Developing Future Rainfall Frequency Grids for the State of Texas

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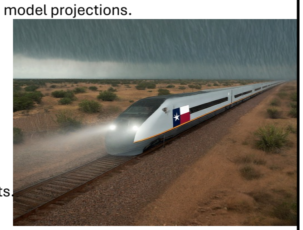
Project Overview

- Develop projected future rainfall frequency grids for Texas by incorporating information from historic trends and climate model projections.
- Improvements to existing Atlas 14 data.
- Gap Filler between Altas 14 and Atlas 15.
- Products can be utilized for future flood mapping, planning, hydraulic infrastructure design projects, and in flood mitigation efforts.



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Project Team

Core Research Team	*Research Review Panel Members*	*TWDB Project Team*
John Nielsen-Gammon Texas A&M University	**Andy Yung** Walter P Moore	**Saul Nuccitelli**
James Doss-Gollin Rice University	**Blake C. Kronkosky** StateTech Engineering	**Srikanth Koka**
William J Baule Texas A&M University	**Todd Ward** Harris County Flood Control District	**Rewati Niraula**
Yuchen Lu Rice University		

Additional review from subject matter experts from federal agencies like NOAA, USGS and USACE will be requested and addressed before the final report and data is shared for public use.

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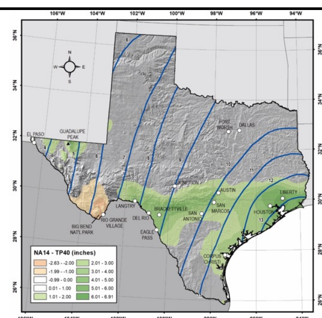
Project Timeline

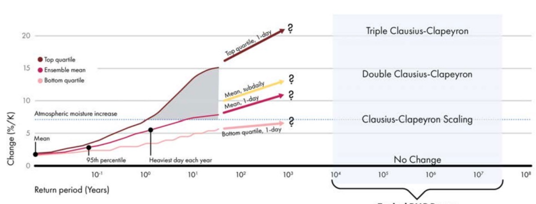
Project Initiation: Fall 2022

Project Draft Report: Fall, 2024

Final Report and Data Dissemination: Spring 2025

- 2018: NOAA Atlas 14: Official estimates of extreme rainfall risk (100-yr events, etc.)
- Analysis includes 2017 rainfall
- Previous analysis dates from 1960s
- Old analysis (contours) and change (shading) in 1-day 100-yr rainfall amounts shown at right

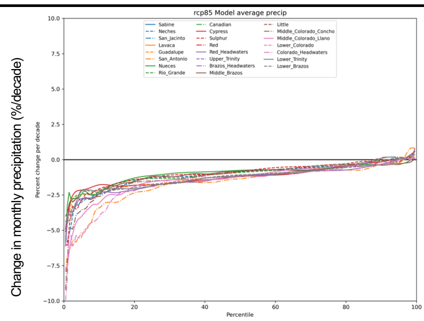




From *Modernizing Probable Maximum Precipitation*, NAS (2024)

Downscaled CMIP5, Texas river basins, high-end scenario: trends least negative (or positive) for wettest months

From *Projected Changes in the Runoff Spectrum in Texas*, John Nielsen-Gammon and William Baule, 2024



Percentile

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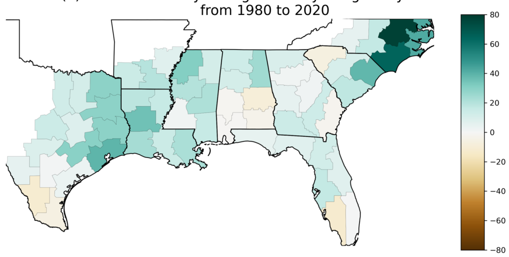
(b) Percent Intensity Change of 100-yr Single-Day Rainfall from 1980 to 2020



From Jorgensen and Nielsen-Gammon (2024) J. Hydromet.

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Coming: NOAA Atlas 15

- Volume 1: Regional Frequency Analysis including nonstationarity
- Volume 2: Projections
- Issues with NOAA Atlas 15:
  - RFA includes same spatial footprint for all moments

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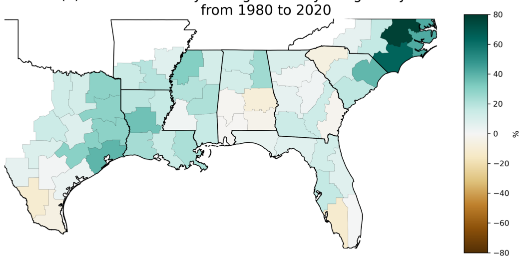

From Jorgensen and Nielsen-Gammon (2024) J. Hydromet.

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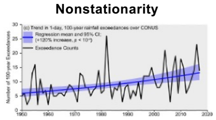
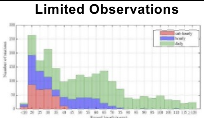
Nonstationarity



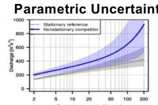
Return level exceedance counts ↑
(Wright et al., 2019)

Limited Observations



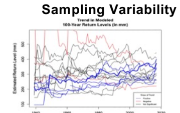
Short durations with limited records
(Perica et al., 2018)

Parametric Uncertainty



Nonstationarity → More parameters →
Uncertainty ↑ (Serinaldi and Kilsby, 2015)

Sampling Variability



Different trend estimates at nearby
stations (Fagnant et al., 2020)

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Coming: NOAA Atlas 15

- Volume 1: Regional Frequency Analysis including nonstationarity
- Volume 2: Projections
- Issues with NOAA Atlas 15:
  - RFA includes same spatial footprint for all moments
    - Higher-order moments require larger sample size
  - Separate treatment of historical trends and future projection
    - Observed trends inform our knowledge of future trends (are models accurate?)
    - Model projections inform our knowledge of current trends (is history noisy?)

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Coming Sooner: TRAIN

(Texas Rainfall Analysis Incorporating Nonstationarity)

- Sponsor: Texas Water Development Board
- Foundation: NOAA Atlas 14 data
- Additional data
  - Longer period of record, shorter durations
- Spatial statistics
  - No regionalization; automatic consistency across durations
- Climate model projections
- Merged analysis of nonstationarity
- Techniques and results may improve NOAA Atlas 15

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Data

- NOAA Atlas 14
- Global Historical Climatology Network – Daily
- United States Climate Reference Network – 5-minute
- Cooperative Network – Hourly
- Automated Surface Observing System – 5-minute
- Jefferson County Drainage District 6 – 5-minute
- Harris County Flood Control Network – 5-minute
- Oklahoma Mesonet – 5-minute
- West Texas Mesonet – 5-minute

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Quality Control

- Outlandishly small numbers
- Outlandishly large numbers
- Statistically weird storms

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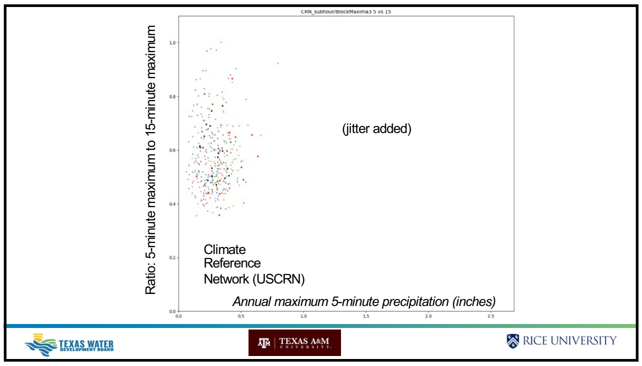
CRN_subhour/BlockMaxima3 5 vs 15
Ratio: 5-minute maximum to 15-minute maximum
(jitter added)
Climate Reference Network (USCRN)
Annual maximum 5-minute precipitation (inches)
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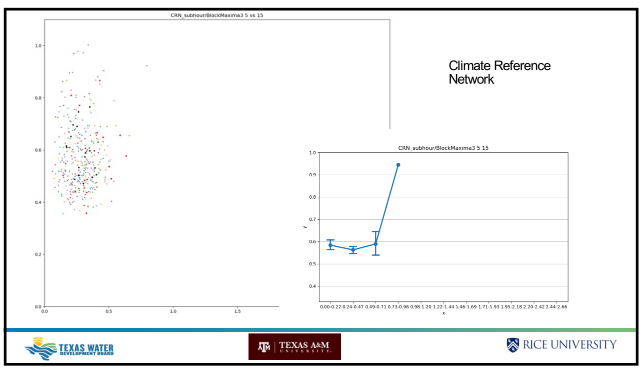
CRN_subhour/BlockMaxima3 5 vs 15
Climate Reference Network
CRN_subhour/BlockMaxima3 5 15
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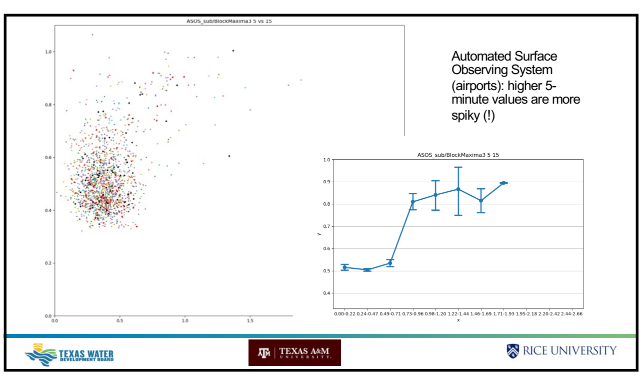
ASOS_sub/BlockMaxima3 5 vs 15
Automated Surface Observing System (airports): higher 5-minute values are more spiky (!)
ASOS_sub/BlockMaxima3 5 15
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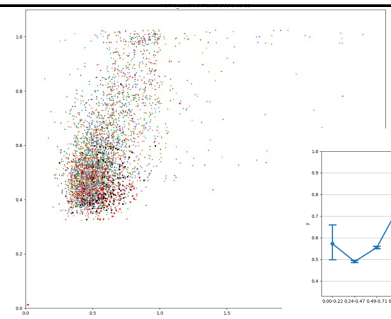

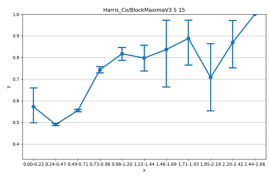

Harris County FCD: not merely spikiness, but pure spikes

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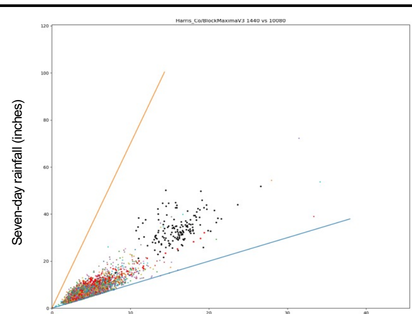

Black: Harvey
Red: Imelda

Challenge (not solved): sparse but spatially correlated sampling of tails

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Spatially Varying and Duration Dependent Covariates Model

Bayesian Hierarchical Model for annual maximum precipitation *y* for station *s*, year *t*, and duration *d*:

$$y(s,t,d) \sim GEV(\mu(s,t,d), \sigma(s,t,d), \xi(d))$$

1. Nonstationarity: parameters conditioned on time-varying covariates

2. Spatially varying parameters: latent spatial fields

3. Duration-dependent GEV distributions (dGEV): learn equations that describe GEV parameters for all durations simultaneously

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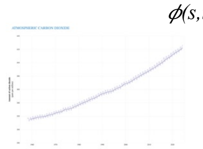
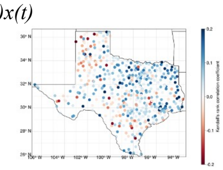
Spatially Varying and Duration Dependent Covariates Model

Process-informed **nonstationary** models condition GEV parameters $\phi(s,t)$ on time-varying covariates $x(t)$

$$\phi(s,t)=\alpha+\beta(s)x(t)$$



CO2 concentration recorded at Mauna Loa Observatory in Hawaii (NOAA)



Correlation between logCO2 and 1d annual maximum series

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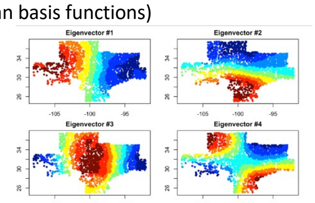
Spatially Varying and Duration Dependent Covariates Model

Spatially varying parameters are described with latent spatial fields (i.e. Moran basis functions)



Example basis functions for the study area – a total of 100 basis functions are used

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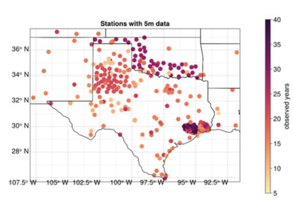
Spatially Varying and Duration Dependent Covariates Model

Duration-dependent GEV (dGEV) equations describe GEV parameters at all durations simultaneously from a few hyper-parameters

$$y(d) \sim GEV(\mu(d), \sigma(d), \xi)$$
$$\mu(d) = \tilde{\mu}(\sigma_0(d+\theta)^{-\eta} + \tau_1$$
$$\sigma(d) = \sigma_0(d+\theta)^{-(\eta+\eta_2)} + \tau_2$$

Shorter durations have limited observation records



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Methodology comparison with Atlas 14

	Atlas 14	Spatially Varying and Duration Dependent Covariates Model
Stationarity	Stationary	Process-Informed Nonstationarity
Regionalization	Region of Influence	Latent spatial fields (i.e. Moran basis functions)
5m/10m estimates	Constant scales from 15m estimates	Duration-dependent GEV
Estimation	L-moments	Bayesian inference

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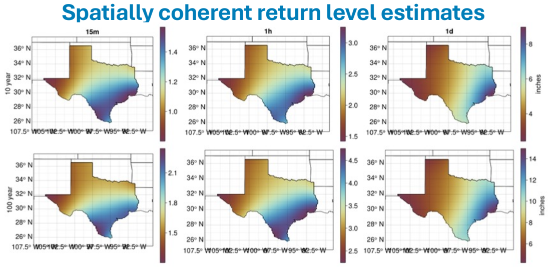
Spatially coherent return level estimates



(T) 10 and (B) 100 year return level estimates in 2022 at (L) 15 minute (M) 1 hour (R) 1 day extreme precipitation. **Preliminary results.**

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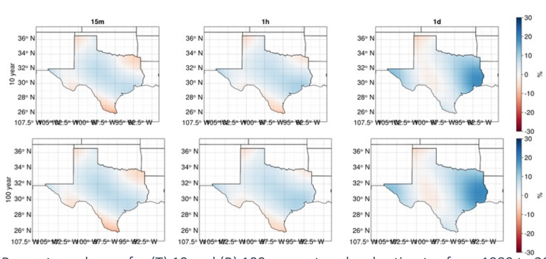
Trends intensify at longer durations



Percentage change for (T) 10 and (B) 100 year return level estimates from 1980 to 2022 at (L) 5 minute (M) 1 hour (R) 1 day extreme precipitation. **Preliminary results.**

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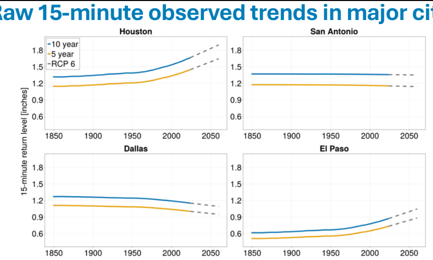
Raw 15-minute observed trends in major cities



5 (orange) and 10 (blue) year return level estimates for 15-minute precipitation in 4 Texas cities. Dashed lines use a mid-range projection for CO2. **Preliminary results.**

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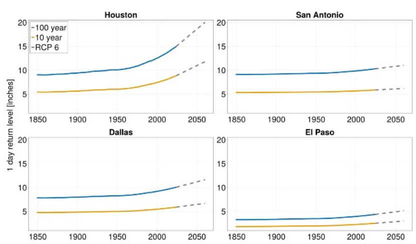
Raw 1-day observed trends in major cities



10 (orange) and 100 (blue) year return level estimates for 1 day precipitation in 4 Texas cities. Dashed lines use a mid-range projection for CO2. **Preliminary results.**

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Summary and Status

- A TRAIN is coming
- Complete:
  - Input data collection
  - Quality control
  - Statistical algorithm implementation
  - Climate model projection analysis
- Nearly complete:
  - Historical data analysis
- To be done:
  - Merger of historic and projected trend information **using planar trend fits**
  - Production of time-dependent return frequency grids
  - Review and release

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Take-Home Messages

- A TRAIN is coming which delivers:
  - Future rainfall frequency grids for Texas
  - Improved present-day rain frequency grids
- Encourage the use of this data for:
  - future flood risk mapping
  - planning
  - hydraulic infrastructure design projects
  - flood mitigation efforts
- Reviews from federal agencies like NOAA, USGS, and USACE will be requested and addressed before sharing for public use.

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References

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