Climate Impacts to Restoration Practices

Restoration Research Question B.4 (Grant # 19278)

Chesapeake Bay Trust Pooled Monitoring Forum

June 21, 2023

Jon Butcher, Tetra Tech,

In conjunction with:

Dr. David Sample, Dr. Tess Thompson, Sami Towsif Khan, Virginia Tech

Prior work under Grant #16928 (2019-2021)

- Developed methods and estimated future climate-modified intensity-duration-frequency (IDF) curves for all MD NOAA Atlas 14 stations
- Evaluated impacts on infrastructure, BMPs, channel restoration stability
- Conclusions
  - Infrastructure such as road culverts likely inadequate to address future large storm events
  - Risk to channel stability will increase, should be a factor in restoration design
  - Smaller storms (e.g., current 90th percentile event will likely not increase in frequency; Environmental Site Design adequate to address future water quality
- Caveats:
  - Results depend on downscaled climate product (LOCA)
  - Analyses based on design storms may not reflect responses of real streams

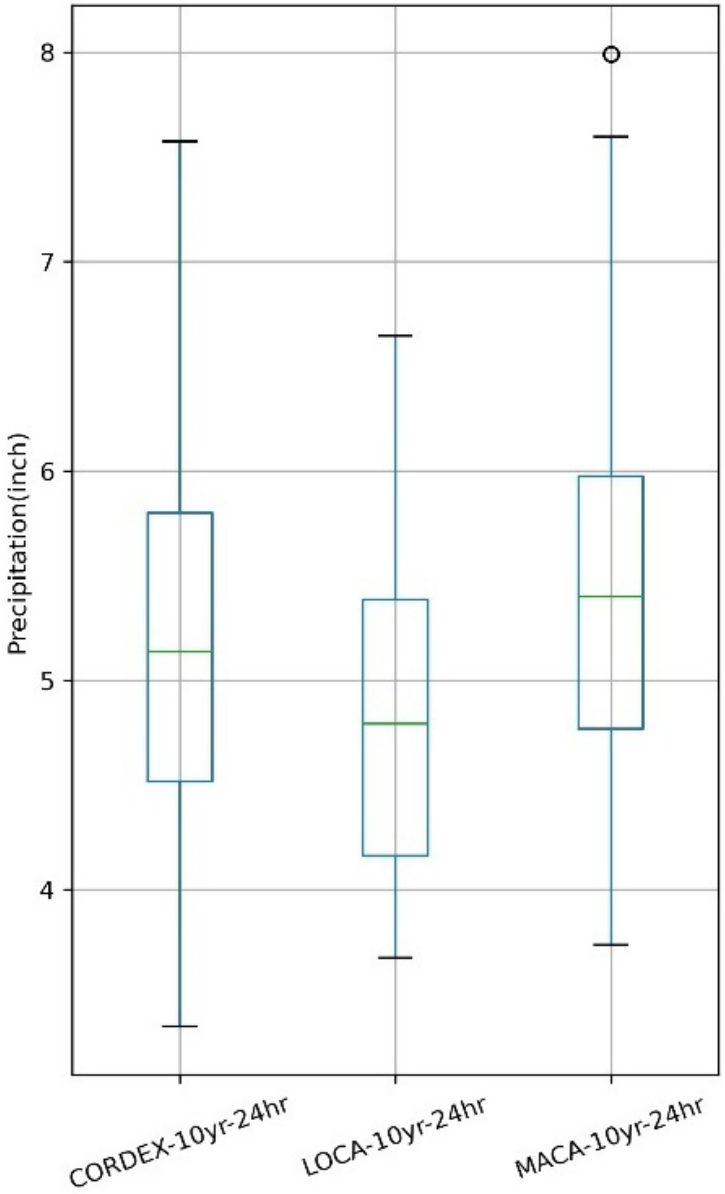
Hypotheses for Grant 19278:

- **H1**. Downscaling methodology introduces biases
- **H2**. Current Environmental Site Design (ESD) requirements will be sufficient to meet management objectives under future climate
- **H3.** Conclusions will hold up under continuous simulation of real watersheds

Results for H1 and H2 presented last year are summarized here. H3 is addressed in Dr. Thompson's presentation this afternoon.

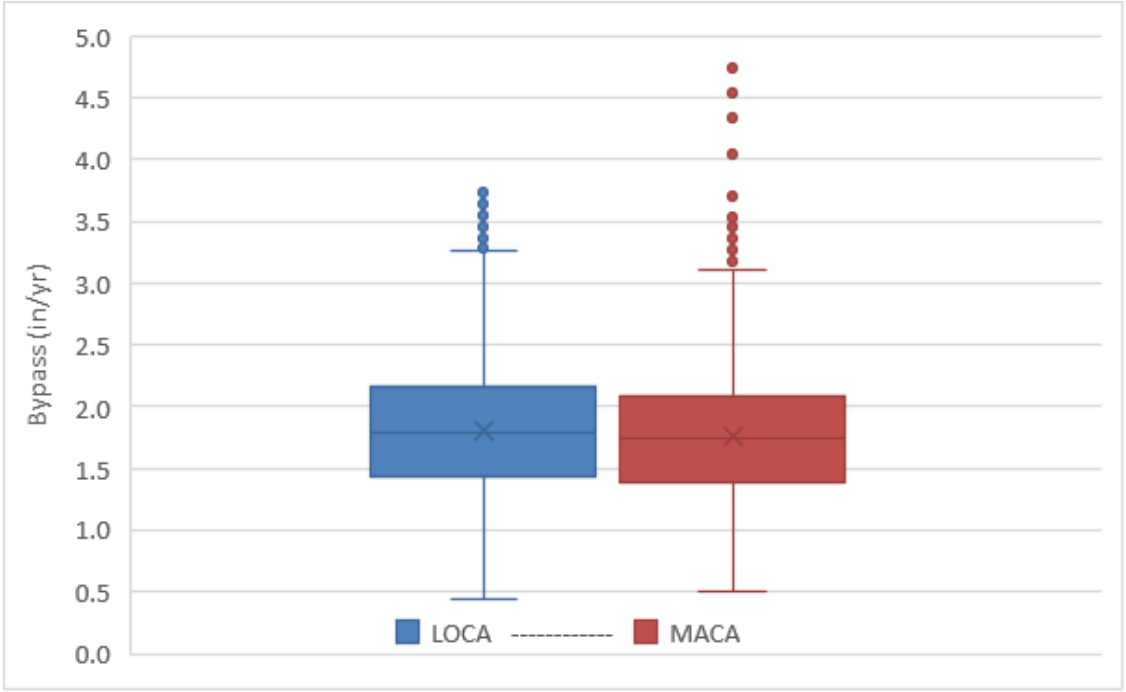
(H1) Downscaling method does introduce biases, especially for extreme events

- Compared IDF results based on LOCA and MACA statistical downscaling and CORDEX dynamical downscaling
- On average, MACA > CORDEX > LOCA
- NA-CORDEX (dynamical) results change with spatial resolution



(H2) ESD is likely to continue to meet goals of controlling runoff from smaller events

- ESD focus is on control of 1-yr and 90th percentile 24-hr storms; both LOCA and MACA suggest relatively small changes in that event
- Compare amount of flow from 90%le storm bypassing bioretention designed to ESD standards for 2070-2100 conditions at all MD Atlas 14 stations



Results are for HSG C soils, 50% impervious cover

(H3) What might happen in the real world?

- ESD is a simplified approach to incorporate water quality controls and maintain hydrology approximating natural conditions for specific high recurrence events
- Channel stability in real streams will depend on the sub-daily sequence of flows and stresses exerted over long periods of time – not just IDF relationships
- Focus here on how to create such time series for future climate conditions
- Results of simulation are in Dr. Thompson's presentation later today

Constructing Future Climate Timeseries

- Channel stability analysis requires sub-daily flows at local scale
- Statistical downscaling products (LOCA, MACA) provide daily precipitation at ~5 km scale calibrated to point data
- Dynamical downscaling available through NA-CORDEX distributed at daily time step although shorter intervals (1 – 6 hr) are available on request. Results are spatial averages at 22 or 44 km scale
- IDF relationships summarize cumulative precipitation of a given duration and recurrence, not sequence within events. Future IDFs may be point gauge-based (depending on how derived).

Continuous Timeseries from Downscaled Climate Projections

- Even the ~5 km scale of statistically downscaled climate products may not be representative of local precipitation event intensities
- Can correct for bias relative to an observed point-gauge sub-daily timeseries (e.g., 5-min) by applying empirical quantile mapping (eQM)
- eQM maps the change from historical to future conditions suggested by the downscaled GCM models to the cumulative distribution function of the historical observed data
- See general method implemented at svn.oss.deltares.nl/repos/openearthtools/trunk/python/applications/hydrotools/hydrotools/statistics/bias_correction.py

Continuous Timeseries from Downscaled Climate Projections

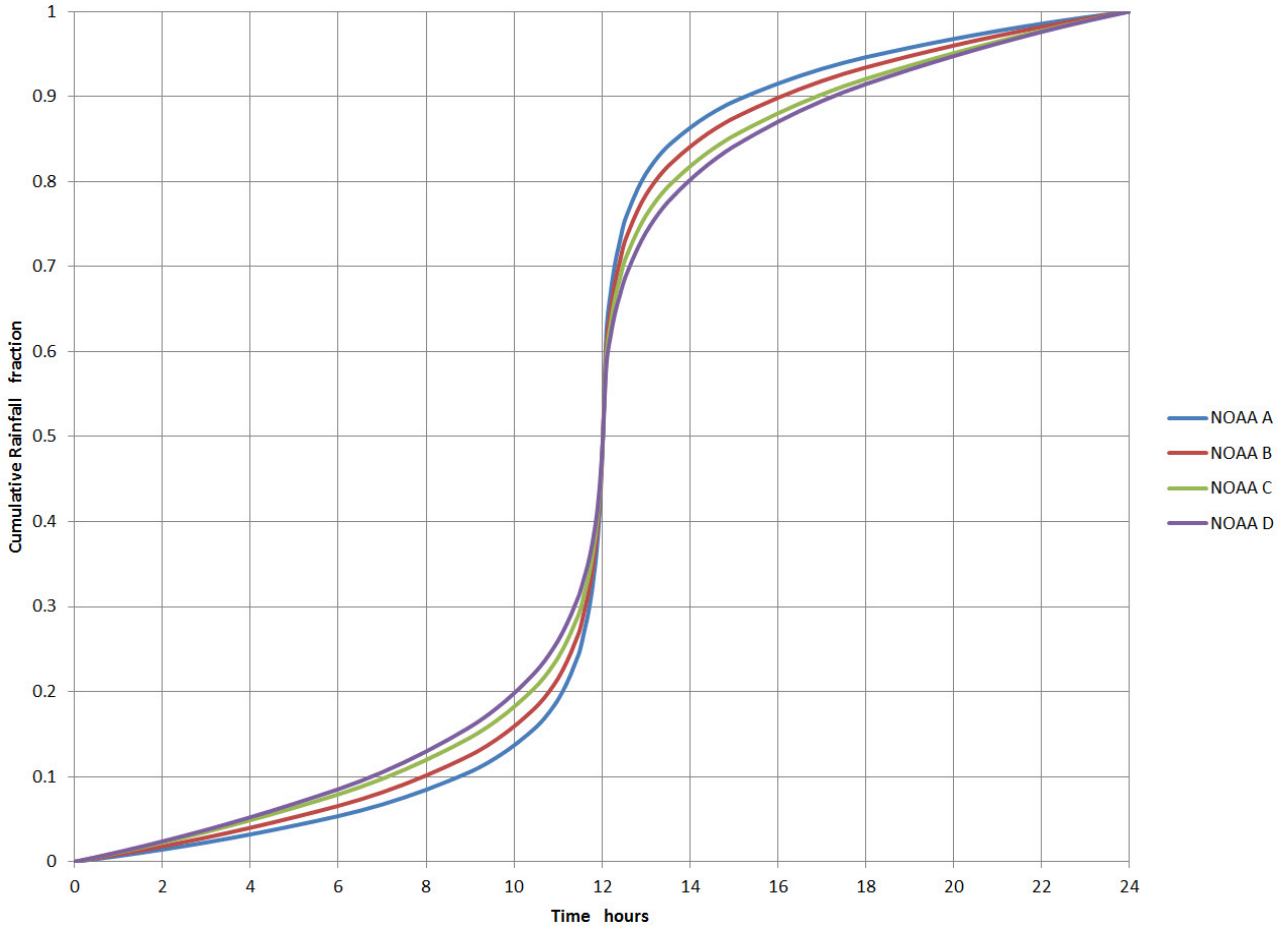
- Options for conversion from daily to sub-hourly time step

1. NRCS Design Storm approach
   - For each day with precipitation assign the sub-hourly distribution based on the cumulative precipitation curve as on previous slide
2. Constructed analog approach
   - Find a “similar” day in the historical record of sub-hourly data
   - Distribute the daily total according to that pattern
3. Fractal scaling
   - Assume the sub-daily pattern within rainfall events is self-similar to the pattern between daily and multi-day rainfall

❖Many other approaches proposed

Timeseries from IDF Results

- Traditionally apply SCS design storm to distribute cumulative results
- This is an “alternating blocks” method in which the estimated recurrence for each duration is nested within the same recurrence for the next longer duration – i.e., the 5-minute 10-yr total falls within the 10-minute 10-yr total
- NRCS EFH-2 recalculated cumulants from Atlas 14 – can apply same approach to estimated future IDF curves



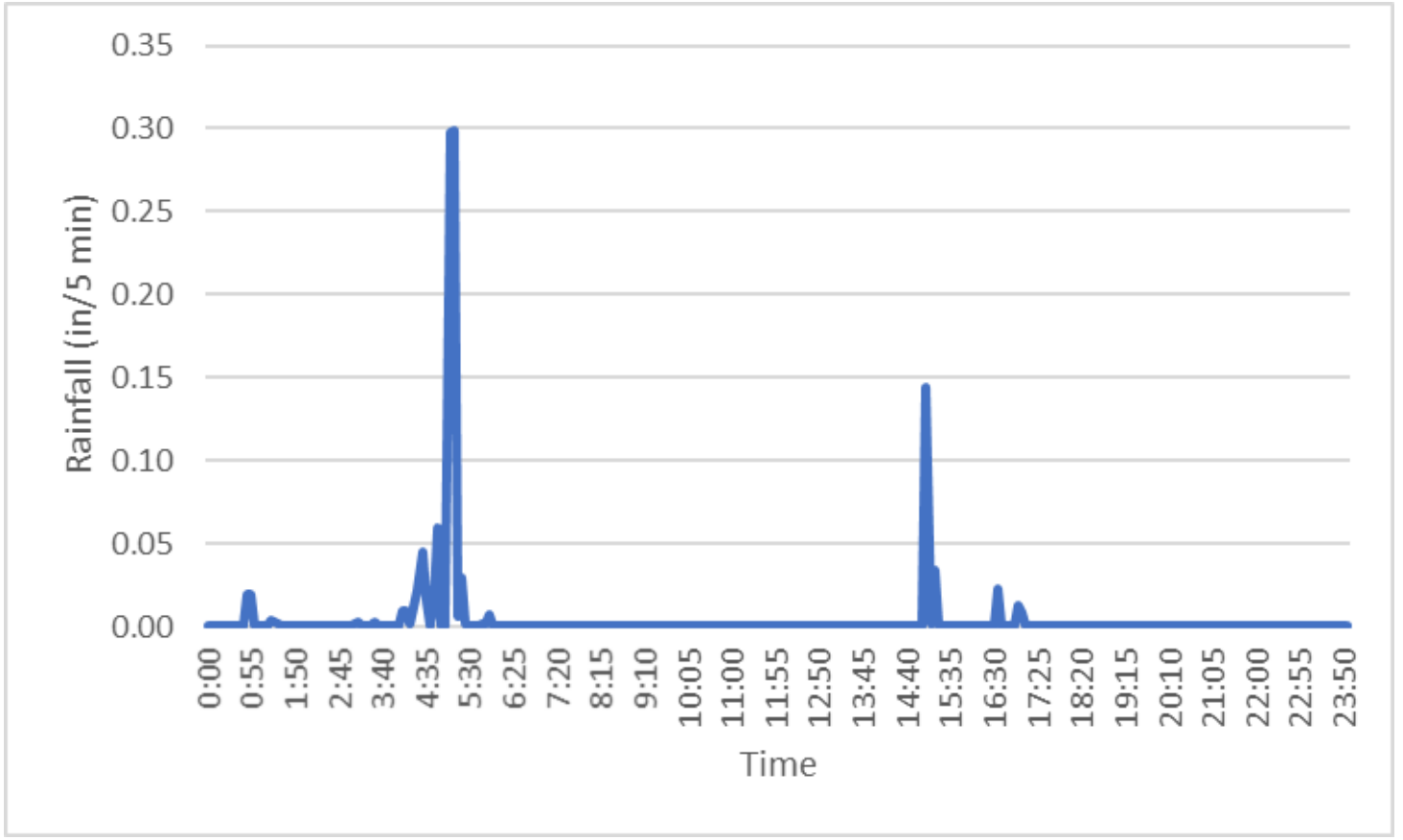
Maryland is Type C curve for Atlas 14 Volume 2

Figure from W.H. Merkel et al., 2017, Design Rainfall Distributions Based on NOAA Atlas 14 Rainfall Depths and Durations, https://acwi.gov/sos/pubs/3rdJFIC/Contents/1F-Merkel.pdf

Fractal Scaling

- Most efficient method to yield plausible daily series
- Uses a random multiplicative cascade approach based on log Poisson distribution with intermittency factor
- Created 104 series spanning 1950-2100
- Full description and Python code provided in project deliverables

Example 1.12 inch (24-hr) precipitation of 7/13/2040 downscaled to 5-minute intervals for Montgomery CO., MD from bcc-csm-1-1 GCM



Summary

Downscaling methods concur in predicting increases in extreme events; smaller changes in more common events

Maryland ESD is likely robust against predicted changes, but this may not be sufficient to maintain channel stability

Downscaling method does affect results, with intensities on average MACA > CORDEX > LOCA

Methods are provided to convert both IDF and continuous timeseries of future climate to model-ready sub-daily time steps.

Statistically downscaled products are prone to producing occasional extreme precipitation results that are not physically realistic

Acknowledgment Slide

- We thank the many partners who support the Restoration Research program for their funding and interest. Major funding for this phase of the work was provided by the U.S. Environmental Protection Agency.

Translation Slides

What are the take home points?
What does this mean for me?

Translation Slides by Guido Yactayo

What does this mean for me?

- Stormwater modeling can provide an accurate depiction of how climate change could affect stream channel stability, and these analyses require the creation of future climate patterns
- Creating future climate information is challenging and currently methods are being designed and compared, and strengths and weaknesses of these methods tested and evaluated

What does this mean for me?

What do I take from this if I am a practitioner:

- It is important that methods on how to create future climate time-series are being developed, we'll need to incorporate these future climate patterns to our existing water quality models for scenario development
- Are there any other climate variable that needs to be included in the analysis? For example, does this analysis framework need to also include air temperature and solar radiation?

What do I take from this if I am a regulator:

- MDE's plans to update stormwater management regulations.
- Incorporate resilient design to restoration projects to minimize risk in vulnerable communities.