

RMC-BestFit: Bayesian Flood Frequency Analysis

DLS-114, Module 1.13



U.S. ARMY



**US Army Corps
of Engineers®**

Dam and Levee
Safety Programs

March 2026 / Version 1

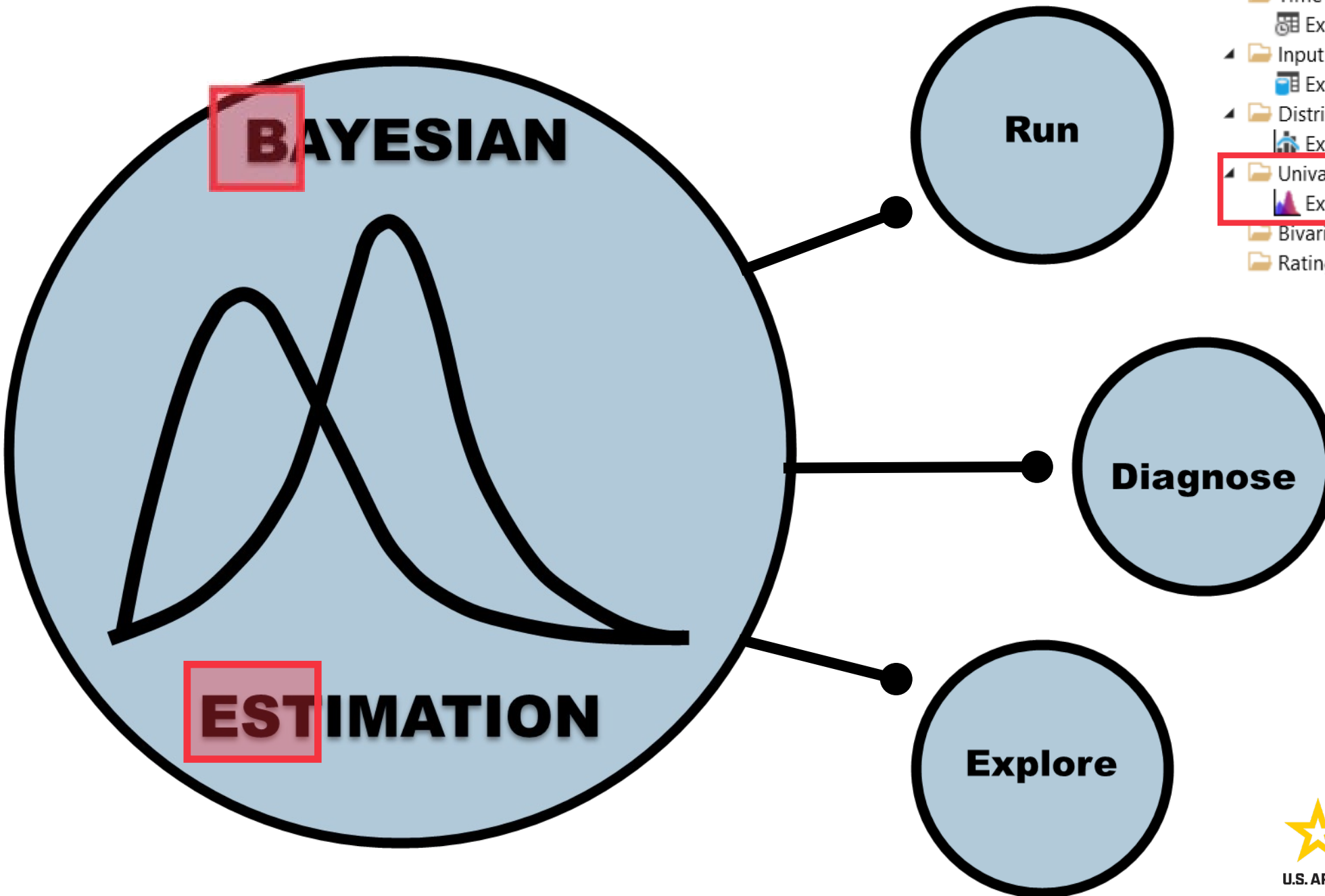
COUGAR DAM, OR (SOURCE: USACE)

Learning Objectives

- Describe the basics of Markov Chain Monte Carlo (MCMC)
- Review Bayes in Univariate Distribution with RMC-BestFit

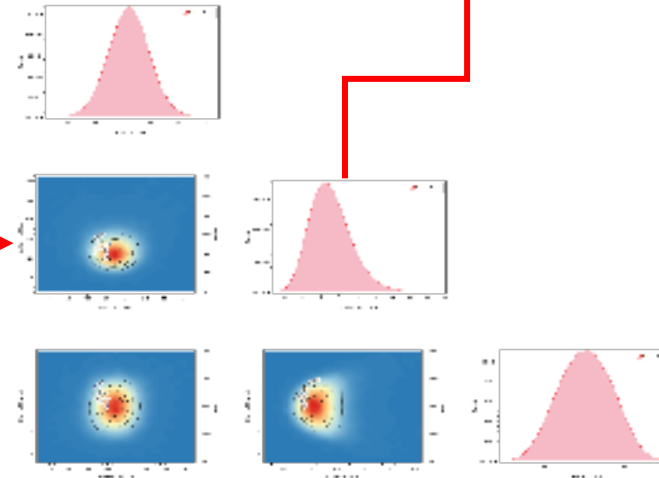
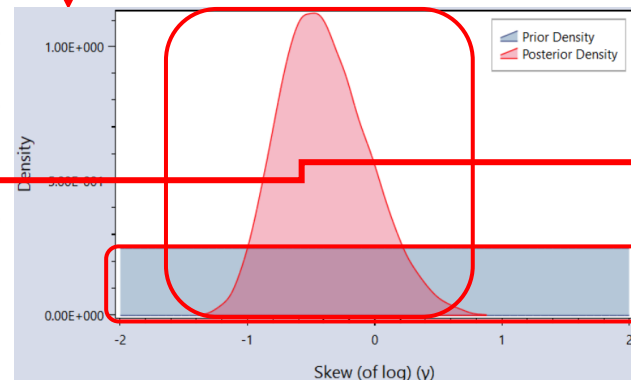
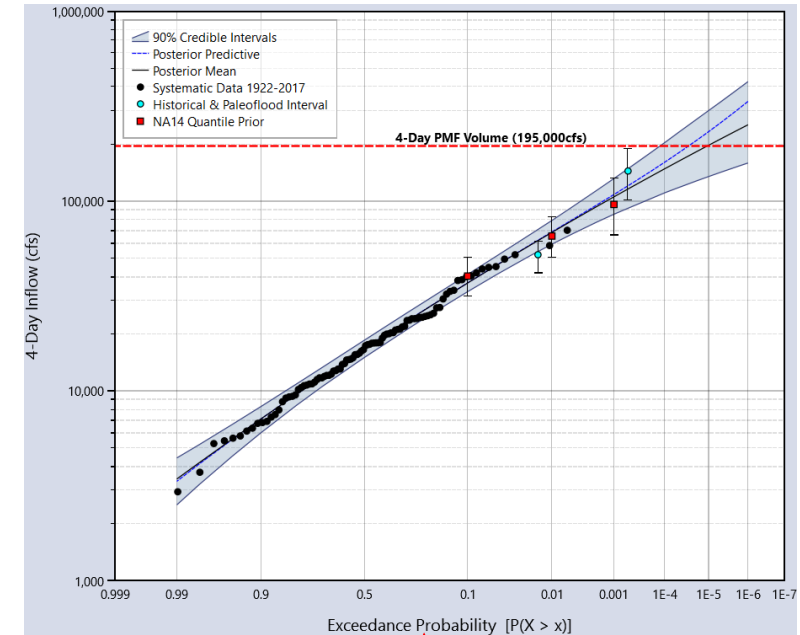
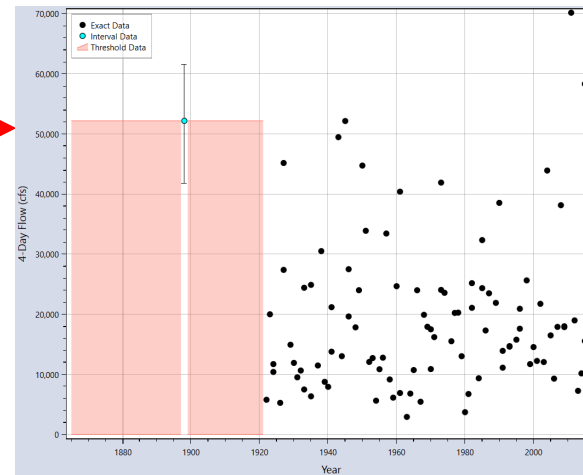
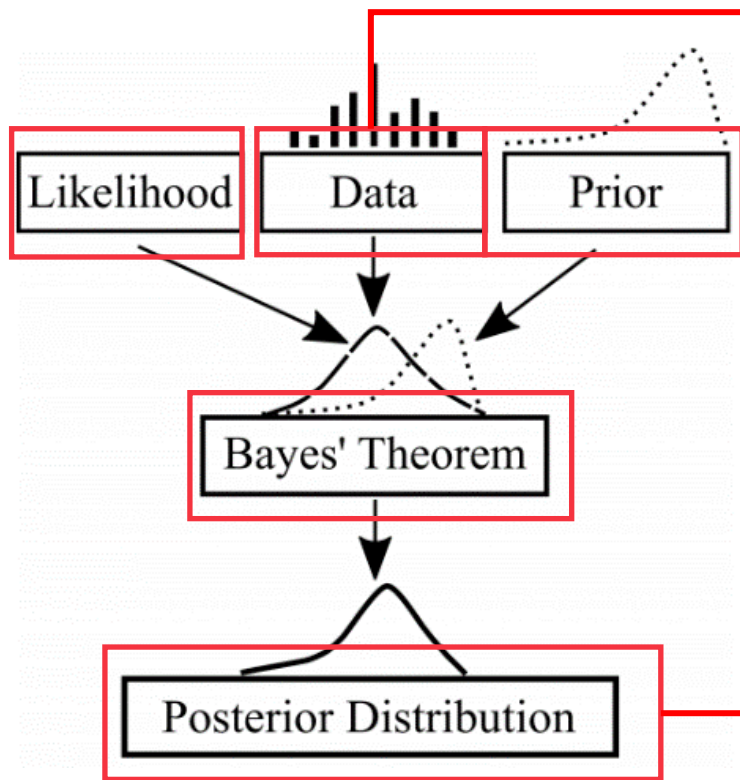


Cougar Dam

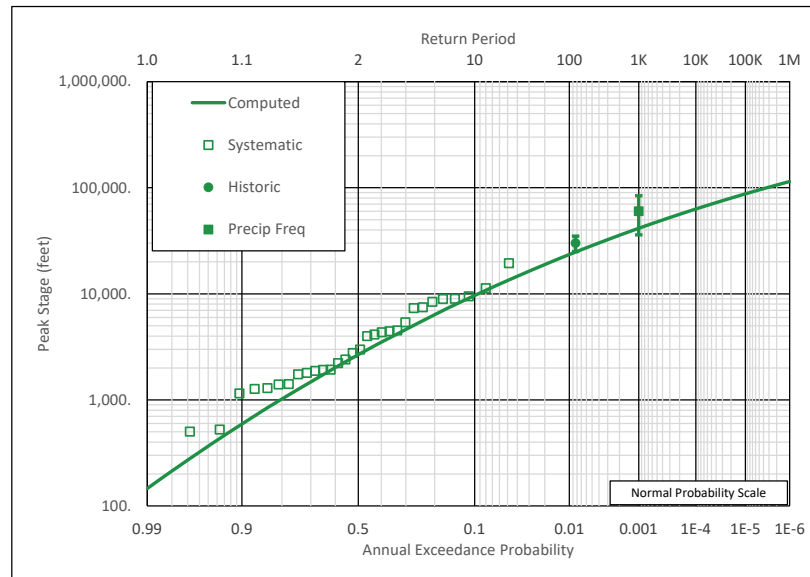


- Simple Example
 - Time Series Data
 - Example Time Series
 - Input Data
 - Example Input
 - Distribution Fitting Analysis
 - Example Distribution Fitting
 - Univariate Distribution Analysis**
 - Example Bayesian Analysis**
 - Bivariate Distribution Analysis
 - Rating Curve Analysis

Univariate Distribution Analysis: Review

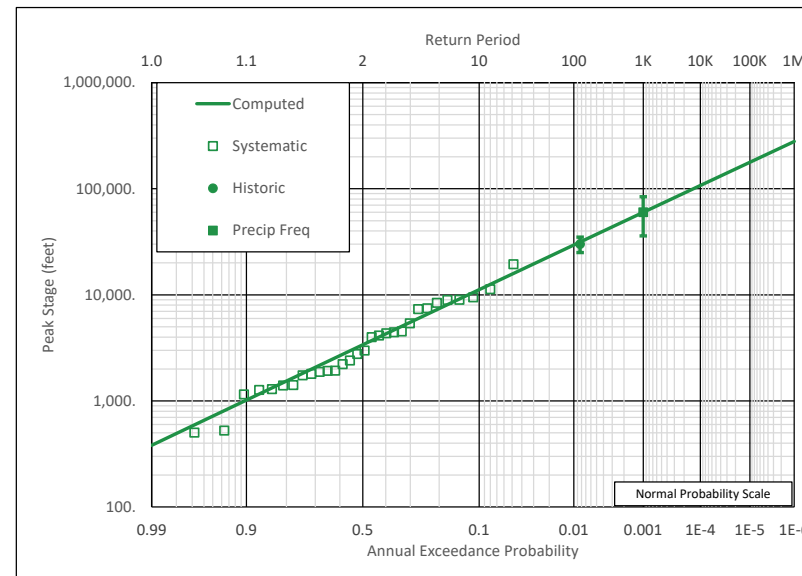


Likelihood Function



Frequency curve A

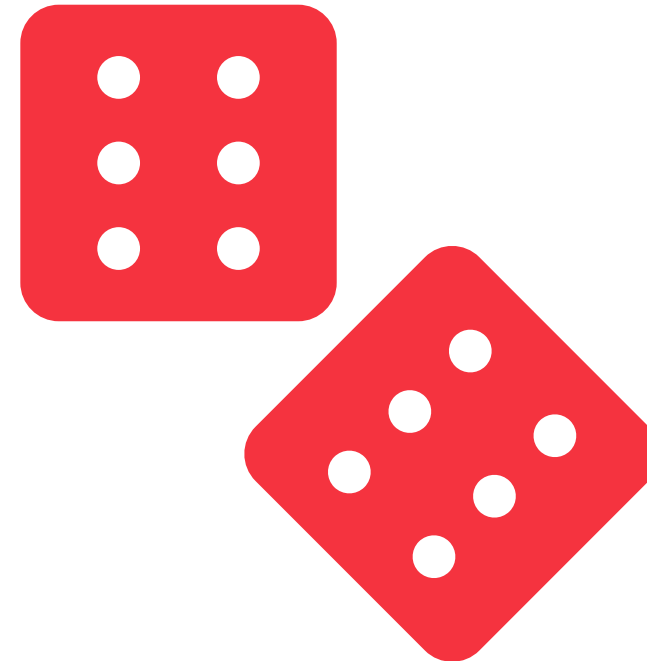
- Which frequency curve has a higher likelihood (better fit) given the observed data?



Frequency curve B

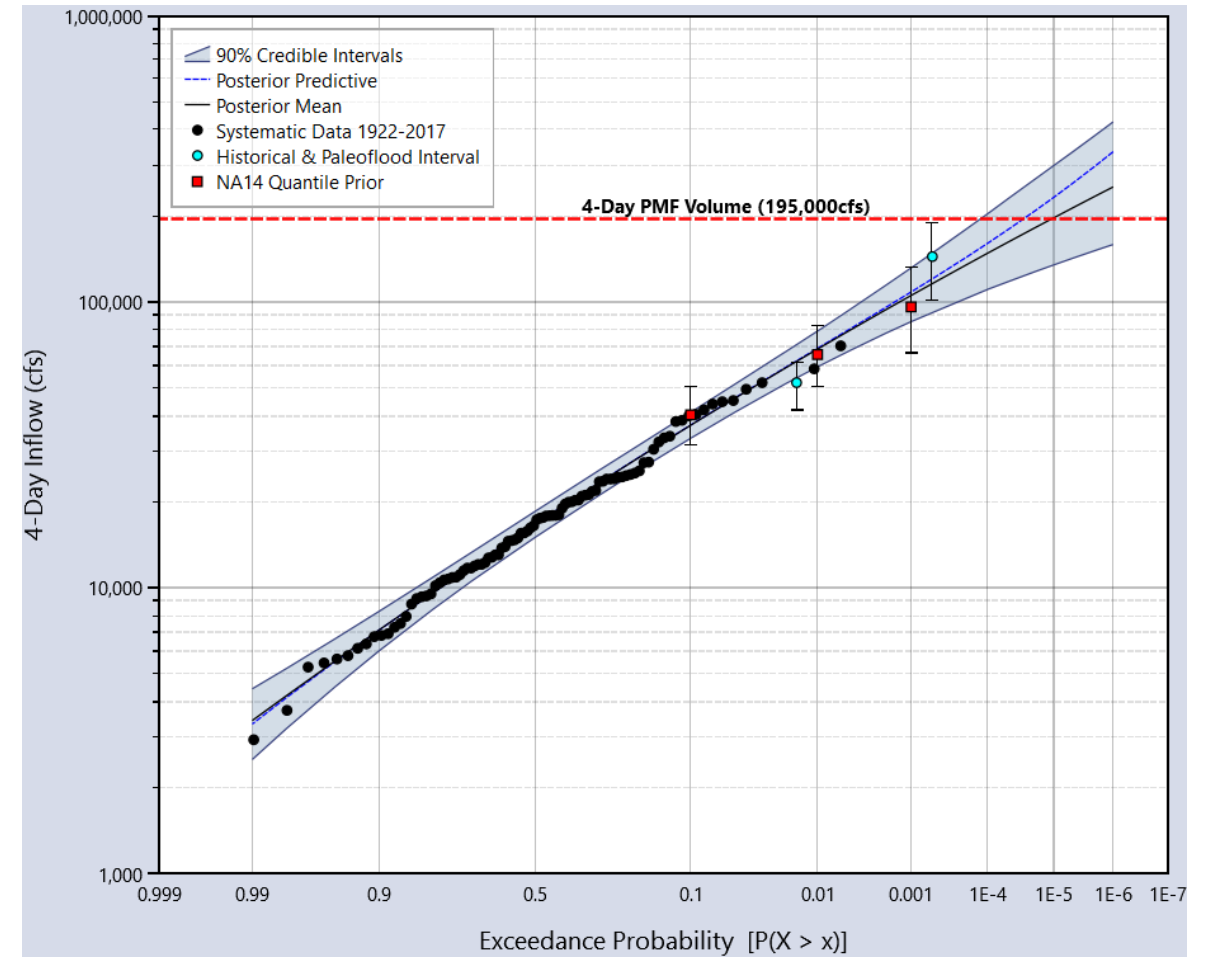
Monte Carlo Method (1 of 2)

- Uses random sampling to solve various problems
- Optimization
 - RMC-BestFit
- Integration
 - Risk model
- Uncertainty
 - RMC-RFA



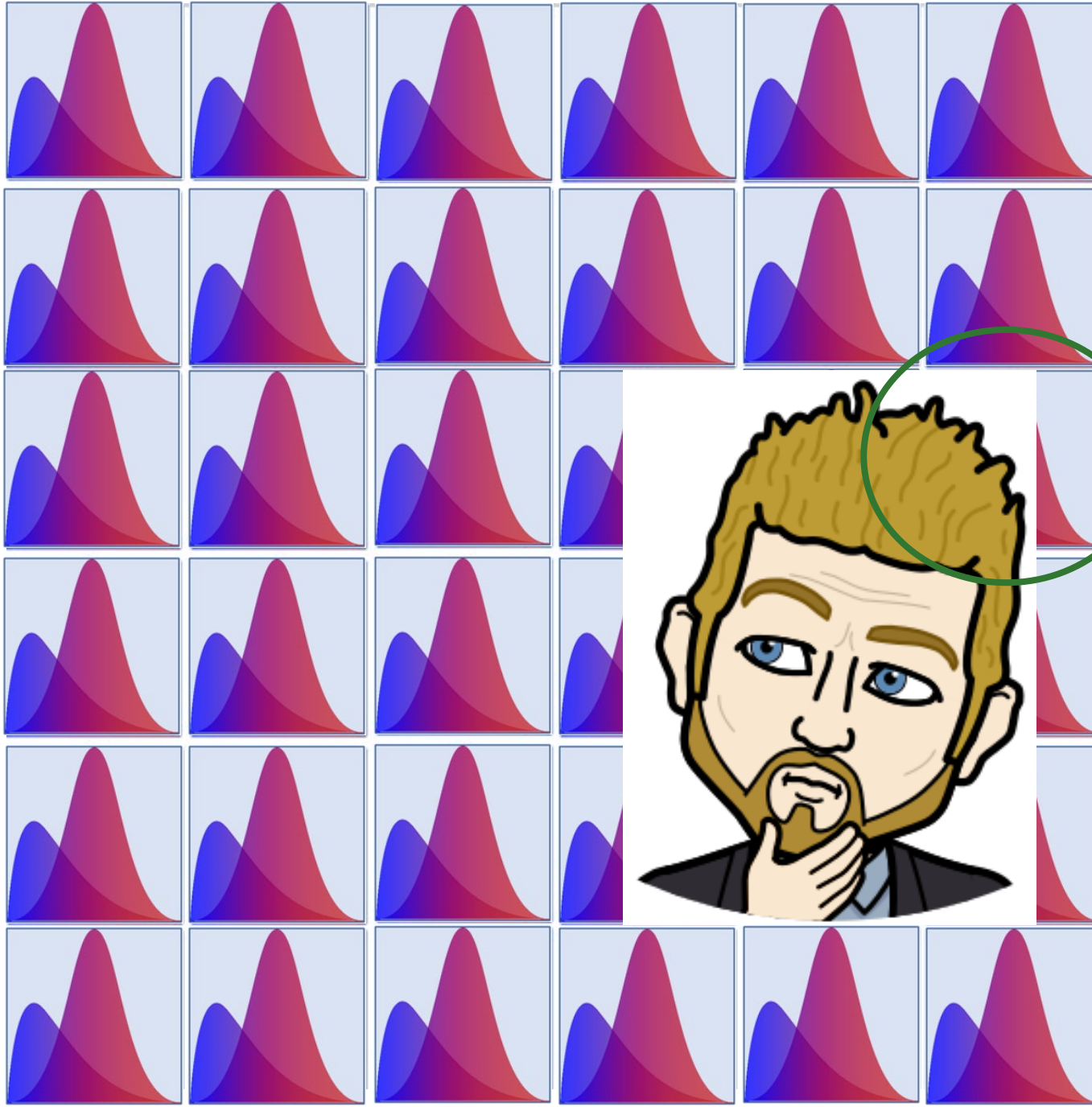
Monte Carlo Method (2 of 2)

- Basic steps:
 1. Build model
 2. Assign probability distributions to model inputs
 3. Sample the model inputs based on their probability distributions
 4. Record the output(s)
 5. Evaluate the probability distributions of the model output(s)



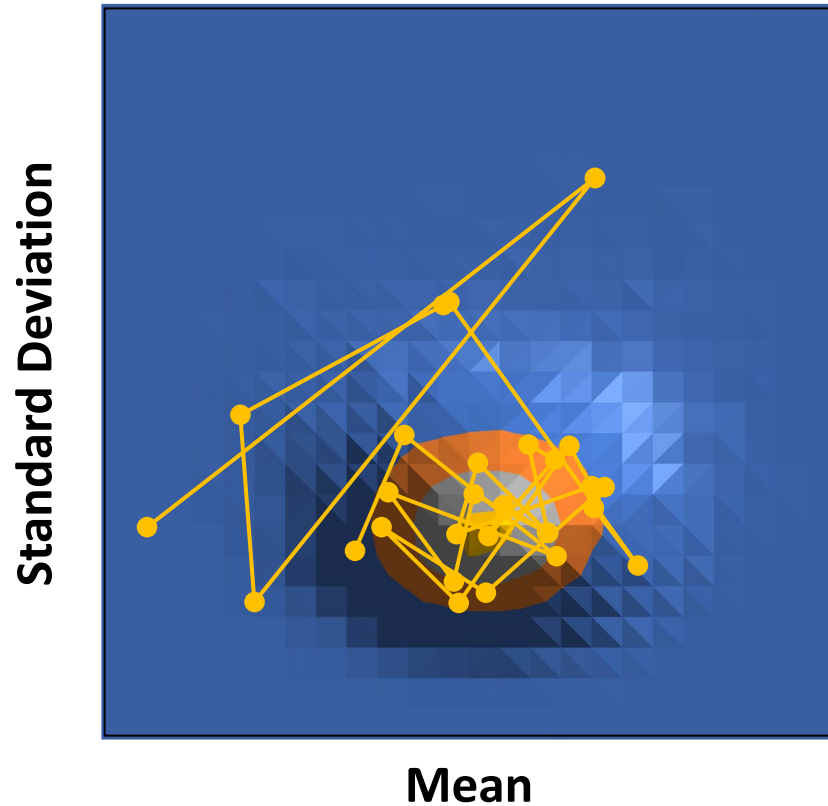
Markov Chain



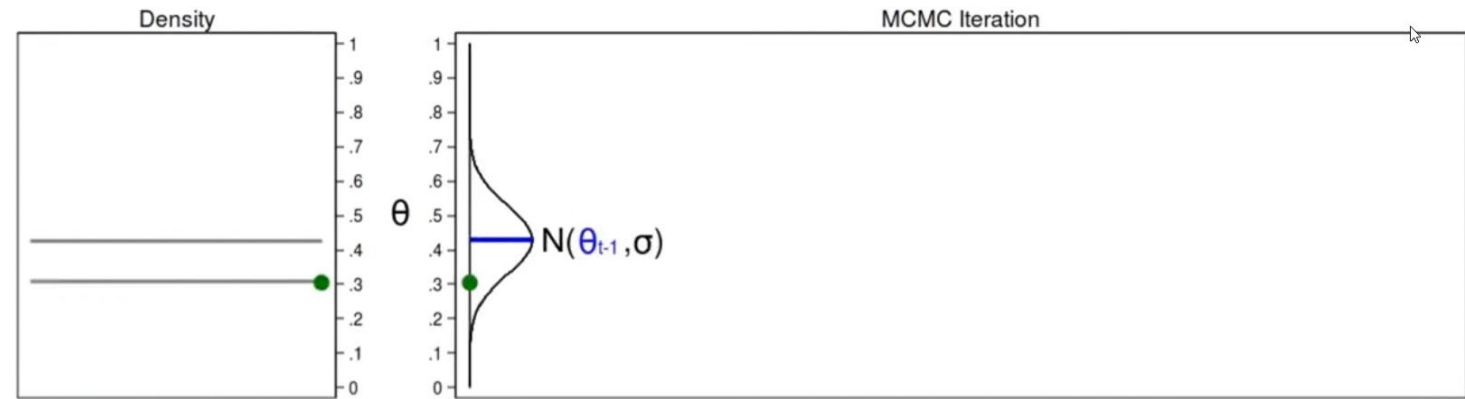


Markov Chain Monte Carlo

Bivariate Plot

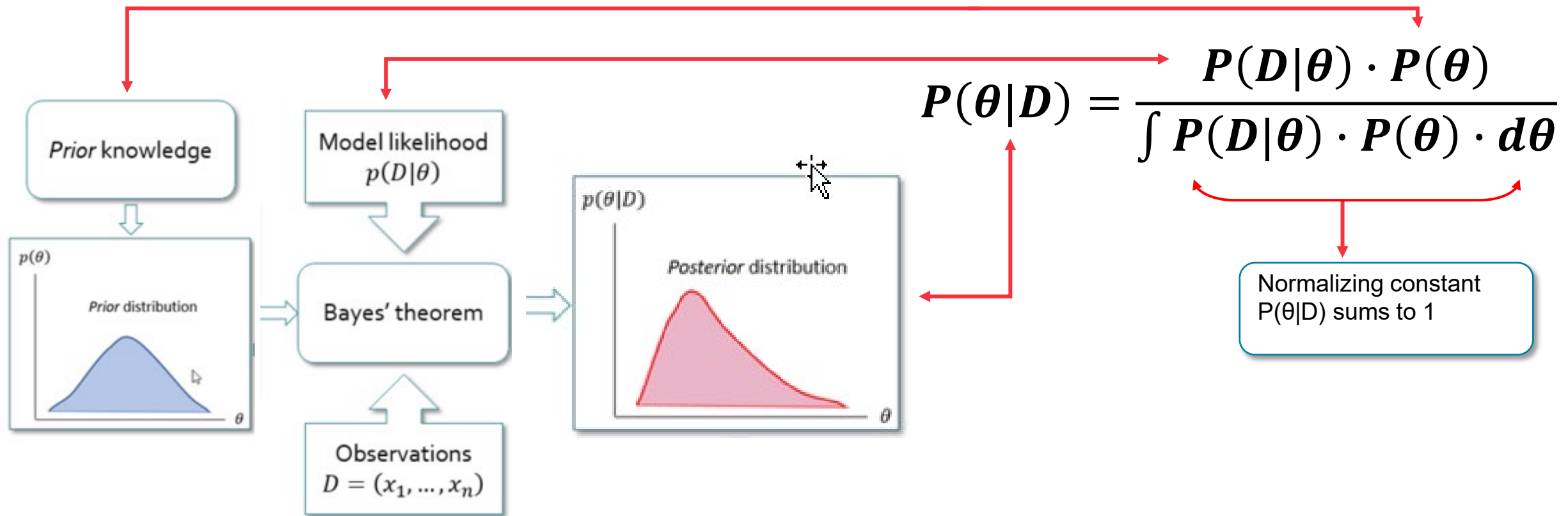


Density Function



<https://youtu.be/OTO1DygELpY>

Bayes' Theorem





Project Explorer

DLS114_2026_BestFit2

Time Series Data

Daily_Inflow

DS_USGS_Daily_Inflow

DS_USGS_Daily_Inflow_Area_Adjusted

Input Data

Period of Record

DS_USGS_Area_Adjusted_POR

Extended Period of Record

Historical

Paleoflood

Distribution Fitting Analysis

Period of Record

Extended Period of Record

Historical

Paleoflood

Univariate Distribution Analysis

Period of Record

Extended Period of Record

Historical

Paleoflood

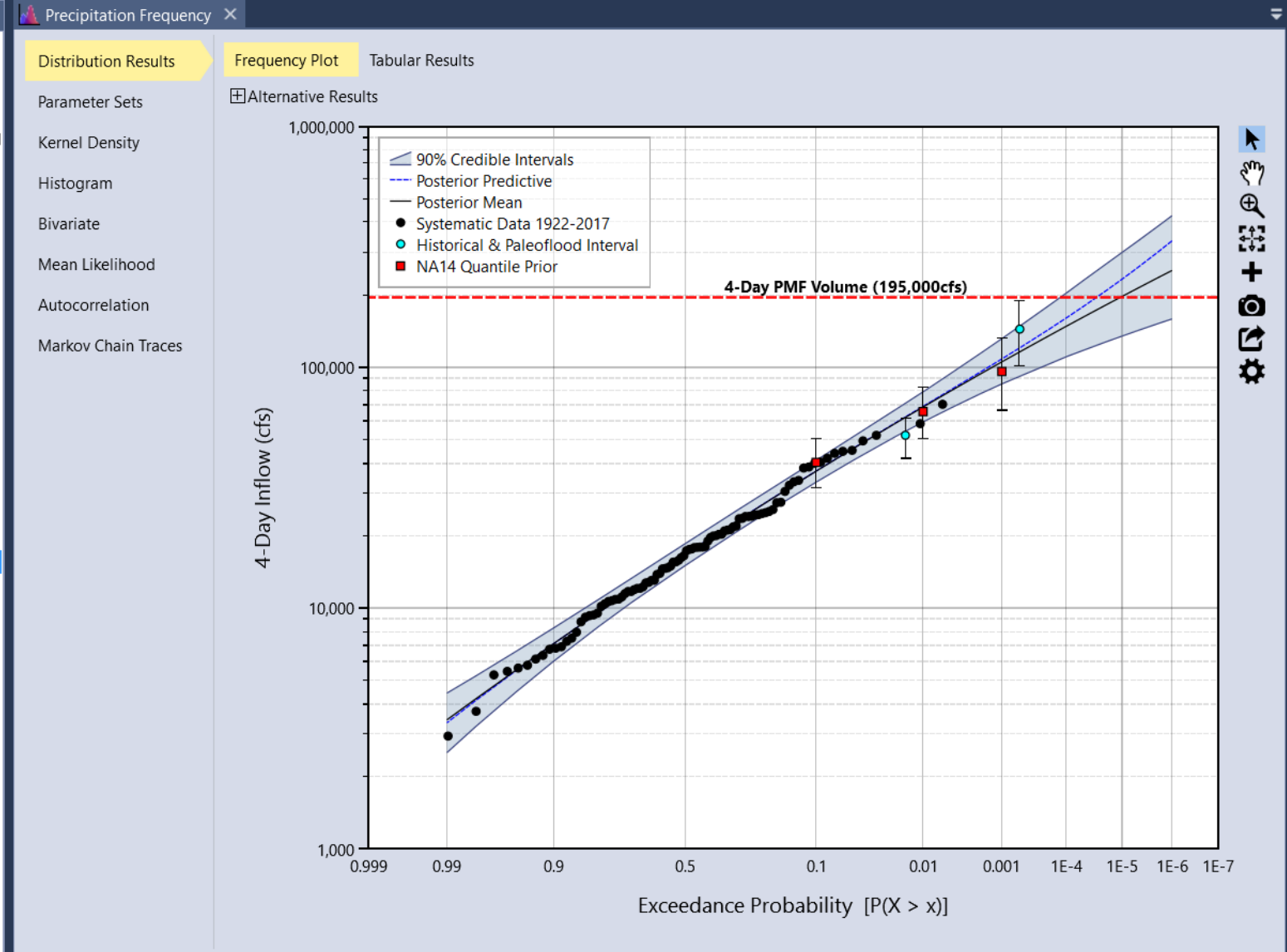
Regional Skew

Precipitation Frequency

Precipitation Frequency Sensitivity

Bivariate Distribution Analysis

Rating Curve Analysis



Properties

General

Options

Output

MODEL OPTIONS

Nonstationary

Time Index 0

Alpha 0.5

| Parameter | Trend Model Type |
|-------------------------------|------------------|
| Mean (of log) (μ) | Constant |
| Std Dev (of log) (σ) | Constant |
| Skew (of log) (γ) | Constant |

SIMULATION OPTIONS

Number of Chains 6

Thinning Interval 30

Warm Up Iterations 1750

Iterations 3500

Use Defaults

ADVANCED OPTIONS

PRNG Seed 12345

Initial Iterations 300

Jump Parameter 0.971630931303994

Jump Threshold 0.1

Snooker Threshold 0.1

Noise Parameter 0.001

Use Defaults

Message Window

0 Errors

0 Warnings

0 of 12 Messages

0 of 2 Events

| Time | Description | Source | Name | Parameter |
|------|-------------|--------|------|-----------|
|------|-------------|--------|------|-----------|

Univariate Distribution Analysis

Uses Bayesian MCMC to estimate distribution parameters from input data based on a specified parent distribution, providing point estimates and quantifying uncertainty.

Informative Prior

Properties ▼ 🔍 ✕

General Options Output

▲ UNIVARIATE ANALYSIS PROPERTIES

Name

Description

Created On

Last Modified

Input Data

Distribution

▲ PARAMETER PRIORS

| Parameter | Distribution |
|-------------------------------|------------------|
| Mean (of log) (μ) | U (0, 6) |
| Std Dev (of log) (σ) | U (0, 2) |
| Skew (of log) (γ) | N (-0.17, 0.346) |

Use Default Flat Priors ☐

Use Jeffreys' Rule for Scale ☒

▲ QUANTILE PRIORS

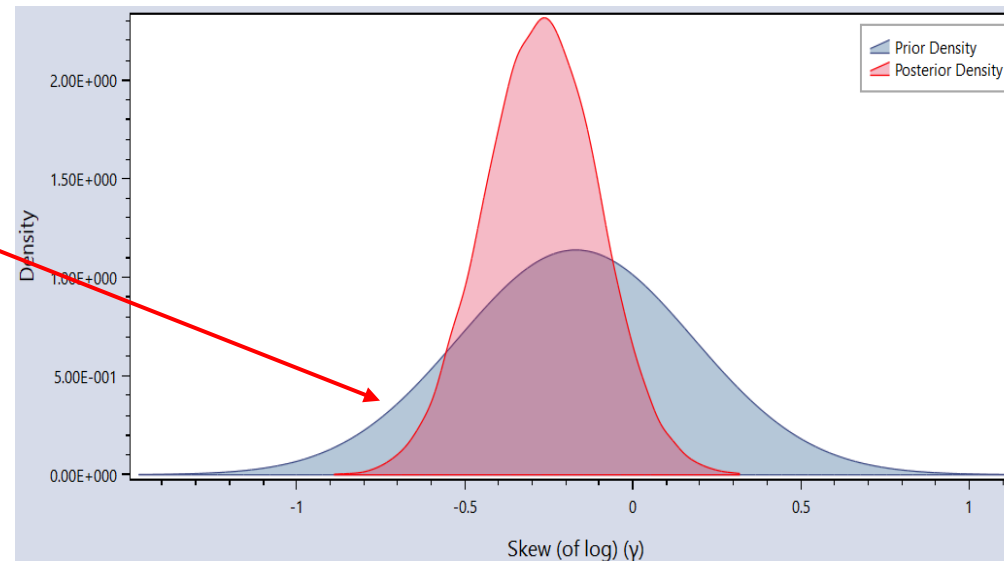
| Ex. Probability | Distribution |
|-----------------|-------------------|
| 0.1 | LN (40500, 5800) |
| 0.01 | LN (65100, 9700) |
| 0.001 | LN (95500, 20100) |

Enable Priors on Quantiles ☒

Use Single Quantile ☐

▶ Estimate

- Prior distribution for parameters
- Parameter = Skew



Causal Information

- Prior distribution for quantiles

Properties ▼ 🔍 ✕

General Options Output

▲ UNIVARIATE ANALYSIS PROPERTIES

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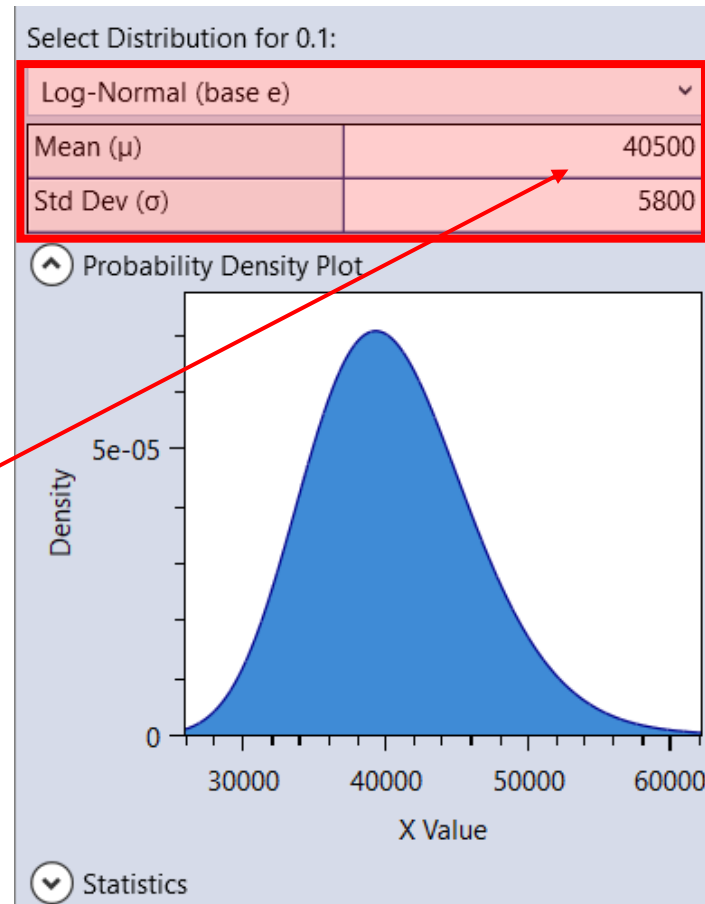
▲ QUANTILE PRIORS

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Enable Priors on Quantiles ☒

Use Single Quantile ☐

▶ Estimate





- Project Explorer
- DL5114_2026_BestFit2
 - Time Series Data
 - Daily_Inflow
 - DS_USGS_Daily_Inflow
 - DS_USGS_Daily_Inflow_Area_Adjusted
 - Input Data
 - Period of Record
 - DS_USGS_Area_Adjusted_POR
 - Extended Period of Record
 - Historical
 - Paleoflood
 - Distribution Fitting Analysis
 - Period of Record
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 - Historical
 - Paleoflood
 - Univariate Distribution Analysis
 - Period of Record
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 - Paleoflood
 - Regional Skew
 - Precipitation Frequency**
 - Precipitation Frequency Sensitivity
 - Bivariate Distribution Analysis
 - Rating Curve Analysis

Precipitation Frequency

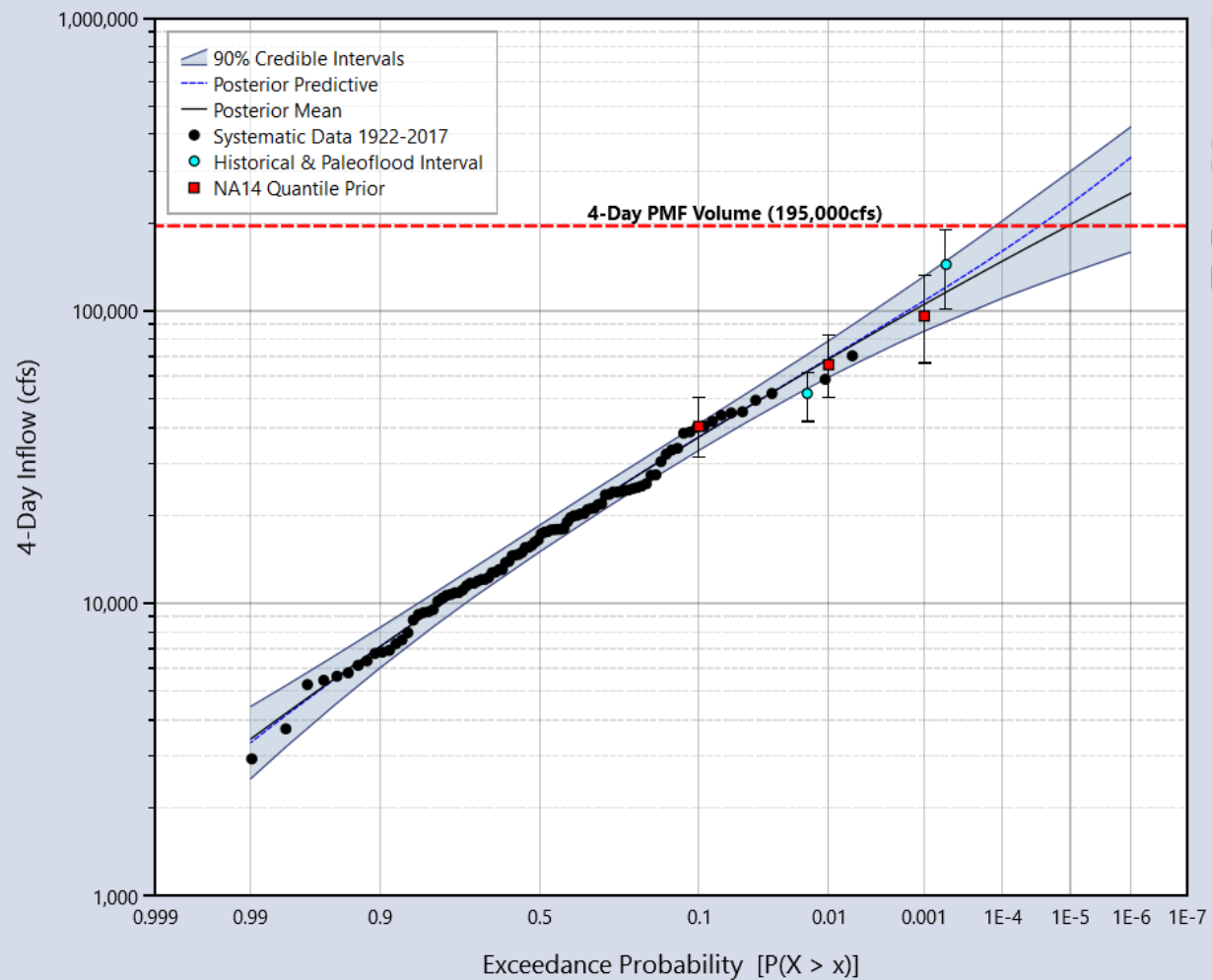
Distribution Results

- Parameter Sets
- Kernel Density
- Histogram
- Bivariate
- Mean Likelihood
- Autocorrelation
- Markov Chain Traces

Frequency Plot

Tabular Results

Alternative Results



Properties

General Options Output

OUTPUT OPTIONS

| | |
|-------------------|----------------|
| Credible Interval | 90% |
| Output Length | 10000 |
| Point Estimator | Posterior Mean |

PROBABILITY ORDINATES

| Probability Ordinates | |
|-----------------------|--------|
| | 1E-06 |
| | 2E-06 |
| | 5E-06 |
| | 1E-05 |
| | 2E-05 |
| | 5E-05 |
| | 0.0001 |
| | 0.0002 |
| | 0.0005 |
| | 0.001 |
| | 0.002 |
| | 0.005 |
| | 0.01 |
| | 0.02 |
| | 0.05 |
| | 0.1 |
| | 0.2 |
| | 0.3 |
| | 0.5 |
| | 0.7 |



Project Explorer

DLS114_2026_BestFit2

Time Series Data

Daily_Inflow

DS_USGS_Daily_Inflow

DS_USGS_Daily_Inflow_Area_Adjusted

Input Data

Period of Record

DS_USGS_Area_Adjusted_POR

Extended Period of Record

Historical

Paleoflood

Distribution Fitting Analysis

Period of Record

Extended Period of Record

Historical

Paleoflood

Univariate Distribution Analysis

Period of Record

Extended Period of Record

Historical

Paleoflood

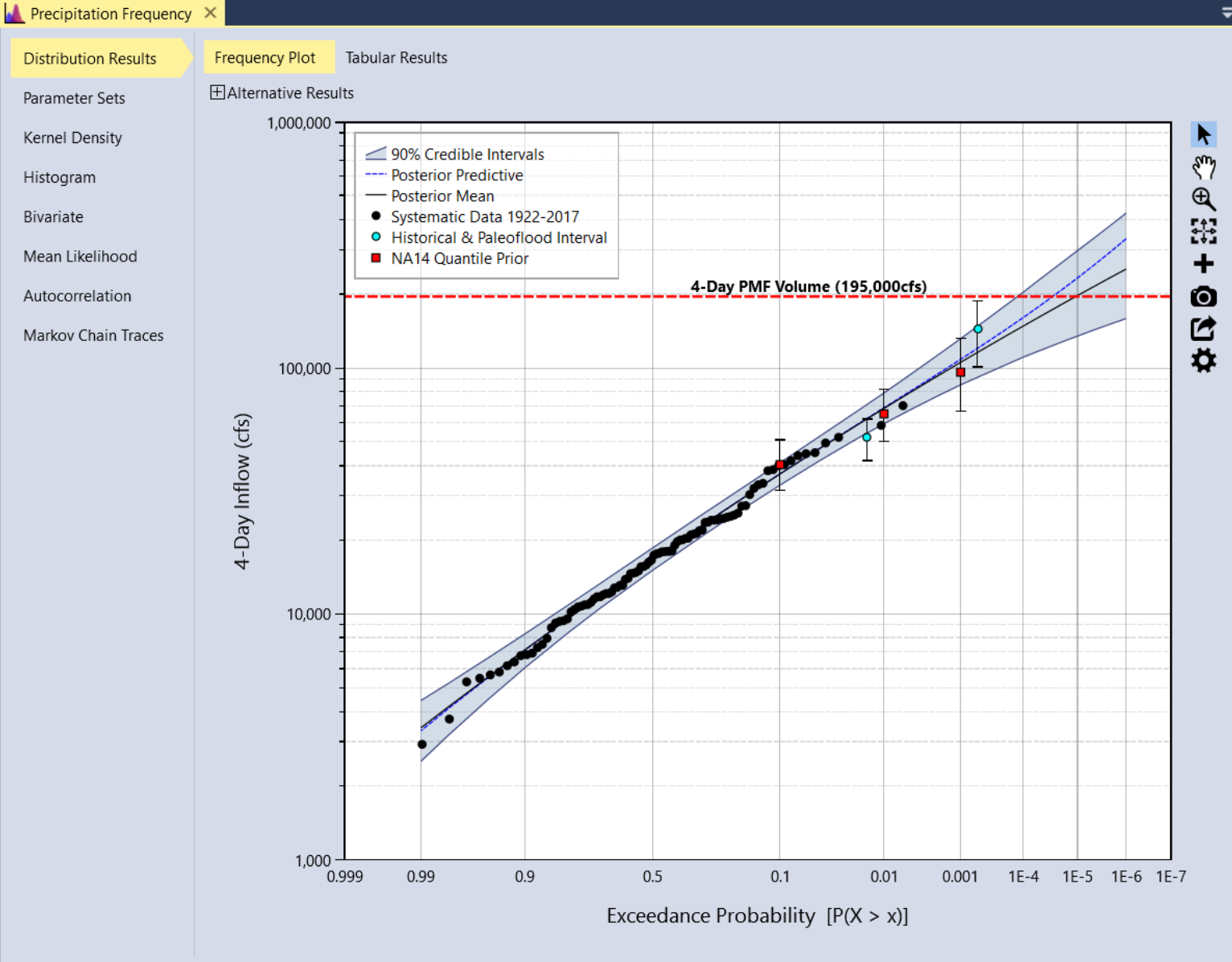
Regional Skew

Precipitation Frequency

Precipitation Frequency Sensitivity

Bivariate Distribution Analysis

Rating Curve Analysis



Properties

General

Options

Output

UNIVARIATE ANALYSIS PROPERTIES

Name

Precipitation Frequency

Description

Created On

1/28/2026 2:00:58 PM

Last Modified

1/31/2026 9:29:47 AM

Input Data

Paleoflood

Distribution

Log-Pearson Type III

PARAMETER PRIORS

| Parameter | Distribution |
|-------------------------------|------------------|
| Mean (of log) (μ) | U (0, 6) |
| Std Dev (of log) (σ) | U (0, 2) |
| Skew (of log) (γ) | N (-0.17, 0.346) |

Use Default Flat Priors

Use Jeffreys' Rule for Scale

QUANTILE PRIORS

| Ex. Probability | Distribution |
|-----------------|-------------------|
| 0.1 | LN (40500, 5800) |
| 0.01 | LN (65100, 9700) |
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Enable Priors on Quantiles

Use Single Quantile

Estimate

Message Window

0 Errors

0 Warnings

0 of 12 Messages

0 of 2 Events

| Time | Description | Source | Name | Parameter |
|------|-------------|--------|------|-----------|
|------|-------------|--------|------|-----------|

Univariate Distribution Analysis

Uses Bayesian MCMC to estimate distribution parameters from input data based on a specified parent distribution, providing point estimates and quantifying uncertainty.



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 - Precipitation Frequency Sensitivity
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Precipitation Frequency

Distribution Results

Parameter Sets

Kernel Density

Histogram

Bivariate

Mean Likelihood

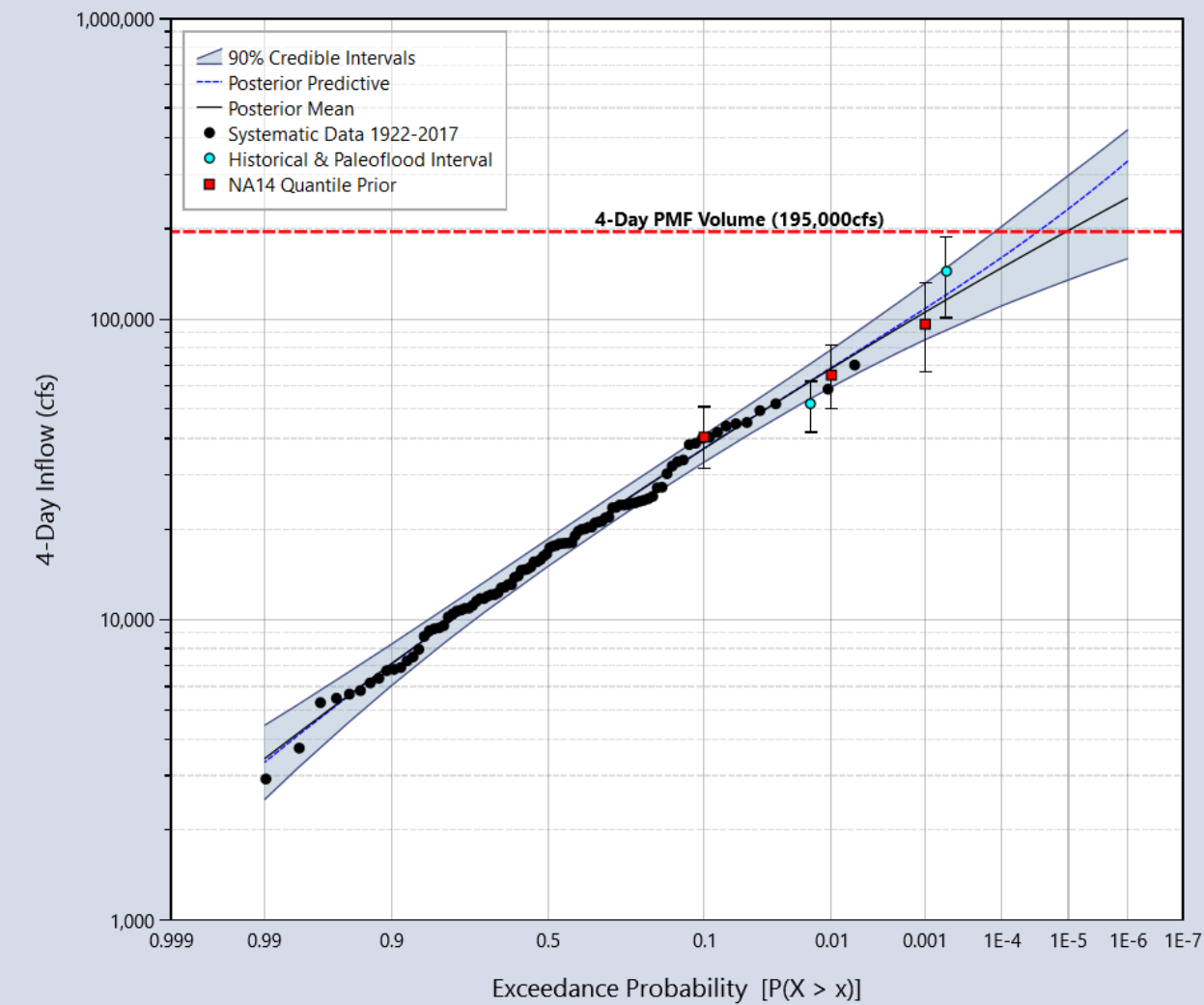
Autocorrelation

Markov Chain Traces

Frequency Plot

Tabular Results

Alternative Results



Properties

General

Options

Output

UNIVARIATE ANALYSIS PROPERTIES

| | |
|---------------|-------------------------|
| Name | Precipitation Frequency |
| Description | |
| Created On | 1/28/2026 2:00:58 PM |
| Last Modified | 1/31/2026 9:29:47 AM |
| Input Data | Paleoflood |
| Distribution | Log-Pearson Type III |

PARAMETER PRIORS

| Parameter | Distribution |
|-------------------------------|------------------|
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| Std Dev (of log) (σ) | U (0, 2) |
| Skew (of log) (γ) | N (-0.17, 0.346) |

Use Default Flat Priors ☐Use Jeffreys' Rule for Scale ☒

QUANTILE PRIORS

| Ex. Probability | Distribution |
|-----------------|-------------------|
| 0.1 | LN (40500, 5800) |
| 0.01 | LN (65100, 9700) |
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Enable Priors on Quantiles ☒Use Single Quantile ☐

Estimate

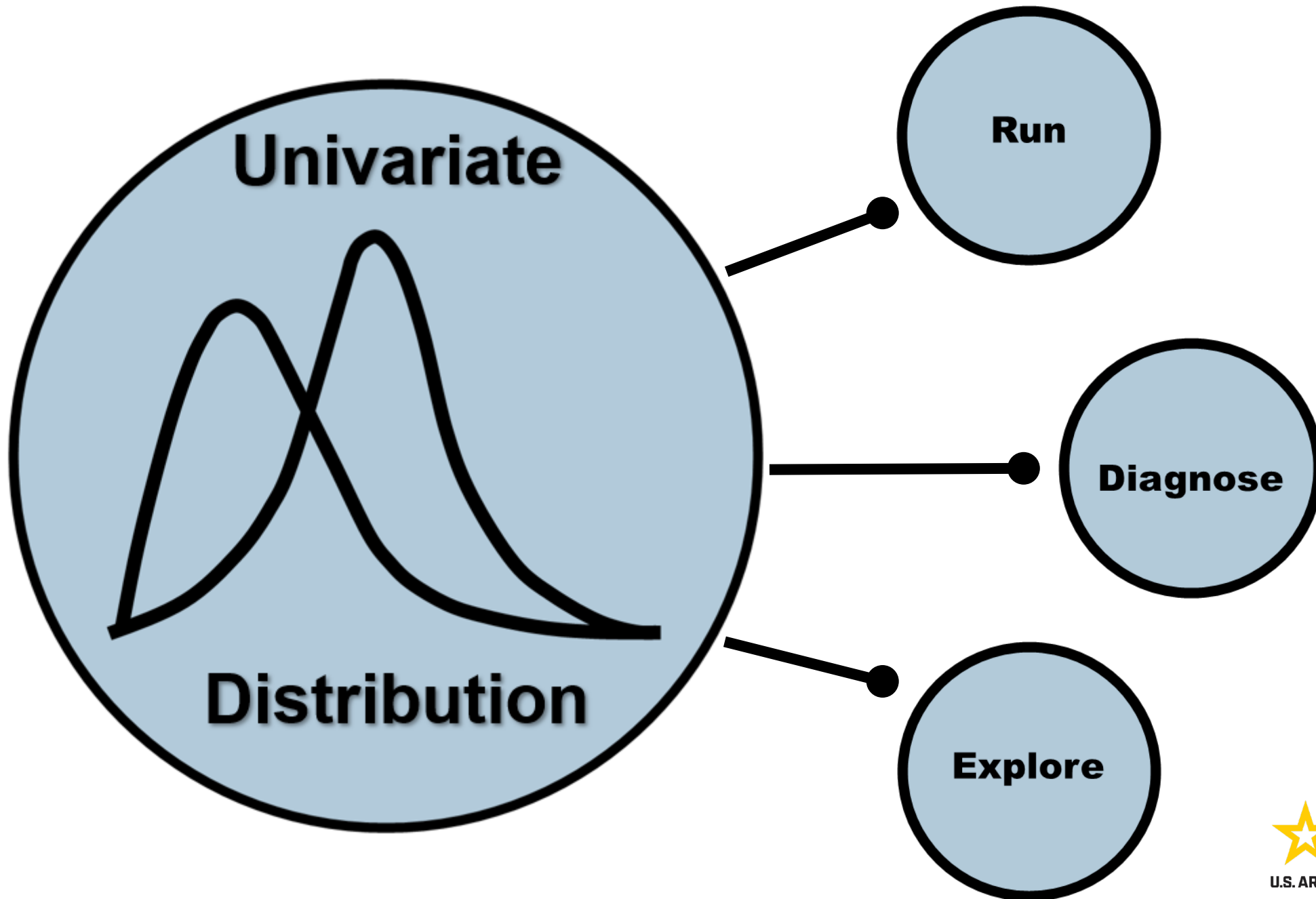
Univariate Distribution Analysis

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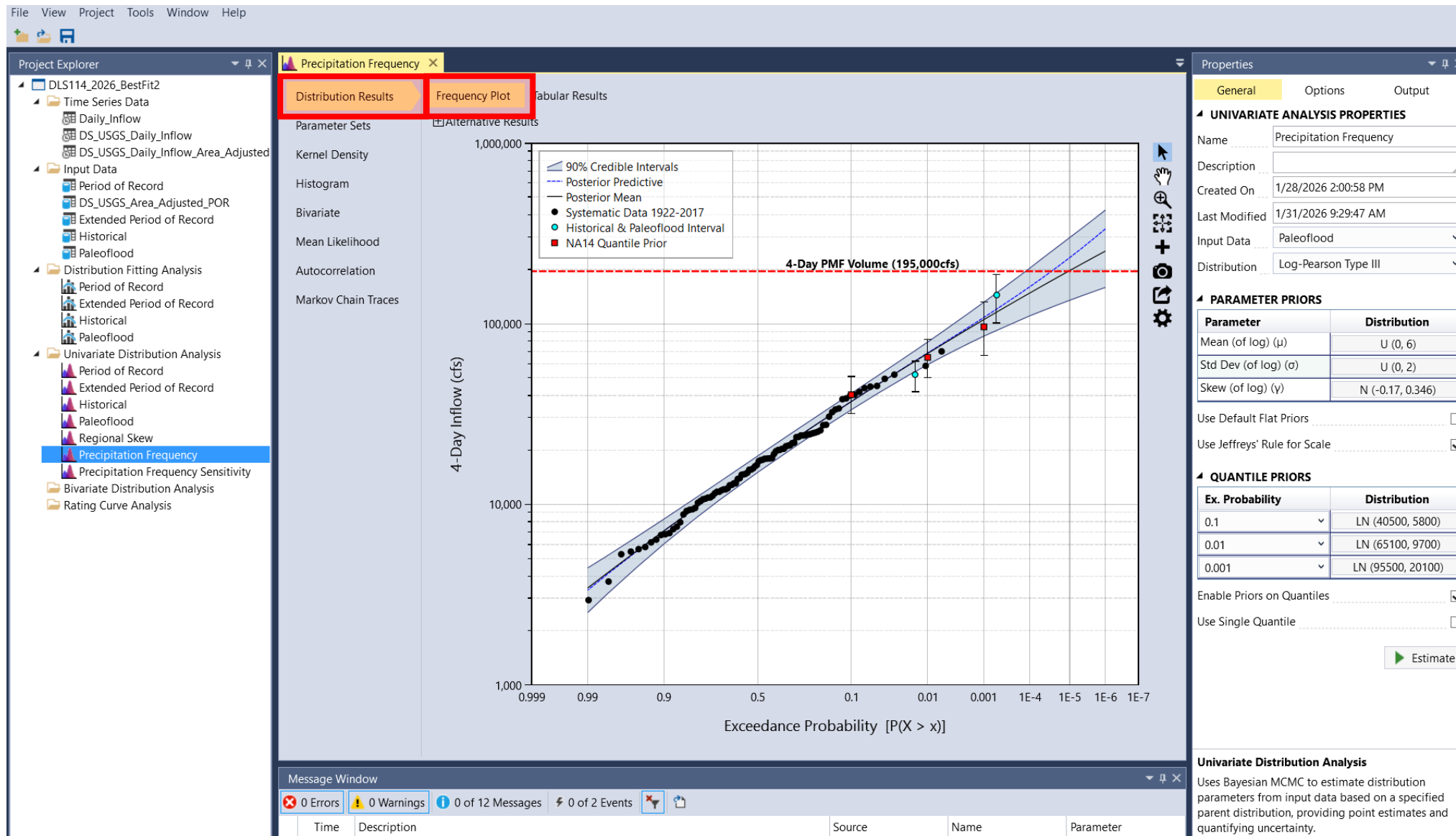
Message Window

0 Errors 0 Warnings 0 of 12 Messages 0 of 2 Events

| Time | Description | Source | Name | Parameter |
|------|-------------|--------|------|-----------|
|------|-------------|--------|------|-----------|



Explore Graphical Results



Explore Tabular Results

File View Project Tools Window Help

Project Explorer

- DLS114_2026_BestFit2
 - Time Series Data
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Precipitation Frequency

Distribution Results Frequency Plot Tabular Results

Parameter Sets

Kernel Density

Histogram

Bivariate

Mean Likelihood

Autocorrelation

Markov Chain Traces

Frequency Curve Results

| Probability | 95.0% CI | 5.0% CI | Posterior Predictive | Posterior Mean |
|-------------|------------|------------|----------------------|----------------|
| 1E-06 | 425,741.1 | 158,727.61 | 335,014.62 | 252,311.95 |
| 2E-06 | 383,848.33 | 151,509.94 | 299,916.4 | 234,876.53 |
| 5E-06 | 333,682.85 | 141,979.88 | 259,155.06 | 212,774.93 |
| 1E-05 | 299,645.16 | 134,697.49 | 232,033.5 | 196,762.63 |
| 2E-05 | 267,943.78 | 127,454.12 | 207,683.33 | 181,350.95 |
| 5E-05 | 229,743.28 | 117,728.72 | 179,188.2 | 161,886.3 |
| 0.0001 | 202,943.29 | 110,511.14 | 160,054.63 | 147,838.56 |
| 0.0002 | 179,026.04 | 102,654 | 142,723.4 | 134,364.1 |
| 0.0005 | 150,567.29 | 92,629.85 | 122,195.16 | 117,415.73 |
| 0.001 | 131,293.09 | 85,267.62 | 108,208.59 | 105,235.11 |
| 0.002 | 113,858.6 | 77,514.75 | 95,352.24 | 93,593.29 |
| 0.005 | 93,230.56 | 67,200.92 | 79,817.28 | 79,007.46 |
| 0.01 | 79,229.71 | 59,415.09 | 68,990.14 | 68,560.27 |
| 0.02 | 66,679.35 | 51,593.35 | 58,824.32 | 58,594.05 |
| 0.05 | 51,629.88 | 41,205.34 | 46,218.61 | 46,102.14 |
| 0.1 | 41,151.35 | 33,418.83 | 37,178.28 | 37,099.67 |
| 0.2 | 31,329.46 | 25,664.63 | 28,416.67 | 28,365.83 |
| 0.3 | 25,749.43 | 21,058.62 | 23,323.69 | 23,288.77 |
| 0.5 | 18,523.87 | 15,032.9 | 16,713.29 | 16,696.05 |
| 0.7 | 13,293.88 | 10,558.05 | 11,876.18 | 11,868.05 |
| 0.8 | 10,894.24 | 8,413.74 | 9,616.83 | 9,613.85 |
| 0.9 | 8,286.66 | 6,036.53 | 7,130.87 | 7,140.87 |
| 0.95 | 6,641.91 | 4,512.25 | 5,530.4 | 5,560.22 |
| 0.98 | 5,201.55 | 3,200.24 | 4,110.02 | 4,174.55 |
| 0.99 | 4,437.59 | 2,513.32 | 3,343.76 | 3,438.16 |

Summary Statistics

| Measure | Posterior Mean |
|-------------------------------|----------------|
| Mean (of log) (μ) | 4.2159 |
| Std Dev (of log) (σ) | 0.2794 |
| Skew (of log) (γ) | -0.1445 |
| Minimum | 0.0000 |
| Maximum | 120765462.8522 |
| Mean | 20094.5217 |
| Std Dev | 13627.2478 |
| Skewness | 2.0363 |
| Kurtosis | 10.7100 |
| AIC | 2073.0631 |
| BIC | 2080.8180 |
| DIC | 2072.5320 |
| RMSE | 1515.8712 |

Explore Parameter Sets

File View Project Tools Window Help

Project Explorer

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Precipitation Frequency

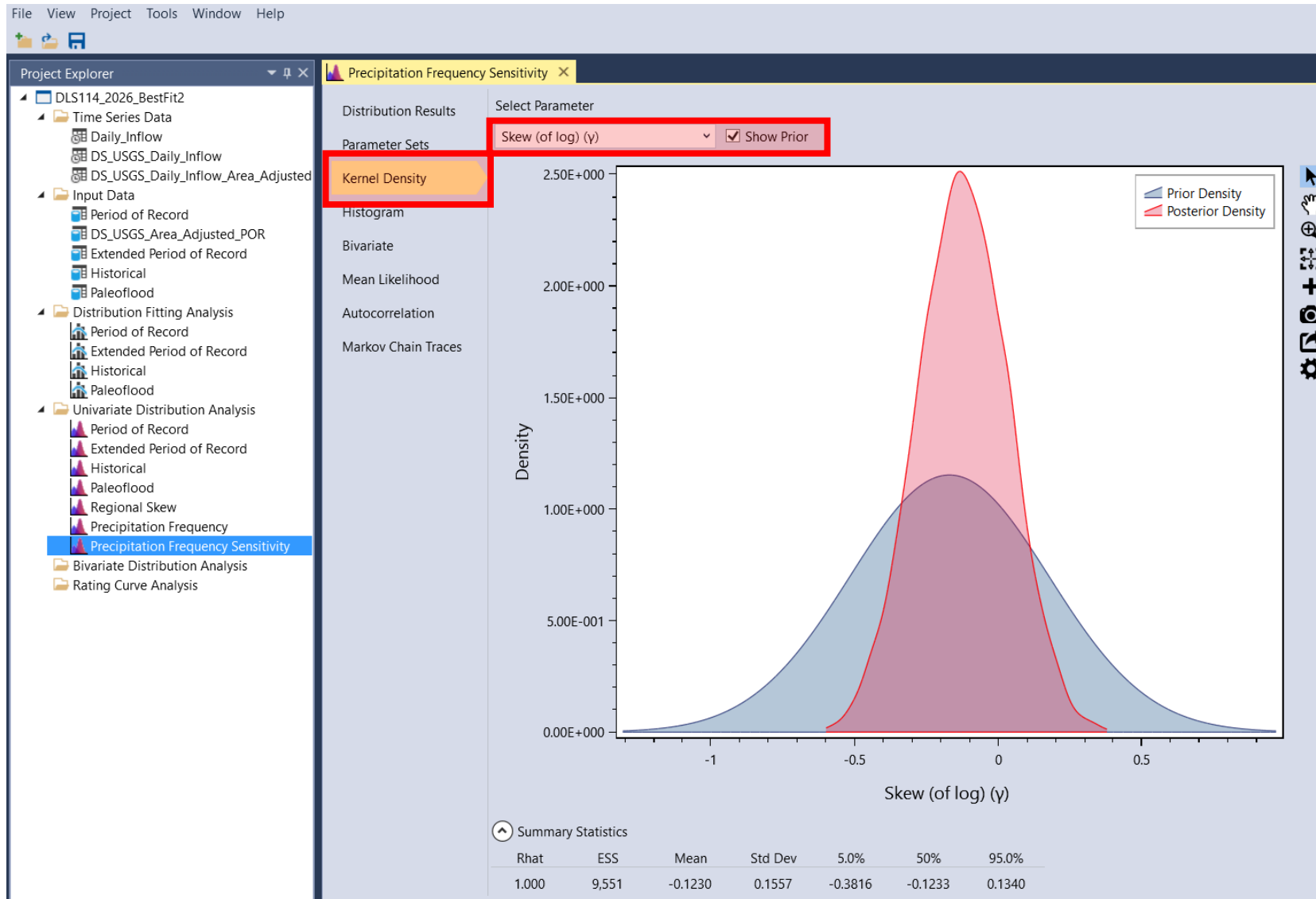
Distribution Results

Parameter Sets

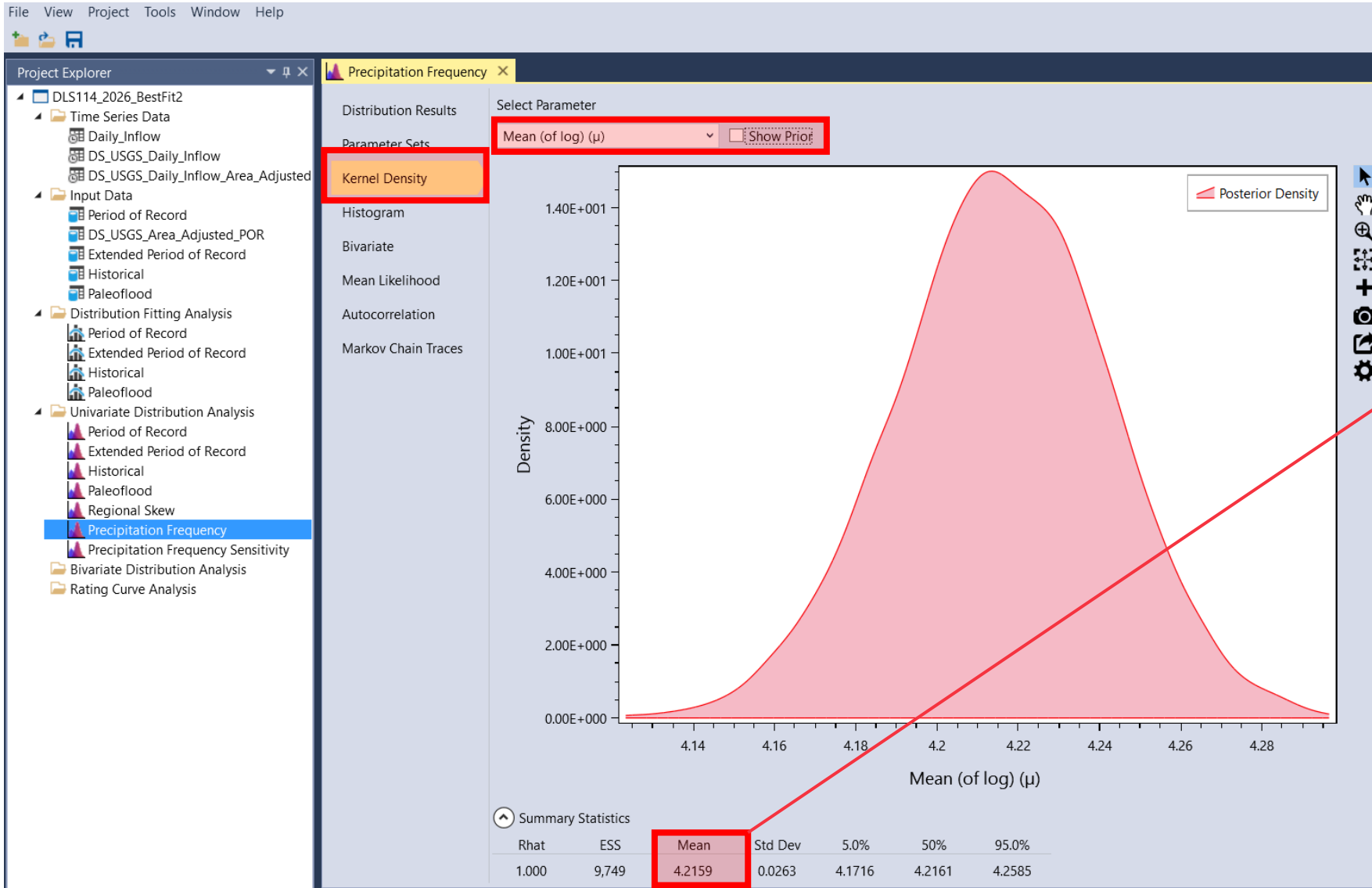
| | Mean (of log) (μ) | Std Dev (of log) (σ) | Skew (of log) (γ) | Log-Likelihood |
|---------------------|-------------------------|-------------------------------|----------------------------|-------------------|
| Kernel Density | 4.22685654189122 | 0.300581332623246 | -0.339286189691154 | -1034.88082474073 |
| Histogram | 4.23598863989687 | 0.259936342600955 | 0.165457585829304 | -1035.90529311107 |
| Bivariate | 4.19098962883779 | 0.286186194305967 | 0.0126136524846334 | -1034.72690208865 |
| Mean Likelihood | 4.25440378147844 | 0.275801452319202 | -0.0489880394143023 | -1035.07020826681 |
| Autocorrelation | 4.1920111896562 | 0.277823757502283 | 0.000696926616185107 | -1034.34891707405 |
| Markov Chain Traces | 4.21599496773081 | 0.331377287353843 | 0.00861991391886831 | -1041.75408335178 |
| | 4.22152401193009 | 0.283168549933979 | -0.258131439226452 | -1033.86178212513 |
| | 4.19610438263815 | 0.298664765737441 | -0.348354978840781 | -1034.85900008247 |
| | 4.26397647363675 | 0.269414417455073 | -0.0345104900320161 | -1035.66972916732 |
| | 4.20577965320736 | 0.285096544292298 | -0.0374558465564012 | -1034.09646395046 |
| | 4.24716573729768 | 0.287580760888739 | -0.456983059346141 | -1036.24217756765 |
| | 4.25424947768065 | 0.25265417052533 | -0.339694973837832 | -1036.89257531491 |
| | 4.23303906036694 | 0.292992185362284 | -0.130522349932502 | -1034.63135650441 |
| | 4.16726653231309 | 0.297571391590941 | -0.420049148509322 | -1037.34473125272 |
| | 4.22839908657057 | 0.300320513169951 | -0.280565970915829 | -1034.75492719064 |
| | 4.19808880260785 | 0.302185356059389 | -0.346055994942611 | -1034.86523248187 |
| | 4.16648063554421 | 0.306968305288044 | -0.334987076601277 | -1036.14322901849 |
| | 4.24243673642341 | 0.253589816494414 | -0.0675516087325686 | -1034.64226961907 |
| | 4.20659525898347 | 0.280352635856203 | -0.0493191395232343 | -1033.84132824996 |
| | 4.17301686577959 | 0.288009704594878 | -0.164708423674299 | -1035.03713194137 |
| | 4.22053671041487 | 0.271176562779442 | -0.0393173966076288 | -1033.70332394107 |
| | 4.23054748313681 | 0.287235631331697 | -0.25557541742784 | -1034.06859644487 |
| | 4.15912970824408 | 0.268096677846541 | -0.225647621232787 | -1038.15191426876 |
| | 4.25289752302946 | 0.282432693835463 | -0.0652210644179604 | -1035.25960914801 |
| | 4.16115999905515 | 0.297023546554551 | -0.185605071327411 | -1035.88327754114 |
| | 4.24775099401362 | 0.280136682284994 | -0.154623720738556 | -1034.41784739466 |
| | 4.23003374249562 | 0.296333038829535 | -0.321119278290282 | -1034.66538161096 |
| | 4.20815073735189 | 0.299253821473952 | -0.321323313315944 | -1034.52266877128 |
| | 4.26944122734155 | 0.270067468281412 | -0.0965483045620169 | -1035.8117869622 |
| | 4.23196579505908 | 0.253802275748954 | -0.154110381788615 | -1034.59054444487 |



Explore Kernel Density

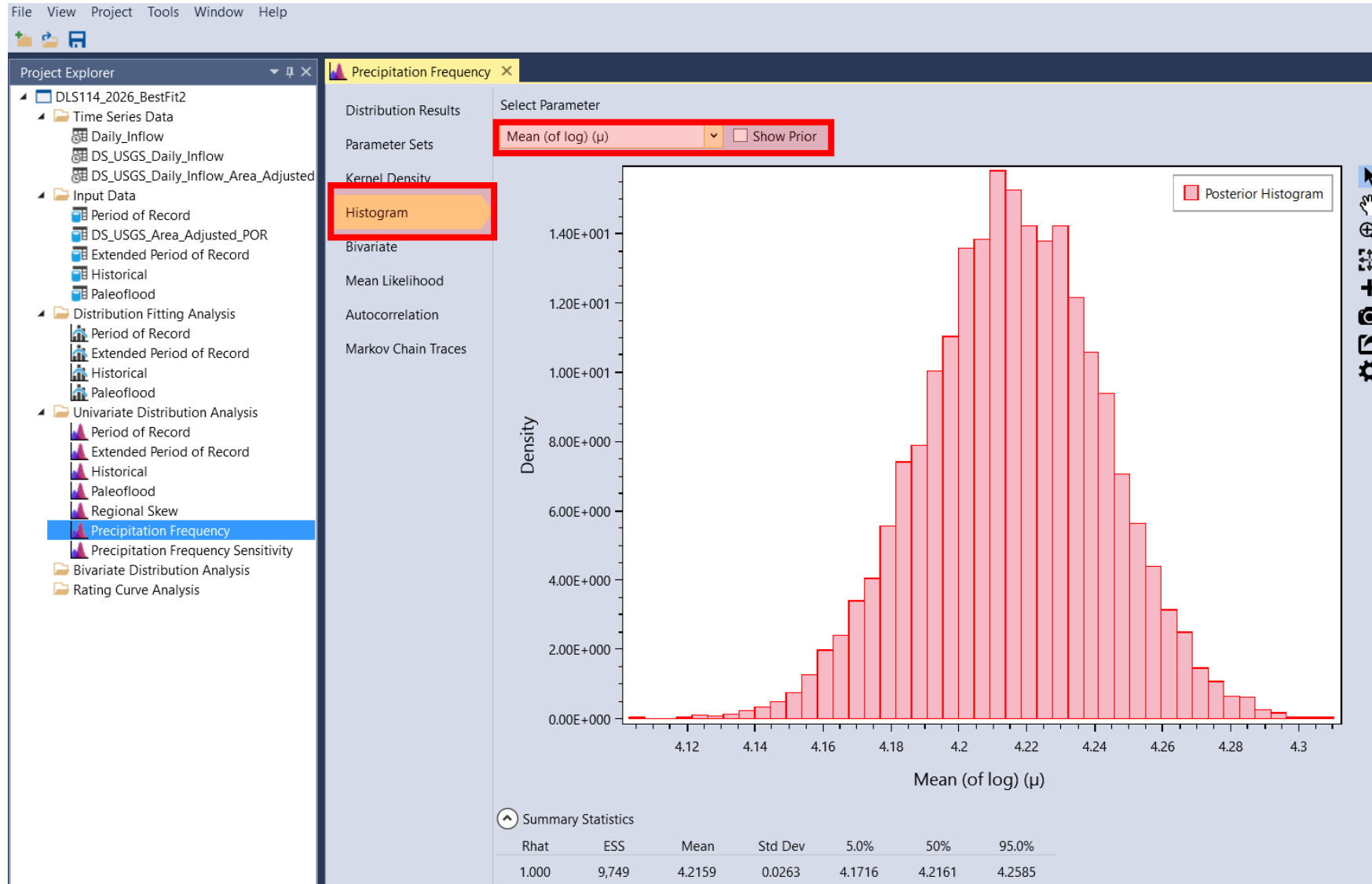


Explore Kernel Density

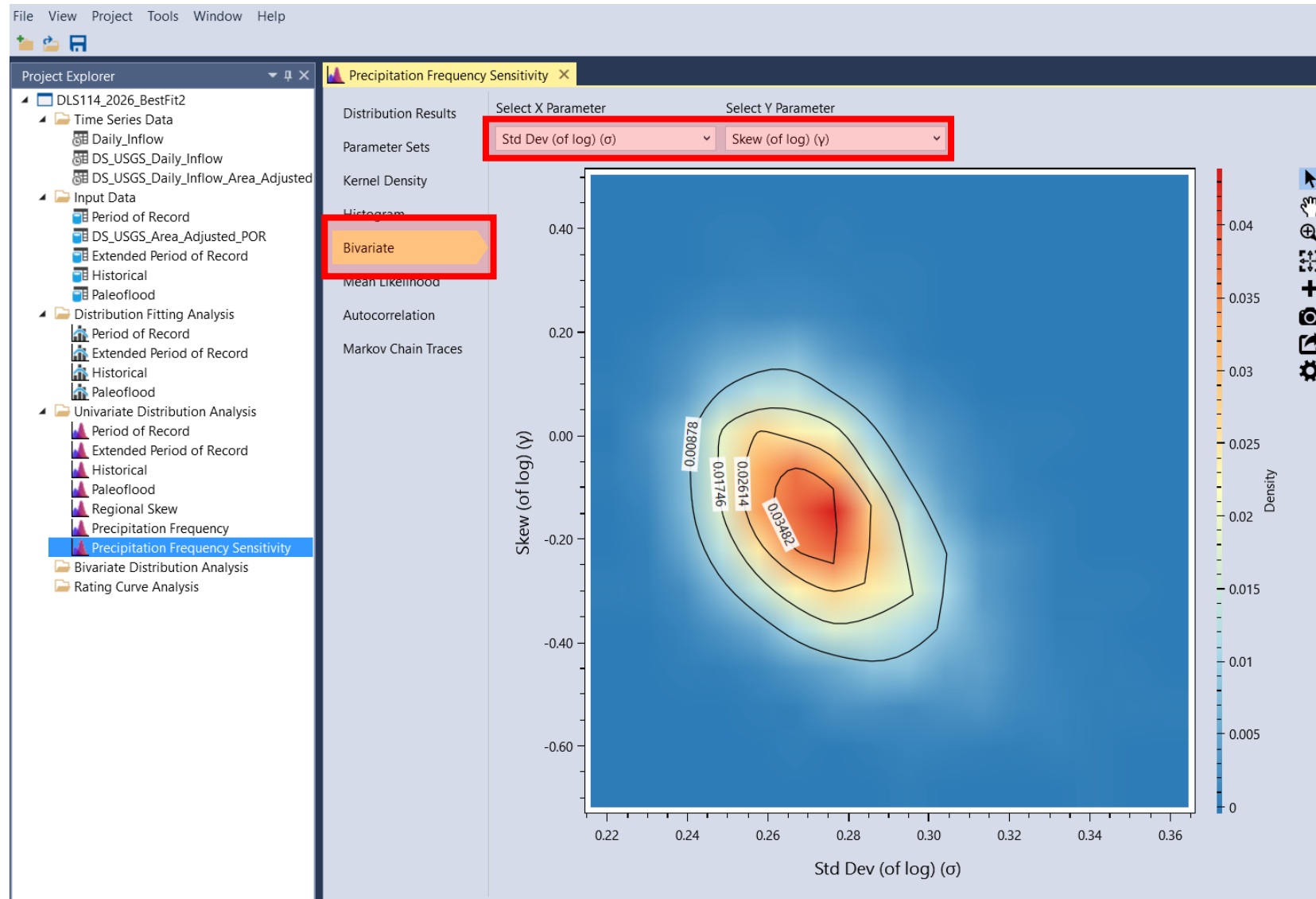


| Summary Statistics | |
|-------------------------------|----------------|
| Measure | Posterior Mean |
| Mean (of log) (μ) | 4.2159 |
| Std Dev (of log) (σ) | 0.2794 |
| Skew (of log) (γ) | -0.1445 |
| Minimum | 0.0000 |
| Maximum | 120765462.8522 |
| Mean | 20094.5217 |
| Std Dev | 13627.2478 |
| Skewness | 2.0363 |
| Kurtosis | 10.7100 |
| AIC | 2073.0631 |
| BIC | 2080.8180 |
| DIC | 2072.5320 |
| RMSE | 1515.8712 |

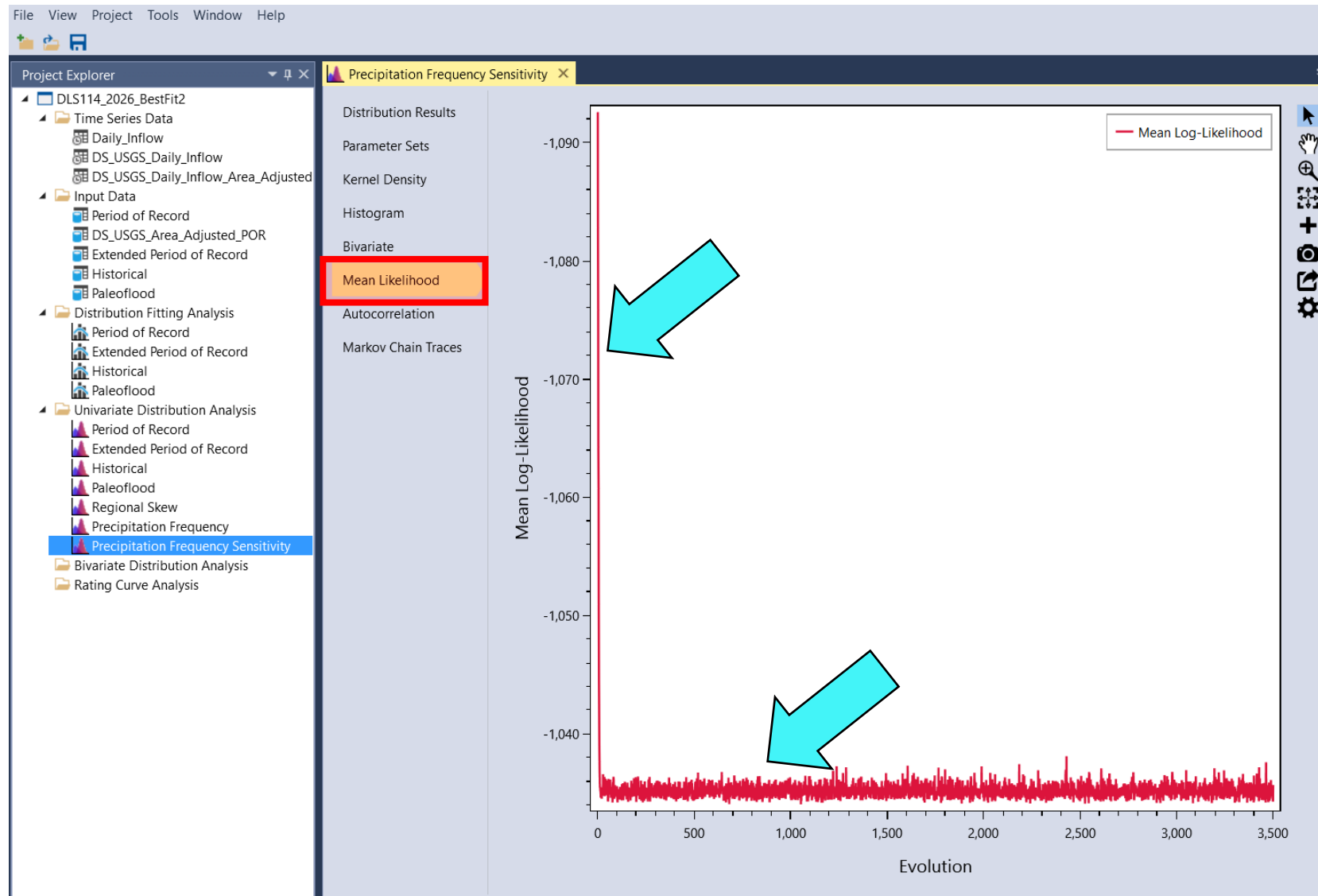
Explore Histogram



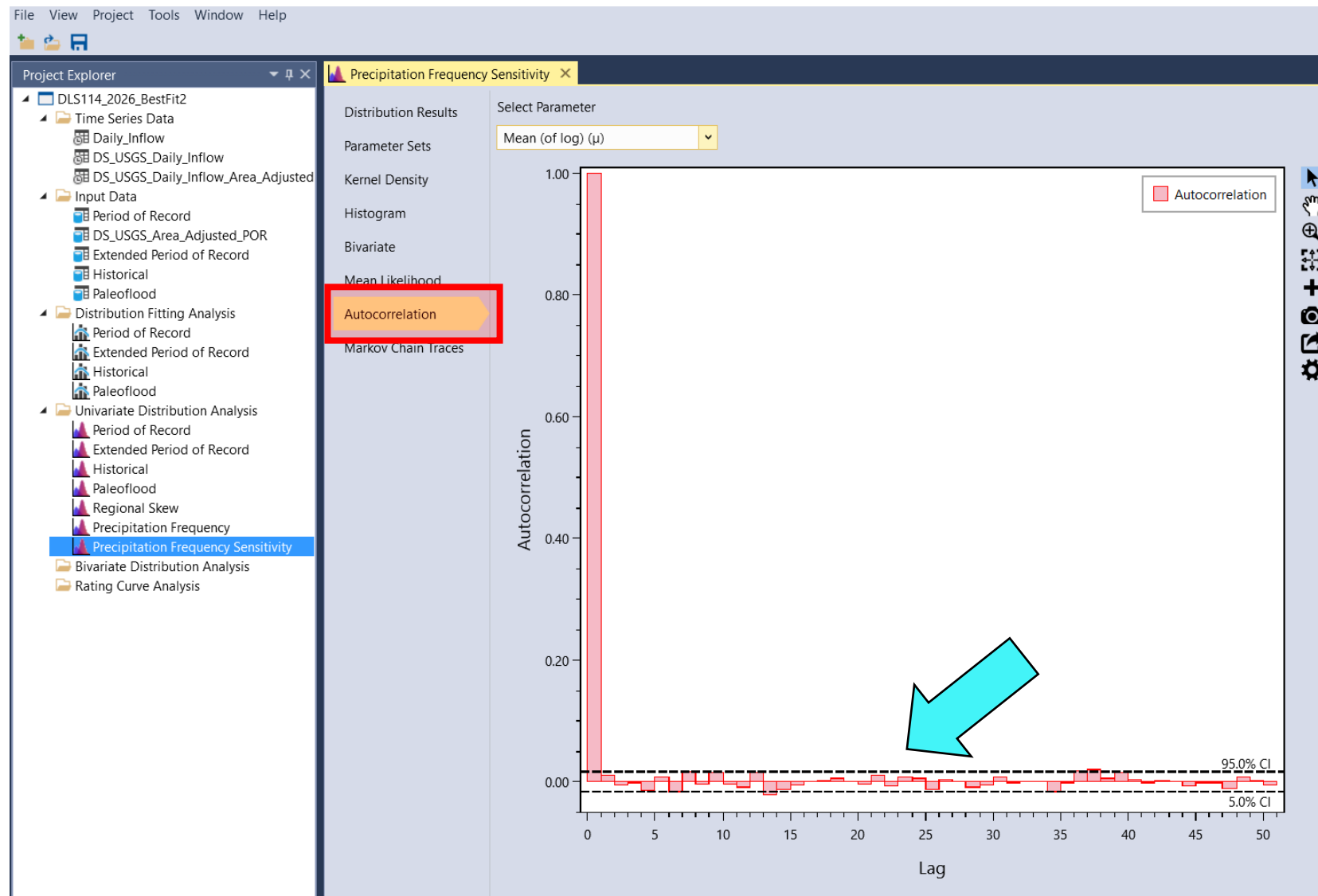
Explore Bivariate



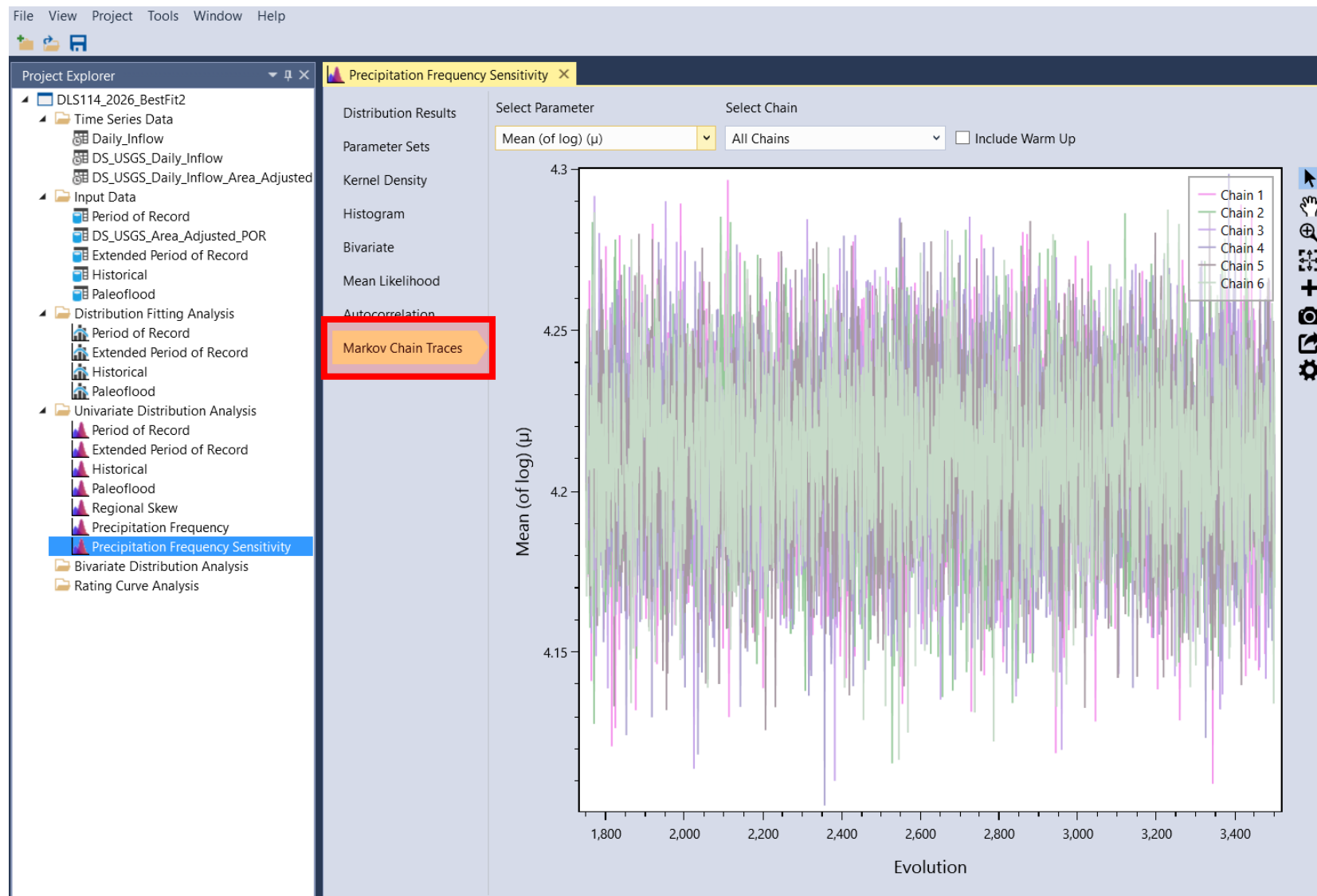
Diagnose Mean Likelihood



Diagnose Autocorrelation



Diagnose Markov Chain Traces



? Questions

