Designing for Storms: Current Approach Assumes Stationarity
- no trend in total rainfall, storm frequency and intensity


Tampa Rain = 12”
While U.S. annual average precipitation has increased about 5 percent over the past 50 years, there have been important regional differences as shown above.

- *Global Climate Change Impacts Report (2009)*
  U.S. Global Change Research Program

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Flood-causing Events are Getting more Frequent and Bigger

-Global Climate Change Impacts Report (2009)
U.S. Global Change Research Program

The map shows percent increases in the amount falling in very heavy precipitation events (defined as the heaviest 1 percent of all daily events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.
Move from Climate Scale to Real Time Focusing on Storms

*Floods don’t happen at climatic time scales.*

To prepare for climate change’s impact to floods, we need to understand how the rainfall regime will change at the level of the individual storm.

How will **frequency** change?

How will **hydrographs** change? Will peaks get higher and happen faster?
Storm Forecast Requirements

1. 2010-2100 Forecast

2. Capture Uncertainty in Forecast to Communicate Risk

3. Short time-step (15min, 60min)
   - Enables calculation of return period
   - Can use in detailed climate change assessments of watershed/estuary model chain

4. Applicable in many geographies

Focus on Tampa as our Case Study
Requirement 1: 2010 to 2100 Time Frame

Use General Circulation Models (GCM) for Forecasting

- Coupled models of the global atmospheric-oceanic-terrestrial system
- Grids are typically 2 deg. lat/lon
- Run for centuries on hourly time step
- Scenarios for Green House Gas emissions control set by U.N. IPCC
- Created and Run at several centers around the world (Germany, France, UK, USA, Japan)
- Common basis for ensemble climate change forecasting

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Requirement 2: Capture Uncertainty

Green House Gas Control Scenarios in GCMS

U.N. IPCC specifies several plausible green house gas (GHG) policy scenarios

Global Warming Projections

GHG Policy

Variability Captured in Ensemble Forecast

Model Methods
Example of GCM grid cells over Florida
GCMs have to be Downscaled to Reflect local Conditions

\[ \text{Pre-Industrial Control} \rightarrow \text{Deltas} \rightarrow \text{Local Climate from Historic Measurements} \rightarrow \text{Localized projection, contains local climate with GCM-based changes in climate} \]
Monthly Rainfall Forecast for Tampa, FL

- Charts above are converted to 48 month moving average to see trend.
- Forecast shows no appreciable trend
- Variability is significant relative to magnitude
- Uncertainty increases into the future
Requirement 3: 15-min Time Step

Building a forecast from historic real storms.

Jan 2010, Rain = 10 in.
If 10 in. > Historical Max Jan Storm (8 in.), Scale Markov Prob by 10/8

Does it Rain? Markov
Historical 15 Min Rainfall

Insert into timeline, repeat for each day
If Month total < 10 in, then scale all storms again.
Repeat for each month

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Storm Scaling

- Major Assumption is storms happen more frequently and get larger as Monthly Rainfall increases

- Verify Assumption through Regression Analysis

**Conclusions:**

- Inflate Markov Probabilities by Forecast P / Max Historic P when Forecast P > Max Historic P

- Scale Storms by Forecast P / Max Historic P when Forecast P > Max Historic P
Historic Analog Library Approach

Approach has following advantages:

- Realistic Storms in terms of internal temporal dynamics are used.
- The full spectrum of weather types (convective, frontal, tropical storm) is represented in the right relative frequencies – due to selection without replacement.

Things to watch out for:

- In months where higher rainfall has never been seen, storm size is linearly scaled. Data supports this, but with some variance. May not reflect complete dynamics.
- Very large tropical storms may still not be captured with analogs and scaling.
Estimating the 100 year Storm

1. From the detailed forecast, evaluate the maximum daily storms in each year.
2. Fit a Weibull Distribution with those maximum storms.
3. Estimate the 100 year storm (storm with 1% probability) from the distribution.

Issue: Highly sensitive to individual storms

Implementing Monte-Carlo Procedure to produce max likelihood estimator of 100 year storm.
StormCaster Algorithm

1. Select Location
2. Get Grid Cells from 4 GCMs, 3 GHG Scenarios each (Monthly time step)
3. Localize to selected location using historic rainfall (Monthly time step)
4. Synthesize high frequency forecast (15 minute time step)
5. Evaluate return period over time from forecast
Assessing Detailed Forecast for shifts in Return Period

- Estimates return period using Gumbel Distribution fitted to historic + forecast data
- Shows fairly constant return period over forecast time horizon for 10 and 100 yr storms
- Wide uncertainty in return period implies need for management to range of return periods
Using All GCM Models to Show Uncertainty in Forecast

- 12 GCM/Scenario Pairs
- Each give an estimate of the 100yr storm
- Range shows uncertainty in 100yr storm estimate due to GCM modeling approach and GHG control policy
- GHG/GCM Model Uncertainty is low compared to Uncertainty in 100 yr storm depth estimation procedure
- Use Full Spectrum for Flood Planning and Management (Expected, Best, Worst-case)
StormCaster Web Tool

- StormCaster Web Tool rolled out on Monday!
- AtkinsStormCaster.Com is the landing page.
- Provides description of how StormCaster works, case study, demo video, and a link to the tool.
StormCaster Web Tool

- Workflow based
- Step 1. Specify Forecast Location & select Historic Site
StormCaster Web Tool

- Historic Site comes from our on-line AtkinsRain web service
  - 3300 historic sites from NCDC (magenta sites below)
  - Total U.S. Sites = 33,000 (green sites below)
  - Configuring Tool to enter your own historic input.
StormCaster Web Tool

- Step 2. Enter GCM Inputs
  - Tool suggests inputs based on specified location
  - Selects overlying grid cells from 4 GCM models
  - Downloads data for 12 model/scenarios (4 GCMs x 3 scenarios each)
• Step 2. Enter GCM Inputs
  • Allows you to plot localized GCM inputs
  • Plots a trend analysis of the inputs
StormCaster Web Tool

- Step 3. Create Forecast and View Results
  - Takes about two minutes
  - Plots 100 year storm assessment as Result
StormCaster Web Tool

- Step 3. Create Forecast and View Results – multiple products

100-year storm analysis

Detailed Forecast

(just one shown, actually 12 of them)

Annual Totals

Climatological Comparison

(Future vs. Historic)
Requirement 4: Applicable in Many Geographies

• Current method generally applicable to a point.

• Reality:
  • Many Climate Types
  • Need to apply to regions – eg. River Basin.

• Can we do better?

Climate zones of the Lower 48, based on zones of the warmest 6 months, coldest month, and moisture index (ratio of precipitation and positive temperature average; 1971-2000 data from PRISM ©BONAP
Jack is a UF Graduate Student
He creates a new storm forecasting method focused on desert Southwest
Jill is an systems ecologist in Phoenix.
She needs a climate change aware precipitation forecast for a new model she’s working on at the Sonoran Preserve – just north of Phoenix.
Introducing StormCaster Network

Jack Submits his method to the Network

The method is suggested as one Jill can use when she creates a forecast for Sonoran Preserve.

The Code

Documentation

Map of where the method is applicable

Select Forecast Location & Historic Rainfall Input

Specify Forecast Parameters & Run Forecast

Result

Forecast Location
Sonoran Preserve

Historic Rainfall
Sky Harbor

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“Forecasting is extremely difficult; especially about the future.”

Niels Bohr
and then Yogi Berra

AtkinsStormCaster.com

Questions