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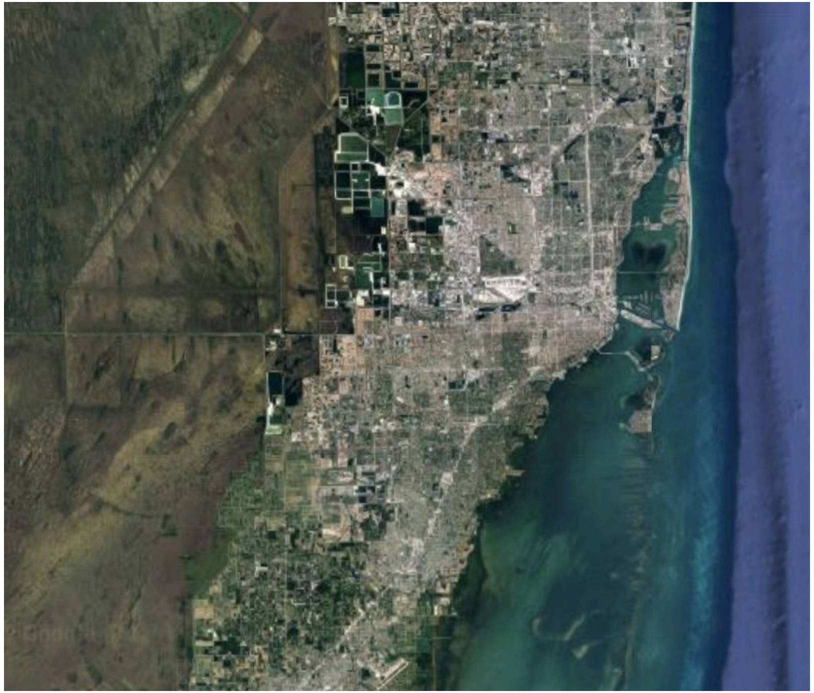
A hybrid dynamical-statistical analog downscaling technique to efficiently explore changes in extreme precipitation

Dr. Luke Madaus -- 16 May 2019 -- Sea Level Solutions Center Rainfall Workshop

Jupiter FloodScore Planning provides physical flood risk at street-level resolution



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Physical hazards that drive flooding in S. Florida

- Extreme rainfall
- Coastal surge
  resulting from tropical cyclones
- Seasonal ('king-tide') flooding

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Jupiter Method Overview

Goal: How are extreme precipitation events expected to change in frequency and magnitude in a future climate?

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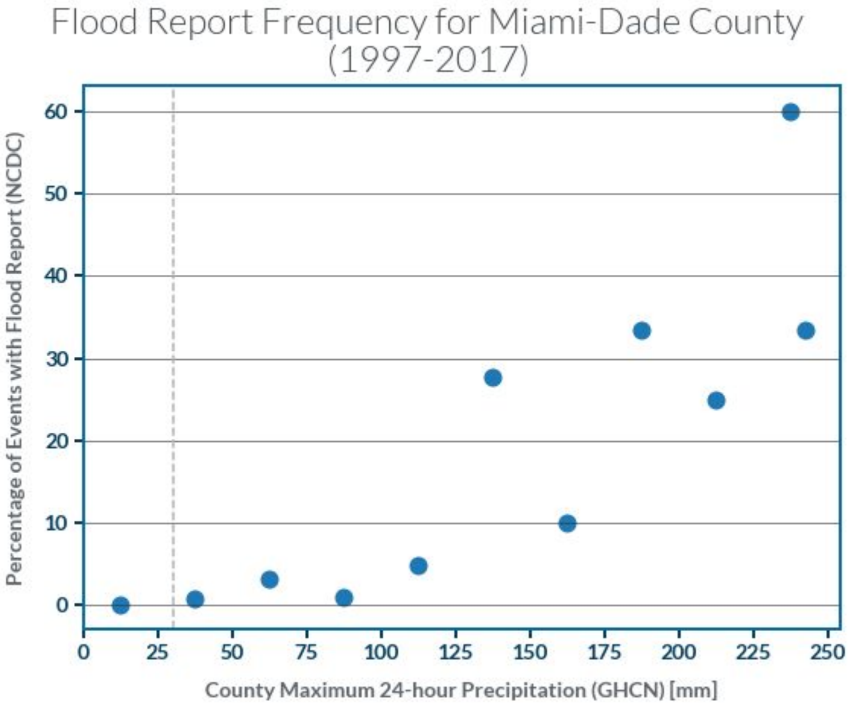
1. Define criteria for candidate "extreme precipitation" events
2. Produce and tune *dynamically-downscaled* simulations (to ~1 km resolution) for historical events that meet these criteria
3. Project changes in **event frequency** with *analog method*
4. Project changes in **event magnitude** with *statistical scaling*
5. Produce climate statistics and feed into flood models

Selection of extreme events

Selection of Extreme Events

All events where either Miami-Dade or Miami Beach ASOS/GHCN stations show at least 30 mm of precipitation in 24 hours

Flood reports to NCEI/NCDC rare below this level



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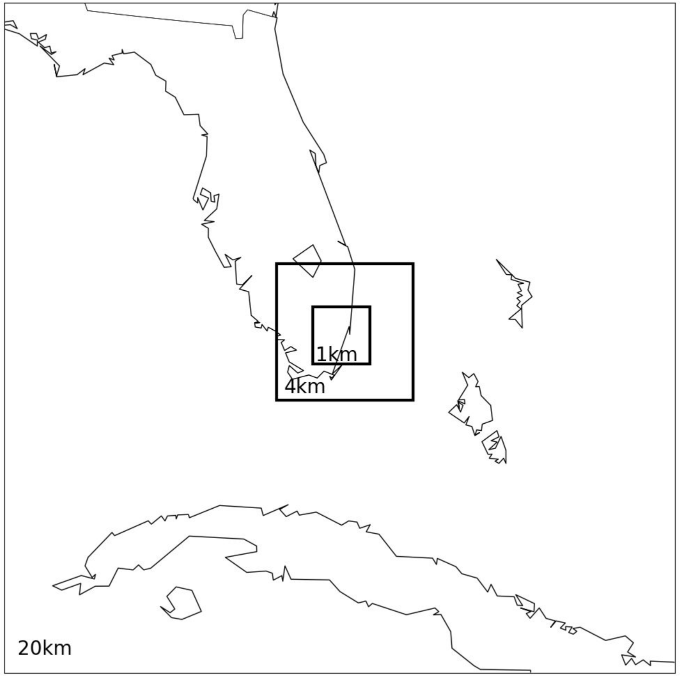
Dynamical downscaling of historic events

WRF Downscaled Simulations

Downscale historic events from reanalyses to 1km grid spacing

Choose WRF configuration suited to South Florida's climate

- Convection-allowing model resolution
    - Can capture individual thunderstorms
- Goddard Microphysics
    - Designed for subtropical warm rain
- Noah Land Surface scheme with National Land Cover Dataset
    - Satellite-based estimates of land surface properties



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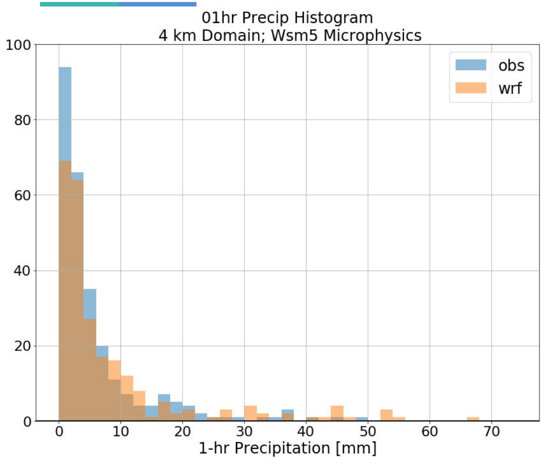
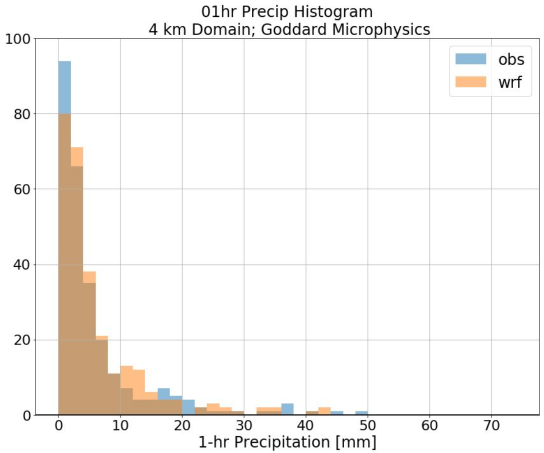
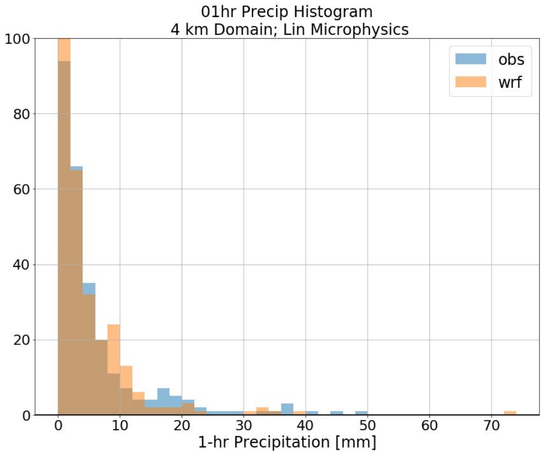
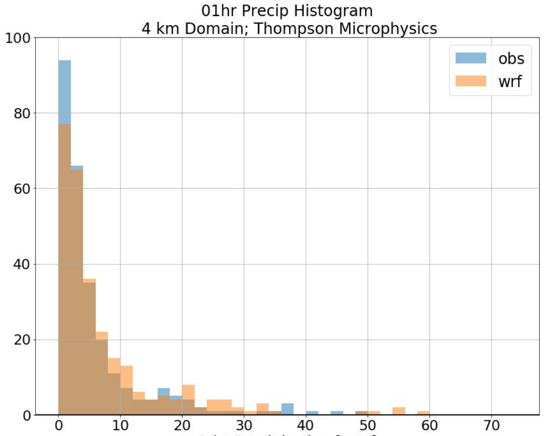
WRF Downscaled Simulations

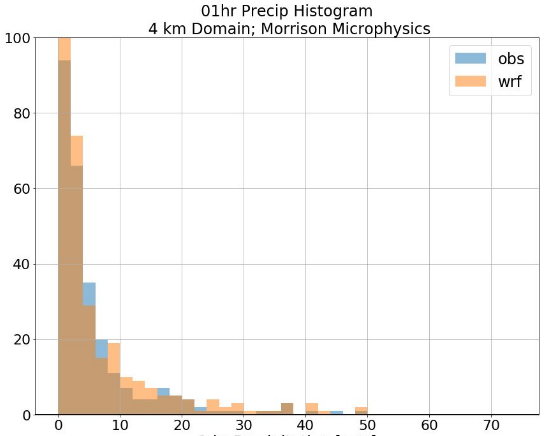




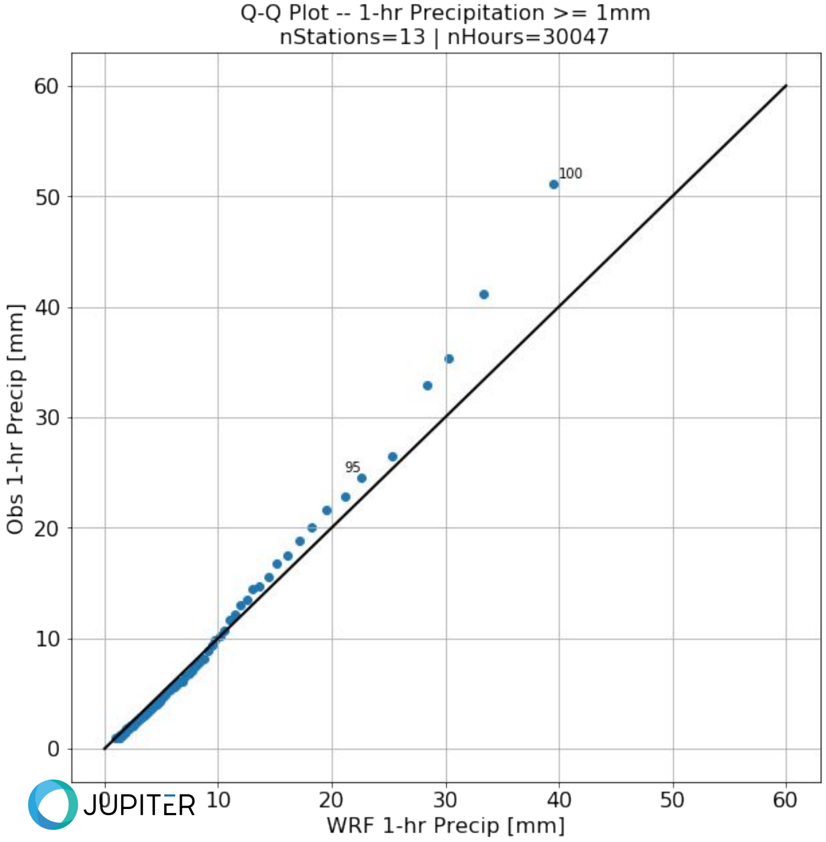


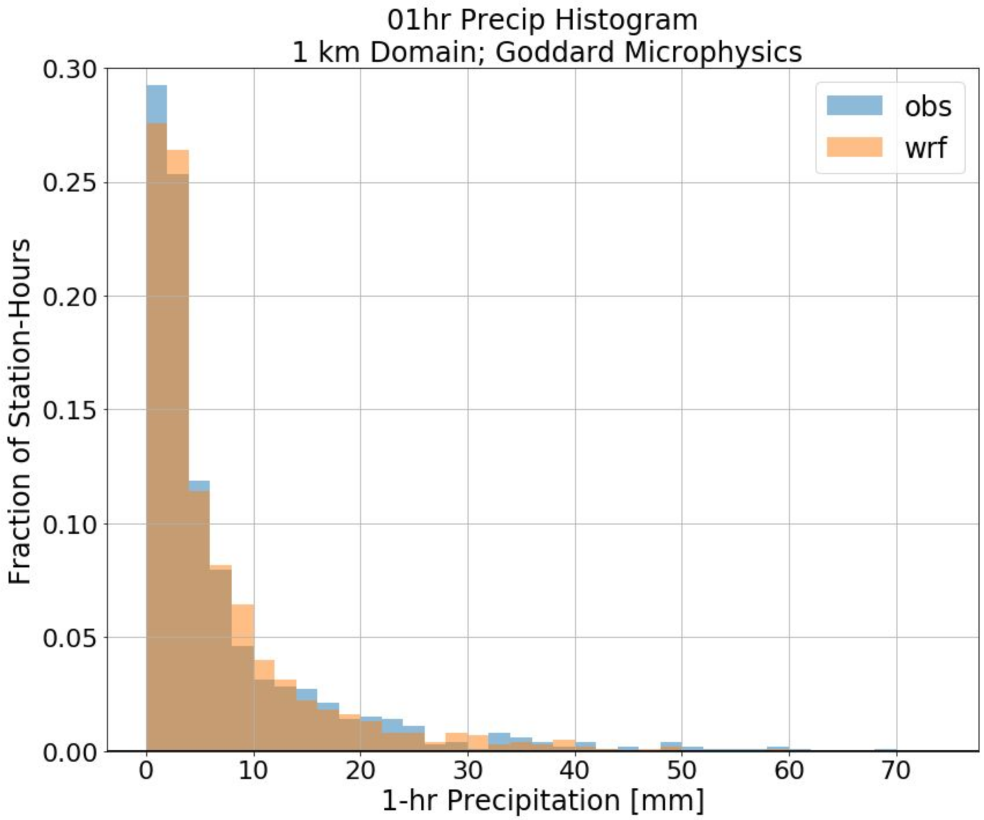
Choose configurations for WRF best suited to South Florida's climate (e.g. warm rain processes dominate)





WRF 1-hr Precipitation Distributions





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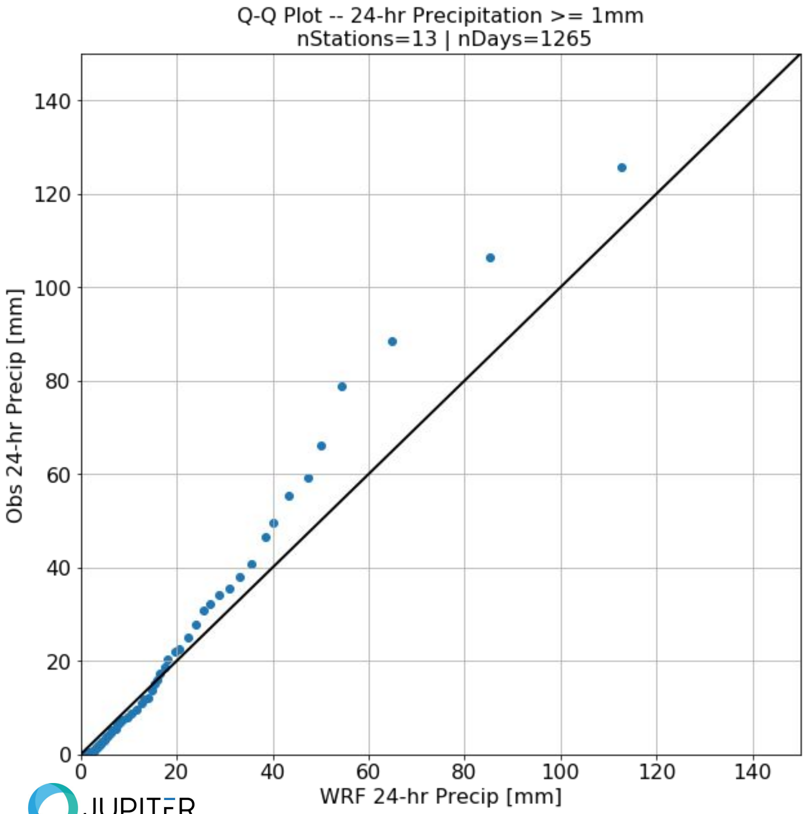
WRF 24-hr Precipitation Distribution



WRF underdoes more extreme hourly and 24-hour precipitation amounts

Bias correction through quantile mapping can alleviate much of this

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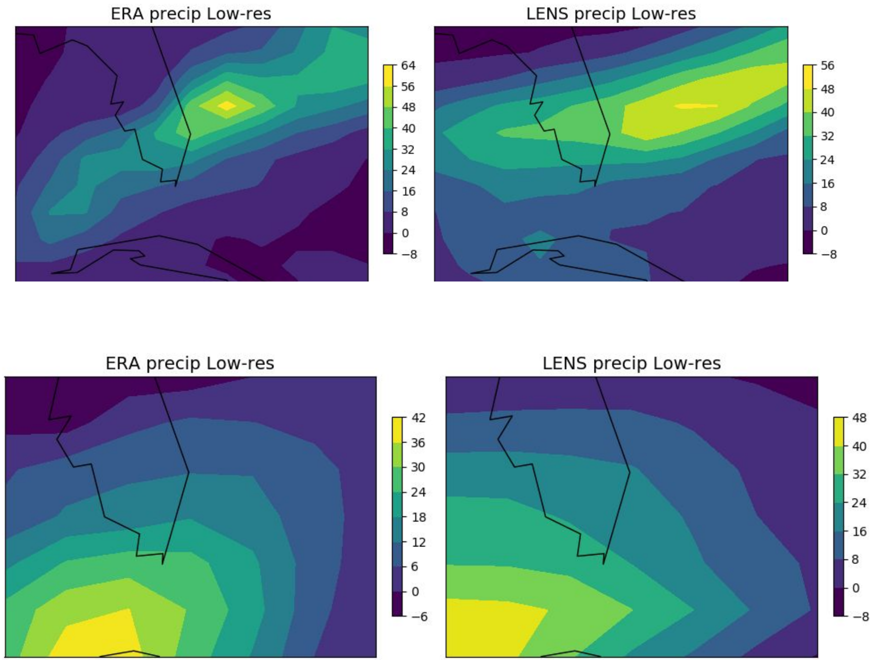
Changes in event frequency with an *analog finder*

Analog Finder



Use a global climate model (here, the CESM-LENS; Kay et al. 2015) and match future days to historic ones

Representative analog precipitation field "matches"

Cross-validation technique to determine optimum predictors for analog matches

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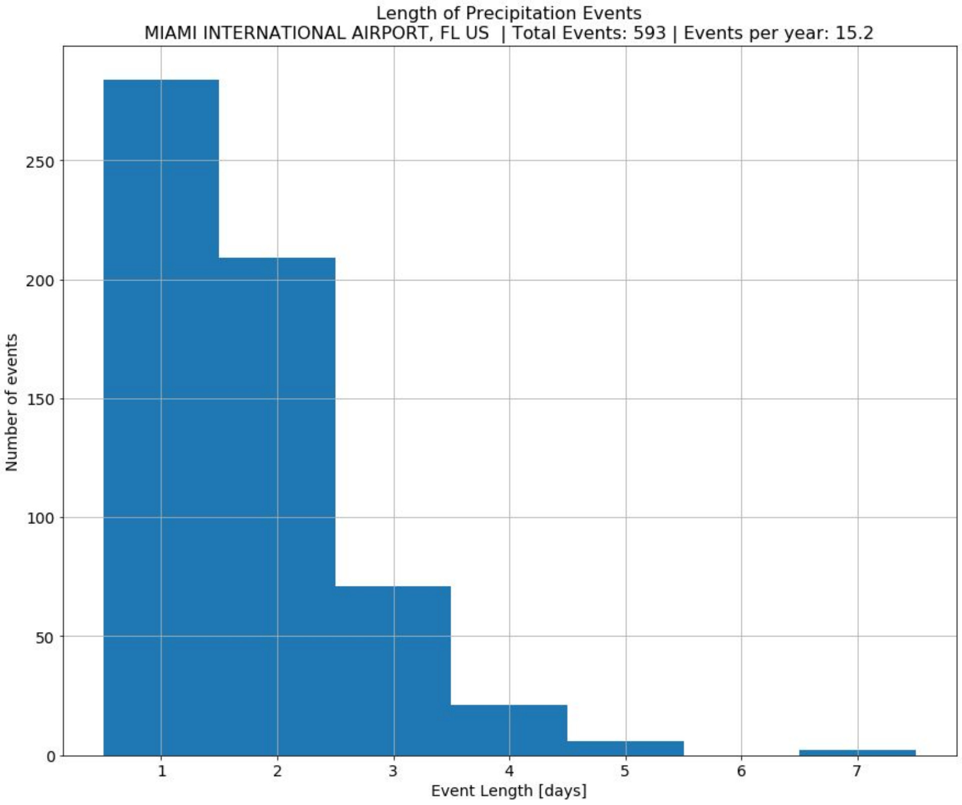
Analog Event Durations

Mostly 1-2 day events, a few 5-7 day events



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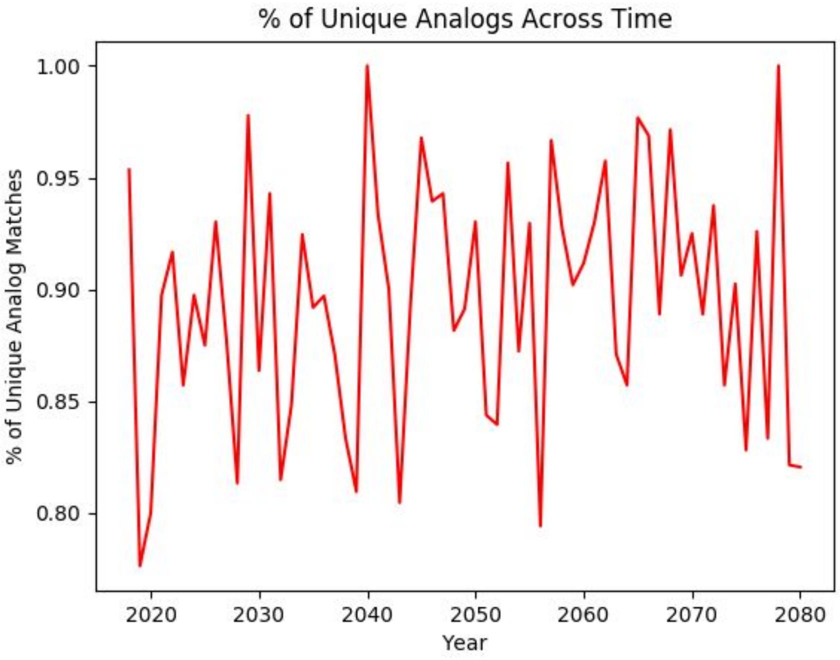
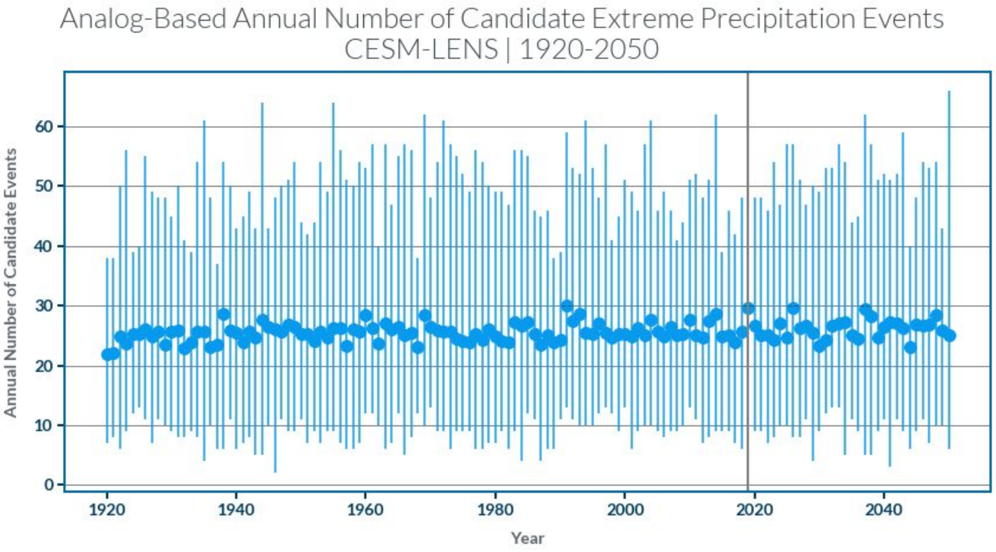
Analog Finder



Analogs are found after bias correcting the climate model and are computed based on *anomalies*

The analog finder samples the historical spectrum of possible extreme precipitation events well

Analog Events Selected per Year



Analog resampling alone does not find an increase in the annual frequency of extreme precipitation events

-> Most extreme precipitation *events* in South Florida is determined by localized thunderstorms/convection and not by large-scale atmospheric patterns

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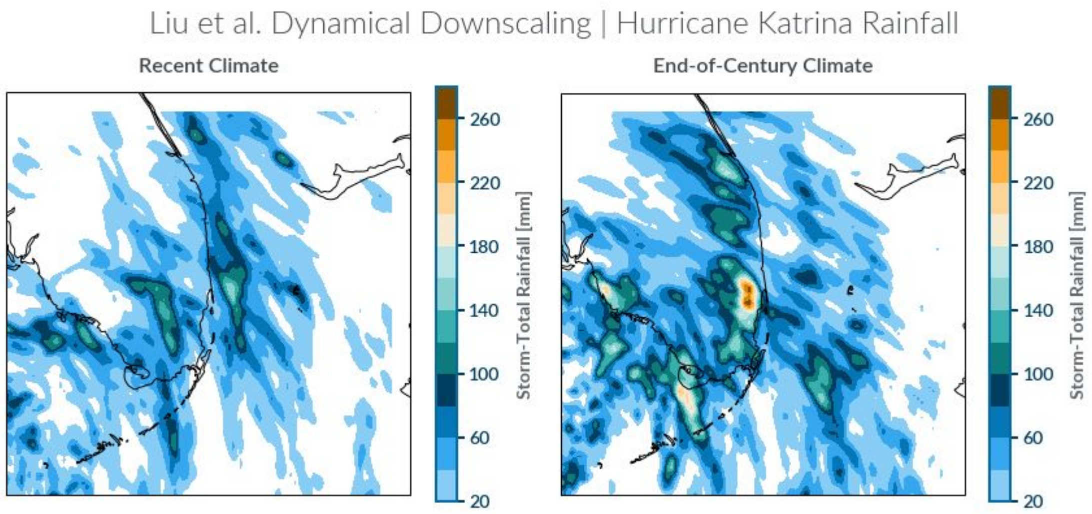
Changes in event magnitude with *statistical scaling*

Future Scaling



Analog-based sampling only samples historical events

- Given the same “historical” event in the future, we expect the event to evolve differently in a future climate
- Need to correct for local thermodynamic changes

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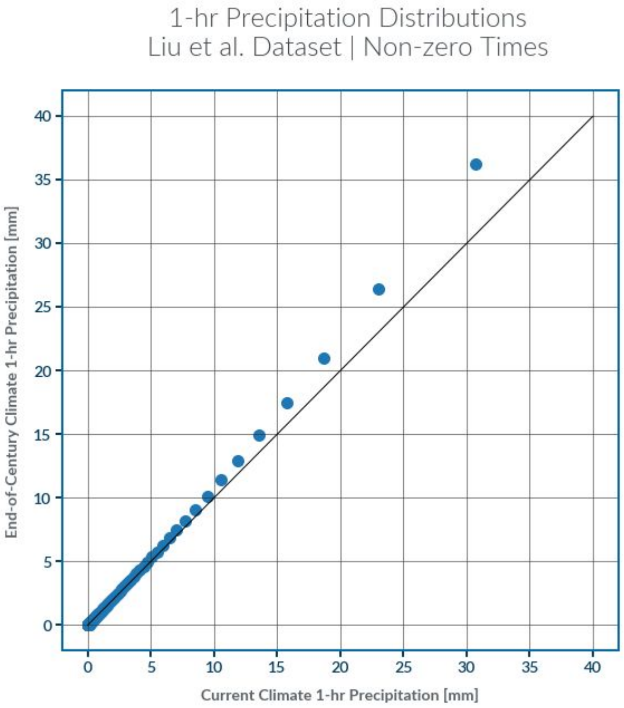
Future Scaling



Leverage existing dynamically-downscaled datasets to explore these changes

- Liu et al. (2017) dynamically downscaled dataset over North America
- "Recent" climate (2000-2013) and "End-of-Century" climate (~2090)
- Same sequence of large-scale weather patterns, but with end-of-century climate
- Can compute scaling factors for localized precipitation

Increase in extreme (>93rd percentile; ~10 mm) hourly precipitation amounts

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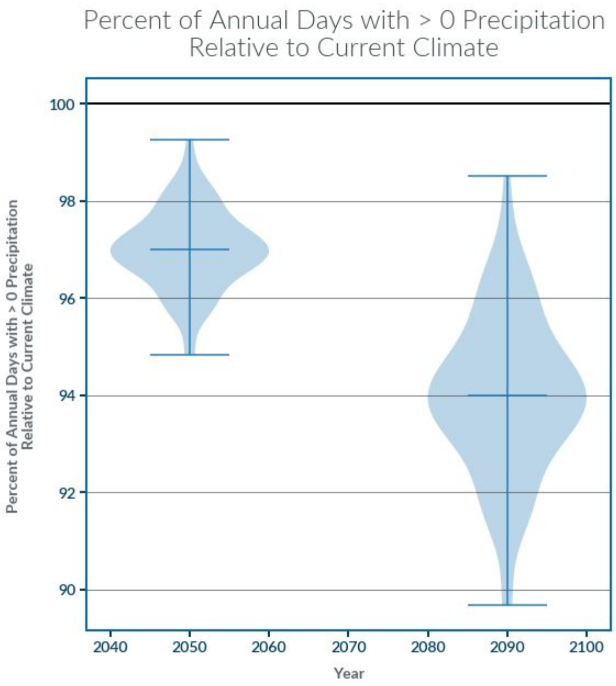
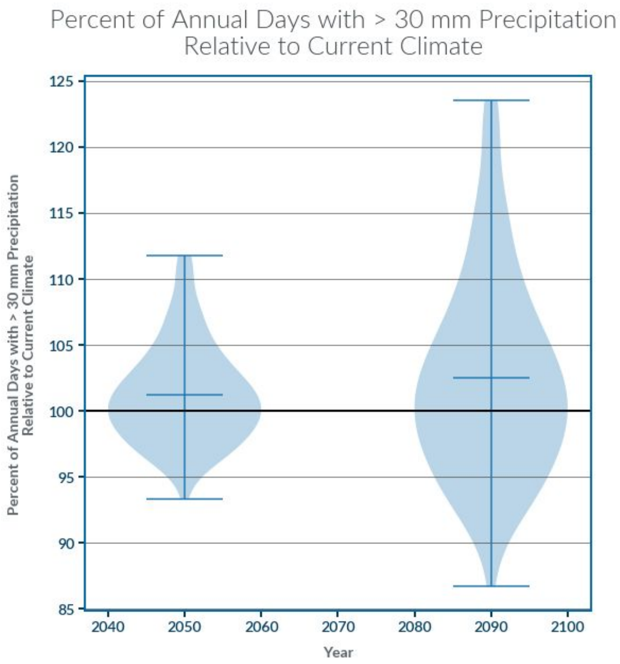
Projections and applications

Future Projections





Combine analog and scaling methods to produce downscaled future projections

<- Example: Number of days with non-zero precipitation decrease, but days with >30 mm of precipitation can possibly increase

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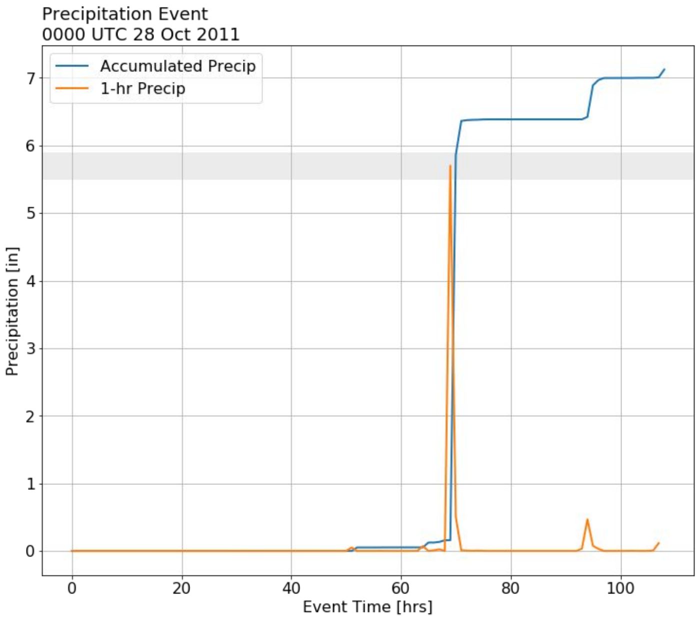
Applications at Jupiter

We use our library of analog-draw and amplitude scaled precipitation events as inputs to hydraulic models to translate precipitation changes to flood risk changes



Can also search for frequency of “design” storms

Example: 5.7 inches in 1 hr

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Jupiter Method Highlights

- **Efficient** -- computational expense is mainly limited to historical simulations and analog search
- **Calibrated** -- rooting the method in historical events allows for calibration against observations
- **Projection independent** -- any global climate model can be used in the analog finder
- **Builds on existing datasets and academic work** -- previous work to build dynamic downscaling datasets can be built upon and expanded with this method

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Modeling street-level flood-peril with climate change: Precipitation-based flooding

Extreme precipitation events → **Event simulation: WRF** → ***Analog-based resampling for future frequency*** → ***Scaled precipitation distributions for future intensity*** → **H&H modeling: HEC-RAS**

Extreme precipitation events

We develop a catalog of historic extreme precipitation events in the local area based on observations

Event simulation: WRF

The Weather Research and Forecasting (WRF) model is used to simulate historical events at kilometer and hourly scales

Analog-based resampling for future frequency

Climate model projections are used to evaluate how frequently events like this historical events will occur in the future

Scaled precipitation distributions for future intensity

Climate model simulations are used to determine how the future intensity of rainfall will change locally

H&H modeling: HEC-RAS

2D modeling forced by scaled WRF precipitation output

Overview of Flood Modeling

Extreme Rainfall Conditions

Seasonal ('High-Tide') Flooding

Tropical Cyclones

Changing Rainfall

Dynamic Weather Modeling

Coastal Surge Modeling

Sea Level Rise

Street-level Hydraulic Modeling

Modeling the probability of flooding using extreme value statistics

UI or API