NOAA Atlas 14 Precipitation Frequency Atlas of the United States

Presenter: Michael St. Laurent

Authors: Sanja Perica[1], Sandra Pavlovic[1,2], Michael St. Laurent[1,2], Carl Trypaluk[1,2], Dale Unruh[1,2]

[1] Hydrometeorological Design Studies Center (HDSC), Office of Water Prediction (OWP), NWS, NOAA

[2] University Corporation for Atmospheric Research

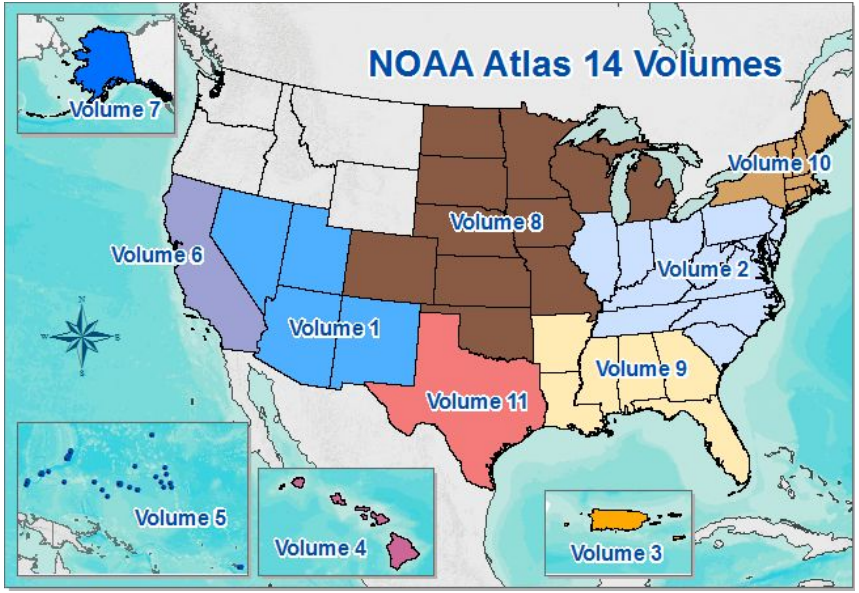
What is NOAA Atlas 14?

- ❑ Since early 2000s HDSC has been updating precipitation frequency estimates for various parts of the United States and affiliated territories.

- ❑ Updated estimates with relevant supplementary information are published in NOAA Atlas 14 "Precipitation-Frequency Atlas of the United States."

- ❑ Funding model dictates that Atlas 14 updates are done in stages based on state boundaries.

  2004: Vols 1 & 2 (19 states)
  …
  2013: Vols 8 & 9 (17 states)
  2015: Vol 10 (7 states)
  2018: Vol 11 (TX)
  ????: Vol 12 (ID, MT, OR, WA, WY).



What are Precipitation Frequency Estimates?

- **Precipitation Frequency Estimate (at a given location)**: Precipitation **D**epth (or **I**ntensity) for a specific **D**uration that has a certain **F**requency of occurring.

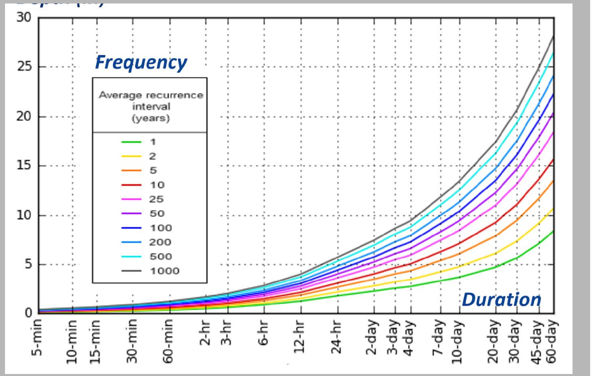
- **Frequency:**

Annual Exceedance Probability ("1-in-N event")

- Probability associated with exceeding a given amount of precipitation for a specified duration at least once in any given year.
- Ex. AEP of 1-in-100 equates to a 1% chance of the amount being exceeded at least once in any year.

Average Recurrence Interval, Return Period ("N-year event")

- Average time between precipitation events exceeding particular magnitude for a specified duration.
- Ex. 100-year amount on average occurs every 100 years.



Depth-Duration-Frequency (DDF) Curves

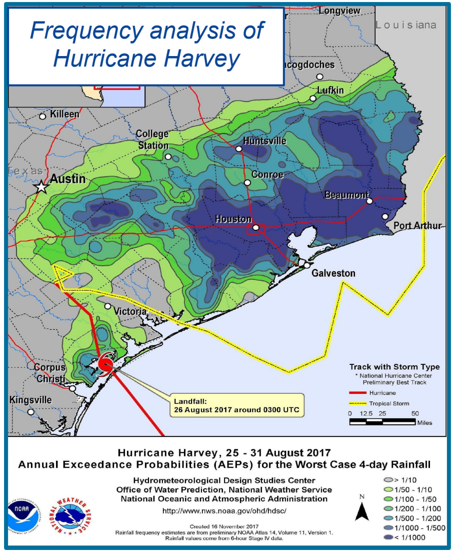
Where are Atlas 14 Estimates Used? – Storm Analysis

- NWS uses Atlas 14 estimates for monitoring observed/forecasted rain to indicate flooding threats.
- Widely used to estimate severity of historic events.

HDSC analysis of selected historic events

Event

- Imelda, 16-20 September 2019
- Remnants of Barry, Arkansas, 15-16 July 2019
- South-Central Nebraska, 8 July 2019
- Arkansas River Basin, April - May 2019
- Hurricane Florence, 13-18 September 2018
- Michigan and Wisconsin, 14-18 June 2018
- Ellicott City, Maryland, 27 May 2018
- Hurricane Maria, 20 September 2017
- Hurricane Harvey, 25-31 August 2017
- Missouri, 28 April - 2 May 2017
- Hurricane Matthew, 6-10 October 2016
- Louisiana, 11-13 August 2016
- Ellicott City, Maryland, 30 July 2016
- Northern Wisconsin, 11-12 July 2016
- West Virginia, 23-24 June 2016
- Lower Mississippi River Valley, 8-12 March 2016
- Corsicana, Texas, 24-25 October 2015
- Austin, Texas, 30 October 2015
- South Carolina, 2 - 4 October 2015
- Central Texas, 23-24 May 2015
- Oklahoma, April - June 2015
- Phoenix, Arizona, 19 August 2014
- Islip, New York, 13 August 2014
- Pensacola, Florida, 29-30 April 2014
- New Mexico, 9-16 September 2013
- Colorado, 9-16 September 2013
- Southern Missouri, 29 July - 8 August 2013
- San Antonio, Texas, 25 May 2013
- Oklahoma City region, 31 May-1 June 2013
- Tropical storm Debby, 24-27 June 2012
- Duluth, Minnesota, 19-20 June 2012
- Tennessee, 1-2 May 2010
- Southeastern New England, March 2010
- Southeastern United States, September 2009
- Ohio Valley, 23 - 27 March 1913



http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/index.html

Media

Where are Atlas 14 Estimates Used? - Infrastructure Design

- NOAA precipitation frequency estimates serve as the de-facto standards for designing, building and operating infrastructure to withstand the forces of heavy precipitation and floods:
  - municipal stormwater management systems, sediment control measures on construction sites, culverts, roadways and bridges, wastewater treatment plants, etc.
- Design criteria are governed by cities, municipalities, local or state governments and depend on an acceptable risk of failure.
  - smaller structures are designed to frequent events,
  - extremely rare estimates are used to assist in design and planning of dams and nuclear power plants.
- Also used for floodplain mapping and regulation of development in floodplains (National Flood Insurance Program).

Highway culverts	
Low traffic	5–10
Intermediate traffic	10–25
High traffic	50–100
Highway bridges	
Secondary system	10–50
Primary system	50–100
Farm drainage	
Culverts	5–50
Ditches	5–50
Urban drainage	
Storm sewers in small cities	2–25
Storm sewers in large cities	25–50
Airfields	
Low traffic	5–10
Intermediate traffic	10–25
High traffic	50–100
Levees	
On farms	2–50
Around cities	50–200
Dams with no likelihood of loss of life (low hazard)	
Small dams	50–100
Intermediate dams	100 +
Large dams	—
Dams with probable loss of life (significant hazard)	
Small dams	100 +

Generalized design criteria for water-control structures.
From Chow, Applied Hydrology

Why Is It Important for Regulatory Authorities to Reference the Most Recent Estimates?

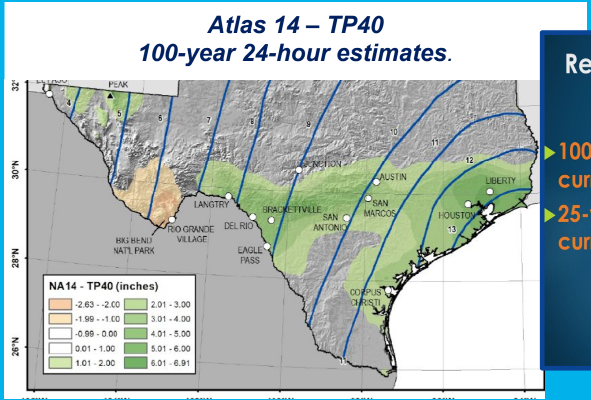
- ❑ Over-estimated precipitation frequency estimates can cause unnecessary cost to taxpayers or developers; under-estimated can result in destruction of property and loss of human life.
- ❑ Atlas 14 supersedes NOAA publications HYDRO35, TP40, TP49 and Atlas 2 published in 1950s to 1970s.
- ❑ New estimates are superior to superseded NOAA estimates in terms of accuracy, reliability, and resolution.

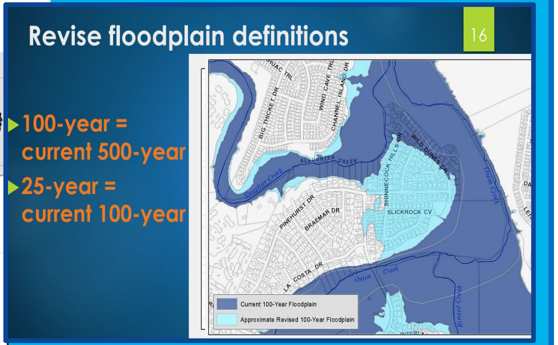
Example from Volume 11 (TX):
City of Austin analysis
(Colorado River floodplain excluded)

500-year floodplain is now 100-year floodplain

100-year floodplain increased ~25%

number of buildings in floodplain increased from ~3700 to ~6500





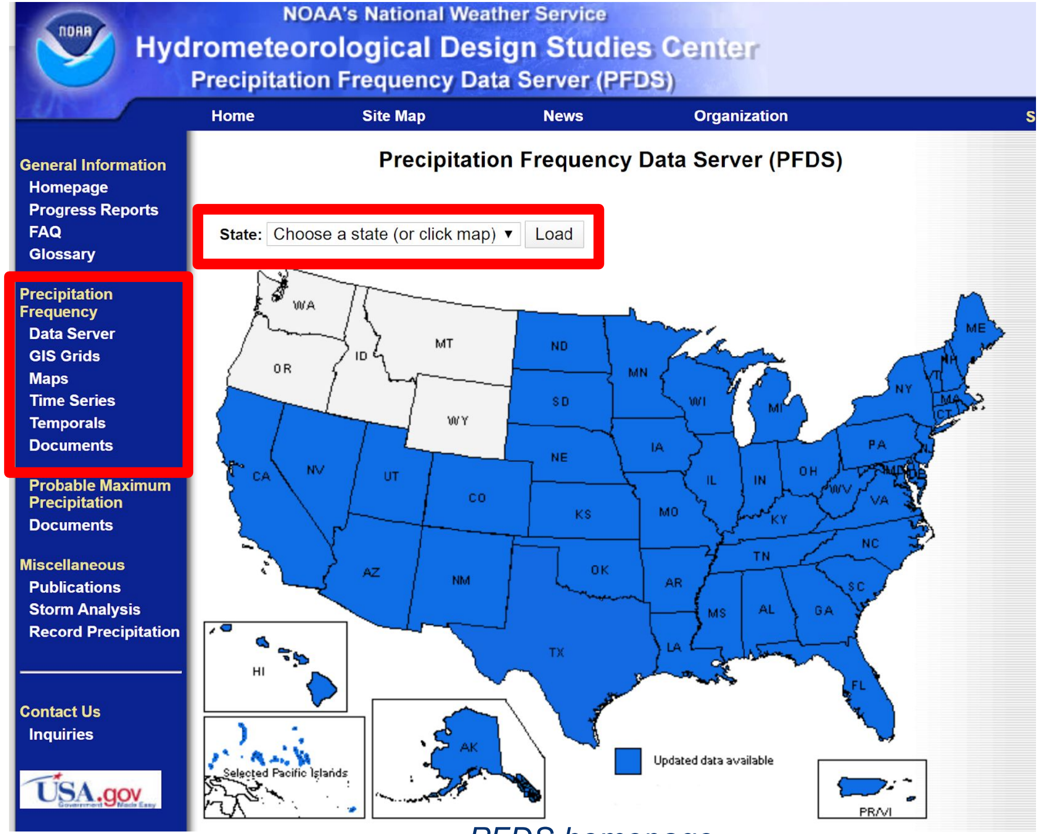
http://www.austintexas.gov/edims/document.cfm?id=302092

Where to Find Atlas 14 Estimates?

- ❑ NOAA Atlas 14 products can be downloaded from **Precipitation Frequency Data Server (PFDS)** (hdsc.nws.noaa.gov/hdsc/pfds/index.html)

- ❑ **Estimates for a specific location** can be retrieved by clicking on appropriate state on the map or selecting the state name from the drop-down menu

- ❑ **Estimates applicable across states in each volume** Can be retrieved from side menu under "Precipitation Frequency" tag

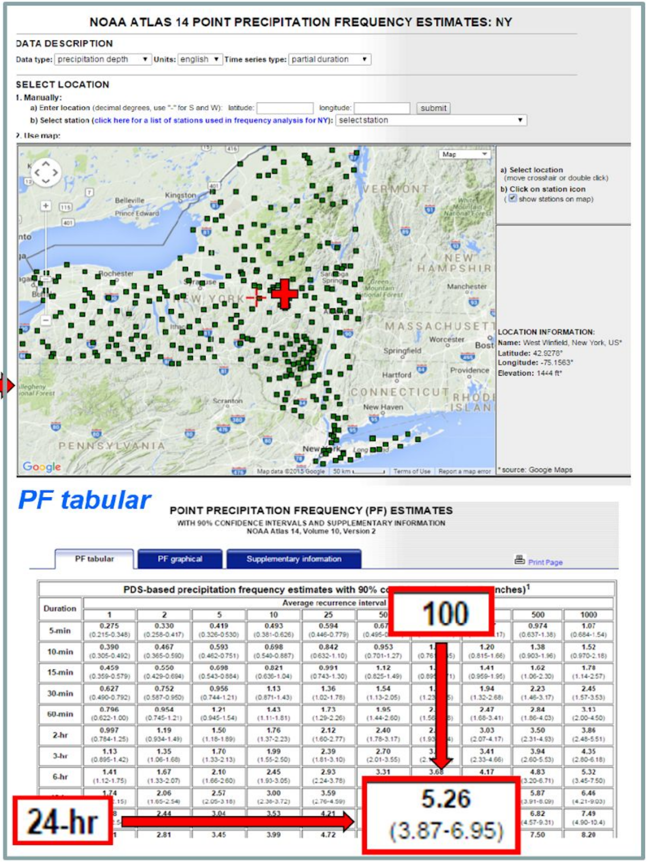


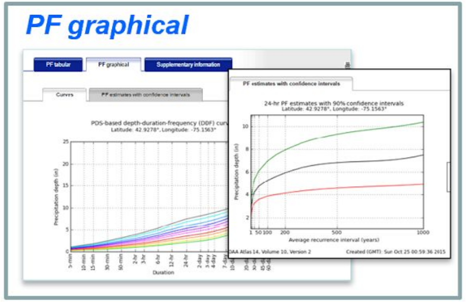
PFDS homepage

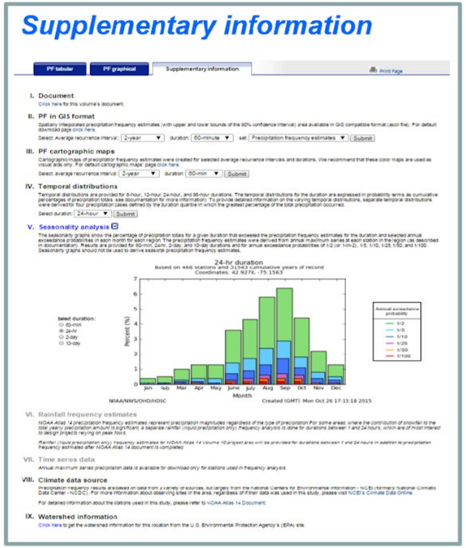
Atlas 14 Products for Selected Location

- **DDF estimates with confidence limits**
  Available in tabular and graphical format.

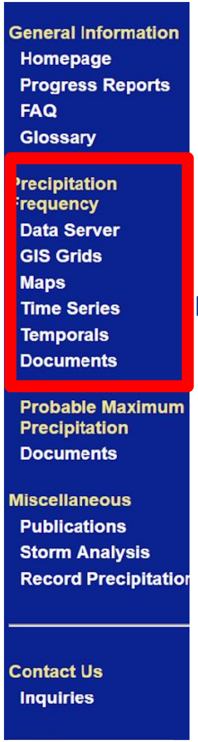
- **Supplementary information**
  - Documentation
  - GIS grids
  - Maps
  - Temporal distributions
  - Seasonality charts
  - Data
  - Rainfall estimates
  - Information on nearby NCEI climate stations and watershed (EPA).

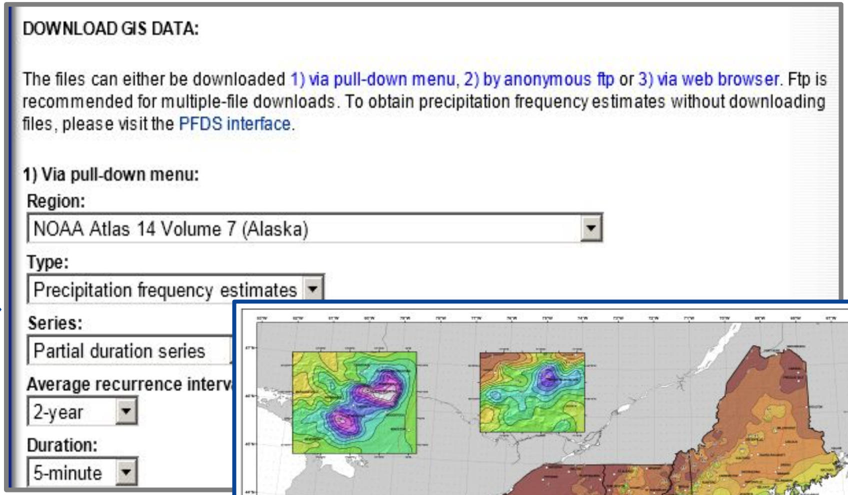


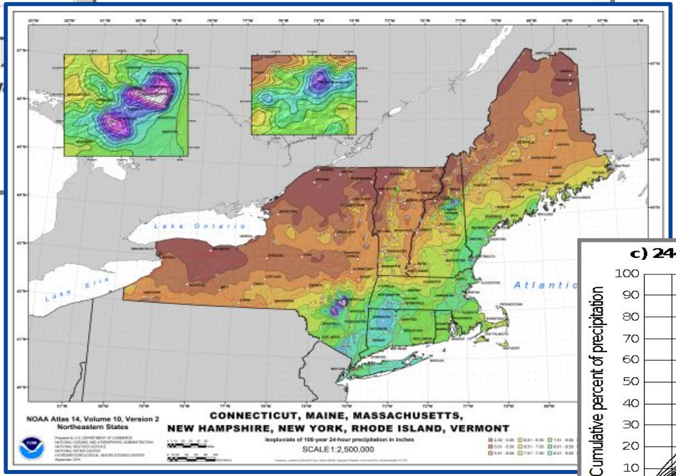


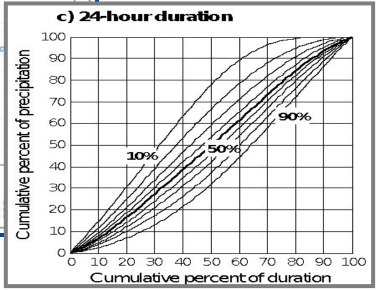


Atlas 14 Products Covering Whole Area within Each Volume

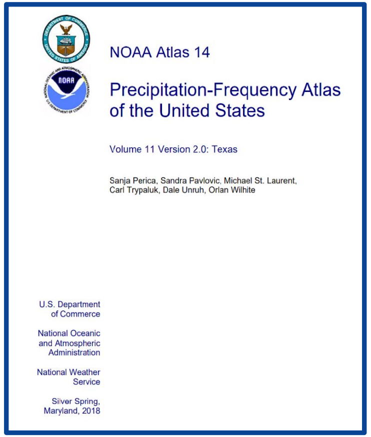






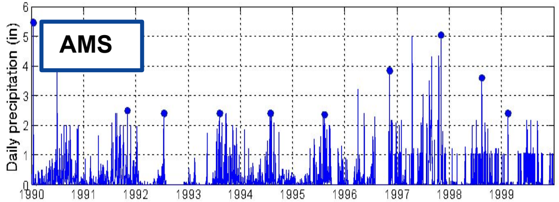


- 30 arc-sec GIS precipitation frequency grids with 95% confidence limits for 5-min to 60-day durations and up to 1,000-year ARI.
- Cartographic maps for selected durations and ARI
- Time series data used in analysis
- Temporals
- Documentation

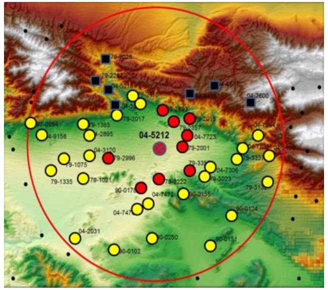


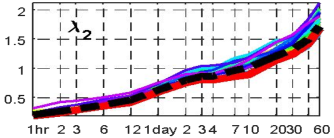
How are the Estimates Calculated?

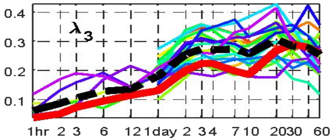
1. **Data collection, Annual Maximum Series (AMS) extraction and QC**
   - Data collection, digitization, formatting
   - Examination of geospatial data and station cleanup
   - AMS extraction for 17 durations and quality control



2. **At-station DDF/IDF curves**
   - Regionalization
   - Derivation of estimates and confidence limits

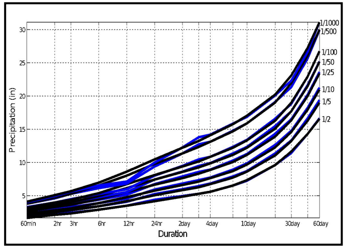


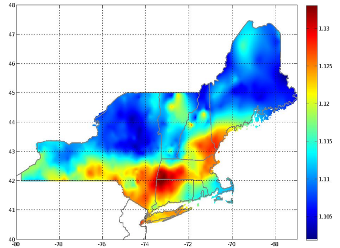




3. **Interpolation to 30 arc-sec grid**
   - PRISM statistical-geographic approach

4. **Peer review**
   - Funding agencies, HDSC list-server subscribers, others





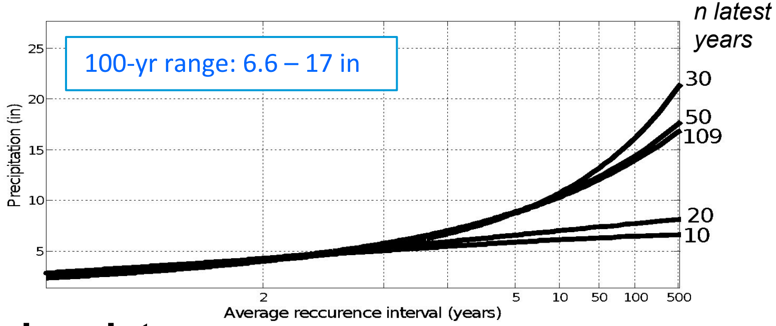
5. **Revision** (back to steps 1 to 3)

6. **Supplementary information**
   - Documentation, confidence intervals, cartographic maps, etc.

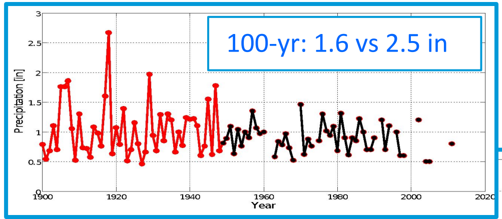
7. **Web publication**

What are Major Sources of Error? - Data!

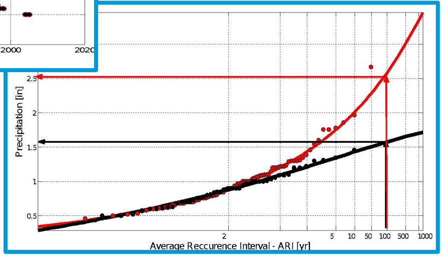
Record length



Missing data

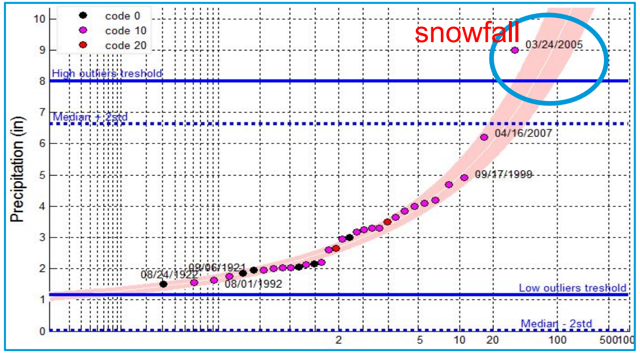


ITHACA, NY. Hourly record extended 49 years (pre-1948) through digitization

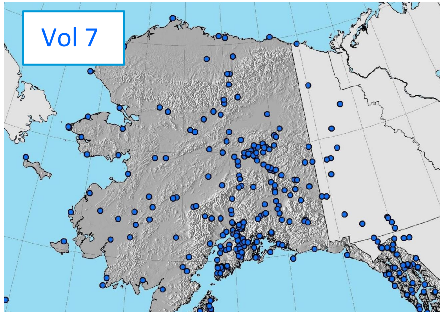


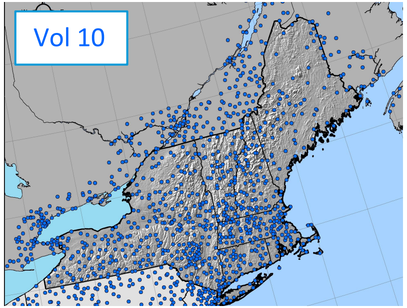
Quality control

Rhinebeck 4SE, NY
9 in of snowfall in 2005 archived as 9.00 in of liquid precipitation



Spatial coverage



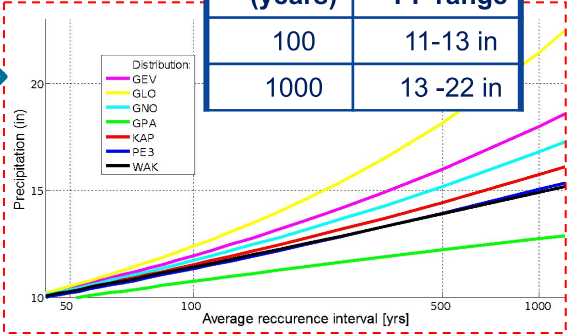


What are Other Major Sources of Uncertainty? Methods

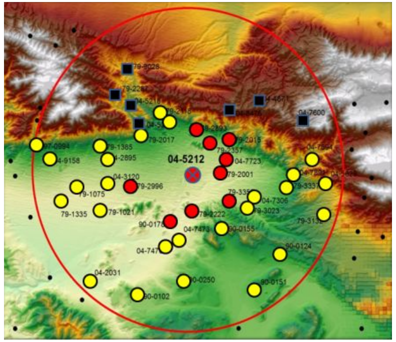
Distribution fitting

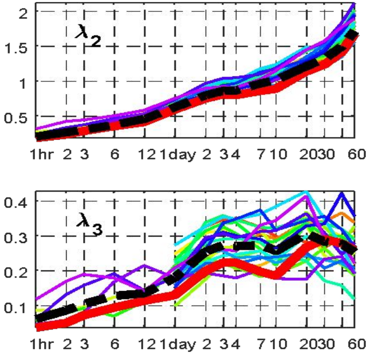
- Distribution selection
- Parameterization method
- Stationary vs non-stationary

ARI (years)	Potential PF range
100	11-13 in
1000	13 -22 in

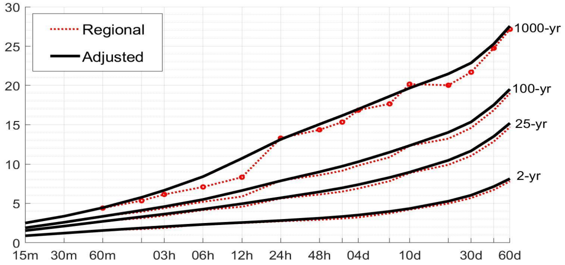


Regionalization

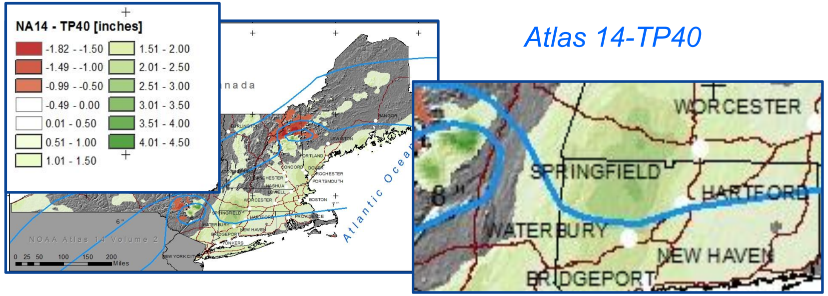




Optimization & consistency checks



Interpolation



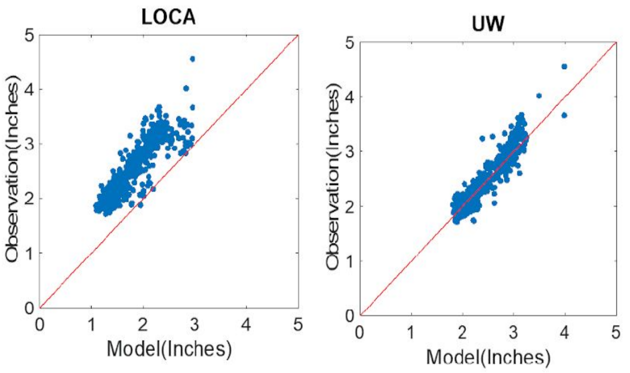
Atlas 14 Proposed Upgrades and Updates - Methodology Changes

Current

- Atlas 14 approach, developed in 1990s is based on assumption that extreme precipitation characteristics do not change in time.

Future

- Stationary Atlas 14 method will be replaced with non-stationary approach that can efficiently translate future climate scenarios into a product useful for NOAA Atlas 14.
- Outputs from two downscaled data sets from CMIP5 (LOCA, University of Wisconsin -UW) will be used (instead of time) to produce projected estimates under RCP4.5 and RCP8.5 emission scenarios.



Observed vs modeled mean AMS for period 1960-2005.
Each point represents one station from Vol 10.

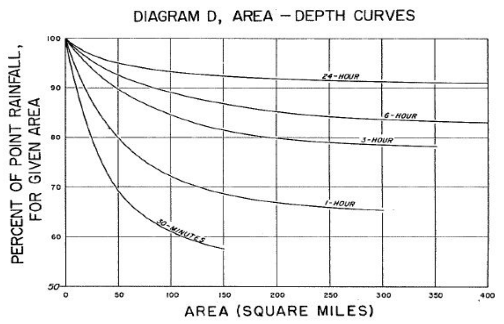
[1] *Datasets evaluated relative to Atlas 14: BCCAv2, LOCA, NA-CORDEX, UW.*

[2] *Development was done in collaboration with Penn State University, University of Illinois at Urbana-Champaign and University of Wisconsin-Madison.*

Atlas 14 Proposed Upgrades and Updates - Additional Products

❑ Areal Precipitation Frequency Estimates

- BACKGROUND: Atlas 14 estimates are point estimates. ARFs are used to convert point precipitation to average precipitation over a watershed. Many ARF methods have been proposed, but Weather Bureau's ARF curves from 1958 are still commonly used.
- PROPOSED: Derive regional ARFs and develop web tool to delineate watershed estimates.



Weather Bureau's ARF curves (1958)

❑ Atlas 14 Design Storm

- BACKGROUND: Atlas 14 provides precipitation frequency estimates for a given duration, but designers often need information on how precipitation is distributed in time and not just the total amount.
- PROPOSED: Develop Atlas 14 design storm product with guidance on how to use the product.

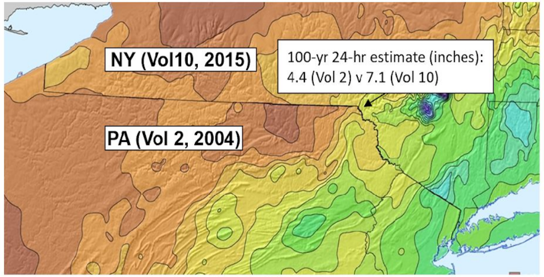
❑ Confidence Intervals

- BACKGROUND: Atlas 14 provides only bounds of 90% confidence interval
- PROPOSED: Development of confidence intervals of variable width

Atlas 14 Proposed Upgrades and Updates - Funding Approach

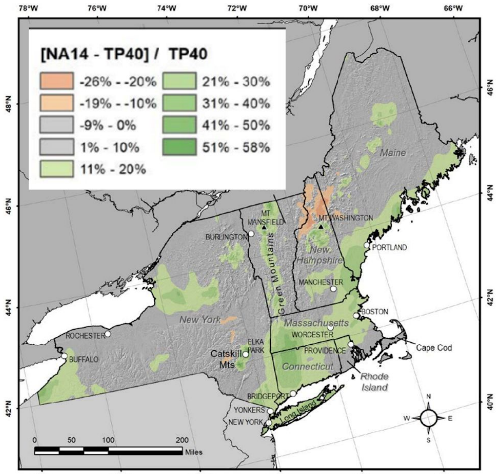
CURRENT

- Estimates are updated in Volumes as funding becomes available.
- Approach results in discontinuities at volumes' boundaries and creates issues for users that typically consider watershed (and not state-based) boundaries.



PROPOSED

- Estimates should be updated on a regular cycle of ~10 years to take advantage of more stations with longer records, addition of most recent data in the analysis and use of modern methods.
- Boundary issues could be avoided by updating all states simultaneously.



Having a continuous and sustainable funding approach will be a small investment that would result in significant return and benefits for infrastructure design in the U.S.

How to Contact Us?

Web: www.nws.noaa.gov/oh/hdsc

Email: HDSC.questions@noaa.gov