Towards NOAA Atlas 15

A National and Climate Informed Update to the NOAA Precipitation Frequency Atlas of the United States

Ed Clark, Sandra Pavlovic, Fernando Salas, Fred Ogden

NOAA/NWS Office of Water Prediction

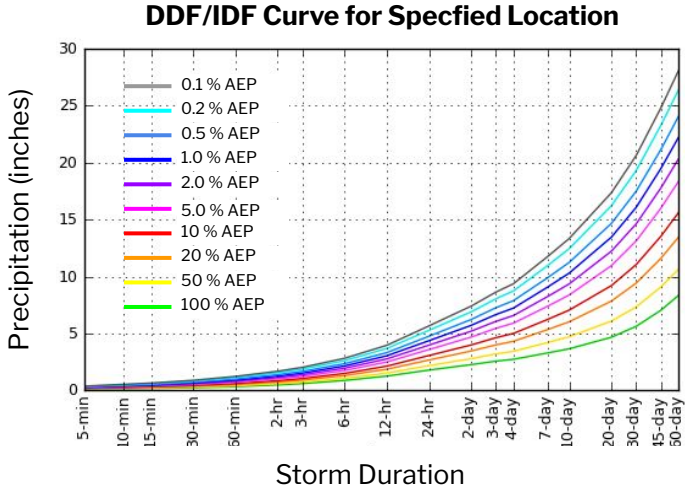
December 12, 2023

Acknowledgements: OWP HDSC Team, IBSS, RTI, Lago, CIROH, NC State, Univ. of Wisconsin, Univ. of Illinois, Penn State, Oregon State, DOT FHWA

OWP | OFFICE OF WATER PREDICTION

What are Precipitation Frequency Estimates?

- Precipitation amounts for a specified storm duration and an annual exceedance probability (or average annual recurrence interval).
- Precipitation **D**epth (or **I**ntensity) for a specified **D**uration and **F**requency (ARI or AEP).



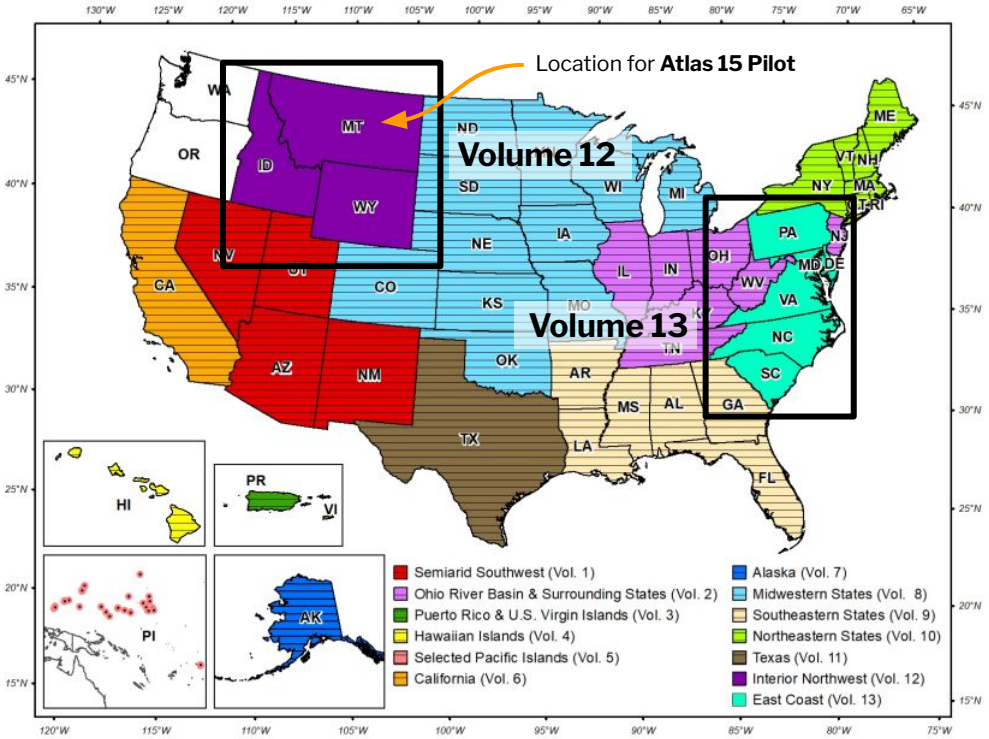
Depth-**D**uration-**F**requency (DDF) curves

Intensity-**D**uration-**F**requency (IDF) curves

How much precipitation would be expected for a storm event that is 10 days in duration and has a 1% chance of being observed?

How rare is it to observe 5 inches of precipitation over 2 days?

NOAA Atlas 14 Product Suite



Performed at request of states and funded through FHWA

Majority of built infrastructure leverages precipitation frequency data for design and planning under federal, state and local regulations

Volumes https://www.weather.gov/owp/hdsc

- Volume 1 (2004): Semi arid Southwest
- Volume 11 (2018): Texas
- **Volume 12 (2024) :** Montana, Idaho, and Wyoming
- **Volume 13 (2025):** Mid-Atlantic

Assumption: Stationary statistics

NOAA Atlas 14: The Generation of Authoritative Data Requires a Rigorous Development Process and Quality Control

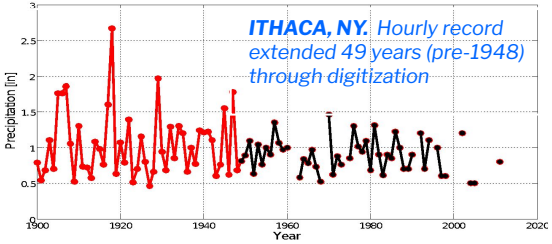
Data

- Period of record
- Missing data
- Quality Control
- Spatial Coverage

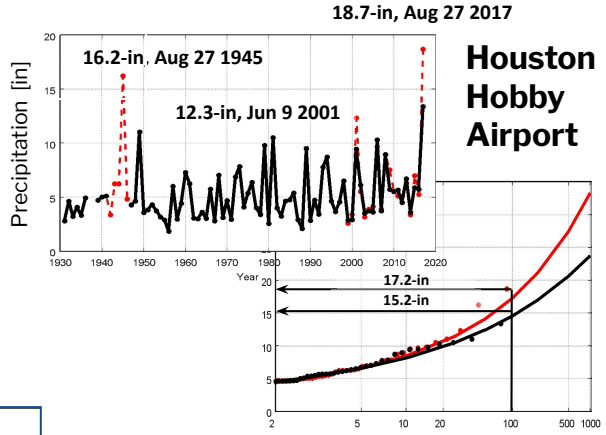
Methods

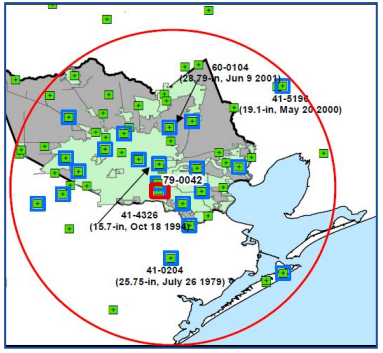
- Distribution selection
- Parameterization method
- Stationary vs non-stationary methodology
- Regionalization
- Interpolation
- Optimization & consistency checks

Missing data and digitization

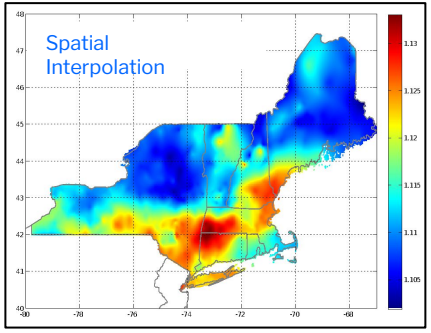


1% AEP
1.6 vs 2.5 in



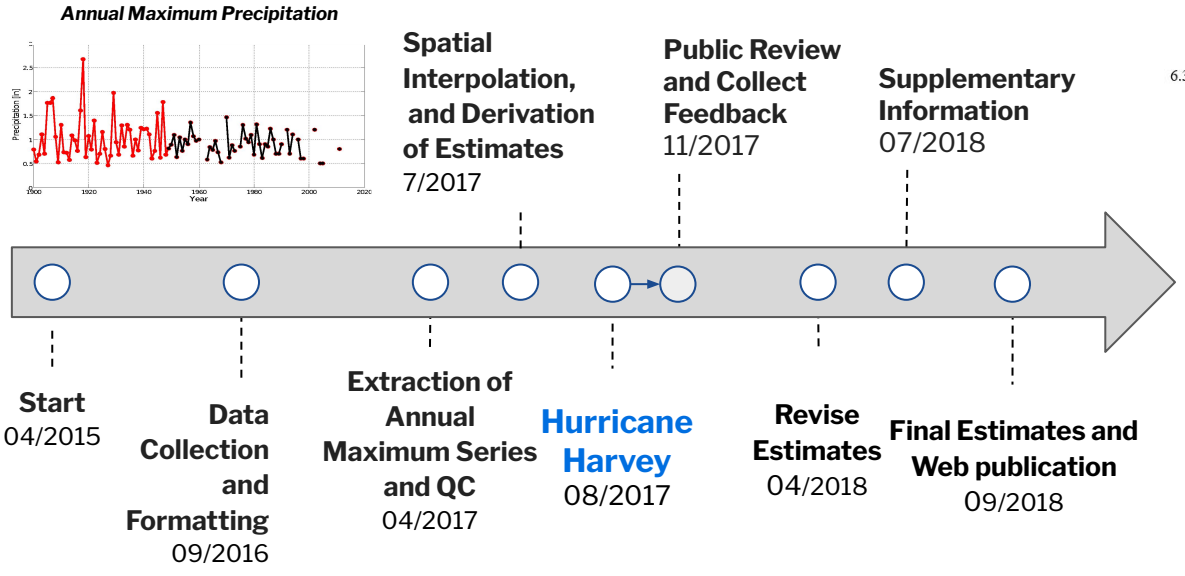


Regionalization



Hurricane Harvey Quality Control and Public Review

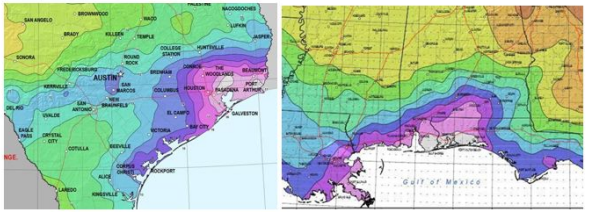
During the production of Atlas 14 Volume 11 (Texas), the **quality control and public review process was essential** to delivering a reliable precipitation frequency product. Stakeholders deemed it necessary to include data from **Hurricane Harvey,** which **increased the product's value**.



Public informed on development through
HDSC Quarterly Progress Reports

6.3.8. There's absolutely no basis why Houston should be 17-18 while El Campo is 13-14. Or why Austin has a local maxima probably related to the high rain gage density there.

In fact, these spurious local maxima can be seen elsewhere too. For example, southern Alabama.



The only way to fix these issue would involve a substantial re-working of the whole method. The current method is simply: Precipitation Frequency Curve (PF) = function (gages within 50 or 100 miles around a gage of interest). Whereas the more rigorous method should be: PF Curve = function (gages within 50 or 100 miles, topography, distance from coastline, local/regional atmospheric enhancement). If you were to do that, the whole coast from Corpus Christ through Wilmington or Cape Hatteras would probably be 16+ inches for a 100-year 24-hour event, a significant increase over current values.

In NA14 we rely on regional frequency approaches to calculate estimates at one station. We use a so-called region-of-influence approach where each station has its own region with a potentially

An excerpt from:

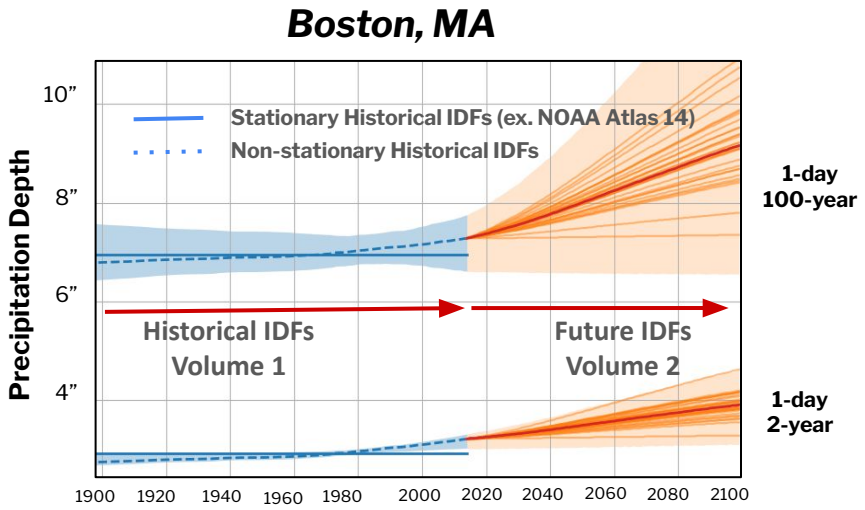
Atlas 14 Volume 11 Appendix A.4. Peer review comments and responses

NOAA Atlas 15 Methodology Developed: Accounting for Nonstationarity

"Analysis Of Impact Of Nonstationary Climate On NOAA Atlas 14 Estimates : Assessment Report"

Objective 1: Assess the suitability of state-of-the-science methodologies for nonstationary precipitation frequency analysis.

Objective 2: Evaluate downscaled global projections' ability to mimic extreme precipitation at the temporal and spatial scales needed for the engineering application.



- Result of extensive, multi-year study conducted with Penn State University, University of Illinois Urbana-Champaign and University of Wisconsin-Madison
- Testing done for Atlas 14 Volume 10 project area (Northeastern States)
- Development of methodology conducted in coordination with, and funded by DOT FHWA

The NOAA Atlas 15 Product

Volume 1: Based on historical gages and observed trends

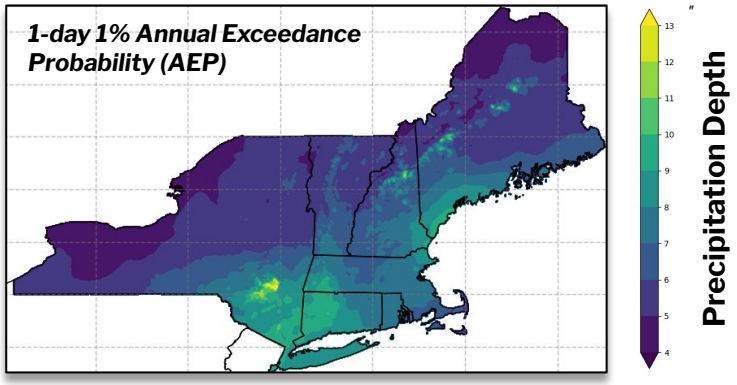
- First-ever, nationally-consistent, precip frequency data that serves as the basis for Volume 2
- Integrated terrain information
- Accounts for trends in historical observations (when it exists)
  - Non-stationary trends represents a major enhancement from Atlas 14

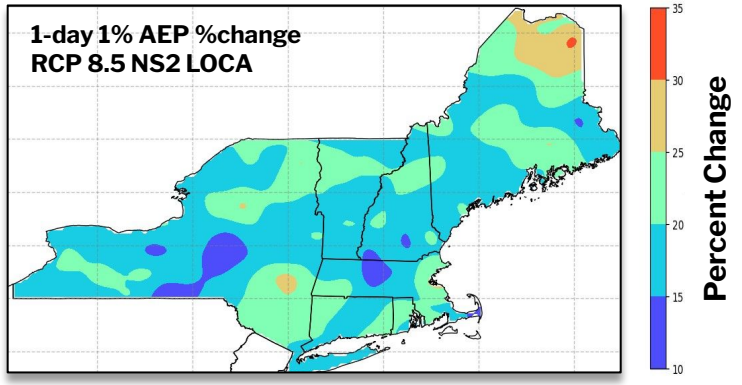
Volume 2: Incorporates climate projection adjustment factors

- Future precipitation informed by global climate models, modeled non-stationary temporal changes
- Provides adjustment factors to Volume 1 to calculate future estimates

1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

2030 2040 2050 2060 2070 2080 2090 2100 2110 2120





Note: Derived from Multiple Models

Bipartisan Infrastructure Law (BIL): First Direct Federal Funding

Bipartisan Infrastructure Law summary: *"Shall be for coastal and inland flood and inundation mapping and forecasting, and next-generation water modeling activities,* ***including modernized precipitation frequency*** *and probable maximum studies."*

"To support the design, development, and operation of our nation's built infrastructure, from new power plants to transportation systems, NOAA ***will update and revise precipitation frequency atlases for the United States that account for climate change***…"

For the first time, NOAA now will apply a nationwide update for precipitation frequency data – a long standing and highly sought need for the future of our nation's infrastructure

NOAA Atlas 15 Road Map

2022/2023

- **Feb. - Aug. 2022** - Published methodology and briefed stakeholders
- **Sept. 2022** - Distributed Public Notification Statement (PNS) and collect public feedback.
- **Jan. 2023** - Hosted technical workshop with federal partners.
- **Apr. - June 2023** - Awarded contracts and grants and initiated product development.

2024

- **Development** - Evolve framework. Create Quality Controlled National Precipitation Database. Evaluate Climate Model Projections
- **Pilot** - Deliver Atlas 15 Vol. 1 and Vol. 2 pilot over Montana.

  Collect and adjudicate feedback on preliminary estimates and Web dissemination strategies.

2025

- **CONUS -** Publish preliminary data
- **CONUS** - Initiate 60-day peer review for Atlas 15 Vol. 1 and Vol. 2 for CONUS (lower 48 states).

  Collect feedback and adjudicate comments on product.

2026

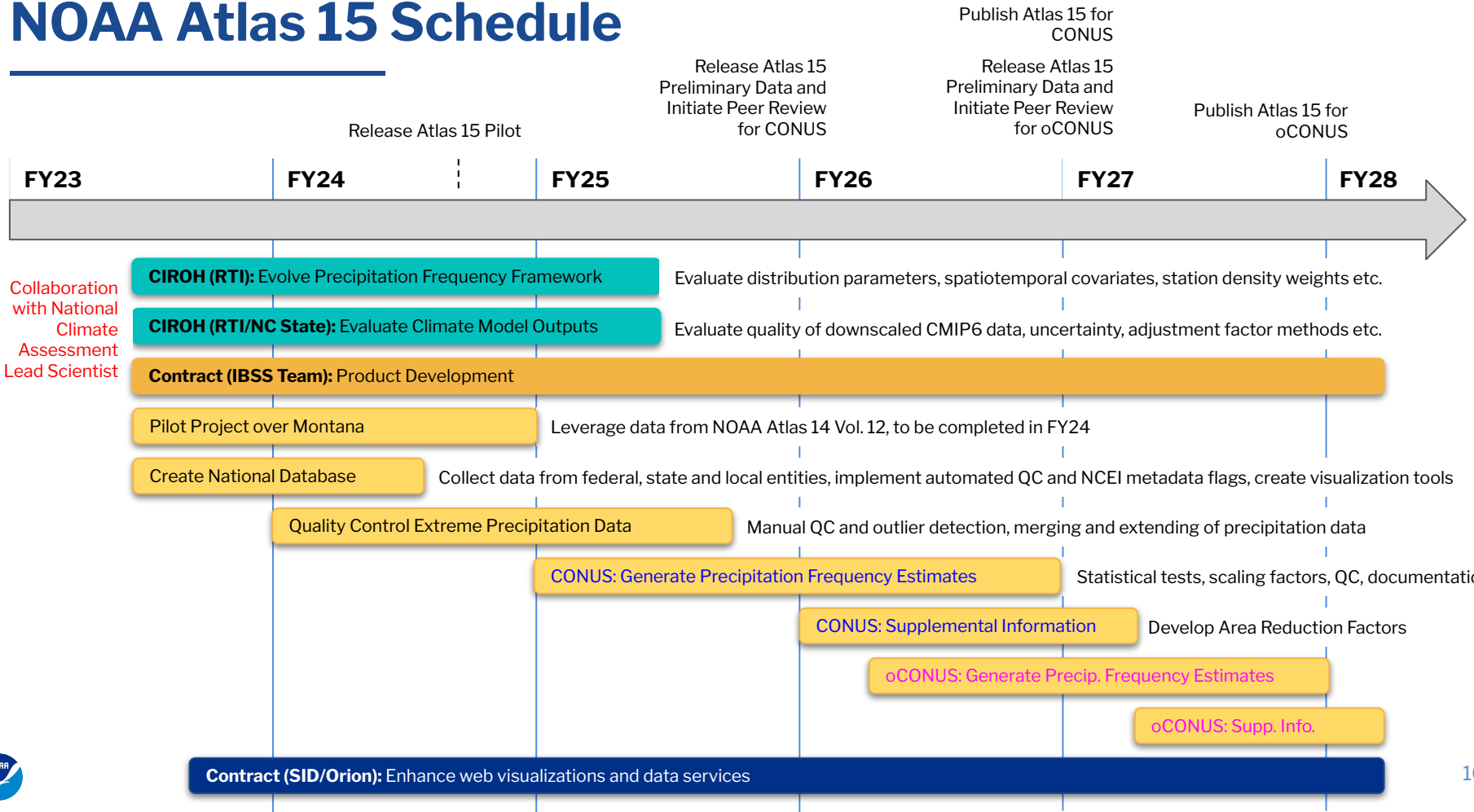
- **CONUS** - Complete Atlas 15 Vol. 1 and Vol. 2 and publish final estimates, documentation and supplementary products to stakeholders.
- **oCONUS** - Initiate peer review for oCONUS (e.g. Hawaii, Alaska, Puerto Rico, U.S. Virgin Islands, Guam).

  Collect feedback and adjudicate comments on product.

2027

- **oCONUS** - Complete Atlas 15 Vol. 1 and Vol. 2 and publish final estimates, documentation and supplementary products to stakeholders.

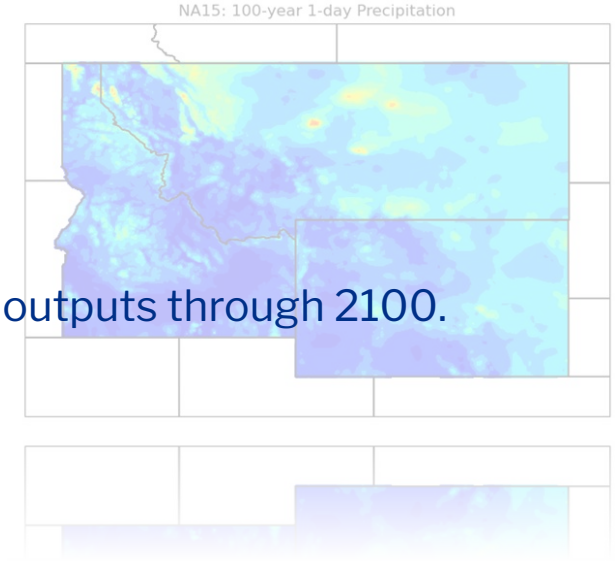
NOAA Atlas 15 Schedule



NOAA Atlas 15 Pilot for Montana: Summary

Volume 1: Estimates derived from trends in historical observations.

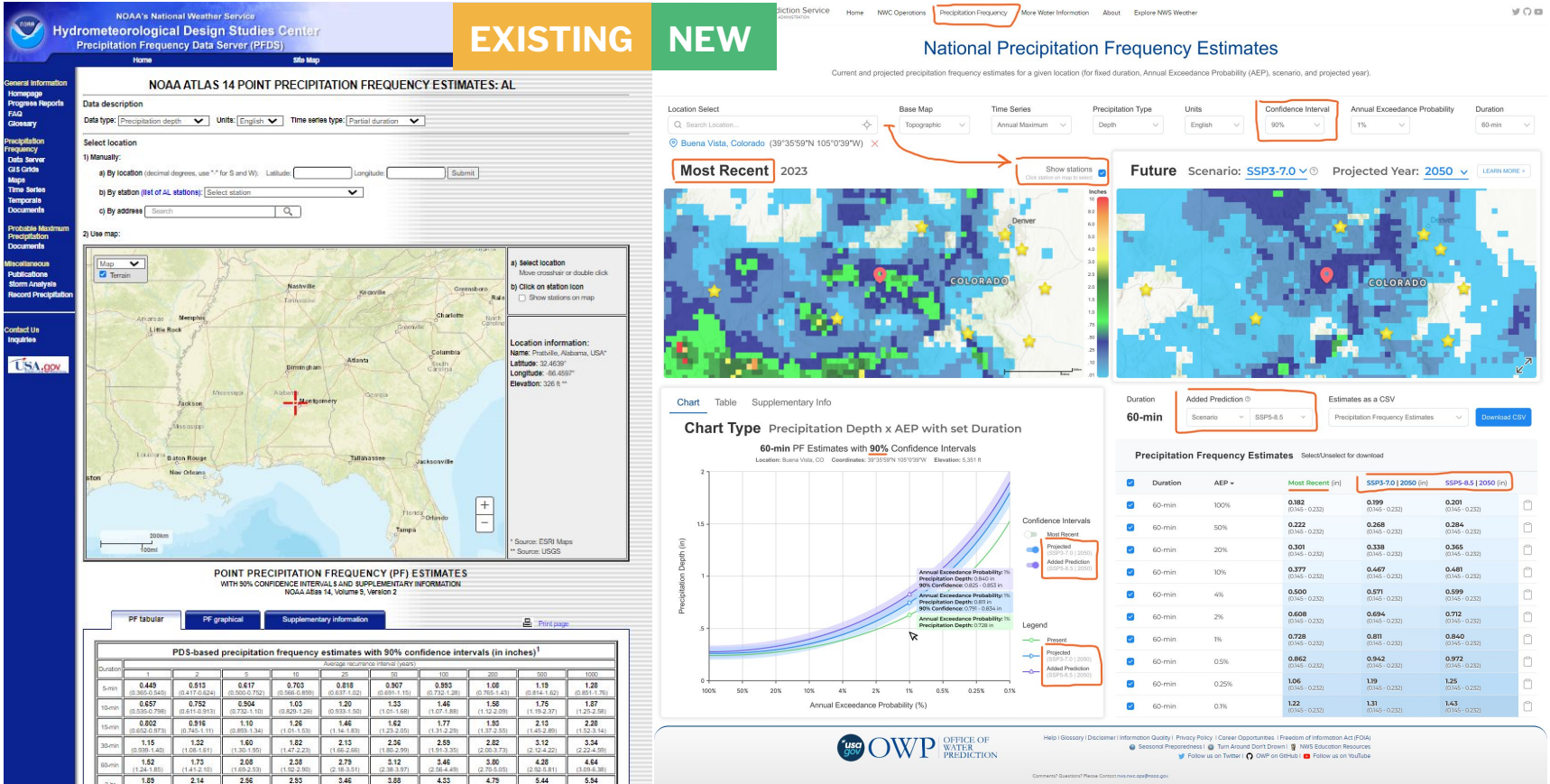
- **Format of AMS-based rasters:** Zarr
- **Durations:** 1 hour to 10 days
- **Annual Exceedance Probabilities:** 50% to 1%
- **Comparisons:** Atlas 14 Volume 12



Volume 2: Adjustment factors derived from climate model outputs through 2100.

- **Format of AMS-based rasters:** Zarr
- **Durations:** 1 hour to 10 days
- **Annual Exceedance Probabilities:** 50% to 1%
- **Scenarios:** SSP2-4.5, SSP5-8.5
- **Climate Datasets:** LOCA2, STAR-ESDM, UWPD, CONUS404

NOAA Atlas 15 Pilot for Montana: Web



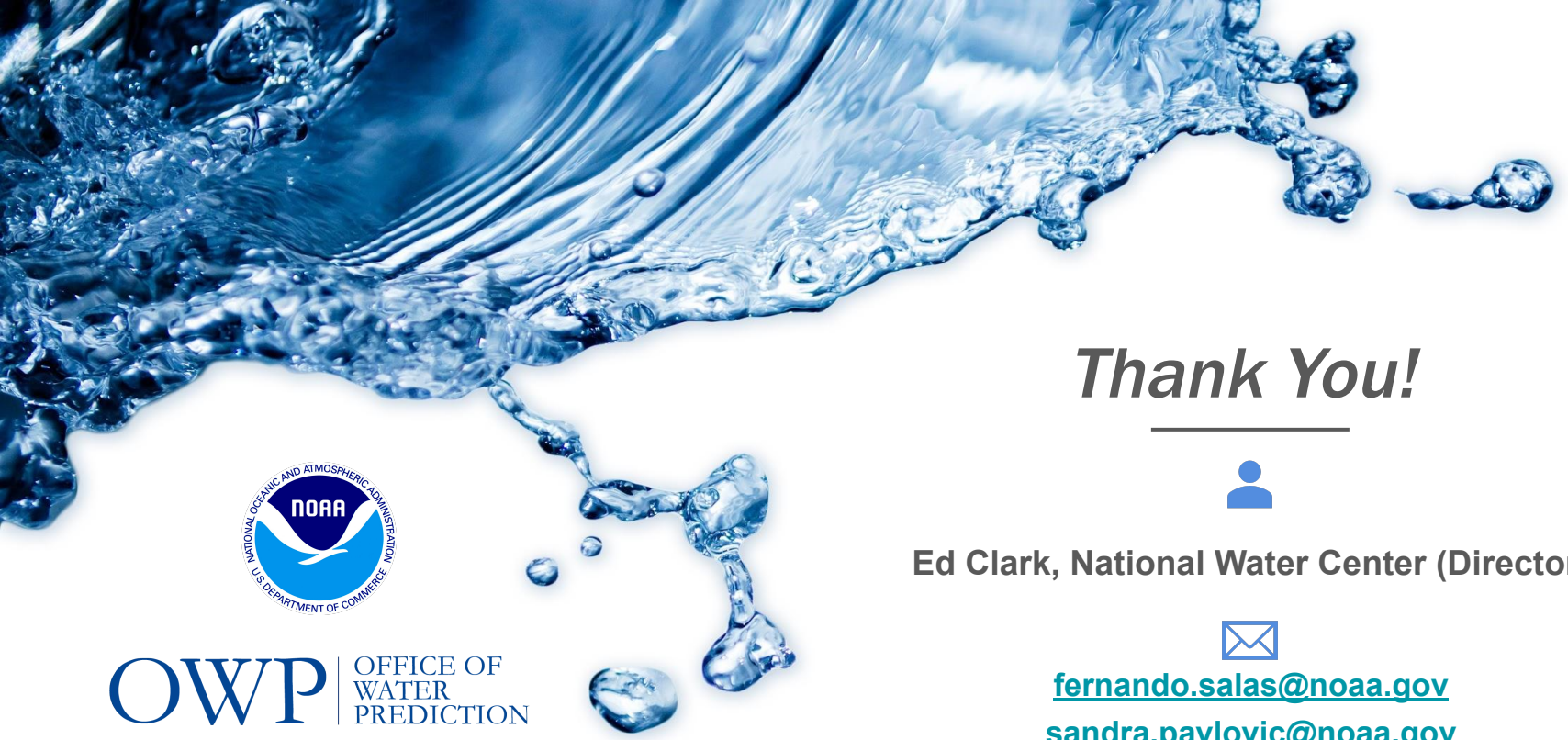
Acknowledgements - Technical Team

NOAA Atlas 14

- **NOAA -** Greg Fall
- **IBSS -** Austin Jordan, Sridhar Mantripragada
- **CIROH / RTI -** Michael St. Laurent, Carl Trypaluk, Dale Unruh

NOAA Atlas 15

- **IBSS / RTI / Lago -** Brian Beitler, Maria Bravo, Ryan Clare, Victoria Clear, Jacquelyn Crowell, Nestor Hernandez, Marcelo Lago, Jennifer Lake, Sydney Lybrand, Sanja Perica, Cody Polera, Kevin Sanchez, Alana, Shuvalau, David Tedesco, **Lynne Trabachino**, Danielle White
- **CIROH / RTI / NC State / Univ. of Wisconsin -** Joshua Eston, **Janel Hanrahan**, Ken Kunkel, David Lorenz, Debbie Martin, Bowen Pan, Liqiang Sun, Xia Sun



Thank You!

Ed Clark, National Water Center (Director)

fernando.salas@noaa.gov

sandra.pavlovic@noaa.gov

https://hdsc.nws.noaa.gov

OWP | OFFICE OF WATER PREDICTION

Extra Slides

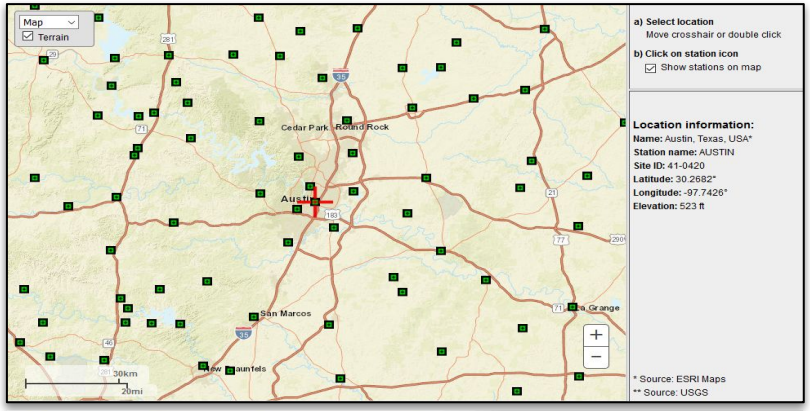
Precipitation Frequency and Probable Maximum Precipitation (PMP)

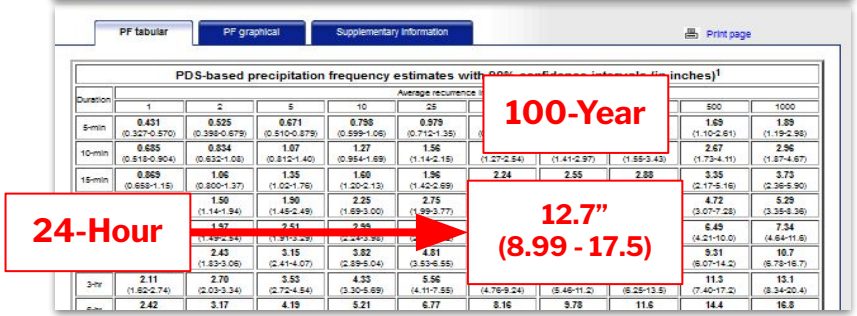
Comparison	PMP	Precipitation Frequency (Atlas 14)
Definition	Defined as the greatest depth of precipitation for a given duration meteorologically possible for a design watershed or a given storm area at a particular location at a particular time of year (World Meteorological Organization, WMO-No. 1045, 2009) Defined for areas such as watersheds; can cover up to 10,000 square miles.	Defined as the precipitation depth, at a particular location and for a given duration that has a statistically-expected 1-in-YY chance of being exceeded in any given year, where YY is the annual recurrence interval. Defined for finite points on the earth surface.
Development	Storm-based approach that uses archived and projected storms to assess extreme rainfall events that can be geographically transposed to the study area. Incorporates meteorologic and statistical methods. Future PMP studies should account for climate change. Method summary in ESEWG recommendations report, Section 4.2.2.	Point-based approach that uses observed point precipitation (e.g., rain gages) without regard to causative storm events. Incorporates statistical methods. Current methods assume stationary climate. Future methods under development are expected to consider non-stationary climate impact on point locations. Method details in Atlas 14, Volume 11, Section 4
Use	Used for design of large-scale, critical facilities and assets (e.g. dams, nuclear power plants) to address high-hazard risks for events involving catastrophic failure. Considered to represent the "worst case" maximum rainfall to be able to occur.	Used for design of engineering projects and planning and development (e.g. transportation, stormwater management, small-scale infrastructure, flood risk) to design at acceptable risk level. Not intended for use beyond 1000-year average recurrence interval, or 1/1000 annual exceedance probability.

PMP used for high impact infrastructure such as dams

- **Bipartisan Infrastructure Law** (FY 2022–2026) and **PRECIP Act** (passed Dec 2022), provide support to NOAA to modernize PMP
- **National Academies of Science, Engineering, and Medicine** conducting review of PMP science (Oct. 2022- Oct. 2024) and will provide recommendations to NOAA and community on how to move forward.
- **PRECIP Act authorizes NOAA** to generate and publicly disseminate new PMP estimates **by 2030**; no appropriation.
- **FLOODS Act authorizes NOAA** to generate and update Precipitation Frequency estimates **once every 10 years**; no appropriation.

NOAA Atlas 14 Features





https://hdsc.nws.noaa.gov/pfds/

Product Features

- from 5 minutes to 60 days
- recurrence intervals of 1 to 1000 years
- confidence intervals
- high spatial resolution (~800 m)
- spatial interpolation (account for terrain, coastal proximity, etc.)
- numerous internal consistency checks
- regional approach that allows for the development of rare frequency
- denser rain gauge networks with longer periods of record, and extensive quality control

Assumptions

- Assumes stationarity in data and methodology; doesn't account for climate change

NOAA Atlas 15 Volume 2 Development

Assessment Report Recommendations
Climate model application to hourly durations and rare AEPs (< 1%) requires further investigation.

- **Subdaily (5-min to 24-hr) Durations: Convection-resolving Climate Models**
  - Evaluate if subdaily relative adjustment factors scale as daily
  - Utilize the Convection-resolving Climate Models (CRCMs) simulations
  - **Limitations:** Active area of research, limited datasets available for CONUS and oCONUS.
- **Rare AEPs (<1%): Large ensemble analysis**
  - Analyze large ensembles to investigate whether there are statistically-robust differences in change factors across the range of 2 and 0.1%
  - **Limitations:** Active area of research, large uncertainty.

Summary

- NOAA is recognized by the engineering and floodplain management communities as **the authoritative** source of precipitation frequency data, and we have a long history of generating these data that serve as the foundation for **built infrastructure nationwide**
- The generation of authoritative precipitation frequency information **requires a rigorous development process and extensive quality control with significant stakeholder interaction**
- To account for a changing climate, NOAA, in coordination with FHWA and the academic community, **developed a new methodology for Atlas 15 that has undergone broad review** by stakeholders and Federal partners over the past year
    - **Atlas 15 Volume 1 is an essential first-step** to develop Atlas 15 Volume 2
- **BIL Provision 3 resources represent the first direct Federal funding** for precipitation frequency development and will support the generation of Atlas 14/15 data
- **Atlas 14 Volumes 12 and 13 are currently under development, and Atlas 15 data are being collected and quality controlled in parallel to framework evolution and climate model evaluation**

The NOAA Atlas 15 Product

Volume 1: Based on historical gages and observed trends

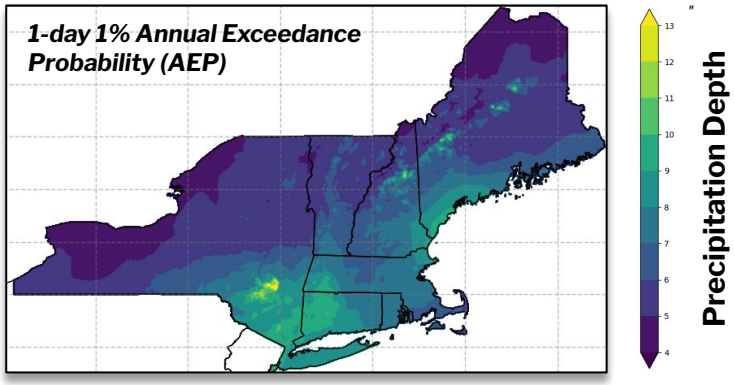
- First-ever, nationally-consistent, precip frequency data that serves as the basis for Volume 2
- Integrated terrain information
- Accounts for trends in historical observations (when it exists)
  - Non-stationary trends represents a major enhancement from Atlas 14

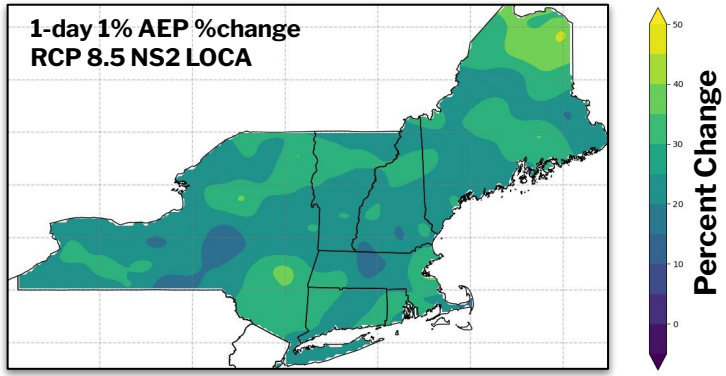
Volume 2: Incorporates climate projection adjustment factors

- Future precipitation informed by global climate models, modeled non-stationary temporal changes
- Provides adjustment factors to Volume 1 to calculate future estimates

1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

2030 2040 2050 2060 2070 2080 2090 2100 2110 2120





Note: Derived from Multiple Models

The NOAA Atlas 15 Product

Volume 1: Based on historical gages and observed trends

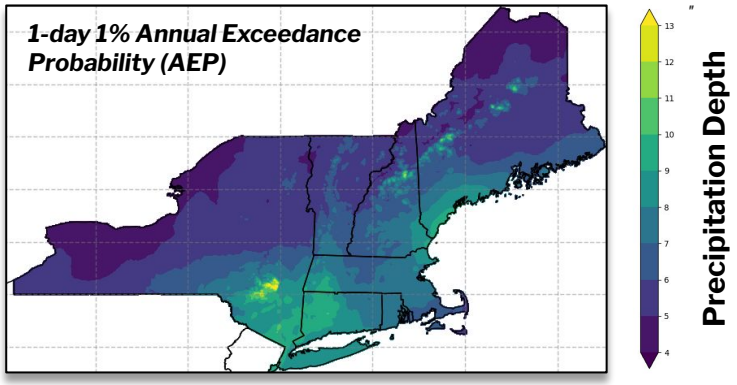
- First-ever, nationally-consistent, precip frequency data that serves as the basis for Volume 2
- Integrated terrain information
- Accounts for trends in historical observations (when it exists)
  - Non-stationary trends represents a major enhancement from Atlas 14

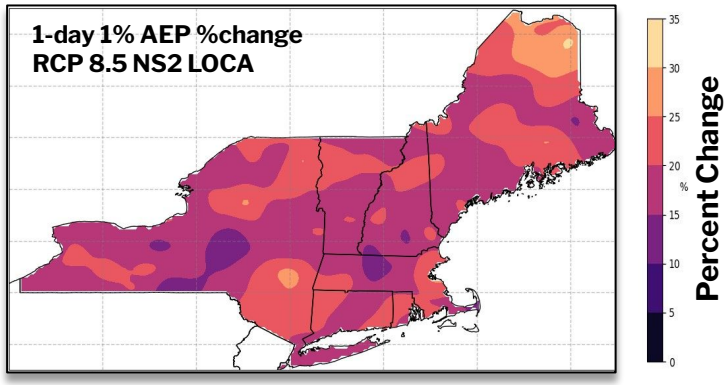
Volume 2: Incorporates climate projection adjustment factors

- Future precipitation informed by global climate models, modeled non-stationary temporal changes
- Provides adjustment factors to Volume 1 to calculate future estimates

1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

2030 2040 2050 2060 2070 2080 2090 2100 2110 2120





Note: Derived from Multiple Models

The NOAA Atlas 15 Product

Volume 1: Based on historical gages and observed trends

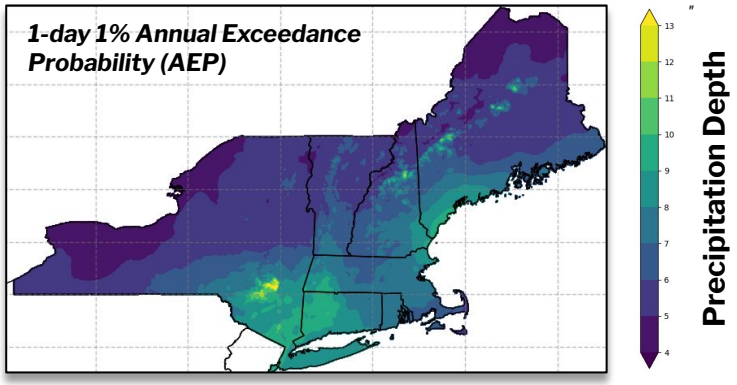
- First-ever, nationally-consistent, precip frequency data that serves as the basis for Volume 2
- Integrated terrain information
- Accounts for trends in historical observations (when it exists)
  - Non-stationary trends represents a major enhancement from Atlas 14

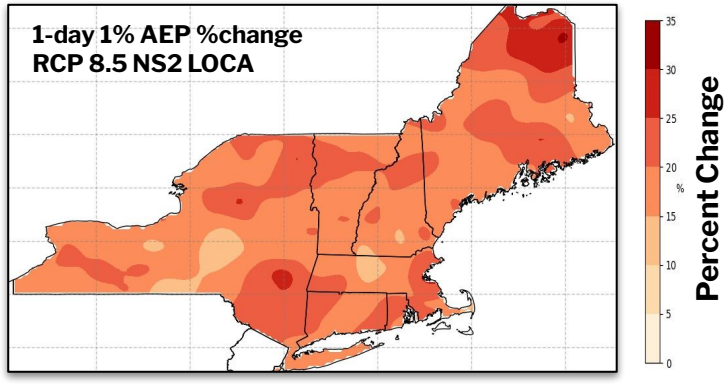
Volume 2: Incorporates climate projection adjustment factors

- Future precipitation informed by global climate models, modeled non-stationary temporal changes
- Provides adjustment factors to Volume 1 to calculate future estimates

1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

2030 2040 2050 2060 2070 2080 2090 2100 2110 2120





Note: Derived from Multiple Models