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
Physical hazards that drive flooding in S. Florida

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

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
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

Q-Q Plot -- 1-hr Precipitation >= 1mm
nStations=13 | nHours=30047

01hr Precip Histogram
1 km Domain; Goddard Microphysics

Obs 1-hr Precip [mm]

WRF 1-hr Precip [mm]

Fraction of Station-Hours

1-hr Precipitation [mm]
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
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.
Analog Event Durations

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


We develop a catalog of historic extreme precipitation events in the local area based on observations. The Weather Research and Forecasting (WRF) model is used to simulate historical events at kilometer and hourly scales. Climate model projections are used to evaluate how frequently events like this historical event will occur in the future. Climate model simulations are used to determine how the future intensity of rainfall will change locally. 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
  - Street-level Hydraulic Modeling
    - Modeling the probability of flooding using extreme value statistics
    - UI or API