Florida Flood Hub Rainfall Workgroup Update

FLORIDA WATER AND CLIMATE ALLIANCE AND FLORIDA FLOOD HUB WORKSHOP

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FLORIDA FloodHub FOR APPLIED RESEARCH AND INNOVATION

Florida Flood Hub Rainfall workgroup

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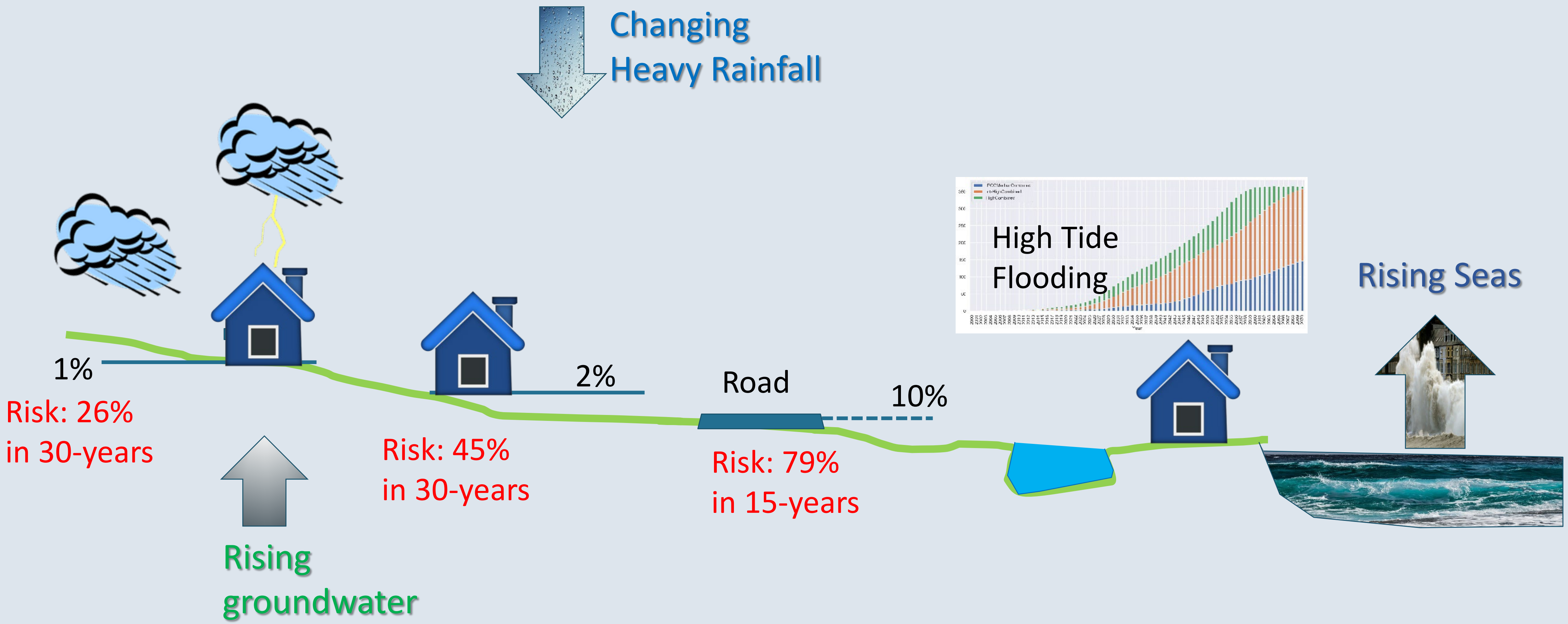
Concepts of Flood Frequency and Increasing Risk: Threat Multipliers

- A measure of flood frequency: 1% chance flood (100 Year-flood)



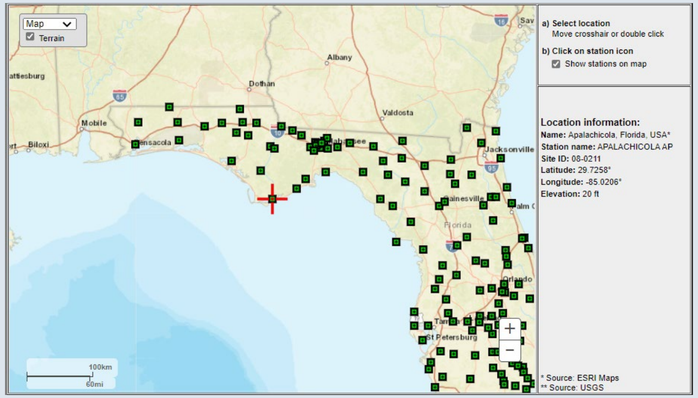
Importance of Future Rainfall Estimates: Nonstationarity

- Florida communities face increasing risks from extreme rainfall and flooding.
- Prarctitioners need accurate rainfall projections for flood management.
- Future-focused stormwater planning is critical for infrastructure resilience.
- The Florida Flood Hub is developing **extreme rainfall projections** covering the entire state
- NOAA Atlas 14 data is the current standard but lacks consideration of future conditions (being addressed by Atlas 15)

TYPE STORM DRAIN	FREQUENCY
General design	3-year
• General design work that involves replacement of a roadside ditch with a pipe system by extending side drain pipes • General design on work to Interstate Facilities	10-year
• Outfalls	25-year
• Interstate Facilities for which roadway runoff would have no outlet other than a storm drain system, such as in a sag inlet or cut section • Outlets of systems requiring pumping stations	50-year

NOAA Atlas 14

(http://hdsc.nws.noaa.gov/hdsc/pfds)



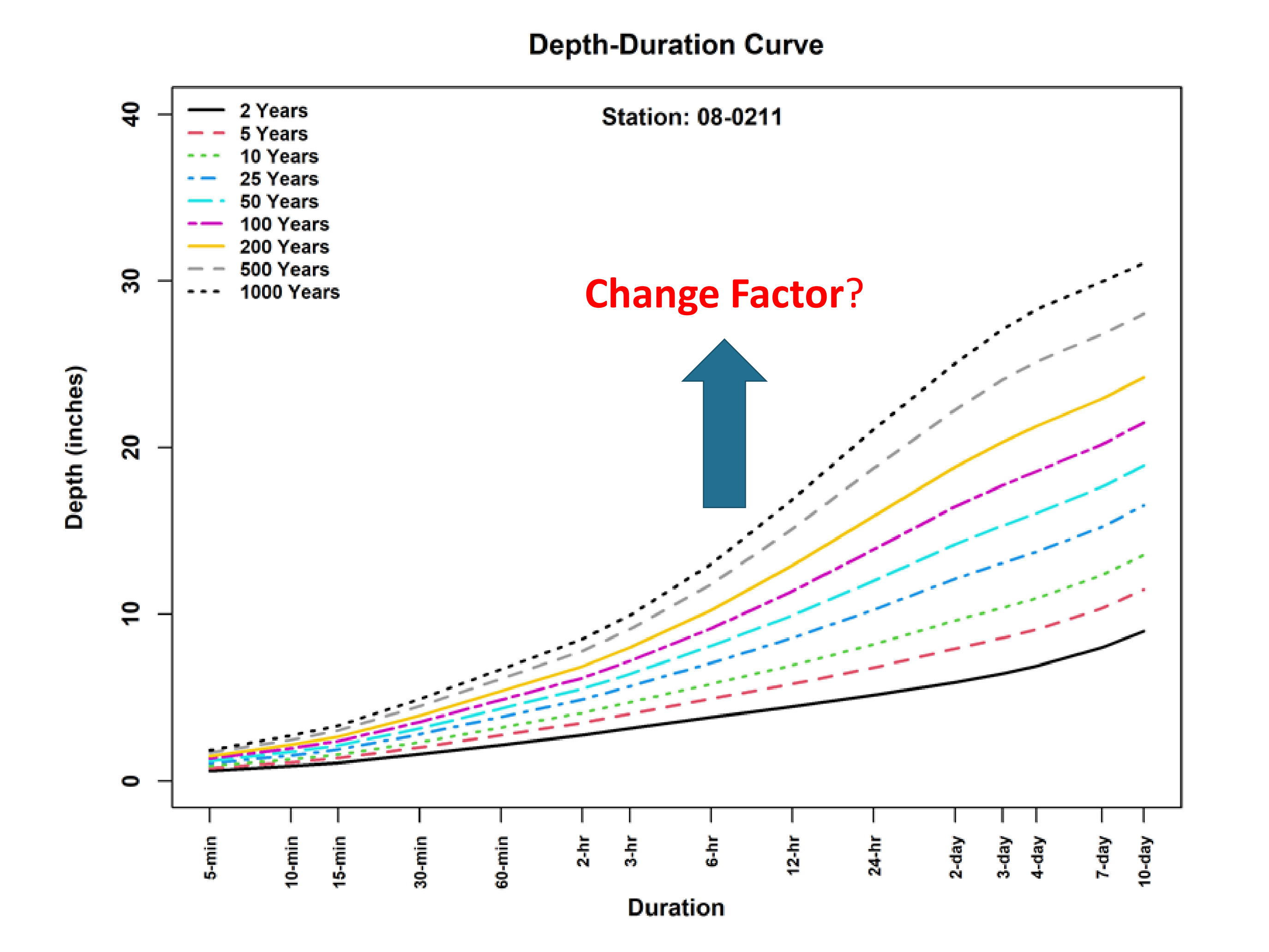
PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.580** (0.493-0.691)	**0.656** (0.557-0.781)	**0.786** (0.665-0.939)	**0.899** (0.756-1.08)	**1.07** (0.863-1.34)	**1.20** (0.944-1.53)	**1.34** (1.01-1.76)	**1.49** (1.07-2.02)	**1.70** (1.16-2.38)	**1.86** (1.23-2.65)
10-min	**0.849** (0.723-1.01)	**0.960** (0.816-1.14)	**1.15** (0.973-1.38)	**1.32** (1.11-1.58)	**1.56** (1.26-1.96)	**1.76** (1.38-2.24)	**1.96** (1.48-2.58)	**2.18** (1.56-2.96)	**2.49** (1.70-3.48)	**2.73** (1.80-3.88)
15-min	**1.04** (0.881-1.23)	**1.17** (0.995-1.40)	**1.40** (1.19-1.68)	**1.61** (1.35-1.93)	**1.90** (1.54-2.39)	**2.14** (1.69-2.73)	**2.39** (1.81-3.14)	**2.66** (1.91-3.61)	**3.03** (2.07-4.25)	**3.32** (2.19-4.73)
30-min	**1.50** (1.28-1.79)	**1.70** (1.45-2.03)	**2.05** (1.74-2.45)	**2.36** (1.98-2.83)	**2.80** (2.27-3.51)	**3.16** (2.48-4.03)	**3.53** (2.66-4.64)	**3.93** (2.81-5.33)	**4.48** (3.06-6.28)	**4.91** (3.25-6.99)
60-min	**2.03** (1.73-2.42)	**2.32** (1.97-2.77)	**2.82** (2.38-3.37)	**3.24** (2.73-3.90)	**3.86** (3.12-4.84)	**4.35** (3.42-5.54)	**4.86** (3.66-6.38)	**5.40** (3.86-7.32)	**6.14** (4.19-8.59)	**6.72** (4.43-9.55)
2-hr	**2.56** (2.19-3.03)	**2.94** (2.51-3.48)	**3.58** (3.04-4.25)	**4.13** (3.49-4.93)	**4.92** (4.00-6.12)	**5.55** (4.38-7.02)	**6.19** (4.69-8.07)	**6.87** (4.94-9.24)	**7.79** (5.35-10.8)	**8.52** (5.66-12.0)
3-hr	**2.93** (2.51-3.45)	**3.37** (2.89-3.98)	**4.13** (3.52-4.88)	**4.77** (4.04-5.68)	**5.70** (4.64-7.07)	**6.44** (5.10-8.12)	**7.21** (5.47-9.35)	**8.01** (5.78-10.7)	**9.10** (6.27-12.6)	**9.95** (6.64-14.0)
6-hr	**3.55** (3.06-4.16)	**4.11** (3.53-4.81)	**5.06** (4.34-5.95)	**5.90** (5.02-6.97)	**7.12** (5.85-8.81)	**8.12** (6.47-10.2)	**9.16** (7.00-11.8)	**10.3** (7.47-13.7)	**11.8** (8.19-16.3)	**13.0** (8.74-18.2)
12-hr	**4.16** (3.60-4.83)	**4.81** (4.16-5.60)	**5.98** (5.14-6.98)	**7.04** (6.02-8.26)	**8.63** (7.15-10.7)	**9.97** (8.01-12.5)	**11.4** (8.78-14.7)	**12.9** (9.49-17.2)	**15.1** (10.6-20.8)	**16.9** (11.4-23.5)
24-hr	**4.76** (4.14-5.50)	**5.56** (4.82-6.43)	**6.99** (6.05-8.11)	**8.31** (7.14-9.70)	**10.3** (8.62-12.7)	**12.0** (9.73-15.0)	**13.9** (10.8-17.8)	**15.9** (11.7-21.1)	**18.8** (13.2-25.7)	**21.1** (14.4-29.1)
2-day	**5.45** (4.76-6.25)	**6.42** (5.60-7.37)	**8.16** (7.09-9.41)	**9.76** (8.43-11.3)	**12.2** (10.2-14.9)	**14.2** (11.6-17.7)	**16.5** (12.8-21.0)	**18.9** (14.0-24.8)	**22.3** (15.8-30.2)	**25.0** (17.2-34.3)
3-day	**5.96** (5.22-6.81)	**6.98** (6.11-7.98)	**8.83** (7.70-10.1)	**10.5** (9.12-12.2)	**13.1** (11.1-16.0)	**15.4** (12.5-19.0)	**17.7** (13.9-22.6)	**20.3** (15.2-26.7)	**24.1** (17.1-32.6)	**27.1** (18.6-37.0)
4-day	**6.39** (5.61-7.28)	**7.44** (6.52-8.48)	**9.34** (8.16-10.7)	**11.1** (9.64-12.8)	**13.8** (11.6-16.8)	**16.1** (13.2-19.8)	**18.6** (14.6-23.6)	**21.3** (15.9-27.8)	**25.1** (18.0-33.9)	**28.3** (19.5-38.5)
7-day	**7.45** (6.57-8.45)	**8.60** (7.57-9.76)	**10.6** (9.33-12.1)	**12.5** (10.9-14.3)	**15.3** (12.9-18.5)	**17.7** (14.5-21.6)	**20.2** (15.9-25.4)	**22.9** (17.2-29.8)	**26.8** (19.2-35.9)	**30.0** (20.8-40.6)
10-day	**8.39** (7.41-9.48)	**9.62** (8.49-10.9)	**11.8** (10.4-13.4)	**13.7** (12.0-15.6)	**16.6** (14.0-19.9)	**19.0** (15.6-23.1)	**21.5** (17.0-26.9)	**24.2** (18.2-31.3)	**28.0** (20.2-37.4)	**31.1** (21.6-42.0)
20-day	**11.1** (9.86-12.5)	**12.6** (11.2-14.1)	**15.1** (13.3-17.0)	**17.2** (15.1-19.5)	**20.3** (17.2-24.0)	**22.8** (18.8-27.3)	**25.4** (20.1-31.3)	**28.0** (21.2-35.8)	**31.7** (22.9-41.9)	**34.6** (24.3-46.5)
30-day	**13.5** (12.0-15.1)	**15.2** (13.5-17.0)	**18.0** (15.9-20.1)	**20.3** (17.9-22.9)	**23.6** (20.0-27.6)	**26.1** (21.6-31.1)	**28.7** (22.8-35.3)	**31.4** (23.8-39.8)	**35.0** (25.4-45.9)	**37.8** (26.6-50.5)
45-day	**16.6** (14.8-18.5)	**18.6** (16.6-20.7)	**21.8** (19.4-24.4)	**24.4** (21.5-27.4)	**27.9** (23.7-32.4)	**30.6** (25.3-36.2)	**33.2** (26.4-40.4)	**35.9** (27.2-45.1)	**39.2** (28.5-51.1)	**41.8** (29.5-55.6)
60-day	**19.4** (17.3-21.5)	**21.6** (19.3-24.0)	**25.2** (22.4-28.1)	**28.1** (24.8-31.4)	**31.8** (27.0-36.6)	**34.5** (28.6-40.6)	**37.2** (29.6-45.0)	**39.7** (30.2-49.7)	**42.9** (31.2-55.5)	**45.2** (32.0-59.9)

[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.



High-Level Strategy & Approximate Timelines

Nov 2022 | July 2023 | May 2024 | June 2025?

Short Term
Short Term
Florida Flood Hub
& USGS

- State-wide change factors (CMIP5 downscaled)
- CMIP5 Data Release & Analysis
- CMIP6 Data Release & Analysis
- Report Release

Long Term
Long Term
Florida Flood Hub
& SFWMD*
USGS
FSU
UM

- UM, FSU, and USGS conduct five 10-year ensemble integrations.
- Covers retrospective and warming scenarios (totaling 150 simulated years). Simulations are staggered, with CESM feeding FSU-RCM, then USGS-WRF. USGS WRF precipitation data validated against historical climate records
- Computation performed on high-performance computing platforms at UM, FSU, and USGS.

*SFWMD is working on DEP Grant Funds, SFWMD-UM agreement, SFWMD-Flood Hub for the long-term effort

Short Term: Available Climate Model Datasets

CMIP5

- **LOCA** : Statistical. Localized Constructed Analogues product by University of California at San Diego.
- **MACA** : Statistical. Multivariate Adaptive Constructed Analogs.
- **CORDEX** : Dynamical. North American Coordinated Regional Downscaling Experiment
- **JupiterWRF** : Hybrid
- **Durations:** 1, 3, 7 , and 10 days
- **Return periods:** 5-200 years

Irizarry-Ortiz, M.M., Stamm, J.F., Maran, C., and Obeysekera, J., 2022, Development of projected depth-duration frequency curves (2050–89) for south Florida: U.S. Geological Survey Scientific Investigations Report, https://doi.org/10.3133/sir20225093.

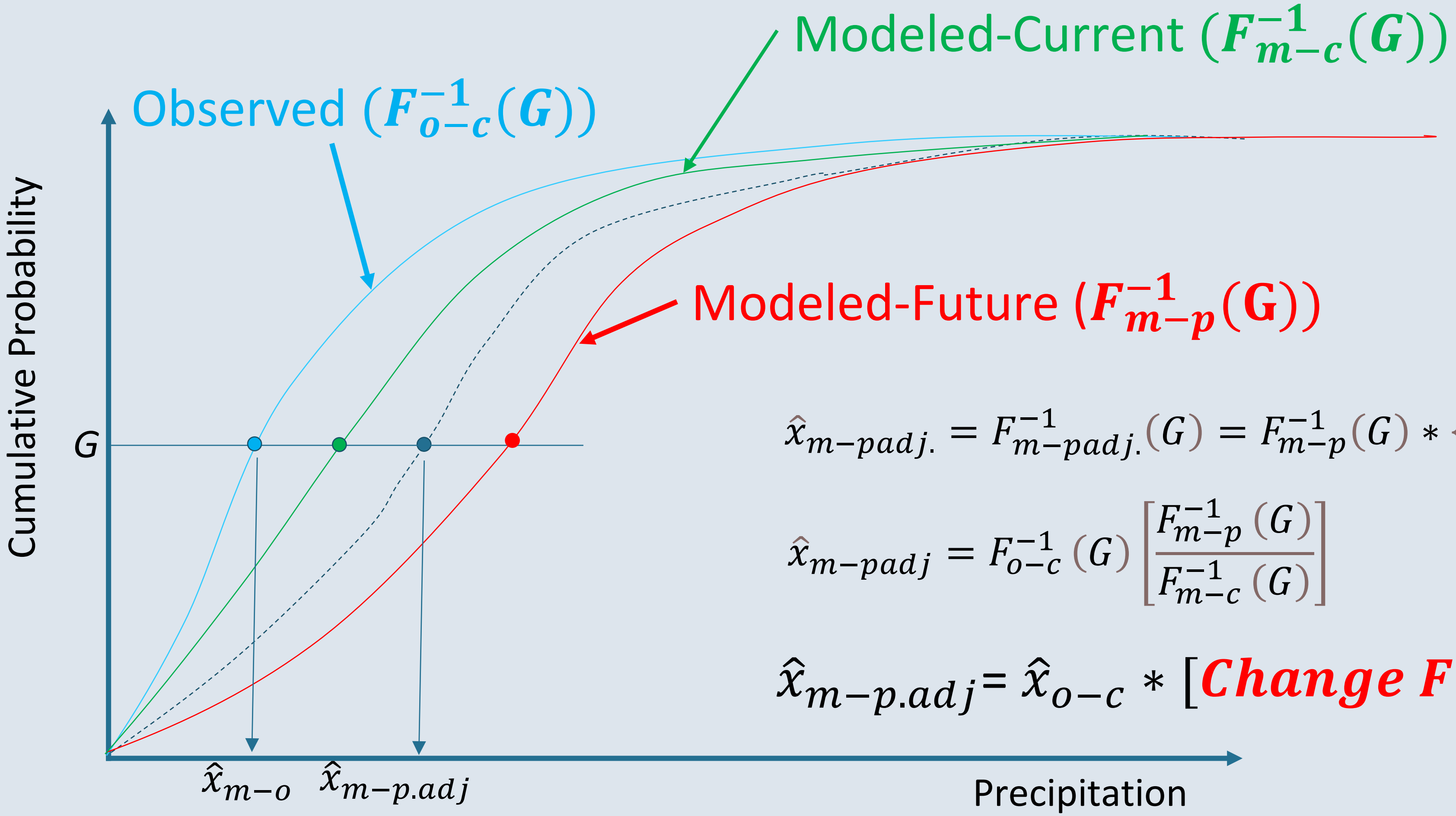
CMIP6

- **NASA** Earth Exchange Global Daily Downscaled Projections
- **LOCA2:** Localized Constructed Analogues version 2 dataset.

The emission scenarios available for LOCA2 include SSP2-4.5, SSP3-7.0, and SSP5-8.5. The NASA dataset includes these in addition to the SSP1-2.6 scenario.

Michelle M. Irizarry-Ortiz, 2023, Change factors to derive projected future precipitation depth-duration-frequency (DDF) curves at 242 National Oceanic and Atmospheric Administration (NOAA) Atlas 14 stations in Florida (ver. 2.0, May 2024): U.S. Geological Survey data release, https://doi.org/10.5066/P9Q3LEIL.

Multiplicative Quantile Delta Mapping



$$\hat{x}_{m-padj.} = F^{-1}_{m-padj.}(G) = F^{-1}_{m-p}(G) * \left\{\frac{F^{-1}_{o-c}(G)}{F^{-1}_{m-c}(G)}\right\}$$

$$\hat{x}_{m-padj} = F^{-1}_{o-c}(G)\left[\frac{F^{-1}_{m-p}(G)}{F^{-1}_{m-c}(G)}\right]$$

$$\hat{x}_{m-p.adj} = \hat{x}_{o-c} * [\textit{Change Factor, CF}]$$

Technical Approach

- **Constrained maximum likelihood (CML) approach** to fitting all durations at once (motivated by Polarski, 1989):

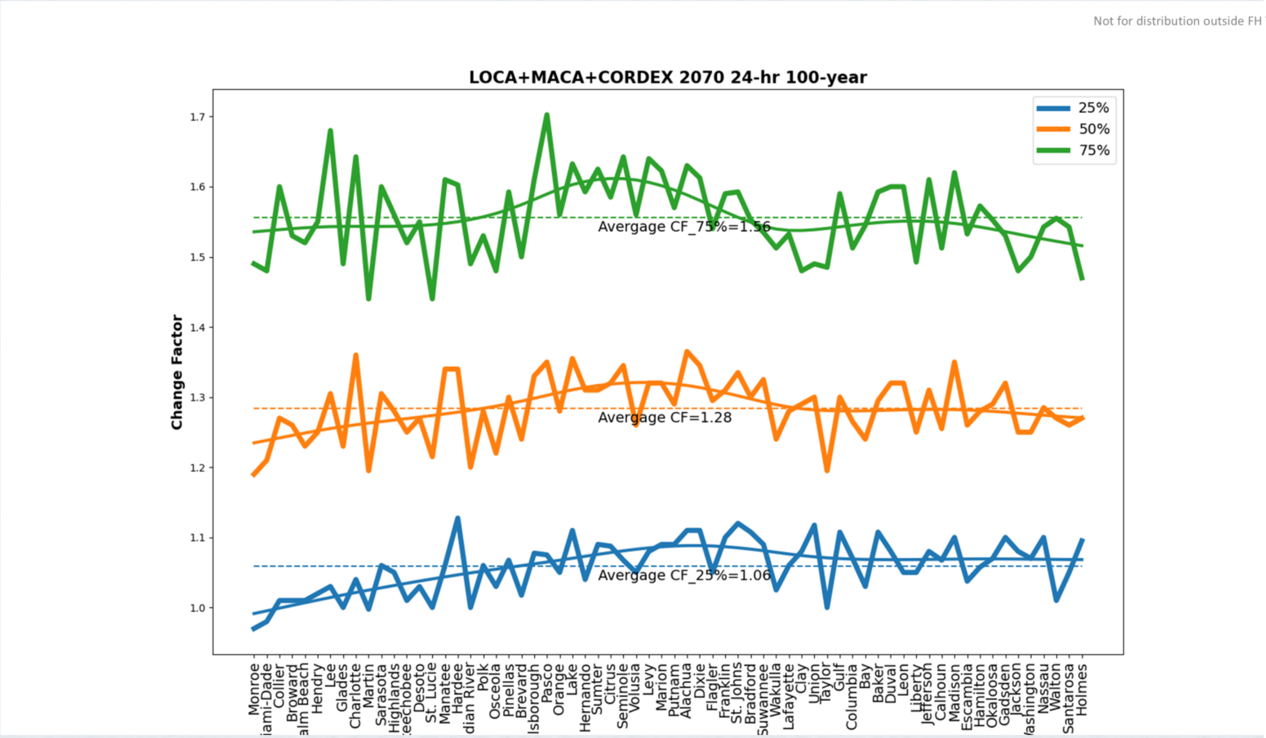
$$\tilde{\sigma}(d) = a_0 + b_0 d$$
$$\xi(d) = a_1 + b_1 d$$

- Assuming that excesses are independent across durations, the joint log-likelihood for GPD fitting all durations at once can be formulated in terms of scale and shape parameters that are a linear function of duration
- In addition to constraints in the traditional ML approach, here we add **constraints to ensure that return levels for a given duration are larger than for a shorter duration** up to a sufficiently high return period (here 1,000 years).

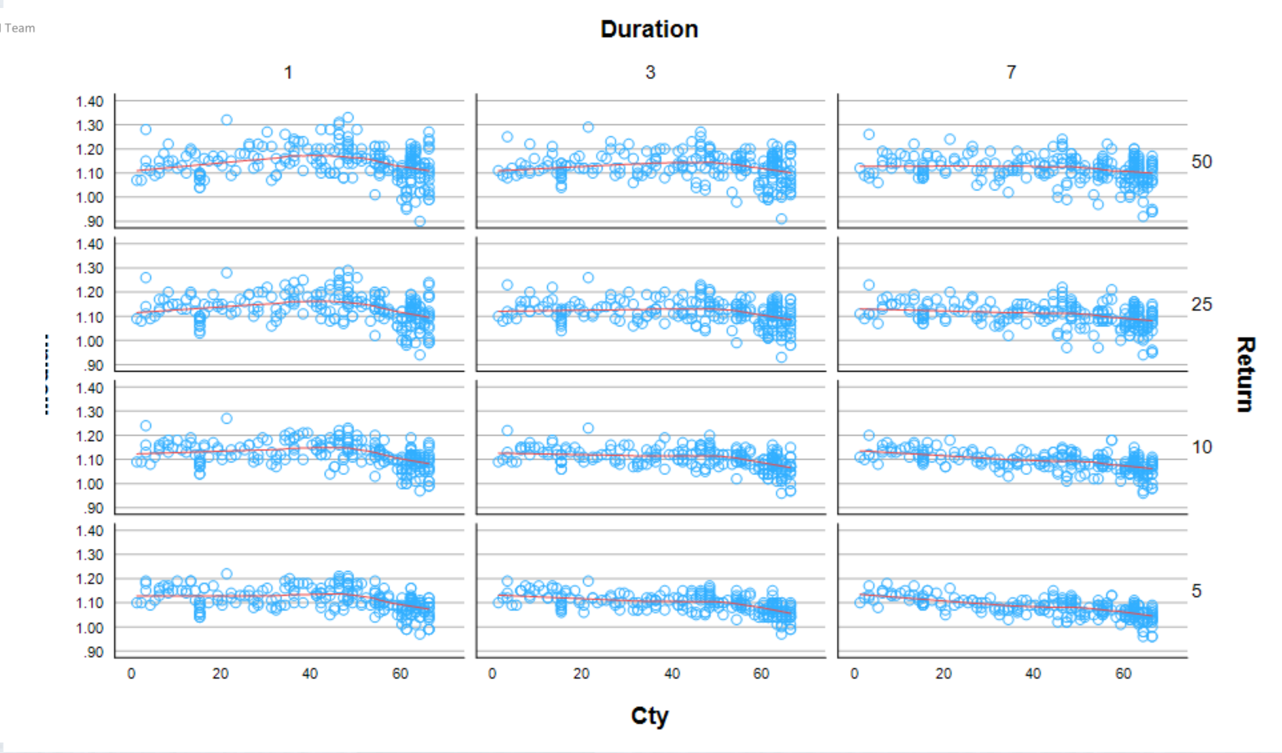
- **Model selection criteria**
  - extremes indices from Expert Team on Climate Change Detection Indices (ETCCDI).
  - Two observational datasets: PRISM and SFWMD Super-grid for the period 1981-2005.
  - 4 indices for annual maxima of various durations (1, 3, 5, 7 days) used in model culling for central FL and south FL regions. 11 additional indices used to inform overall dataset performance.
  - Evaluation based on how well the models reproduce the observed climatology and interannual variability of climate extreme indices.

Spatial pattern in CMIP6

CMIP5: All Datasets, 2070, 100 Year

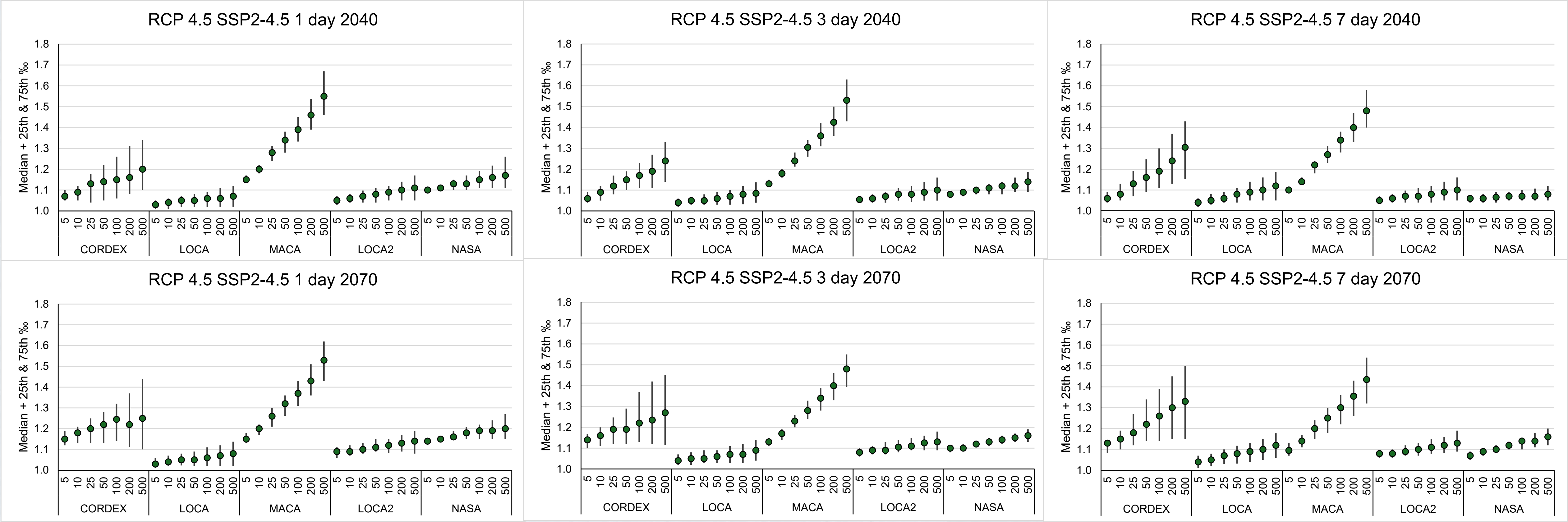


CMIP6: LOCA2 RCP 8.5/SSP5-8.5 2070



Range 0.9–1.4

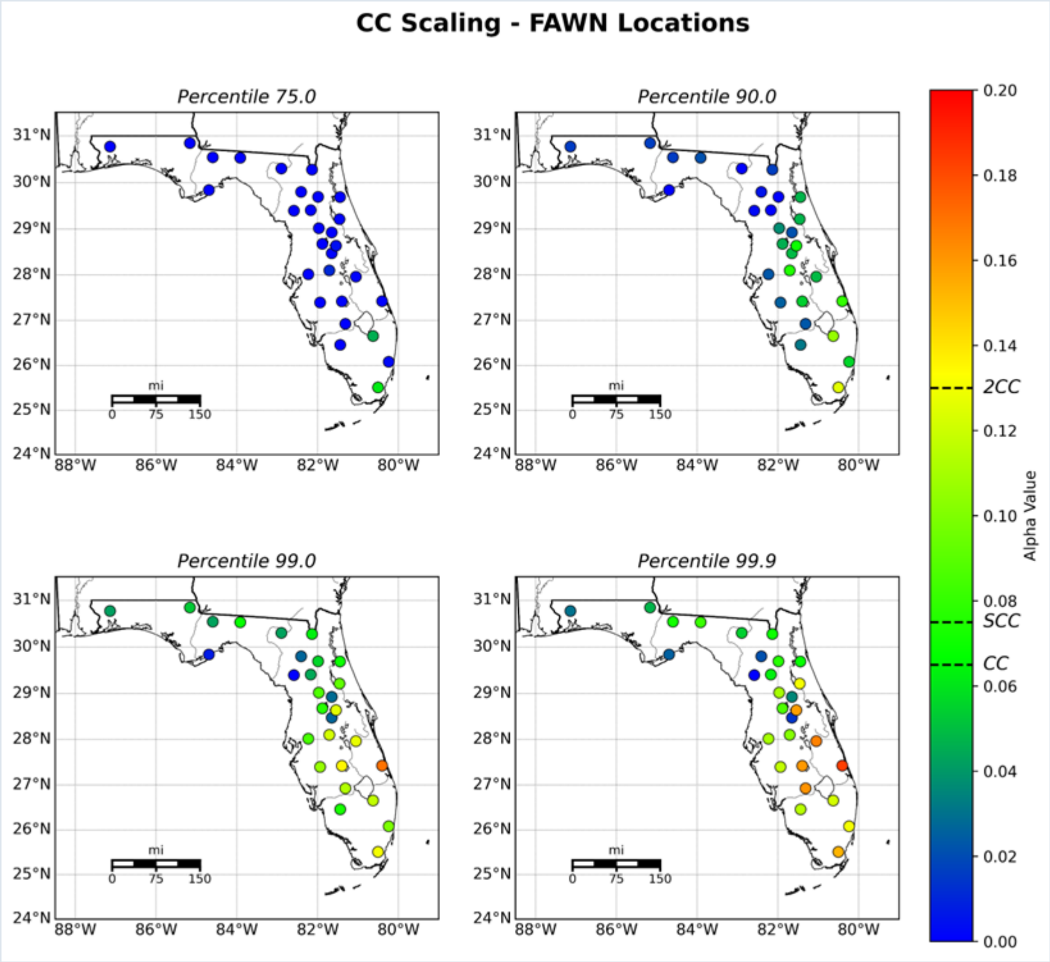
CMIP5 & CMIP6



242 stations

Temperature Scaling

- Deriving the exponential relationship between precipitation and temperature to find the rate of change (slope) Jones, et. et al. (2010):
  - $P_{t+\Delta t} = P_t(1 + \alpha)^{\Delta t}$
- Results in the increase of the water-holding capacity of the atmosphere by ~ 7% for every 1°C (1.8°F) rise in temperature (empirically): **Clausius-Clapeyron (CC)**
  - > 7% = Super relationship (SCC)
  - > 14% = Double relationship (2CC)



- Credit: Samuel Robles et al. FIU

CMIP6 & Clausius-Clapeyron scaling (DRAFT)

IPCC value – 0.85 °C to adjust from 1850-1900 baseline

SSP	Increase in global surface temperature (°C)				
	2021-2040	2041-2060	2061-2070*	2071-2080*	2081-2100
2-4.5	0.65	1.15	1.29	1.43	1.85
3-7.0	0.65	1.25	1.55	1.85	2.75
5-8.5	0.65	1.55	1.95	2.35	3.55

SSP	CC-based Change factor	
	2040	2070
2-4.5	1.05	1.09
3-7.0	1.05	1.11
5-8.5	1.05	1.14

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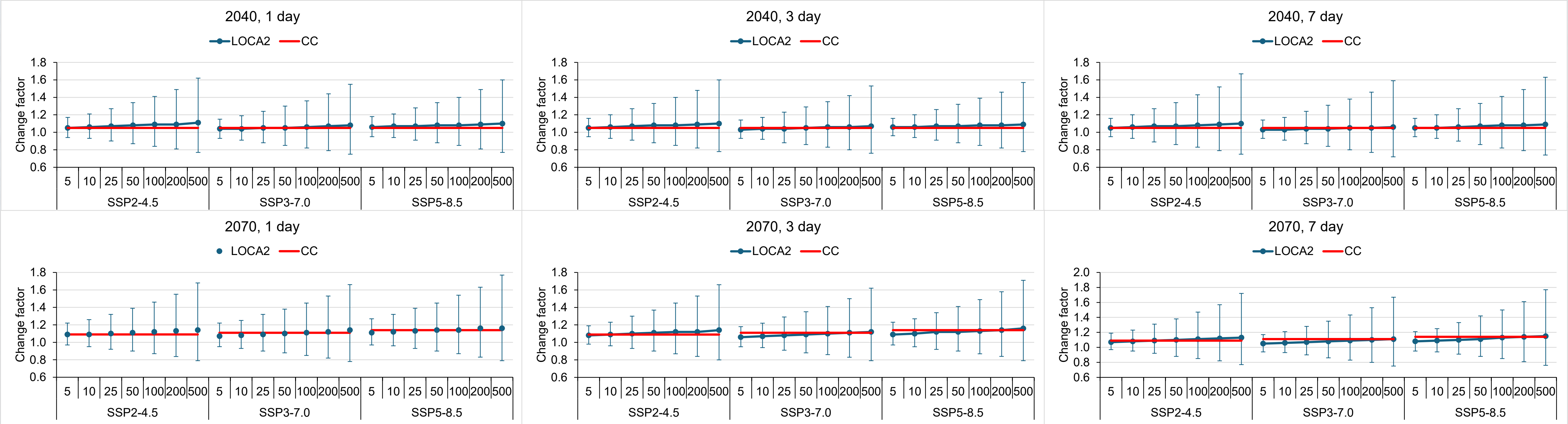
CMIP6 & Clausius-Clapeyron scaling

Median, 17th ‰, and 83rd ‰



Questions & Decisions

- CMIP5, CMIP6, or CMIP5 + CMIP6? **CMIP6**
- Individual datasets or combine (LOCA2 & NASA)? **LOCA2 only**
- Individual SSPs or combine? **Individual**
- Spatially differentiated values or statewide values? **Statewide values**
- Cull using Clausius-Clapeyron scaling? **Probably not – medians are consistent**

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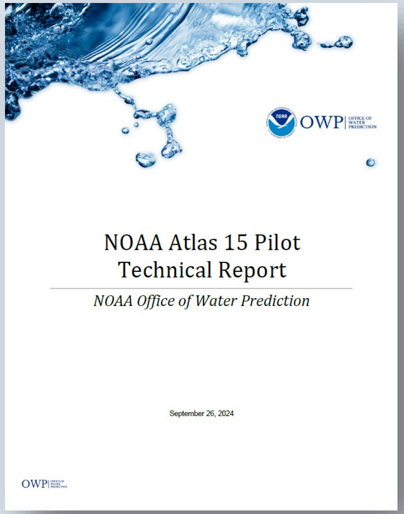
Atlas 15

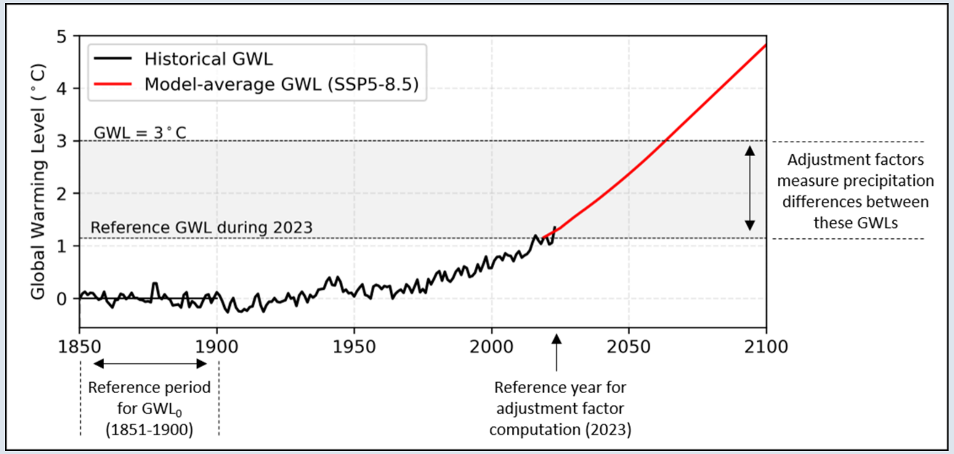
- ➢ NOAA Atlas 15 Pilot-Montana
- ➢ Volume 1-Historical data+trends
- ➢ Volume 2-Downscaled projections under different emission scenarios
- ➢ Non-stationary Generalized Extreme Value methods are being applied to model data
  - ✓ Annual Maximum Series data
  - ✓ Global Warming Level as covariate **– all climate model analysis is being performed in the GWL framework**
  - ✓ **For estimates based on scenarios and time, GWL results are transformed into that variable space**



$$PF_{VOL2}(x,t) = (1 + 0.01 \times AF(x,t)) \times PF_{VOL1}(x)$$

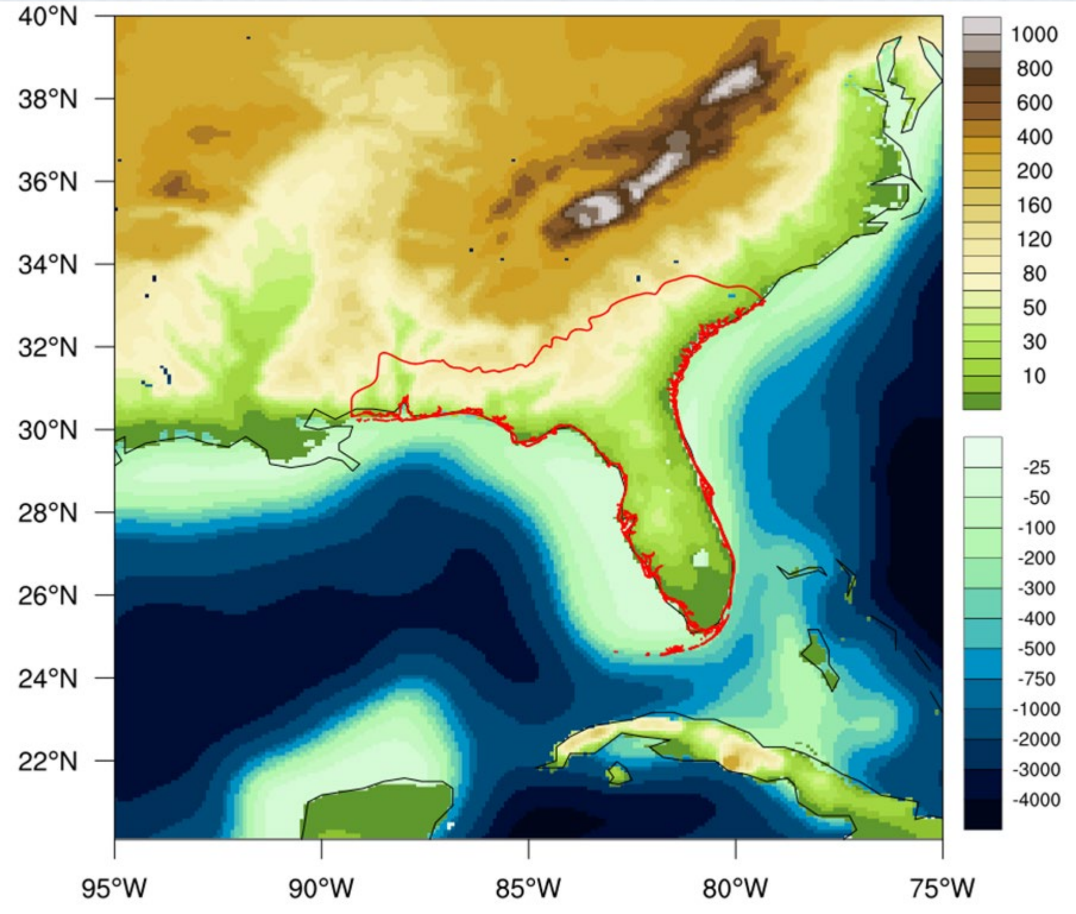
PF = Precipitation Frequency Value

"AF" = Climate Change Adjustment Factor (%) ~f(GWL, GHGpathway, Time, Location, Duration)



- Credit: Ken Kunkel

Long-Term Effort: The value of dynamical downscaling (FSU)



- Historical run from CESM2: 1986 - 2014 (from CMIP6)
- Atmosphere component (CAM6) - 1.25° longitude x 0.95° latitude ; Ocean component (POP2) - nominal 1° horizontal resolution
- The regional climate model RSM-ROMS runs at 10 km grid spacing both for atmosphere (RSM) and ocean (ROMS) component

Selected Highlights

- RSM-ROMS shows a robust Loop Current System
- Improves some of the seasonal mean bias in precipitation, and surface temperature relative to coarse resolution CESM2 historical run
- Shows reasonable fidelity of diurnal variations of precipitation in the summer

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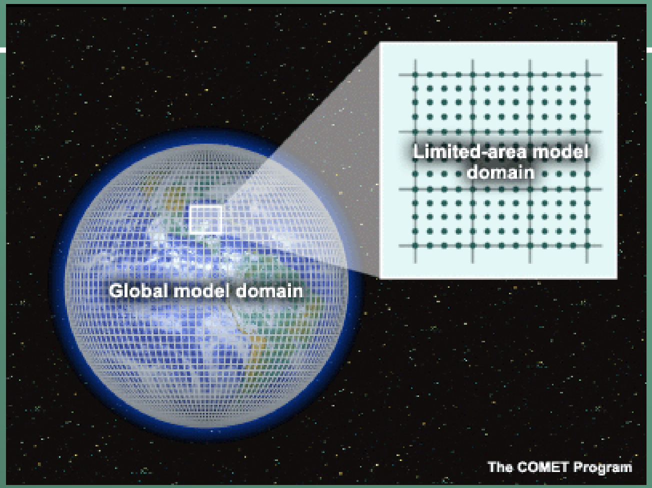
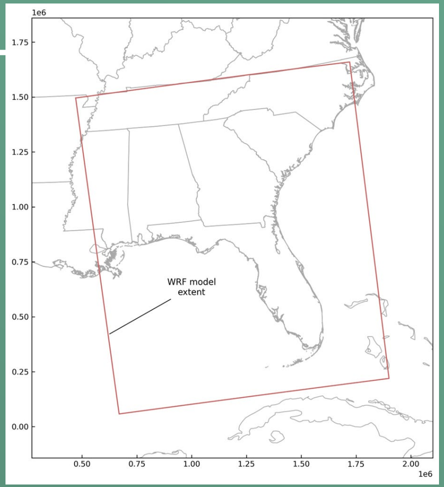
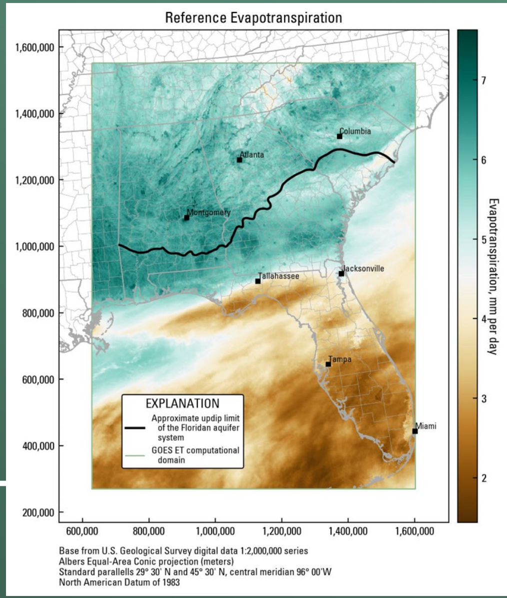
- Credit: Vasu Misra

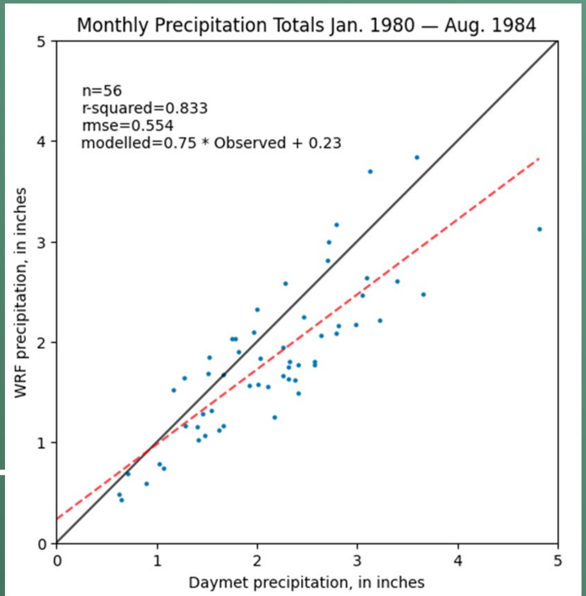
Historical Reanalysis with WRF: 1975-2020

- Long-term simulation of weather over SE USA for 1975-2020 at 4km
- Performance results (warm/wet, cold/dry, etc.) used to analyze bias of the model which will be applied to future warming-scenarios
- Simulation currently underway, results available through August 1984
- Comparison of 56 monthly precip totals vs Daymet shows a dry-bias









USGS

Summary Points

- Extensive analysis of climate model data provides the basis for estimates of future changes from a range of levels of increased greenhouse gas forcing
- Future changes are applied as adjustments to observations-based present-day precipitation frequency values
- Adjustment magnitudes:
  - Increase with decreasing annual exceedance probability (larger increases for the rarer levels)
  - Increase for shorter durations (larger increase for hourly durations than for daily durations
  - Increase with higher global warming levels (of course)