



USACE: Connecting Science to Action



USACE
CLIMATE
PREPAREDNESS
AND RESILIENCE

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**Lead, Climate Preparedness and
Resilience Community of Practice**

Silver Jackets Panel: USACE Policies and Frameworks
that Support Flood Risk Management | 3 Nov2015

BLUF

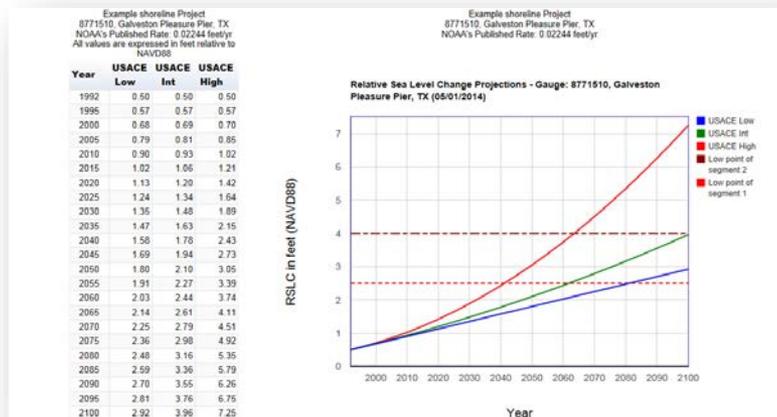
- Climate science is complex and data-intensive
- Climate preparedness and resilience actions require translation of science to actionable information for decision-makers
- Science translation for changing sea levels is fairly mature
- Science translation for hydrologic impacts is dependent on evolving science and is making progress

Coastal Climate Change Impacts

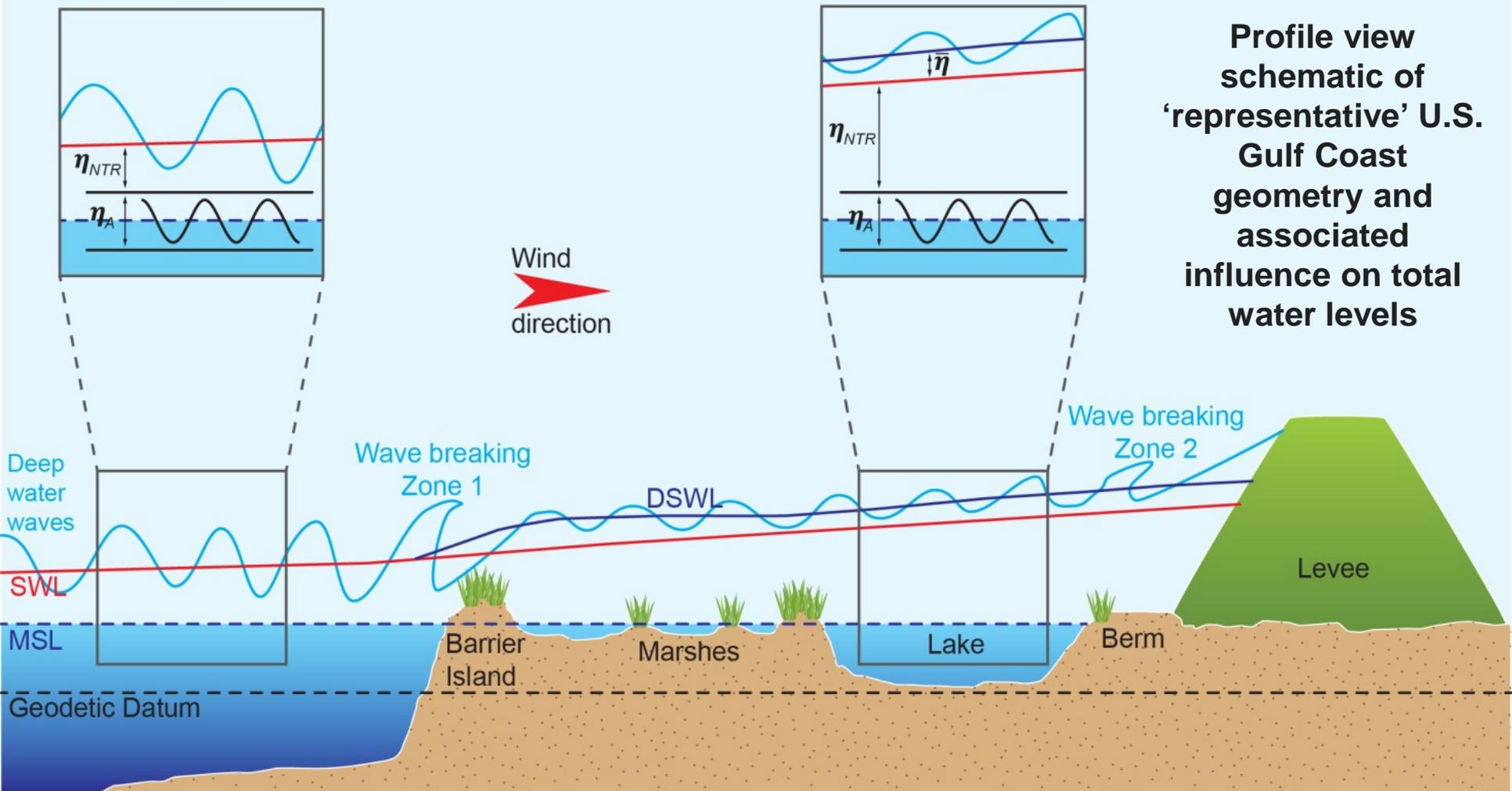
- Strong evidence basis for projected increases in coastal flooding due to changing sea levels
 - Scenario approach can be used to address future uncertainty
 - Reasonable agreement to 2100
 - Can take action now
- Less evidence for projected changes in tropical and extra-tropical events
 - Wait for science to evolve
- Compute local relative sea level change from global (eustatic) sea level rise accounting for regional and local vertical land movement
- For tide gauges with >40 years of record this is relatively straightforward
- Tools:
 - USACE Sea Level Calculator
 - NOAA Sea Level Rise Viewer

Tools: Coastal Climate Change

- Sea level change calculator
 - Supports repeatable results
 - Relies on NOAA tide gauge data
 - Includes some long-term non-NOAA tide gauges in the Louisiana Gulf Coast area
 - Publicly available
 - Part of Interagency Sandy Sea Level Rise tool
 - Supports comparisons to
 - NOAA 2012 scenarios
 - New York City Panel on Climate Change
 - NRC 2012 Pacific Coast
 - Includes extreme water levels
- Reference: ER 1100-2-8162 and ETL 1100-2-1



Profile view schematic of 'representative' U.S. Gulf Coast geometry and associated influence on total water levels



Key

η_{NTR}	non tidal residual	MSL	mean sea level	DSWL	dynamic still water level
η_A	astronomical tide	SWL	still water level	R	wave runup
$\bar{\eta}$	wave setup	S	swash	TWL	total water level

Progress: Hydrologic Nonstationarity

From this.....

To this.....

POLICYFORUM

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

P. C. D. Milly¹, Julio Beaneau², Melin Falkenmark³, Robert M. Hirsch⁴, Zsigmon W. Kundzewicz⁵, Dennis P. Lettenmaier⁶, Ronald J. Stedler⁷

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water resource engineering. It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year-periodic) probability density function (pdf), whose properties can be estimated from the instrument record. Under stationarity, pdf estimation errors are acknowledged, but have been assumed to be reducible by additional observations, more efficient estimators, or regional or paleohydrologic data. The pdfs, in turn, are used to evaluate and manage risks to water supplies, waterworks, and floodplains; annual global investment in water infrastructure exceeds US\$500 billion (1).



An uncertain future challenges water planners.

The stationarity assumption has long been questioned by human disturbances in river basins. Flood risk, water supply, and water quality are affected by water infrastructure, channel modifications, drainage works, and land-cover and land-use change. Two other (sometimes indistinguishable) challenges to stationarity have been externally forced, natural climate changes and low-frequency, internal variability (e.g., the Atlantic multidecadal oscillation) enhanced by the slow dynamics of the ocean and ice sheets (2, 3). Planners have tools to adjust their analyses for known human disturbances with river basins, and uncertainty or not, they generally have considered natural change and variability to be sufficiently small to allow stationarity-based design.

In view of the magnitude and ubiquity of the hydroclimatic change apparently now under way, however, we assert that stationarity is dead and should no longer serve as a central, default assumption in water-resource risk assessment and planning. Finding a suitable successor is crucial for human adaptation to changing climate.

How did stationarity die? Stationarity is dead because substantial anthropogenic natural forced, natural climate changes and low-frequency, internal variability (e.g., the Atlantic multidecadal oscillation) enhanced by the slow dynamics of the ocean and ice sheets (2, 3). Planners have tools to adjust their analyses for known human disturbances with river basins, and uncertainty or not, they generally have considered natural change and variability to be sufficiently small to allow stationarity-based design.

Anthropogenic climate warming appears to be driving a poleward expansion of the subtropical dry zone (4), thereby reducing runoff in some regions. Together, circulatory and thermodynamic responses largely explain the picture of regional gainers and losers of sustainable freshwater availability

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

that has emerged from climate models (see figure, p. 574).

Why now? That anthropogenic climate change affects the water cycle (5) and water supply (6) is not a new finding. Nevertheless, sensible objections to discarding stationarity have been raised. For a time, hydroclimatic had not demonstrably exited the envelope of natural variability and/or the effective range of optimally operated infrastructure (11, 12). Accounting for the substantial uncertainties of climate parameters estimated from short records (13) effectively hedged against small climate changes. Additionally, climate projections were not considered credible (14, 15).

Recent developments have led us to the opinion that the time has come to move beyond the wait-and-see approach. Projections of runoff changes are bolstered by the recently demonstrated reproductive skill of climate models. The global pattern of observed annual streamflow trends is unlikely to have arisen from unforced variability and is consistent with modeled response to climate forcing (15). Paleohydrologic studies suggest that small changes in mean climate might produce large changes in extremes (16), although attempts to detect a recent change in global flood frequency have been equivocal (17, 18). Projected changes in runoff during the multi-decade lifetime of major water infrastructure projects began now are large enough to push hydroclimate beyond the range of historical behaviors (19). Some regions have little infrastructure to buffer the impacts of change.

Stationarity cannot be revived. Even with aggressive mitigation, continued warming is very likely, given the residence time of atmospheric CO₂ and the thermal inertia of the Earth system (4, 20).

A successor We need to find ways to identify nonstationary probabilistic models of relevant environmental variables and to use those models to optimize water systems. The challenge is daunting. Patterns of change are complex; uncertainties are large; and the knowledge base changes rapidly.

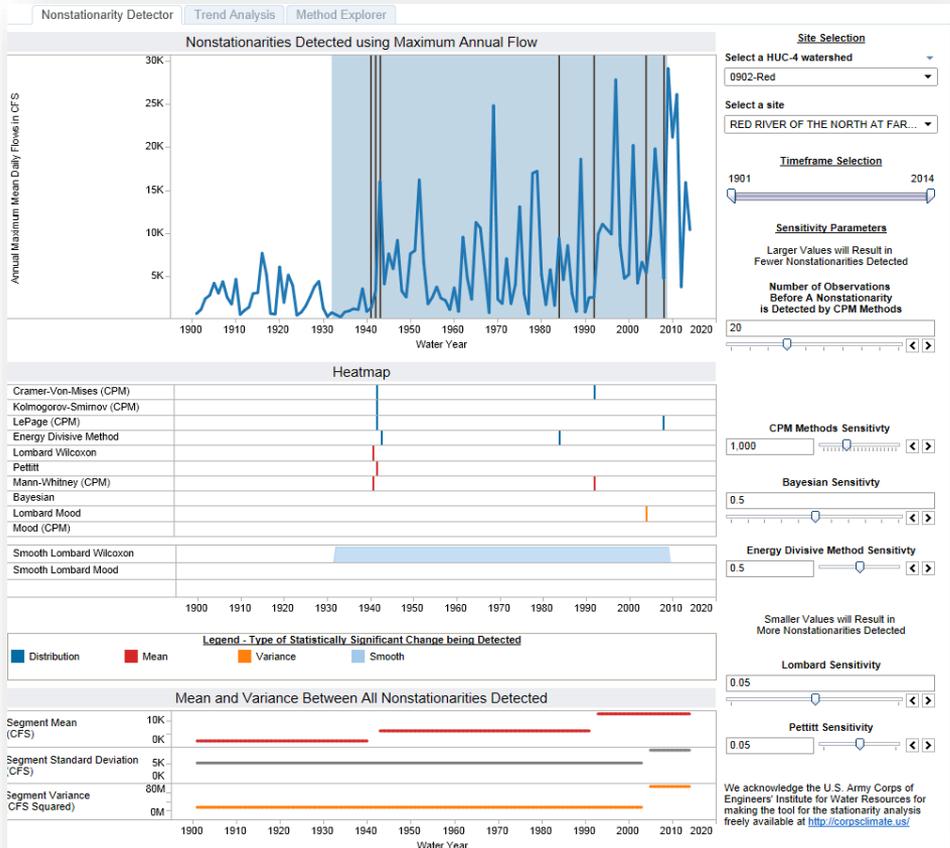
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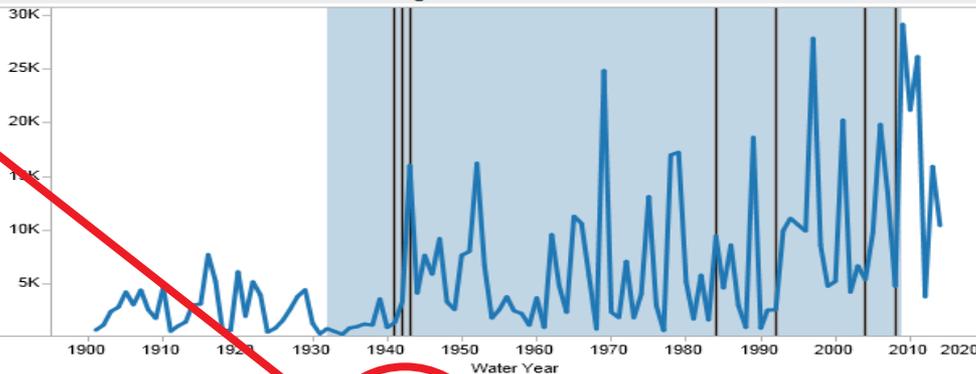


Tool

Tools: Detection of Hydrologic Nonstationarity

Nonstationarity Detector Trend Analysis Method Explorer

Nonstationarities Detected using Maximum Annual Flow

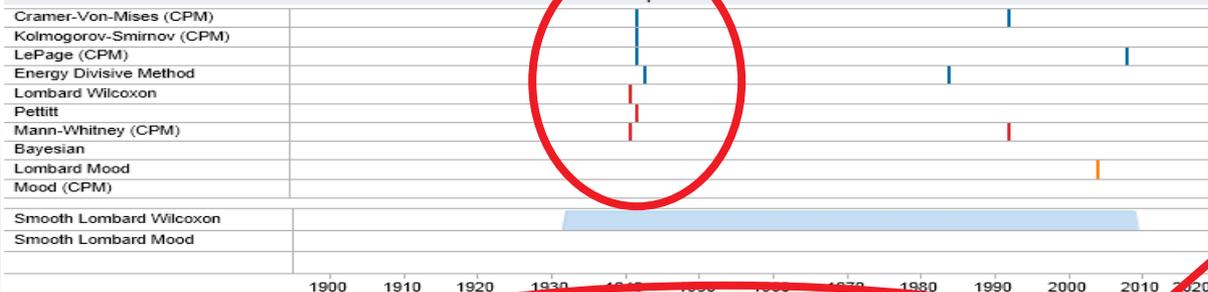


Site Selection
Select a HUC-4 watershed: 0902-Red
Select a site: RED RIVER OF THE NORTH AT FAR...

Timeframe Selection
1901 - 2014

Sensitivity Parameters
Larger Values will Result in Fewer Nonstationarities Detected
Number of Observations Before A Nonstationarity is Detected by CPM Methods: 20

Heatmap

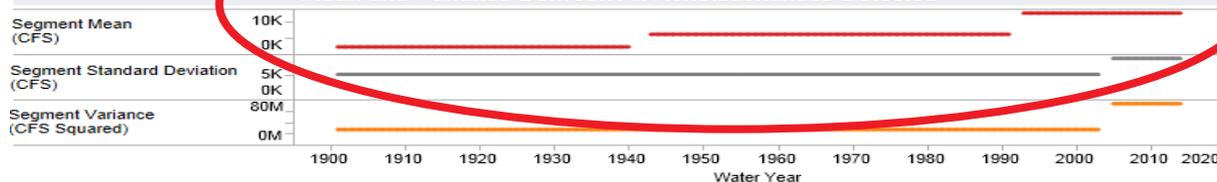


Change in mean

Legend - Type of Statistically Significant Change being Detected

- Distribution
- Mean
- Variance
- Smooth

Mean and Variance Between All Nonstationarities Detected



CPM Methods Sensitivity
1,000
0.5
Energy

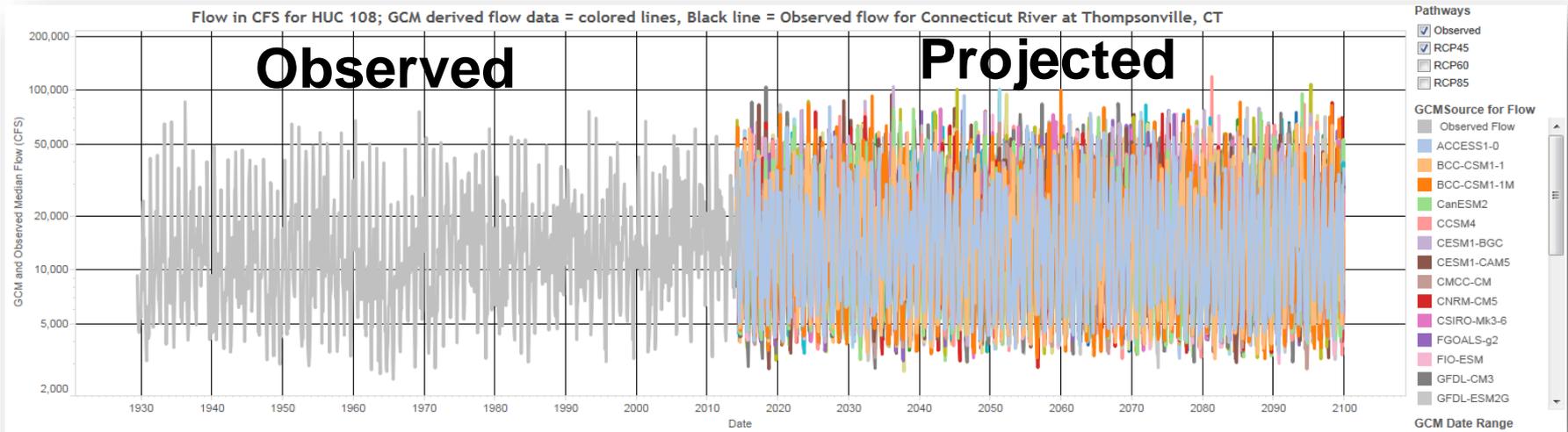
Smaller Values will Result in More Nonstationarities Detected

Lombard Sensitivity: 0.05

Pettitt Sensitivity: 0.05

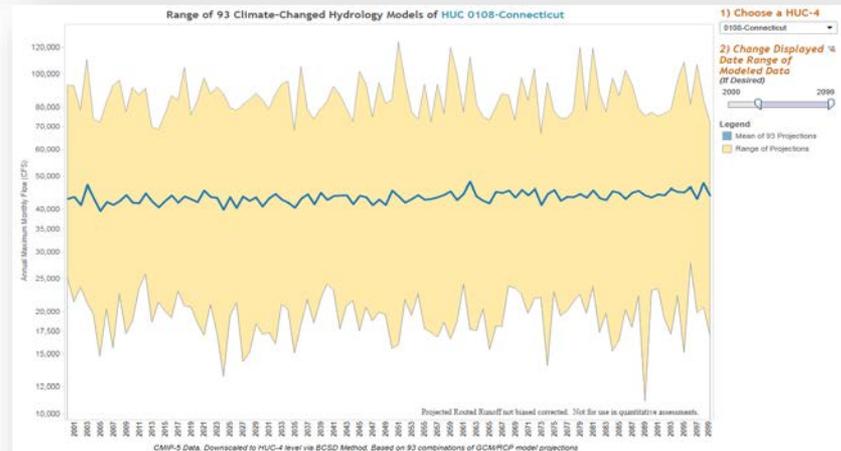
We acknowledge the U.S. Army Corps of Engineers' Institute for Water Resources for making the tool for the stationarity analysis freely available at <http://corpsclimate.us/>

Projected Climate Hydrology



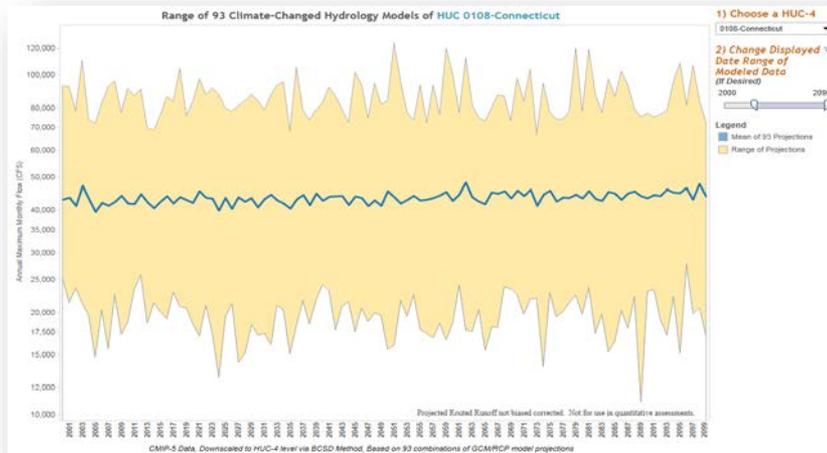
From this.....

To this.....

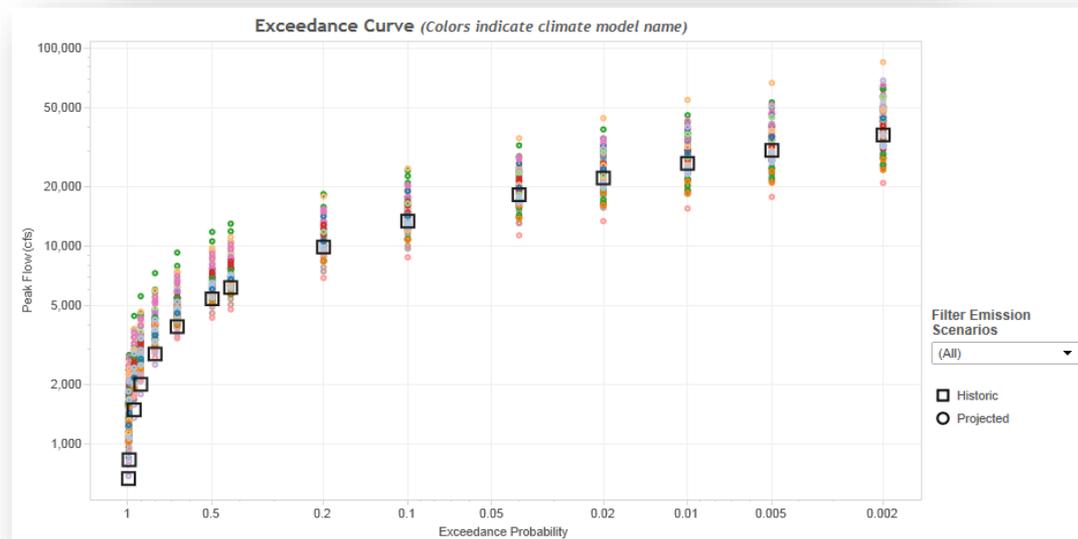


Projected Climate Hydrology

And from this.....



To this.....



Status Check

- Do we have all the answers?
 - No
- Are we getting there?
 - Yes, we have coastal and are moving toward climate hydrology approaches that are supported by actionable science developed in collaboration with our partners and stakeholders, AND will not require major adjustments
 - Next steps: heat waves and supply chain

