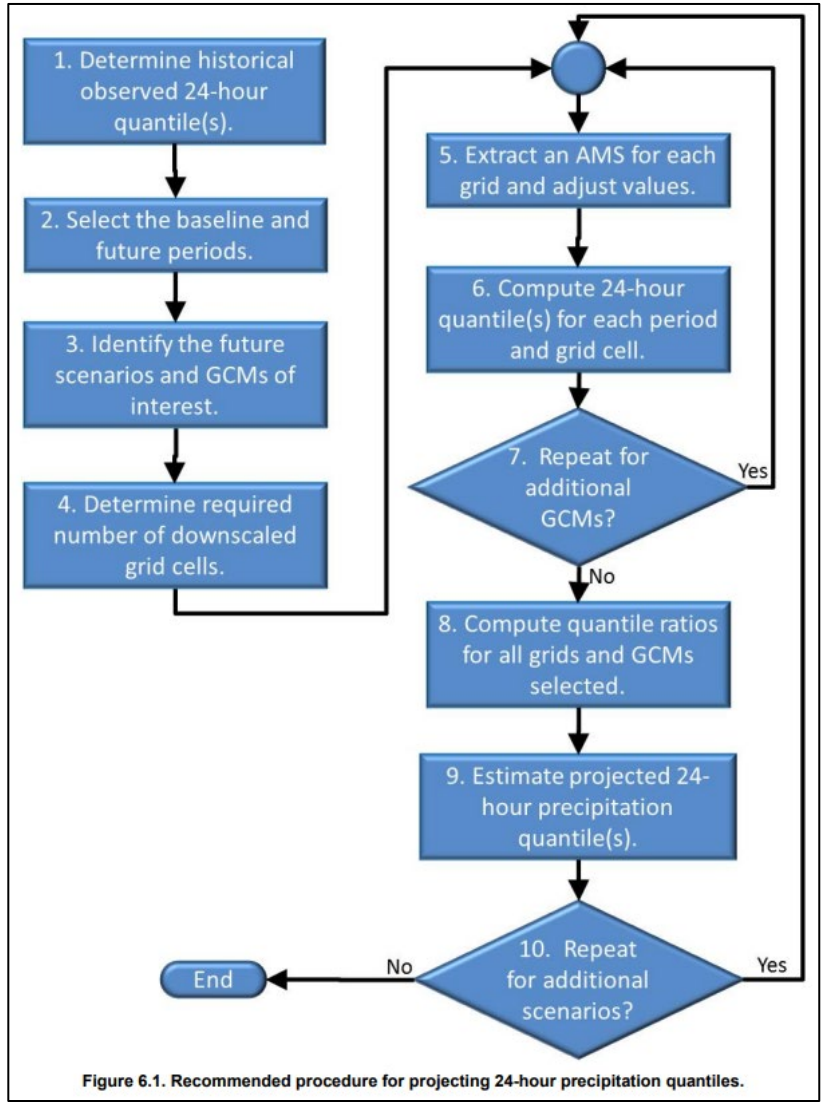


Figure 6.1. Recommended procedure for projecting 24-hour precipitation quantiles.

Results

- Area-Weighted
  - 75 downscaled CMIP5 grid cells

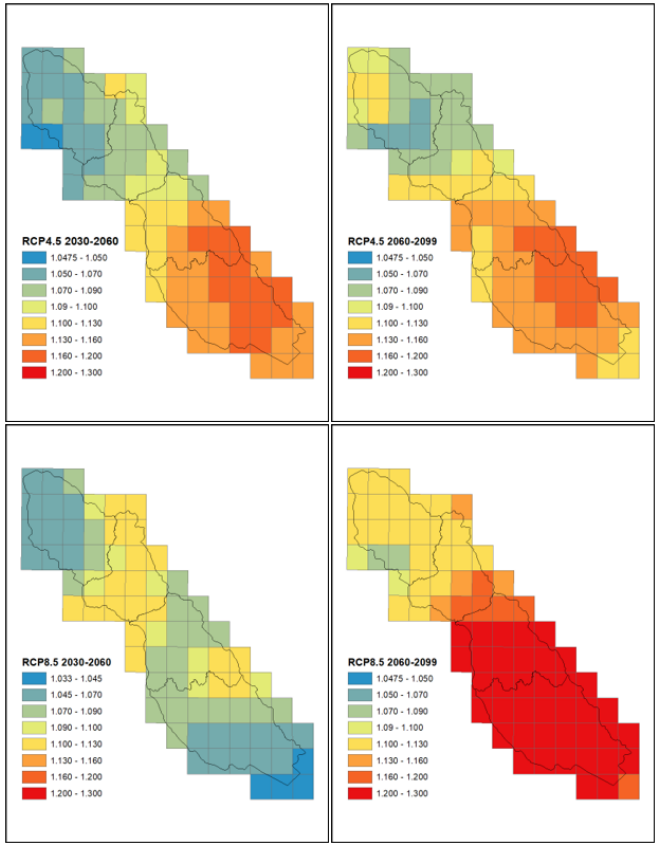
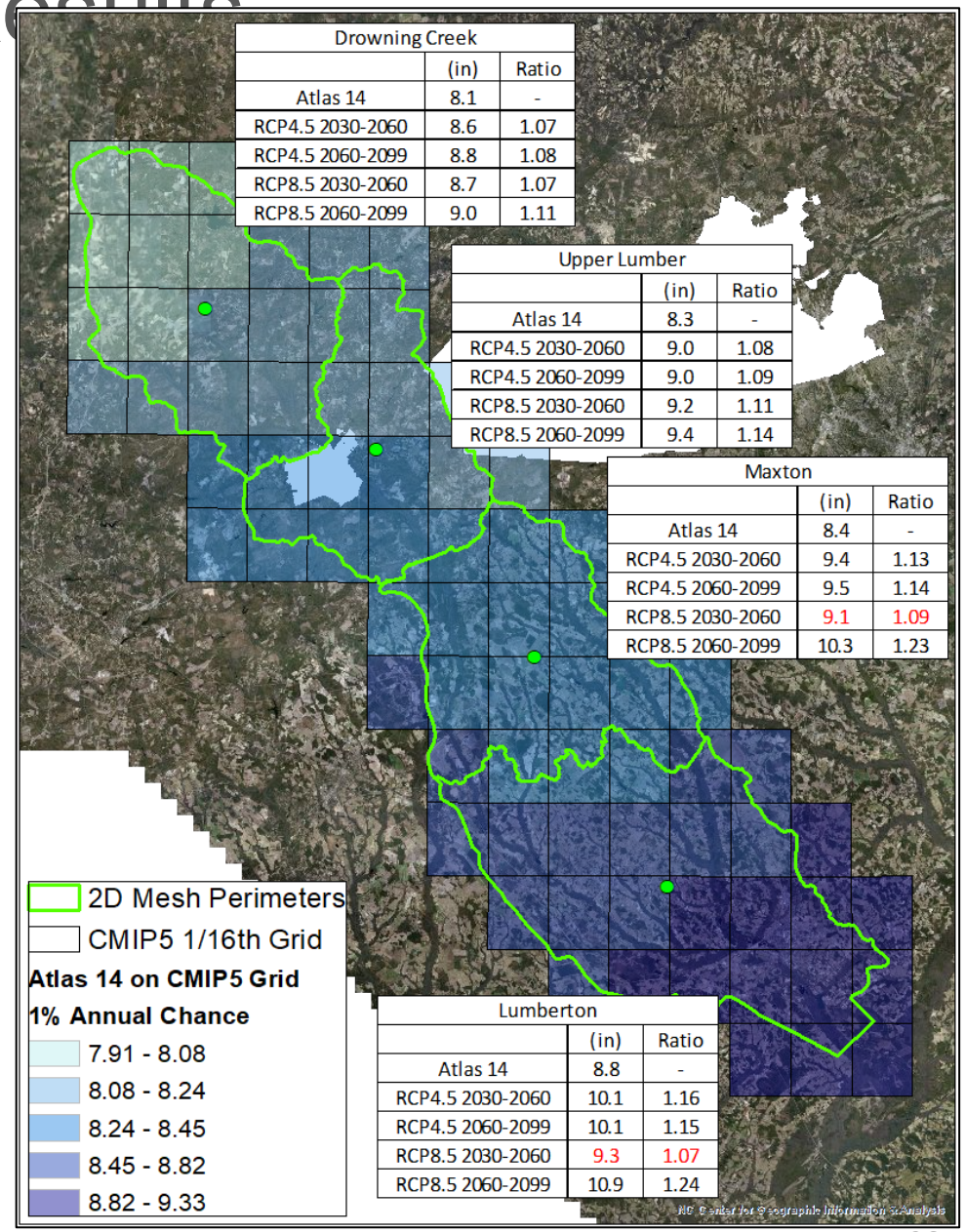


Figure 8. RCP4.5 and RCP 8.5 Gridded Projected Ratios for 2030-2060 and 2060-2099 Future Periods



Drowning Creek	(in)	Ratio
Atlas 14	8.1	-
RCP4.5 2030-2060	8.6	1.07
RCP4.5 2060-2099	8.8	1.08
RCP8.5 2030-2060	8.7	1.07
RCP8.5 2060-2099	9.0	1.11

Upper Lumber	(in)	Ratio
Atlas 14	8.3	-
RCP4.5 2030-2060	9.0	1.08
RCP4.5 2060-2099	9.0	1.09
RCP8.5 2030-2060	9.2	1.11
RCP8.5 2060-2099	9.4	1.14

Maxton	(in)	Ratio
Atlas 14	8.4	-
RCP4.5 2030-2060	9.4	1.13
RCP4.5 2060-2099	9.5	1.14
RCP8.5 2030-2060	9.1	1.09
RCP8.5 2060-2099	10.3	1.23

Lumberton	(in)	Ratio
Atlas 14	8.8	-
RCP4.5 2030-2060	10.1	1.16
RCP4.5 2060-2099	10.1	1.15
RCP8.5 2030-2060	9.3	1.07
RCP8.5 2060-2099	10.9	1.24

Results

- Centroid Grid Cell
  - 4 downscaled CMIP5 grid cells

Table 2. Area-Weighted CMIP5 Grid Cell 1% Projected Rainfall Ratios

2D Mesh / Subarea	RCP 4.5		RCP 8.5	
	Projected Rainfall			
	2030-2060	2060-2099	2030-2060	2060-2099
Drowning Creek	1.07	1.08	1.07	1.11
Upper Lumber	1.08	1.09	1.11	1.14
Maxton - Lumber	1.13	1.14	1.09	1.23
Lumberton	1.16	1.15	1.07	1.24

Table 4. Subbasin Centroid CMIP5 Grid Cell 1% Projected Rainfall Ratios (2030-2060, 2060-2099)

2D Mesh / Subarea	RCP 4.5		RCP 8.5	
	Projected Rainfall Ratios			
	2030-2060	2060-2099	2030-2060	2060-2099
-79.59375, 35.15625 (Drowning Creek)	1.07	1.08	1.09	1.11
-79.40625, 35.03125 (Upper Lumber)	1.08	1.09	1.11	1.14
-79.28125, 34.84375 (Maxton)	1.13	1.14	1.09	1.23
-79.15625, 34.65625 (Lumberton)	1.16	1.16	1.07	1.25

Results

- Centroid Grid Cell, RCP4.5 and **RCP8.5**
  - 2000-2049
  - 2030-2060
  - 2050-2099
  - **2060-2099**

Table 6. Subbasin Centroid CMIP5 Grid Cell 1% Projected Rainfall Ratios (2000-2049, 2030-2060, 2050-2099, 2060-2099)

2D Mesh / Subarea	RCP 4.5			
	Projected Rainfall Ratios			
	2000-2049	2030-2060	2050-2099	2060-2099
-79.59375, 35.15625 (Drowning Creek)	1.02	1.07	1.09	1.08
-79.40625, 35.03125 (Upper Lumber)	1.03	1.08	1.10	1.09
-79.28125, 34.84375 (Maxton)	1.06	1.13	1.15	1.14
-79.15625, 34.65625 (Lumberton)	1.09	1.16	1.16	1.16

Table 7. Subbasin Centroid CMIP5 Grid Cell 1% Projected Rainfall Ratios (2000-2049, 2030-2060, 2050-2099, 2060-2099)

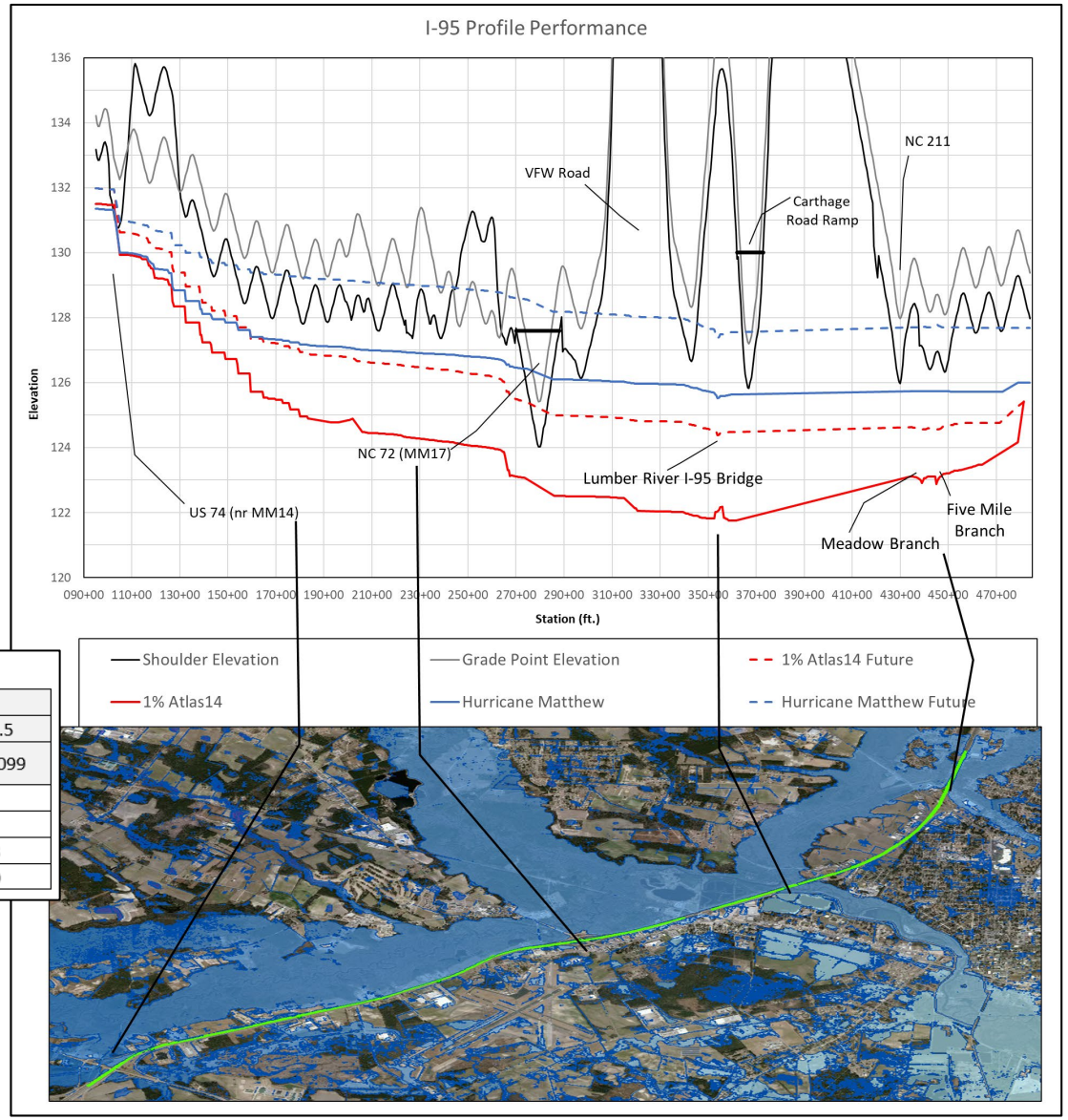
2D Mesh / Subarea	RCP 8.5			
	Projected Rainfall Ratios			
	2000-2049	2030-2060	2050-2099	2060-2099
-79.59375, 35.15625 (Drowning Creek)	1.03	1.09	1.09	**1.11**
-79.40625, 35.03125 (Upper Lumber)	1.07	1.11	1.12	**1.14**
-79.28125, 34.84375 (Maxton)	1.08	1.08	1.18	**1.23**
-79.15625, 34.65625 (Lumberton)	1.08	1.06	1.20	**1.25**

Results

- Projected 24-Hour 1% Event WSEL increase
  - US74
    - 0.5’
  - NC72
    - 2.4’
  - Lumber River bridge
    - 2.3’
  - Five Mile Branch culvert
    - 1.7’

Table 9. Future Rainfall Ratios, and 1% Atlas 14 and 1% Future Rainfall Depths

2D Mesh / Subarea	1% Projected Rainfall Ratio *(centroid method)	1% Rainfall (in)	
		Atlas 14	RCP 8.5 2060-2099
-79.59375, 35.15625 (Drowning Creek)	1.11	8.1	9.0
-79.40625, 35.03125 (Upper Lumber)	1.14	8.3	9.4
-79.28125, 34.84375 (Maxton)	1.23	8.4	10.3
-79.15625, 34.65625 (Lumberton)	1.25	8.8	11.0



Conclusions

- RCP 8.5 2060-2099 ratios selected, most aggressive
- Projected increase in rainfall for the Lumberton mesh suggests the future 24-hour 1% annual chance rainfall is half an inch less than a historical 24-hour 500-year rainfall of 11.5”.
- Using grid cells containing subarea centroids (4 grid cells) produced very similar ratios to area-weighted values (75 grid cells).
- Connectivity maintained for future 1%, not for future Matthew for sections.
- Ratios from later projected time periods may be less than from earlier

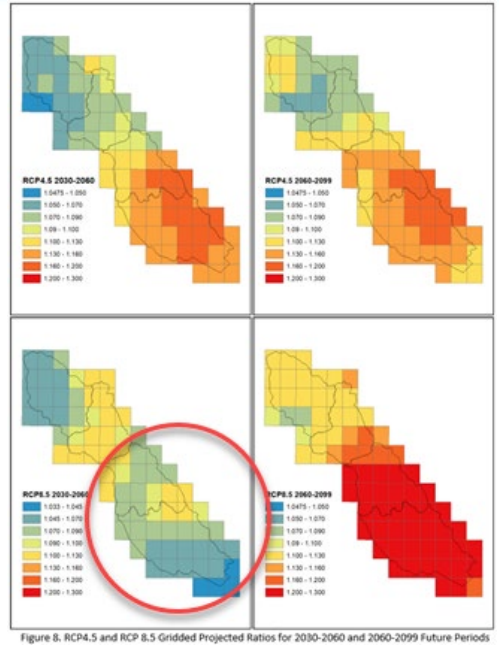


Figure 8. RCP4.5 and RCP 8.5 Gridded Projected Ratios for 2030-2060 and 2060-2099 Future Periods

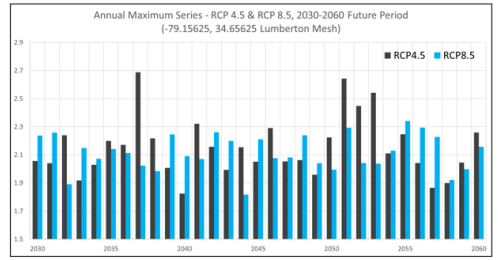


Figure 9. RCP4.5 and RCP 8.5 Projected AMS for 2030-2060 Future Period

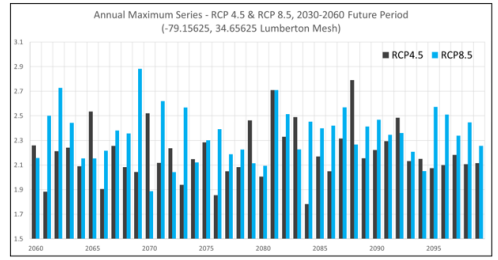


Figure 10. RCP4.5 and RCP 8.5 Projected AMS for 2060-2099 Future Period

NCDOT Climate Precipitation Research

RP-2057 – Future Precipitation for Resilient Design

PI - Dr. Jared Bowden, NCSU, Department of Applied Ecology
Co-PI, Dr. Gary Lackmann, NCSU - Marine, Earth, and Atmospheric Sciences
Co-PI, Dr. Kenneth Kunkel, NCSU - North Carolina Institute for Climate Studies
Co-PI, Dr. Kathie Dello, NCSU - State Climate Office of North Carolina
Co-I, Rebecca Ward, NCSU – State Climate Office of North

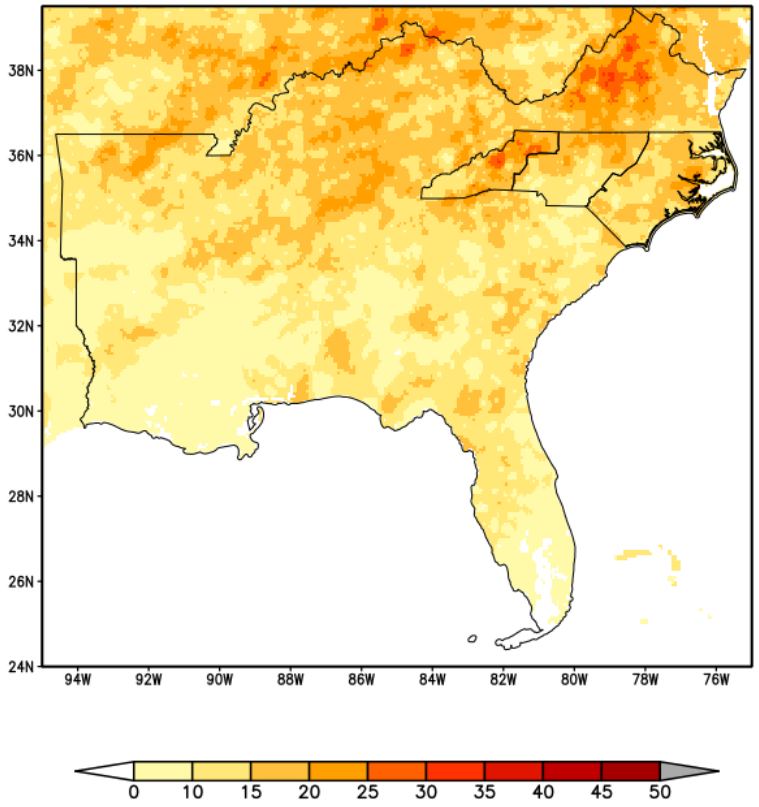
Objectives:

1. Assist NCDOT with climate adaptation
2. Improve confidence in future flood risk using:
    1. existing downscaling data/ methodologies
    2. tailored high-resolution climate model projections – Floyd, Matthew, Florence

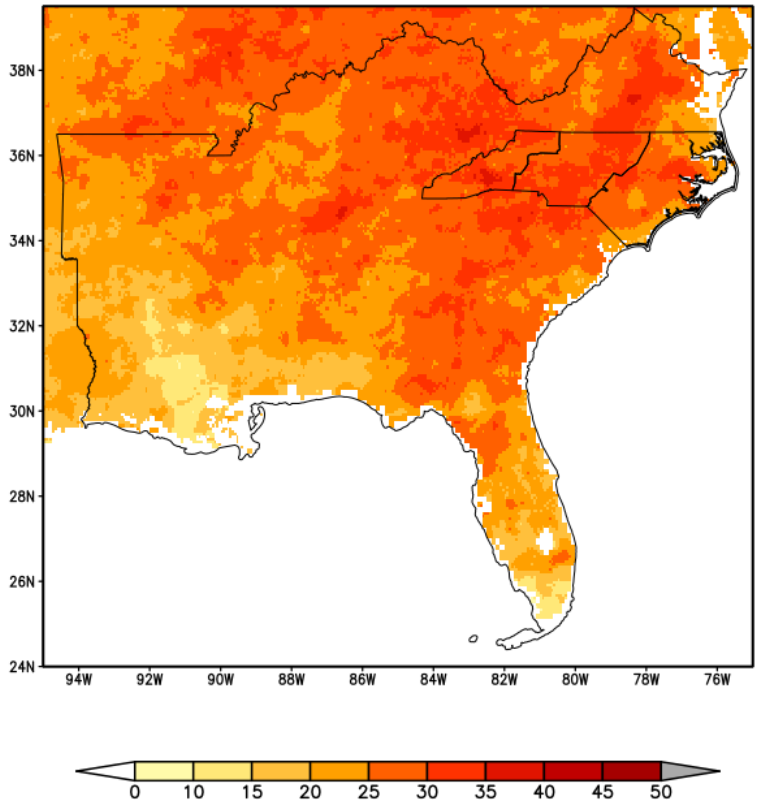
Daily (24hr duration) Annual Maximum Series Difference (%)

Average of RCP8.5 (2070-2099) Relative to Average Historical (1976-2005)

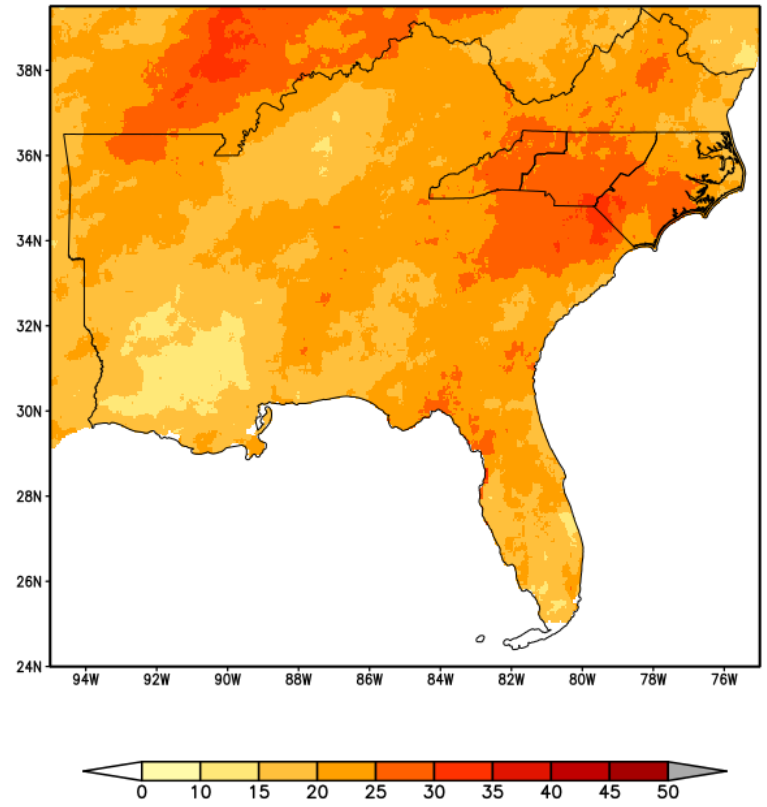
Ensemble LOCA



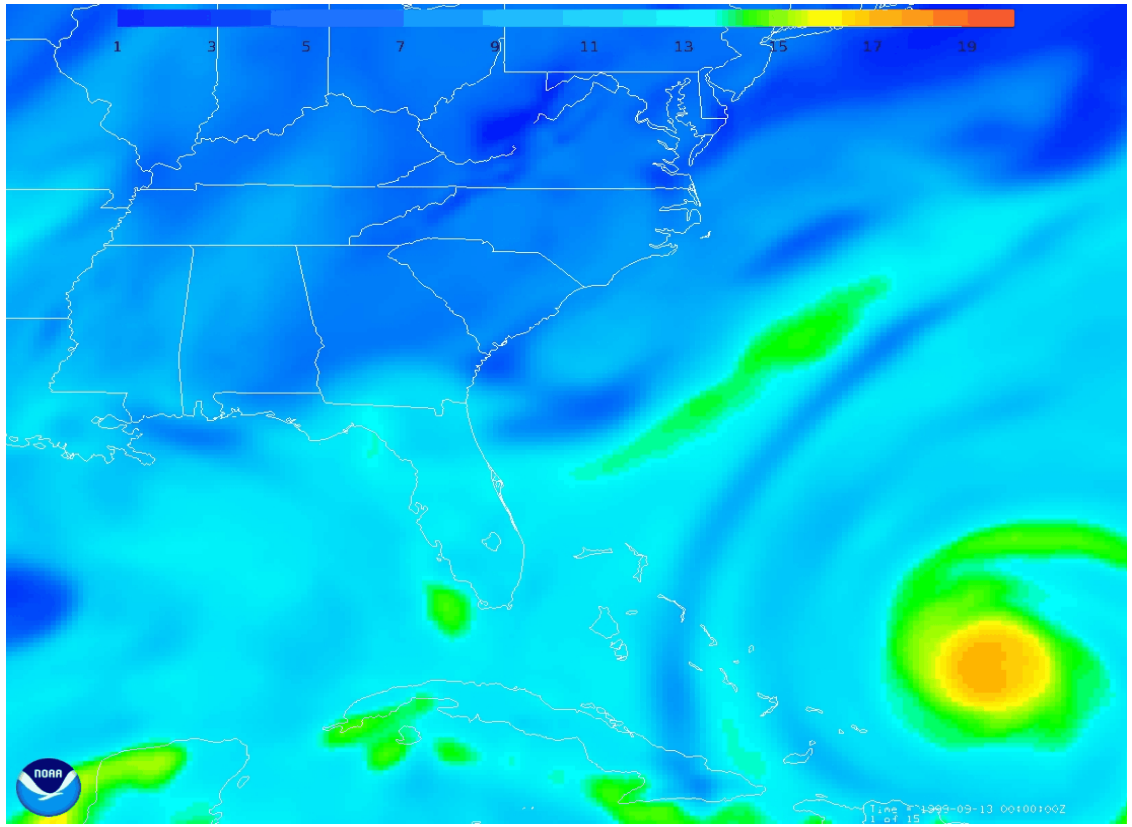
Ensemble MACA–Livneh

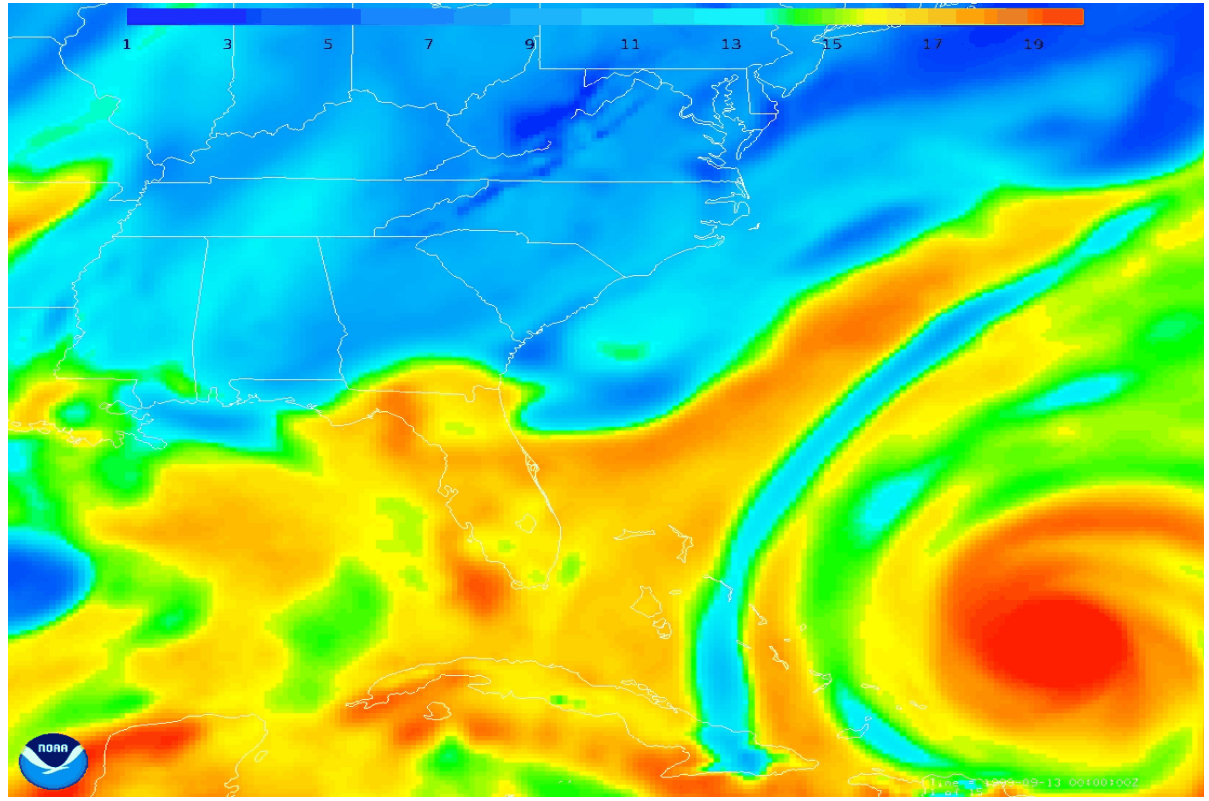


Ensemble MACA–Metdata



Hurricane Floyd: Water Vapor Comparison Loop





Current (1999)

~1.5 km altitude (.863 level) water vapor

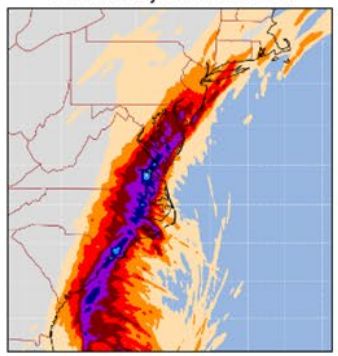
Future (2099)

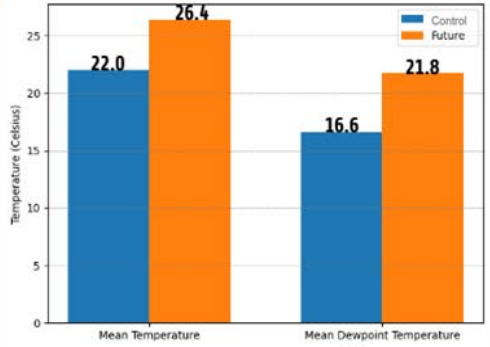
Hurricanes Floyd and Matthew in a Future Climate

Changes in Precipitation – Process and Preliminary Results

Floyd

Control: Floyd Total Rainfall

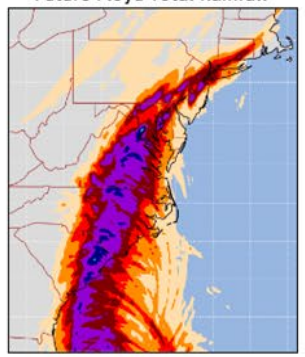


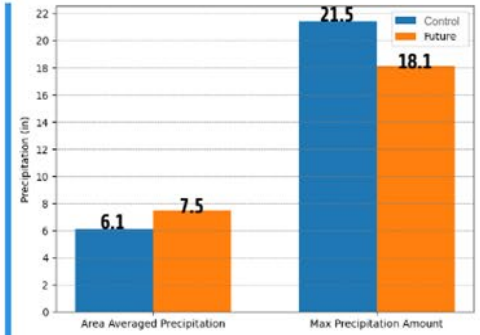


Warmer

More moisture

Future Floyd Total Rainfall





More total rainfall

Smaller max accumulation

1 Re-create precipitation from hurricane in a model simulation

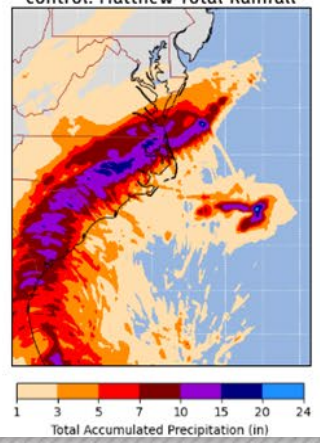
2 Adjust environment to resemble expected future climate conditions

3 Re-run simulation with expected future climate conditions

4 Compare precipitation statistics over North Carolina to control

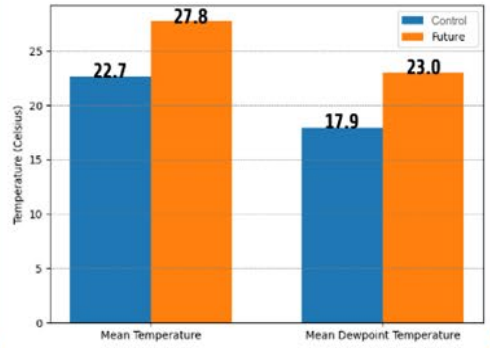
Matthew

Control: Matthew Total Rainfall

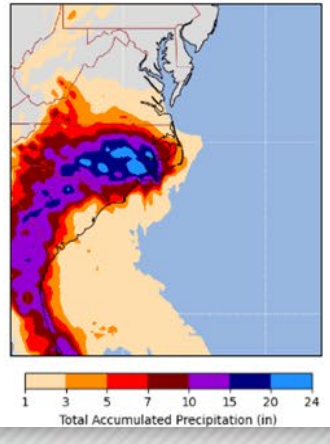


Warmer

More moisture

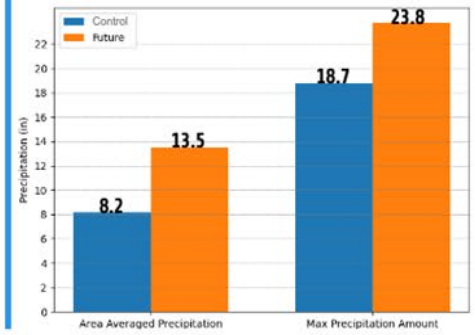


Future Matthew Total Rainfall



More total rainfall

Larger max accumulation



Next Steps:

- NCDOT /NCORR will continue to work with FHWA/NOAA to complete NC Atlas 14 update
- Complete Future Precipitation Research and develop climate adaptation design tools
- Develop climate adaptation design guidelines that incorporate future uncertainty
- Maintain strong partnerships with state, federal, and private entities

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919-621-0443

Strong Partnerships

NCORR
DEQ
ACEC
FHWA
TRB
TRANSPORTATION RESEARCH BOARD
Rijkswaterstaat
Ministry of Infrastructure and Water Management
ncarPo
NCAMPO
North Carolina Coastal Federation
NFWF
THE UNIVERSITY OF NORTH CAROLINA SYSTEM
NORTH CAROLINA CLIMATE OFFICE
AASHTO
USGS
science for a changing world
FEMA
US Army Corps of Engineers
NOAA
US Engineering Solutions

=

Questions?

Please Remember to Complete the End of Workshop Evaluation

https://bit.ly/2021EscEval

NC STATE UNIVERSITY
Crop & Soil Sciences

NORTH CAROLINA
Department of Environmental Quality
DEQ

IECA
Southeast Chapter