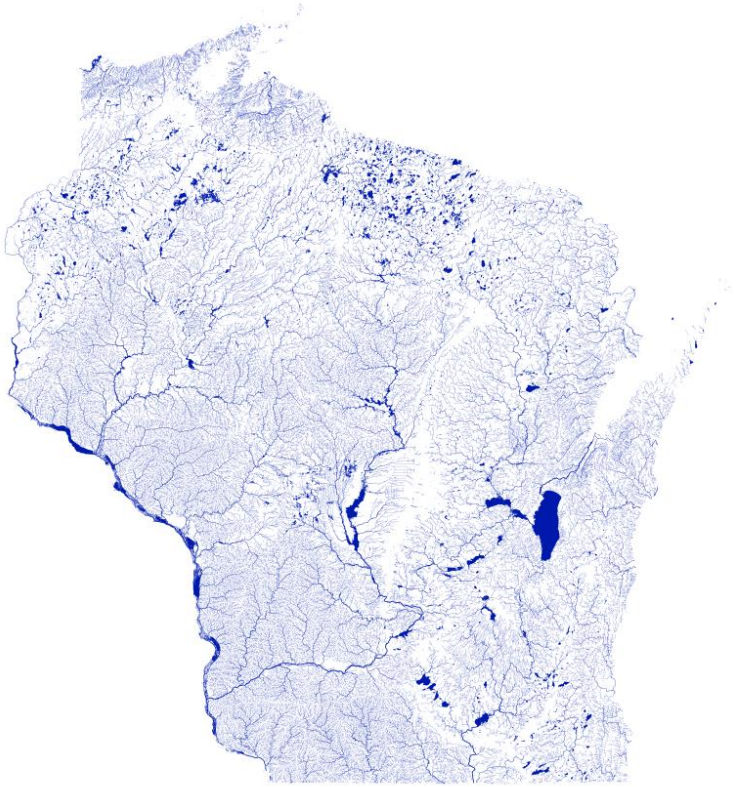
Understanding and Forecasting Variation on Water Levels

Bob Smail
Wisconsin DNR
Water Use Section

AWRA - WI
Appleton, WI
March, 8 2018



Lake Michigan

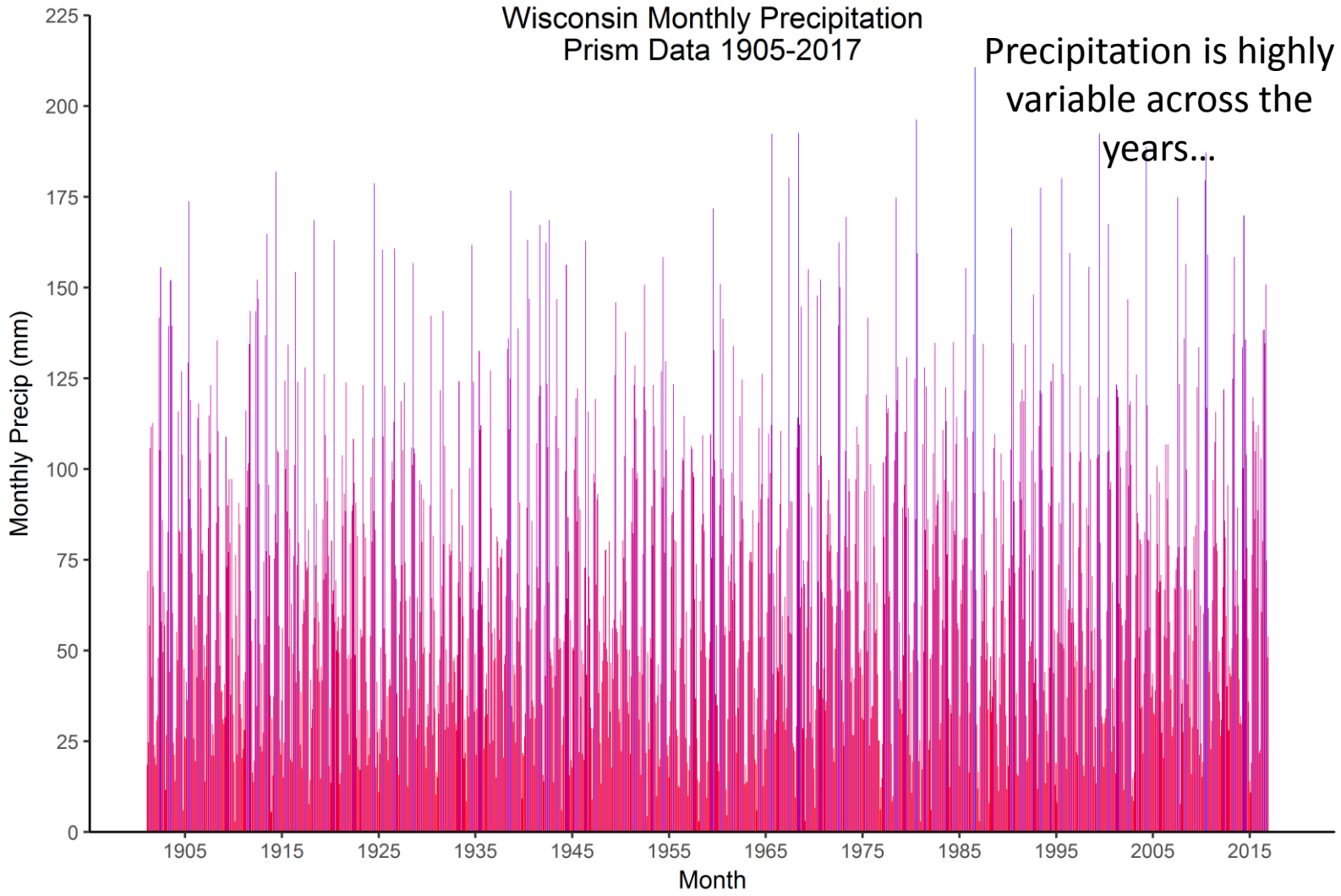
Long Lake
Waushara Co, WI

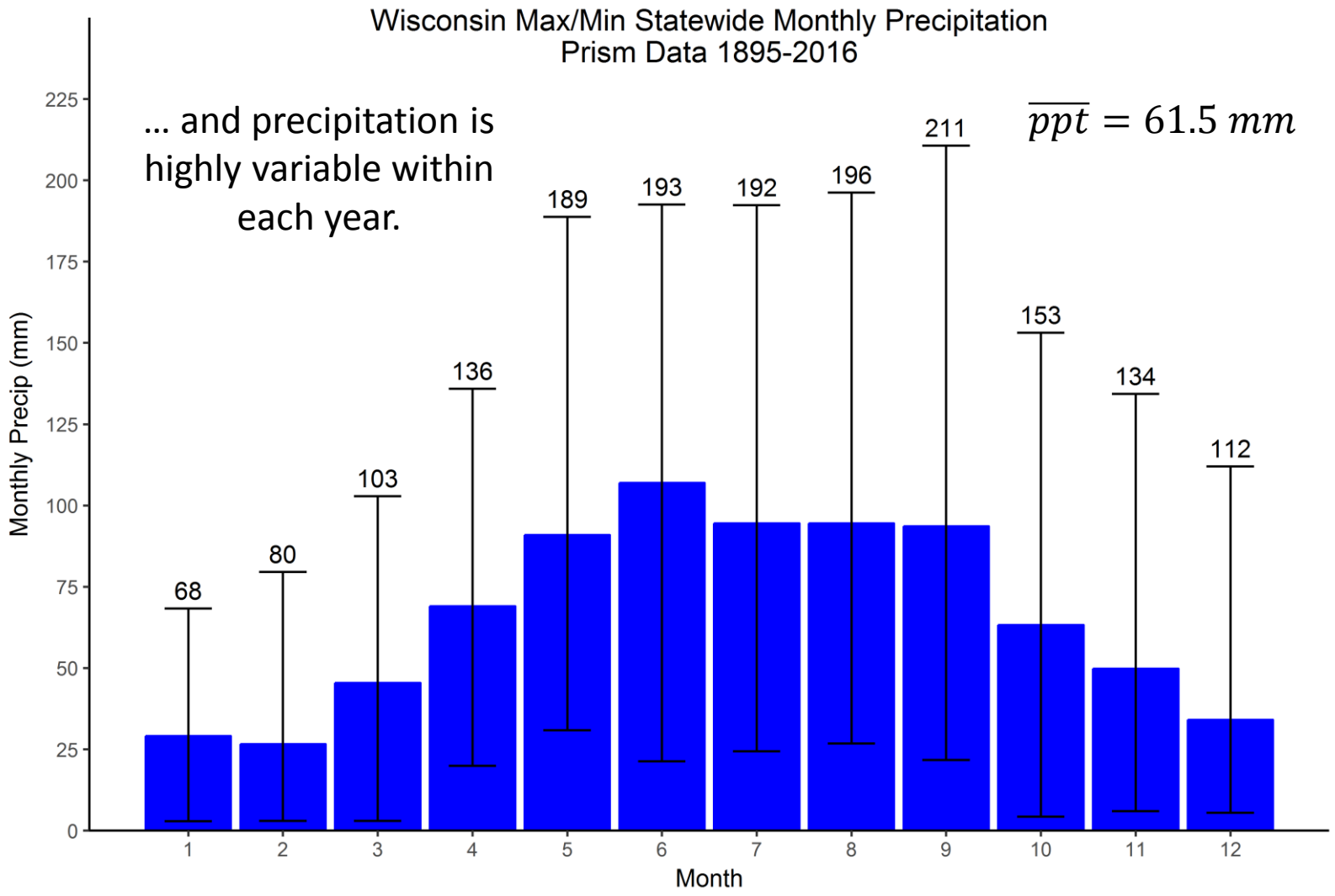
WI Center for
Investigative Journalism

Lost Land Lake
Sawyer Co, WI

Understanding and Forecasting Variation on Water Levels

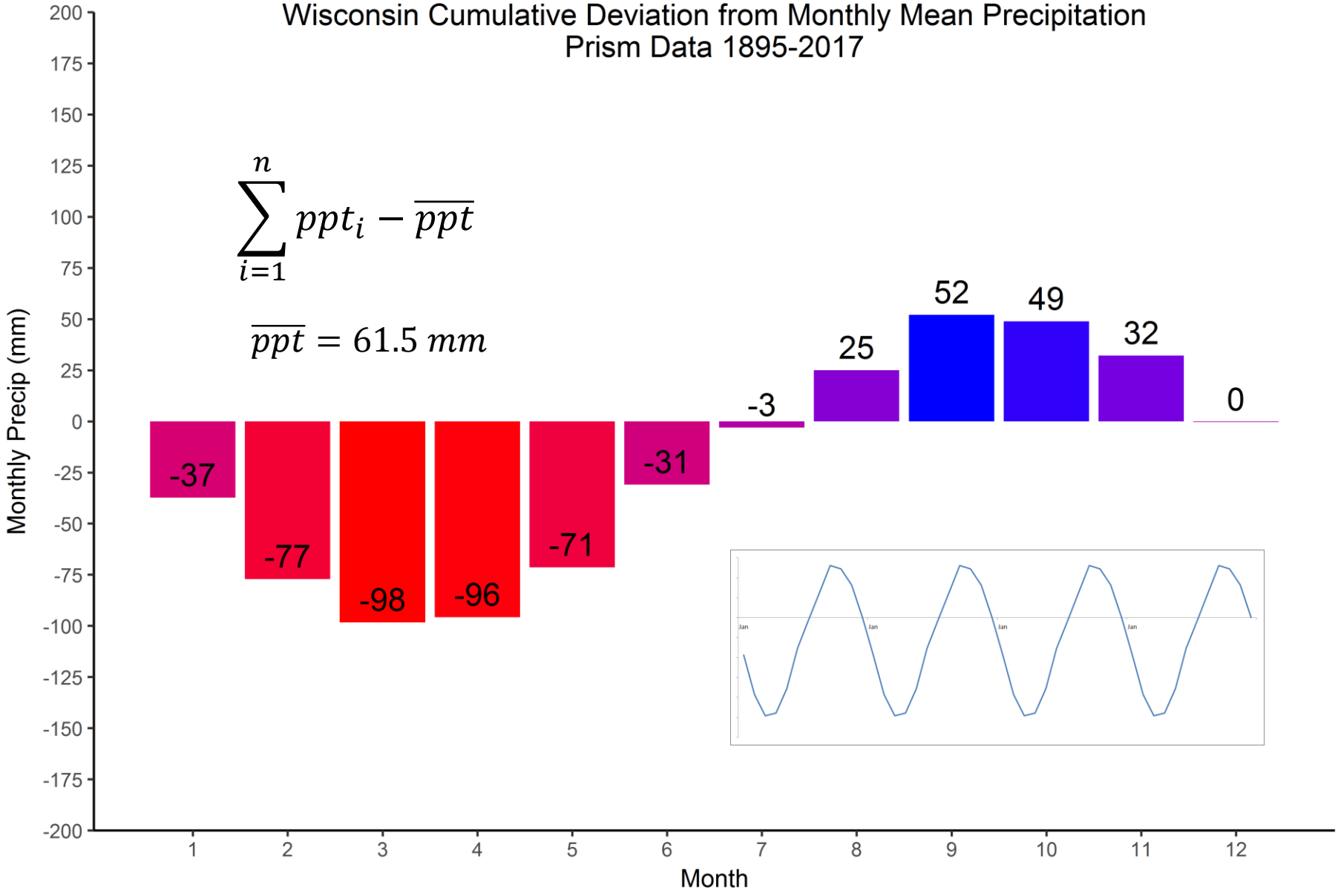
- ✓ Interpreting Precipitation
- ❑ Drivers of Water Level variation
- ❑ Forecasting Future Water Levels

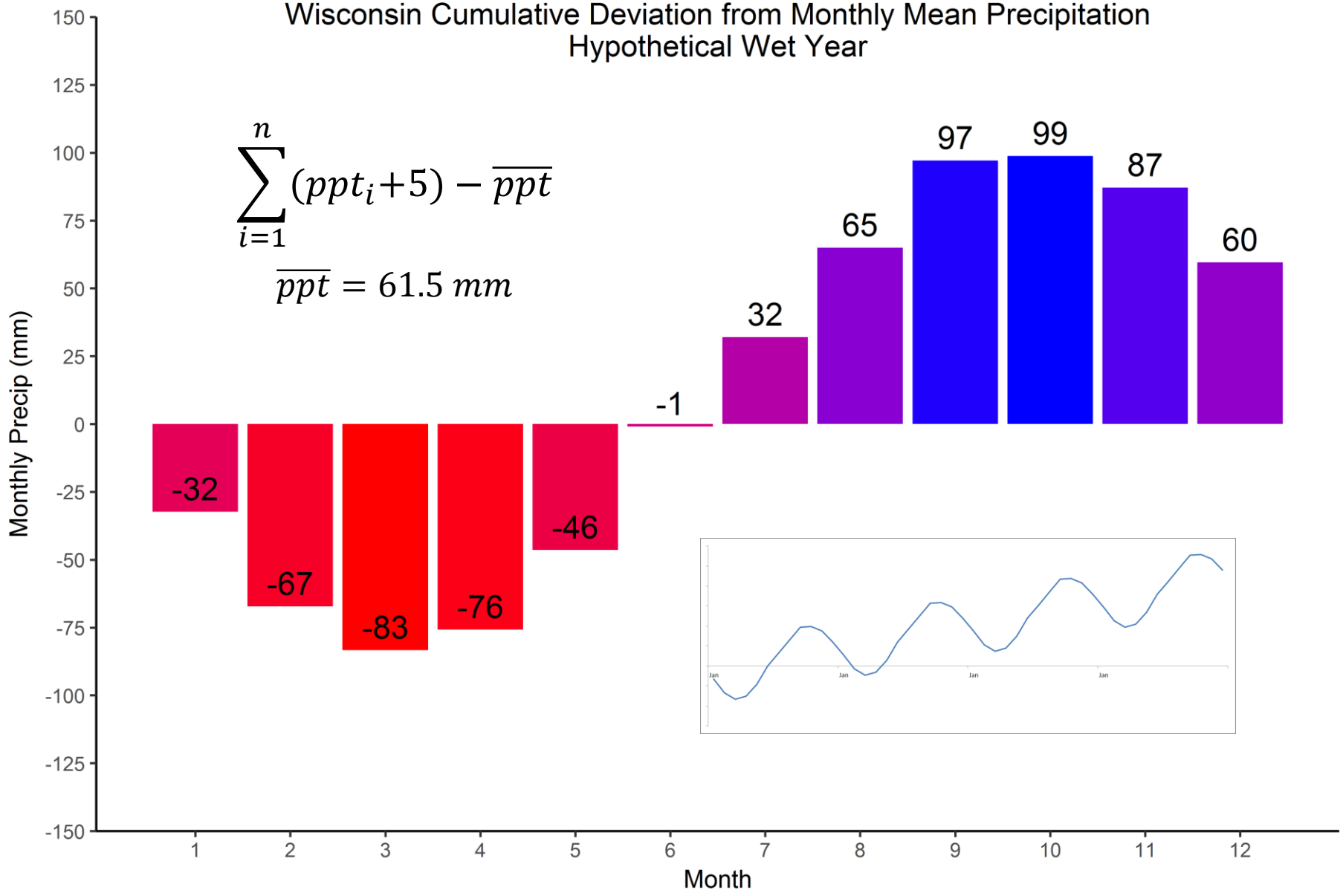

Wisconsin Monthly Precipitation
Prism Data 1905-2017
Precipitation is highly variable across the years…
Monthly Precip (mm)
225
200
175
150
125
100
75
50
25
0
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
2015
Month


Wisconsin Max/Min Statewide Monthly Precipitation
Prism Data 1895-2016
… and precipitation is highly variable within each year.
$\overline{ppt} = 61.5\ mm$
Monthly Precip (mm)
0
25
50
75
100
125
150
175
200
225
68
80
103
136
189
193
192
196
211
153
134
112
1
2
3
4
5
6
7
8
9
10
11
12
Month

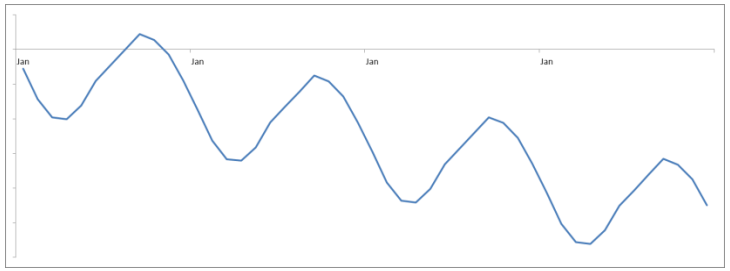
Understanding and Forecasting Variation on Water Levels

- We know that variability in precipitation is strongly related to changes in water levels.
- Hydrological models are best answer but are very time intensive, costly and usually limited to smaller areas.
- Can precipitation data be interpreted to serve as the expected water level given local weather?


Wisconsin Cumulative Deviation from Monthly Mean Precipitation
Prism Data 1895-2017
$\sum_{i=1}^{n} ppt_i - \overline{ppt}$
$\overline{ppt} = 61.5\ mm$
Monthly Precip (mm)
200
175
150
125
100
75
50
25
0
-25
-50
-75
-100
-125
-150
-175
-200
-37
-77
-98
-96
-71
-31
-3
25
52
49
32
0
1
2
3
4
5
6
7
8
9
10
11
12
Month


Wisconsin Cumulative Deviation from Monthly Mean Precipitation
Hypothetical Wet Year
$\sum_{i=1}^{n}(ppt_i+5)-\overline{ppt}$
$\overline{ppt} = 61.5\ mm$
Monthly Precip (mm)
Month
150
125
100
75
50
25
0
-25
-50
-75
-100
-125
-150
1
2
3
4
5
6
7
8
9
10
11
12
-32
-67
-83
-76
-46
-1
32
65
97
99
87
60
Jan
Jan
Jan
Jan

Wisconsin Cumulative Deviation from Monthly Mean Precipitation
Hypothetical Dry Year



sumdev Precip (mm)

150
125
100
75
50
25
0
-25
-50
-75
-100
-125
-150

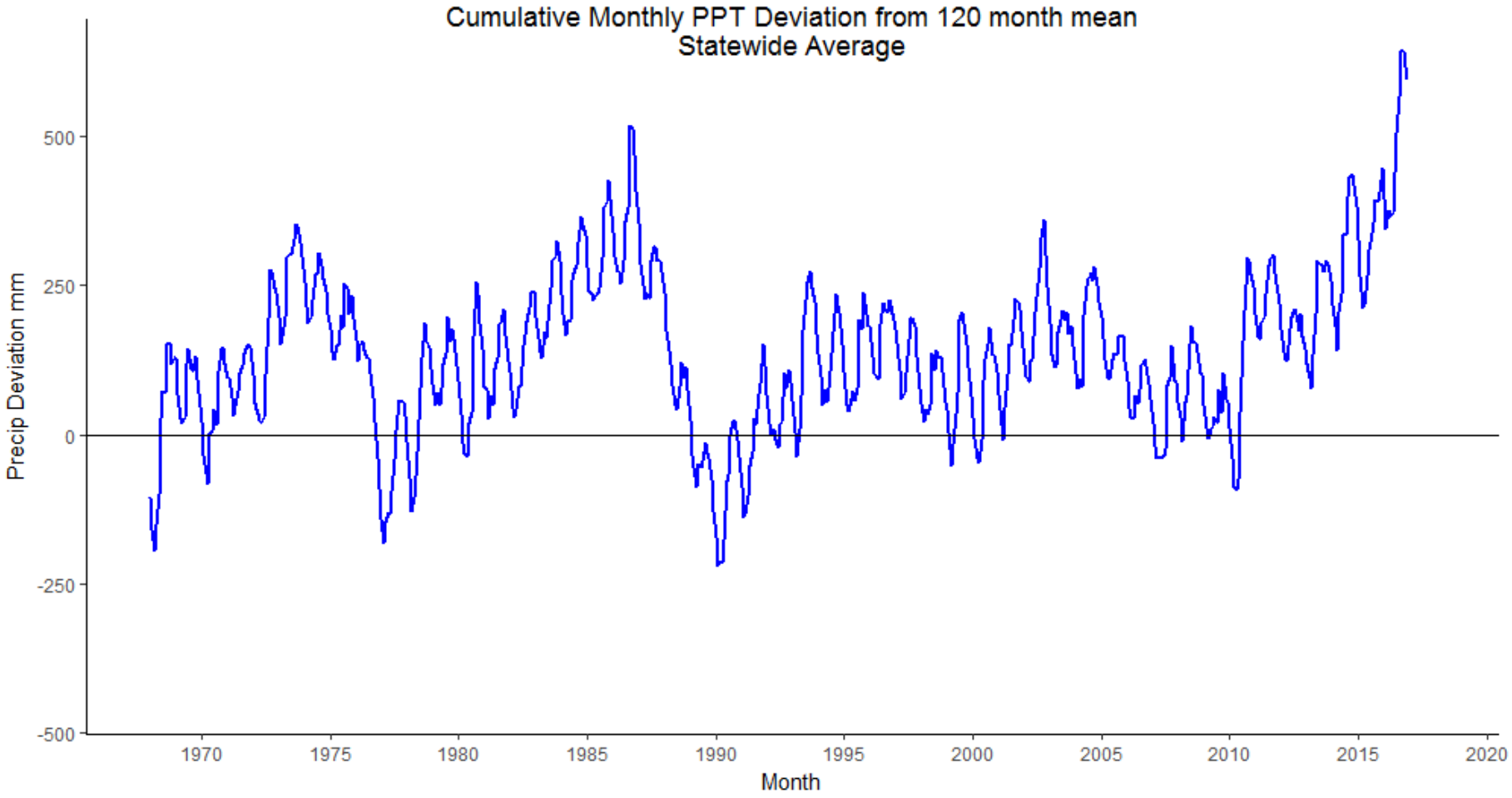
-42
-87
-113
-116
-96
-61
-38
-15
7
-1
-23
-60

1 2 3 4 5 6 7 8 9 10 11 12

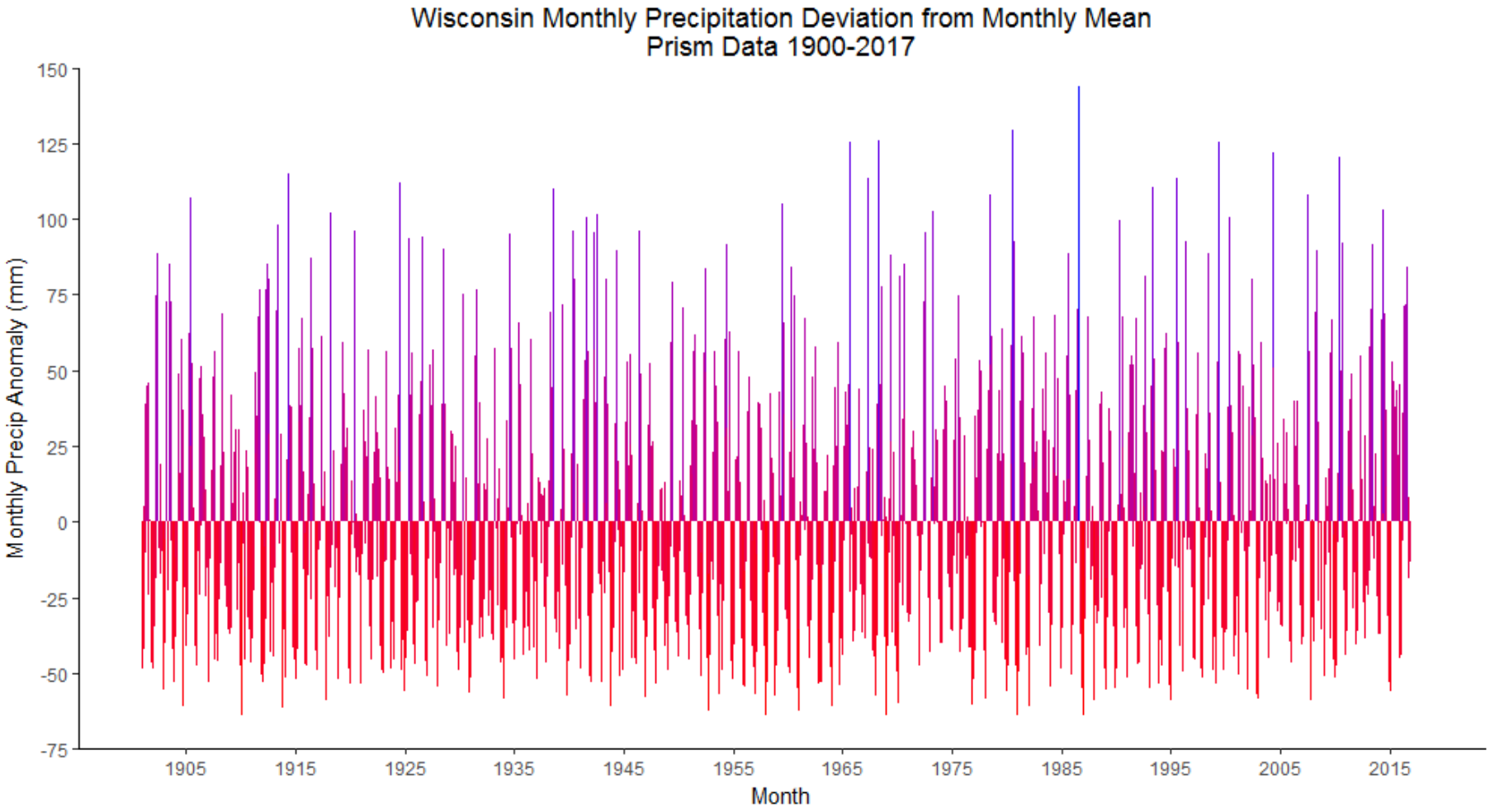
Month

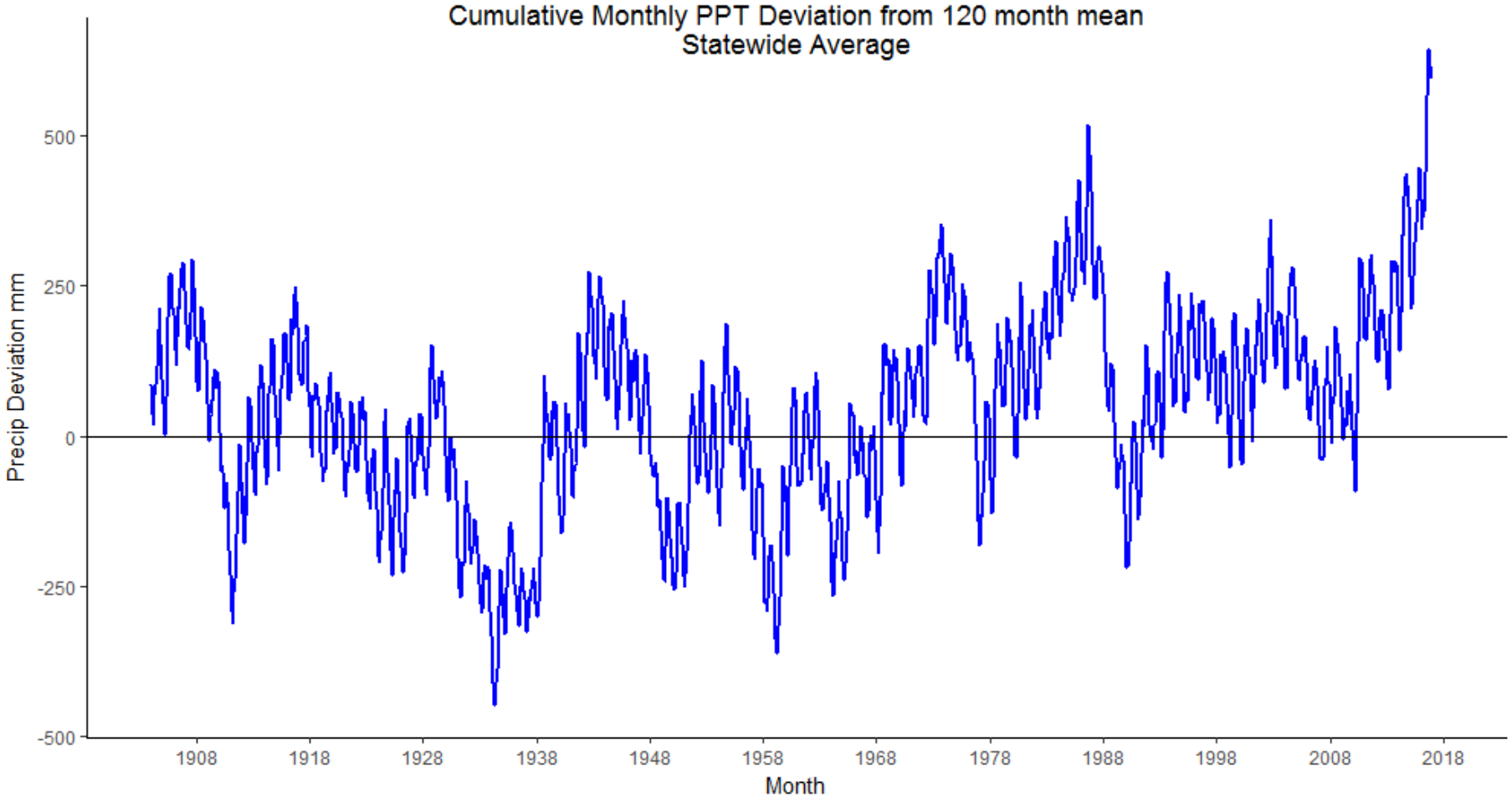
$$\sum_{i=1}^{n}(ppt_i - 5) - \overline{ppt}$$

$$\overline{ppt} = 61.5\ mm$$

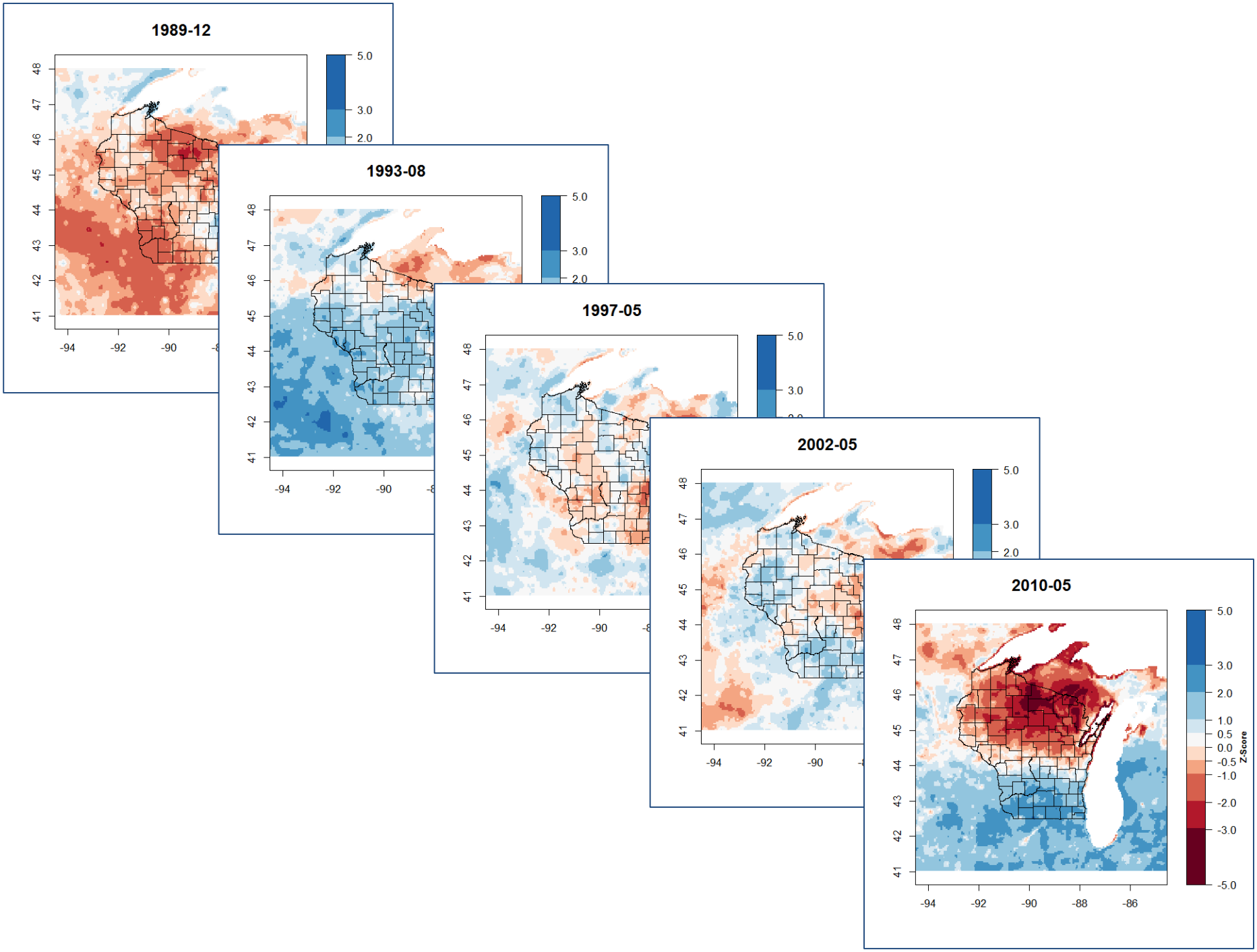


$$\sum_{i=1}^{n}(ppt_i) - \overline{ppt}_{MA120}$$


Wisconsin Monthly Precipitation Deviation from Monthly Mean
Prism Data 1900-2017
Monthly Precip Anomaly (mm)
150
125
100
75
50
25
0
-25
-50
-75
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
2015
Month



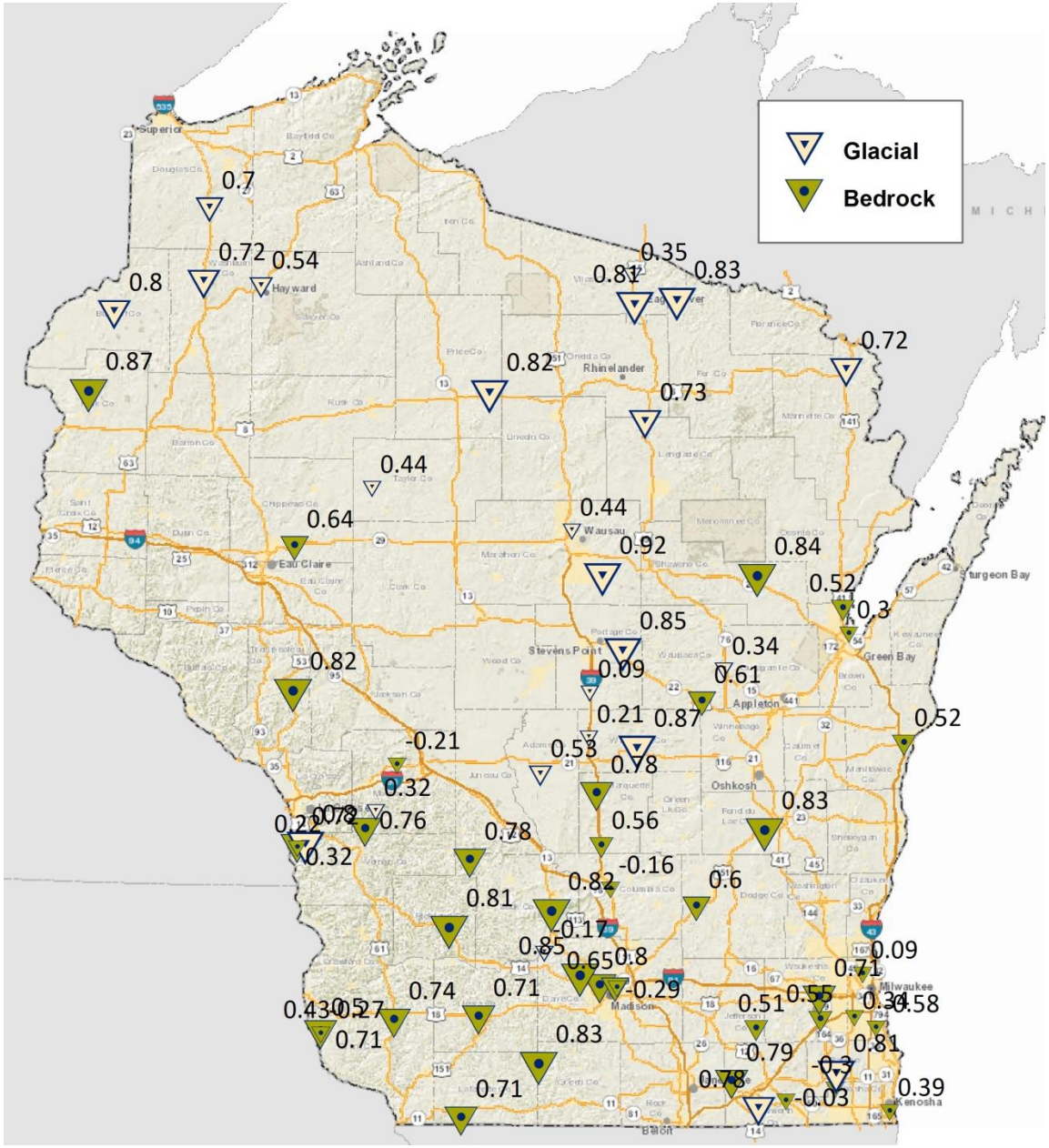
$$\sum_{i=1}^{n}(ppt_i) - \overline{ppt}_{MA120}$$

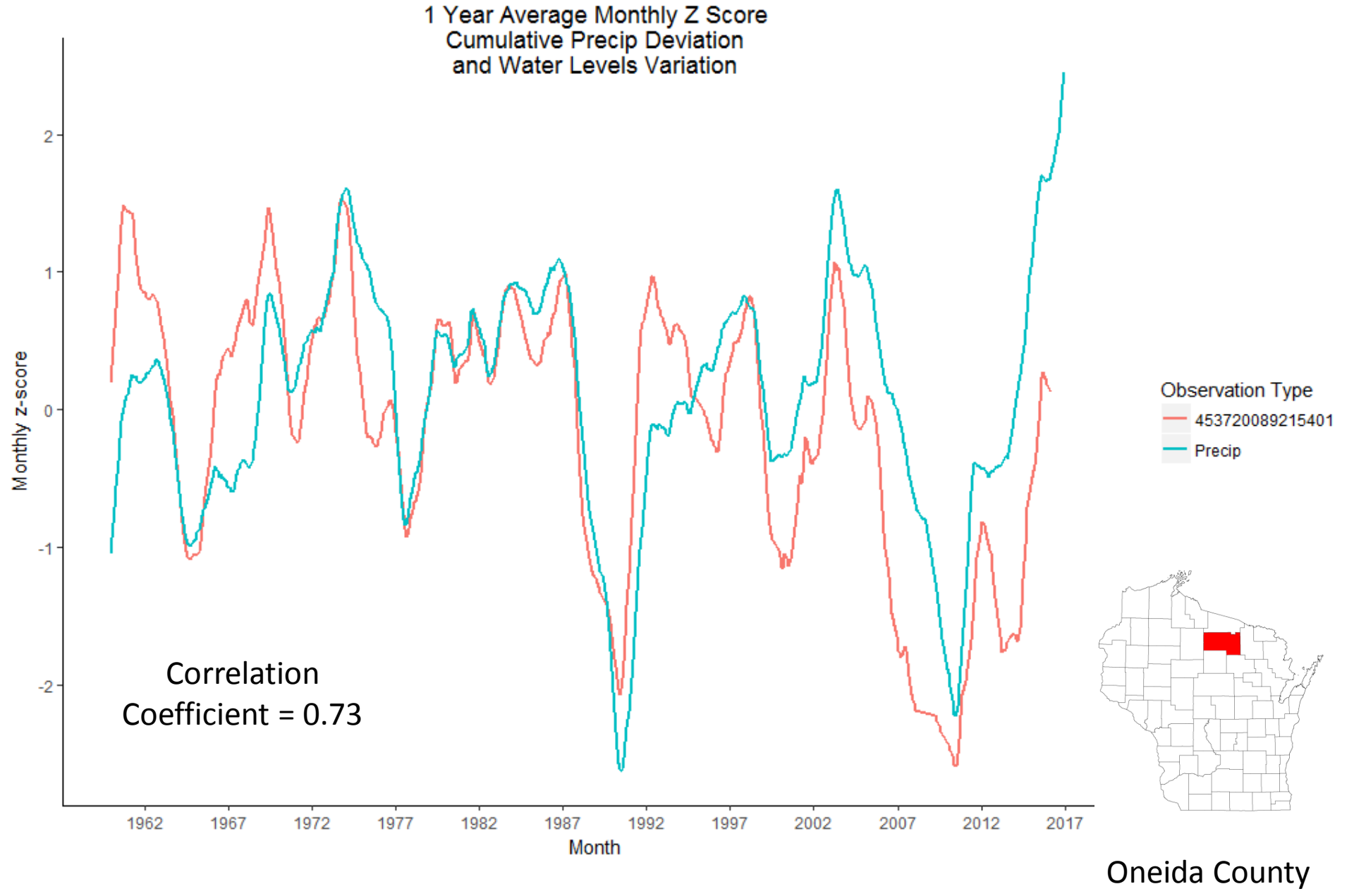

1989-12
1993-08
1997-05
2002-05
2010-05
Z-Score
5.0
3.0
2.0
1.0
0.5
0.0
-0.5
-1.0
-2.0
-3.0
-5.0
-94
-92
-90
-88
-86
41
42
43
44
45
46
47
48

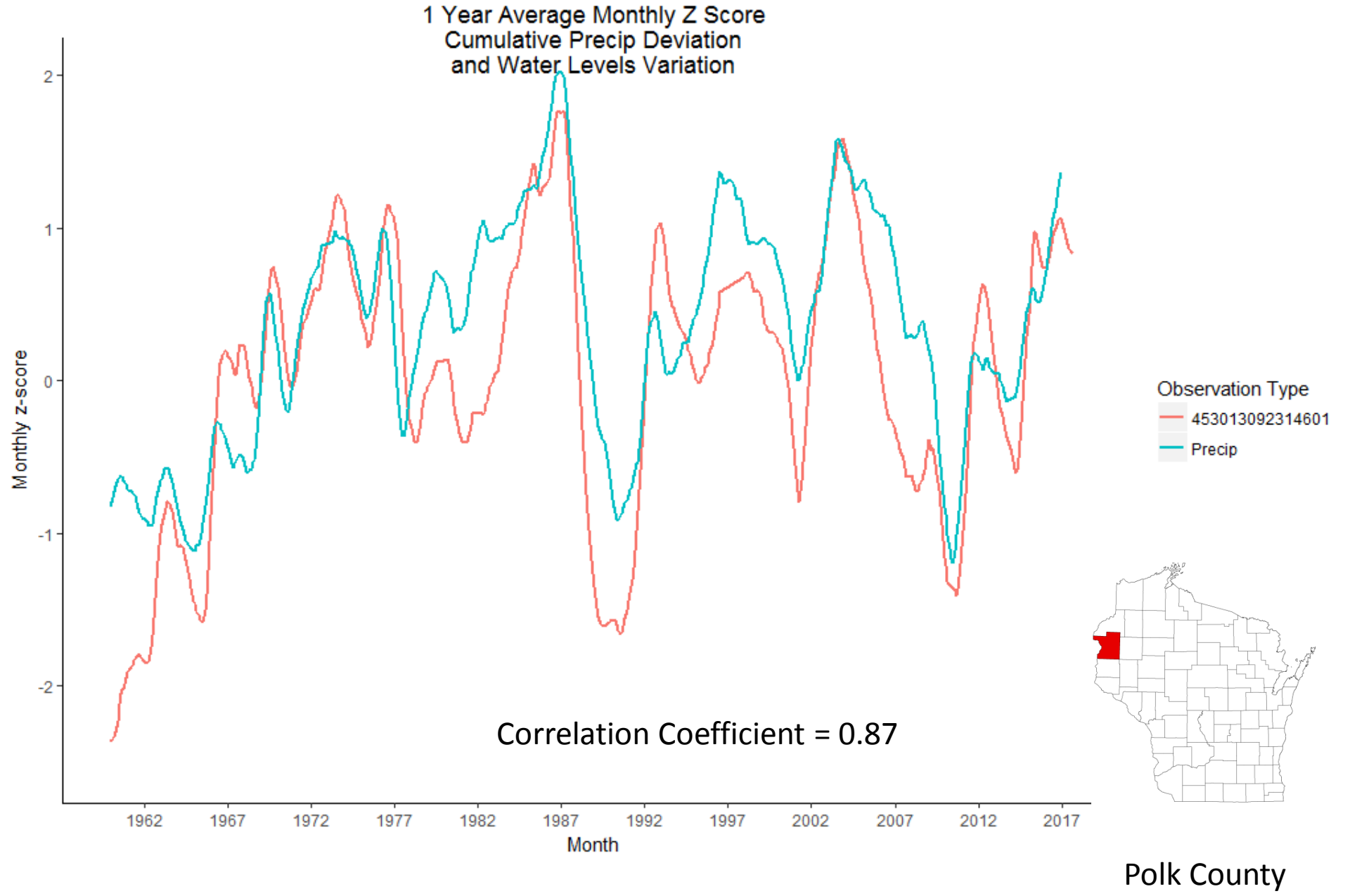
Understanding and Forecasting Variation on Water Levels

- ❑ Interpreting Precipitation
- ✓ Drivers of Water Level variation
- ❑ Forecasting Future Water Levels

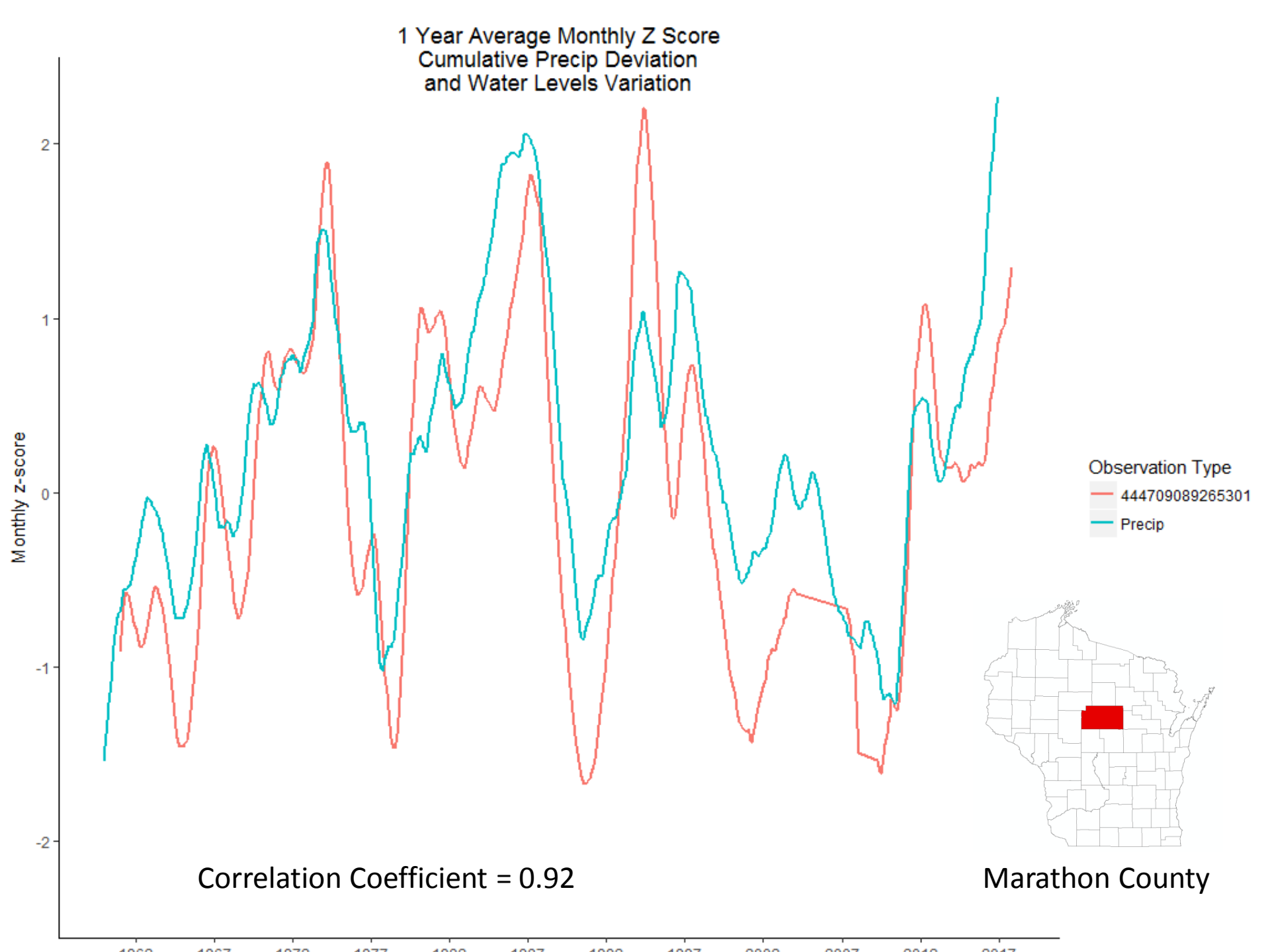
- 68 USGS Gage Sites with data from 1987 to 2017
- Standardized and smoothed to rolling 12 month average
- Compared to cumulative deviation from mean at location lat/long
- 70% had pearson correlation > 0.50
- 50% had pearson correlation coef >.70
- No difference in glacial vs. bedrock formations

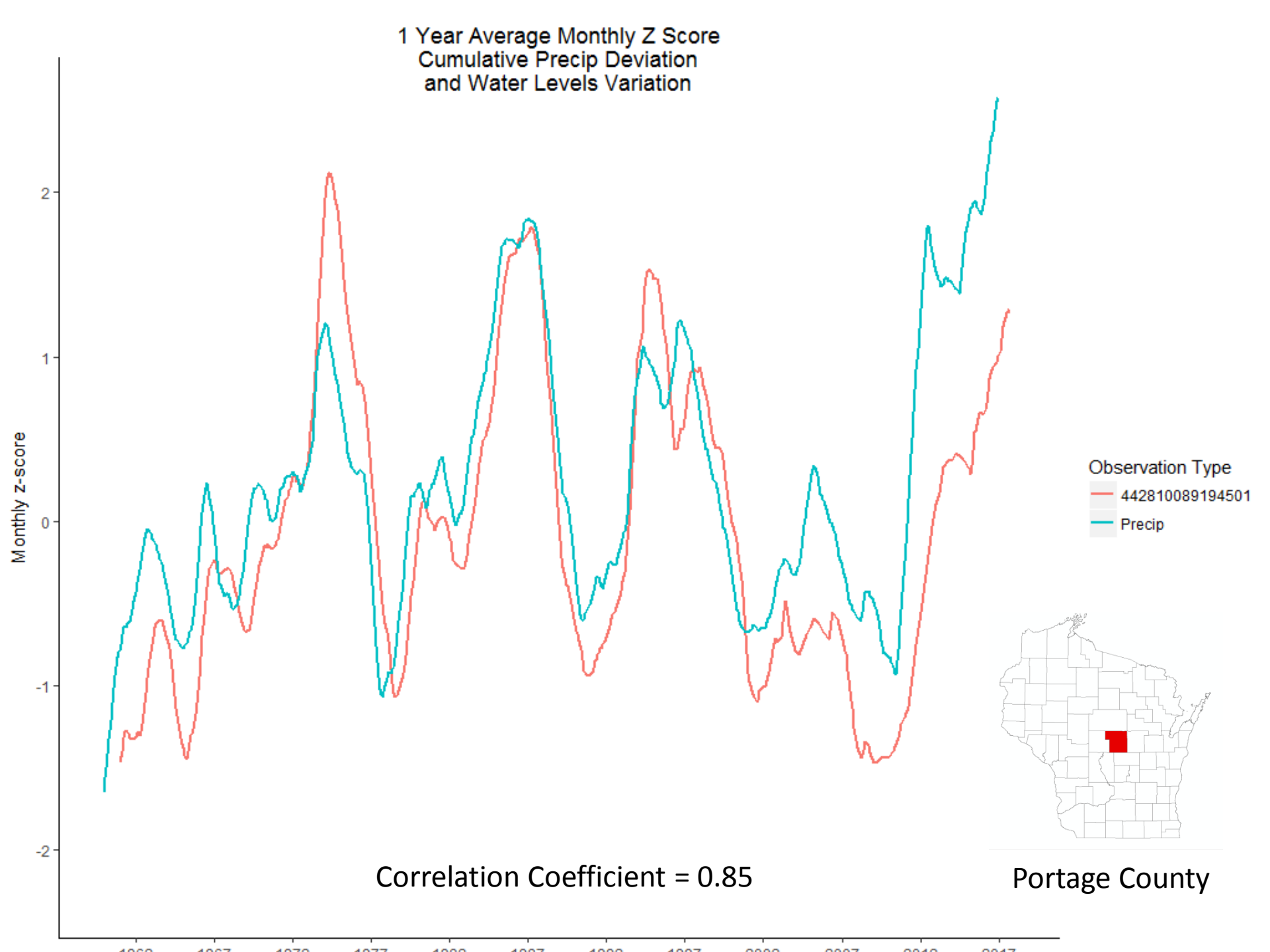


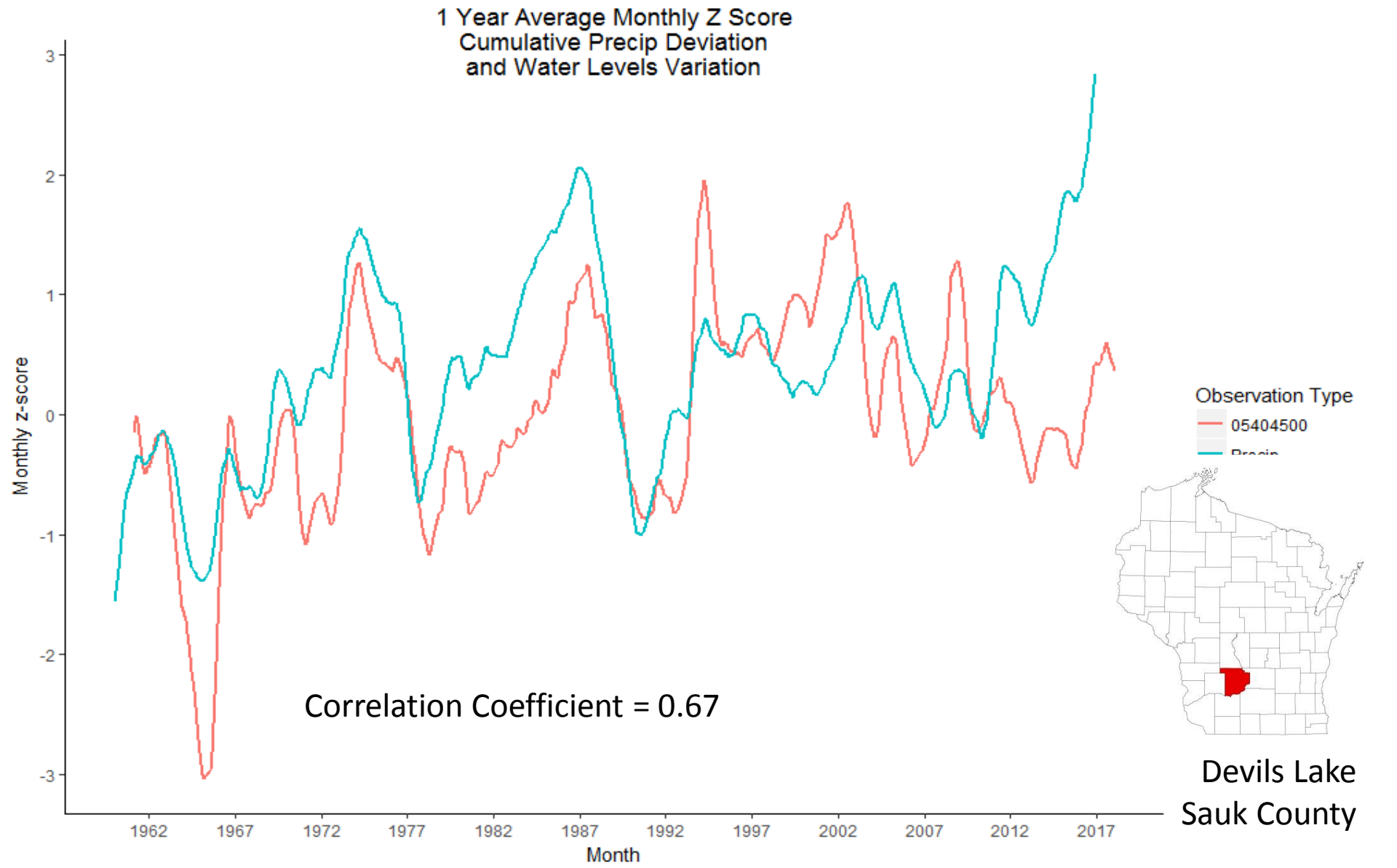

1 Year Average Monthly Z Score
Cumulative Precip Deviation
and Water Levels Variation
Monthly z-score
2
1
0
-1
-2
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
2012
2017
Month
Correlation
Coefficient = 0.73
Observation Type
453720089215401
Precip
Oneida County

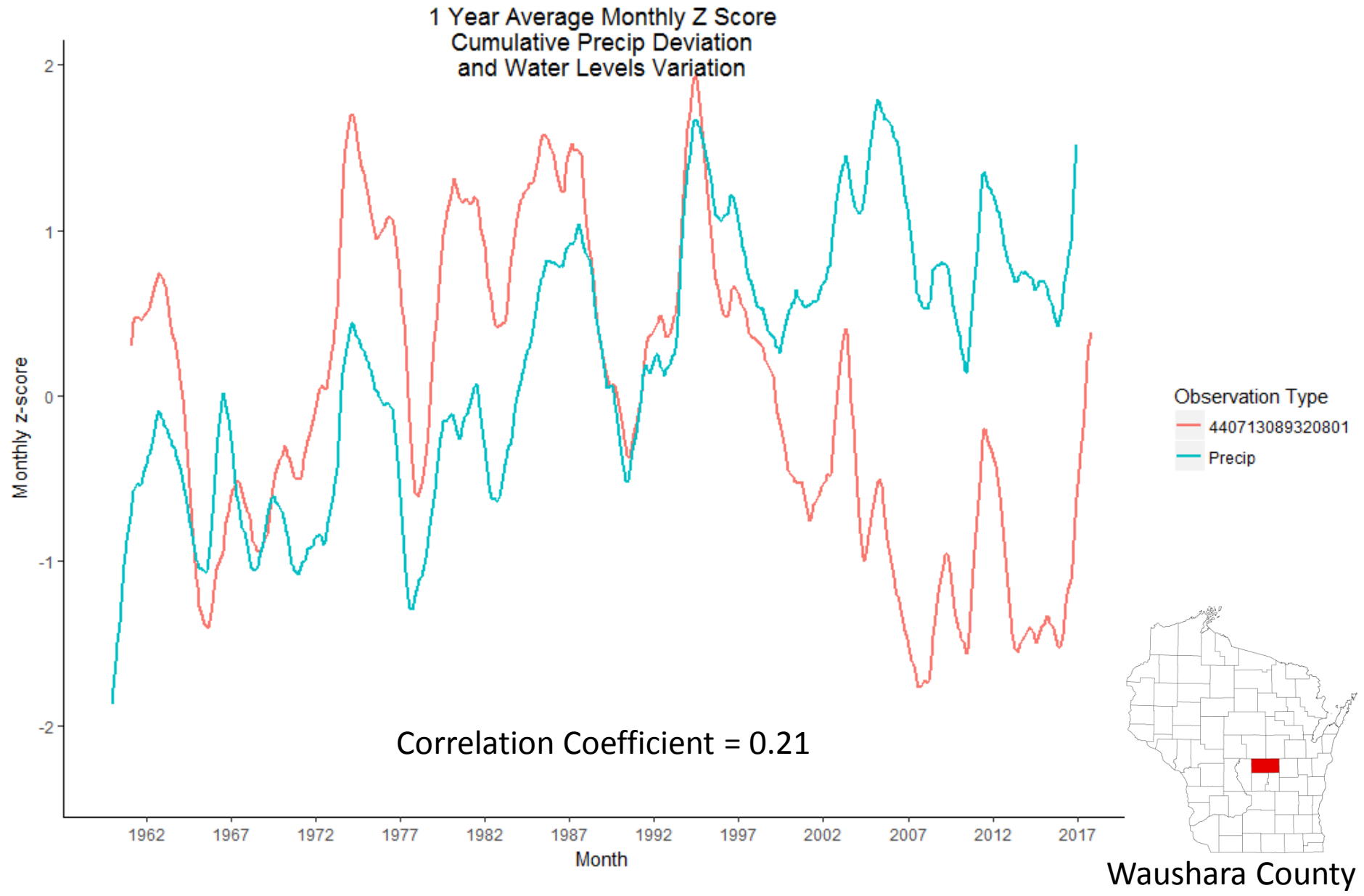

1 Year Average Monthly Z Score
Cumulative Precip Deviation
and Water Levels Variation
Monthly z-score
2
1
0
-1
-2
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
2012
2017
Month
Observation Type
453013092314601
Precip
Correlation Coefficient = 0.87

Polk County

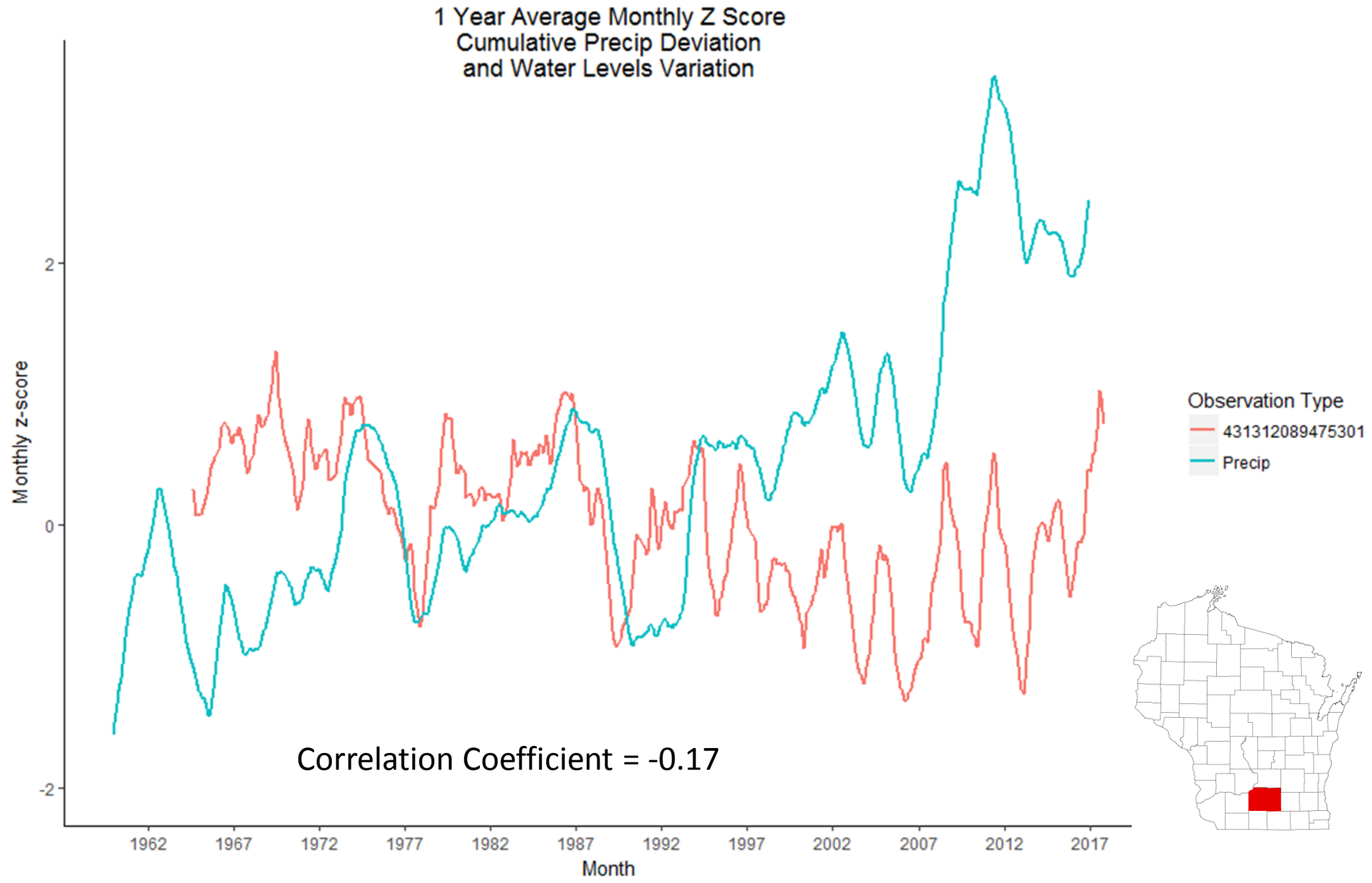

1 Year Average Monthly Z Score
Cumulative Precip Deviation
and Water Levels Variation
Monthly z-score
2
1
0
-1
-2
Observation Type
444709089265301
Precip
Correlation Coefficient = 0.92
Marathon County


1 Year Average Monthly Z Score
Cumulative Precip Deviation
and Water Levels Variation
Monthly z-score
2
1
0
-1
-2
Observation Type
442810089194501
Precip
Correlation Coefficient = 0.85
Portage County


1 Year Average Monthly Z Score
Cumulative Precip Deviation
and Water Levels Variation
Monthly z-score
3
2
1
0
-1
-2
-3
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
2012
2017
Month
Observation Type
05404500
Correlation Coefficient = 0.67
Devils Lake
Sauk County



Waushara County


1 Year Average Monthly Z Score
Cumulative Precip Deviation
and Water Levels Variation
Monthly z-score
2
0
-2
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
2012
2017
Month
Observation Type
431312089475301
Precip
Correlation Coefficient = -0.17

Dane County

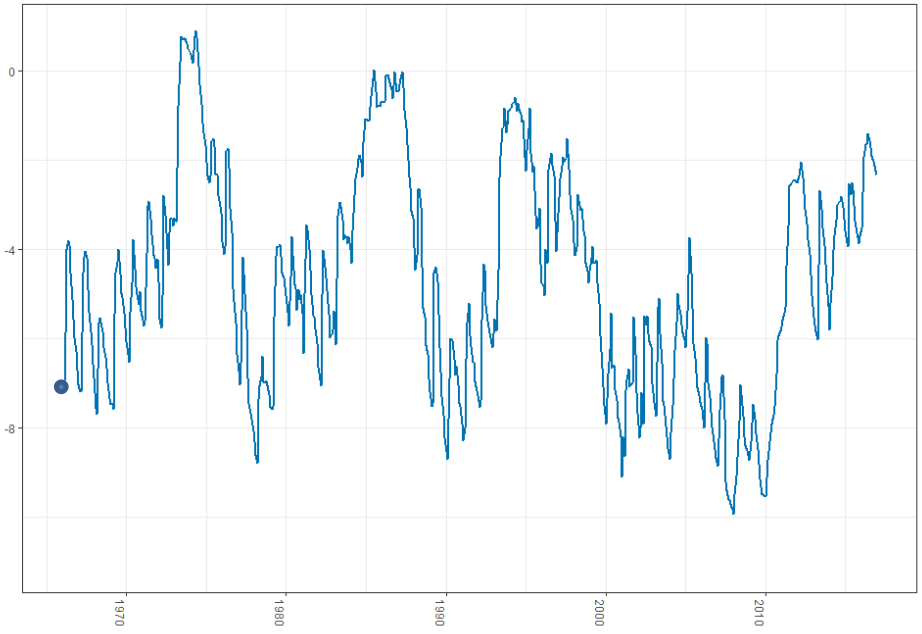
Understanding and Forecasting Variation on Water Levels

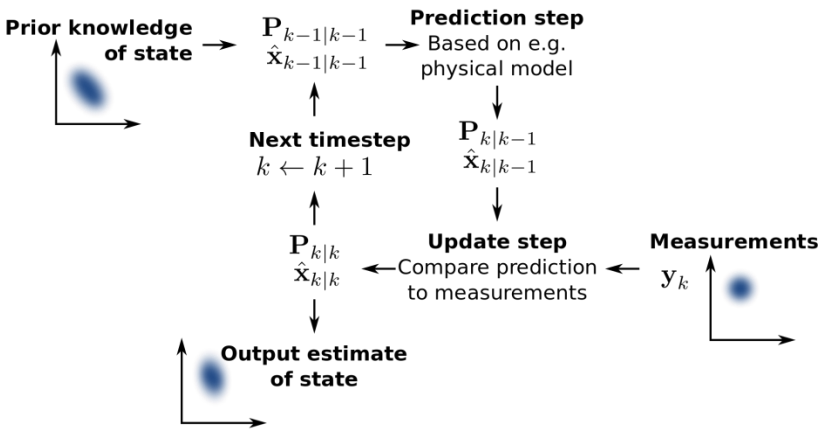
- ❑ Interpreting Precipitation
- ❑ Drivers of Water Level variation
- ✓ Forecasting Future Water Levels

Understanding and Forecasting Variation on Water Levels

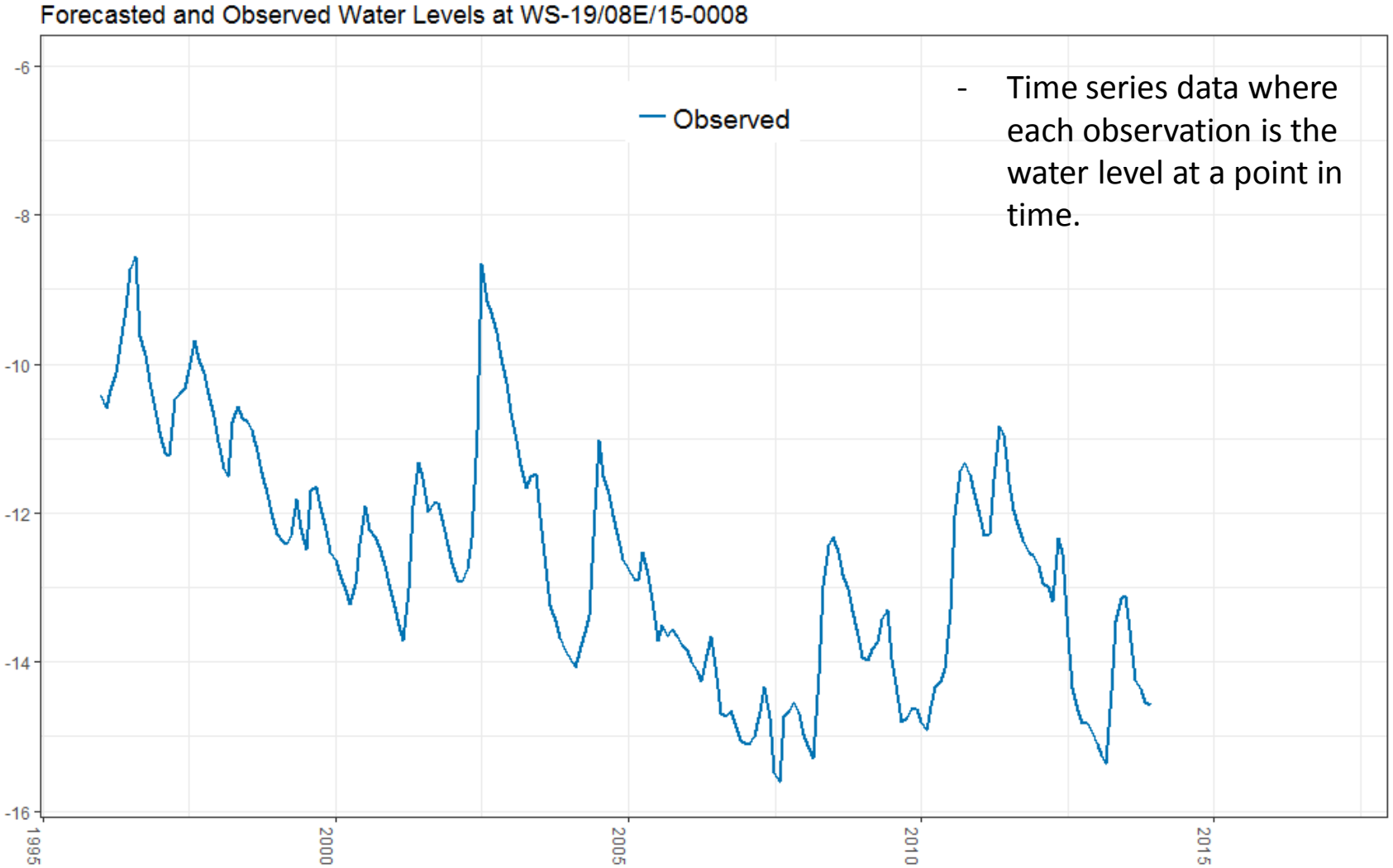
Bayesian Structural Time Series

- Machine learning technique for time series data forecasting
- Models the probability of the next step based on past likelihoods
- Incorporates seasonal cycle
- Provides likelihood that that prediction will fit the observation
- Predictor data can be added to substantially improve the model.
  - Precip deviations
  - Monthly Precip
  - Evapotranspiration
  - Withdrawals
  - Global weather indices



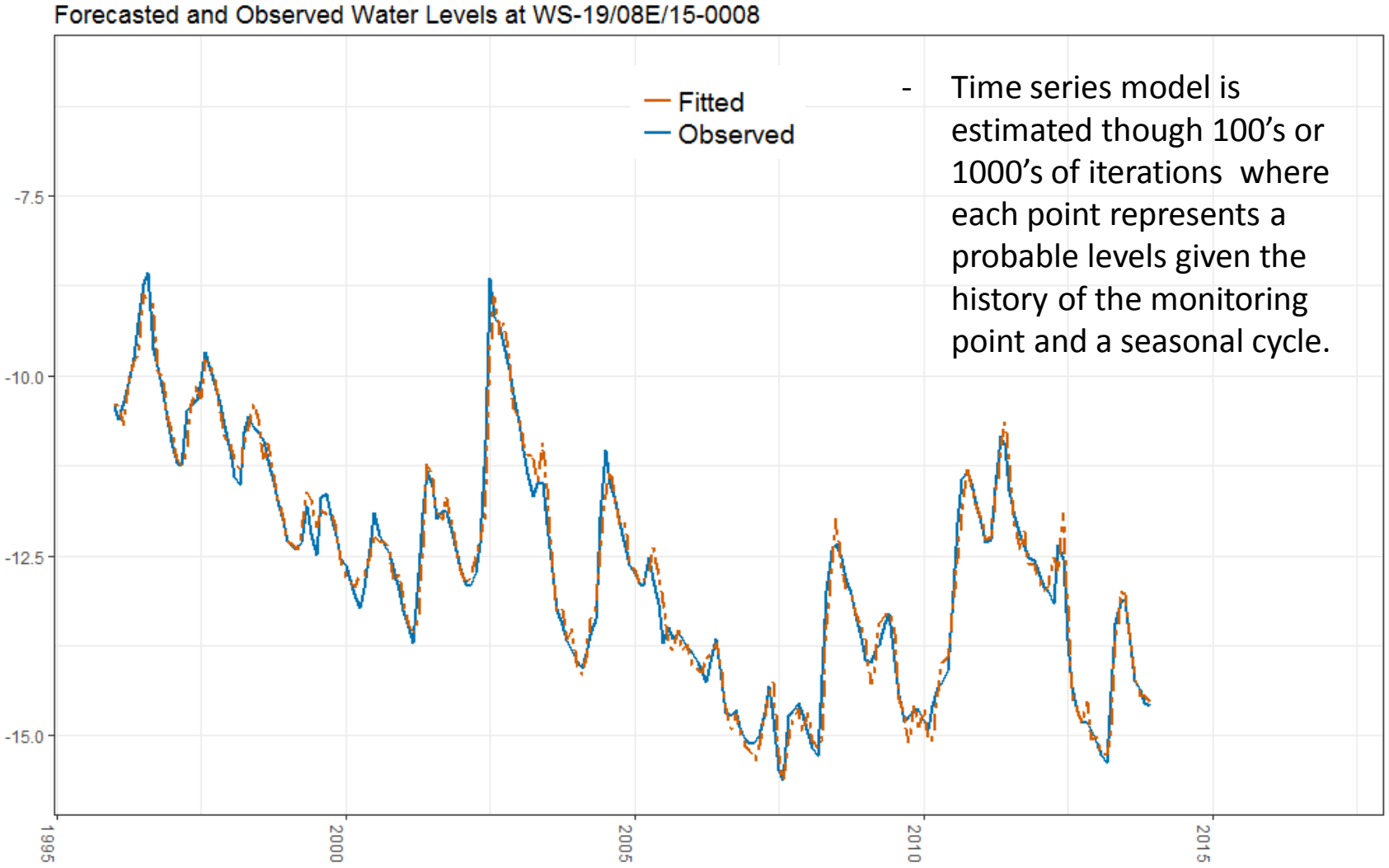


Understanding and Forecasting Variation on Water Levels



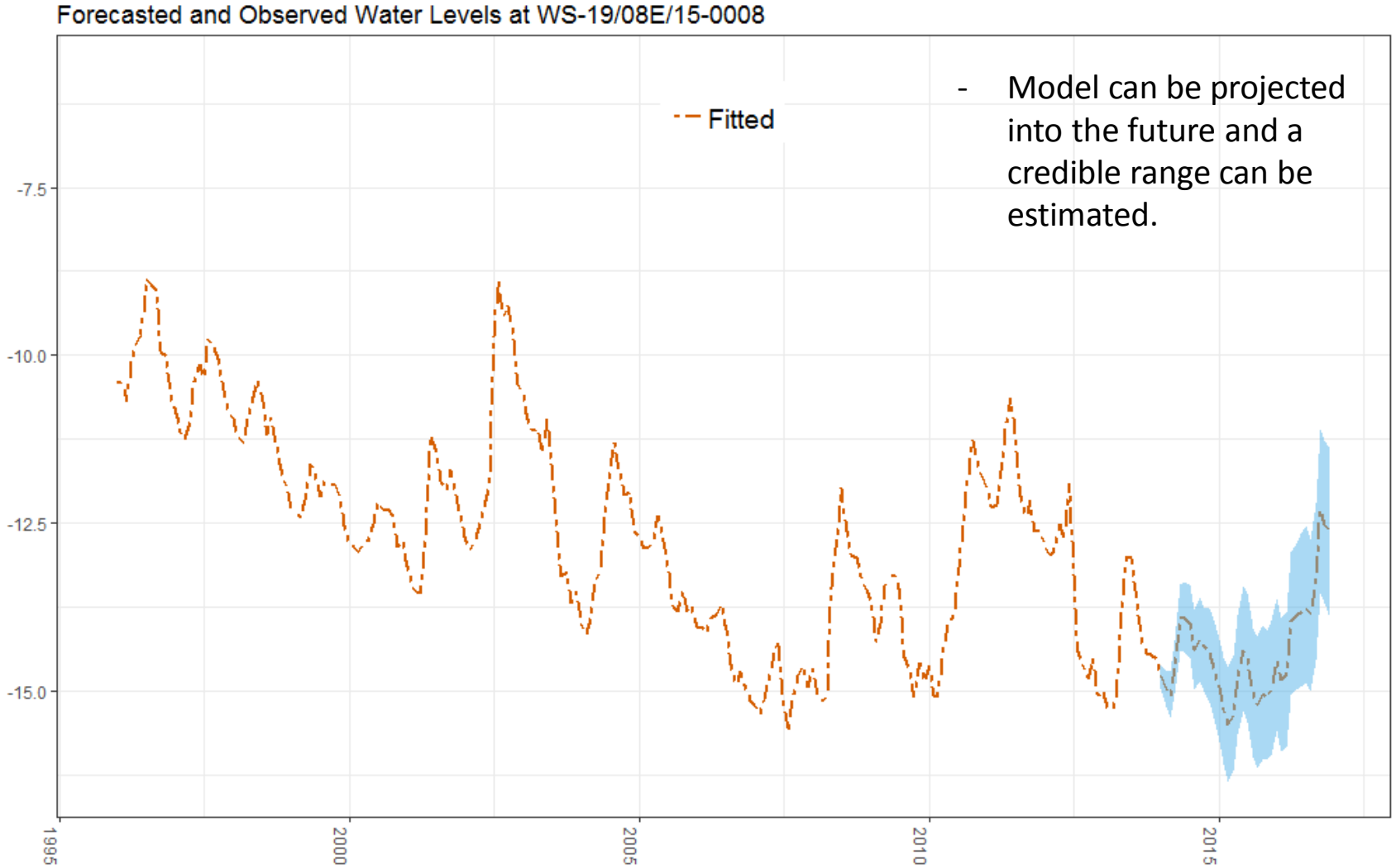
- Time series data where each observation is the water level at a point in time.

Understanding and Forecasting Variation on Water Levels



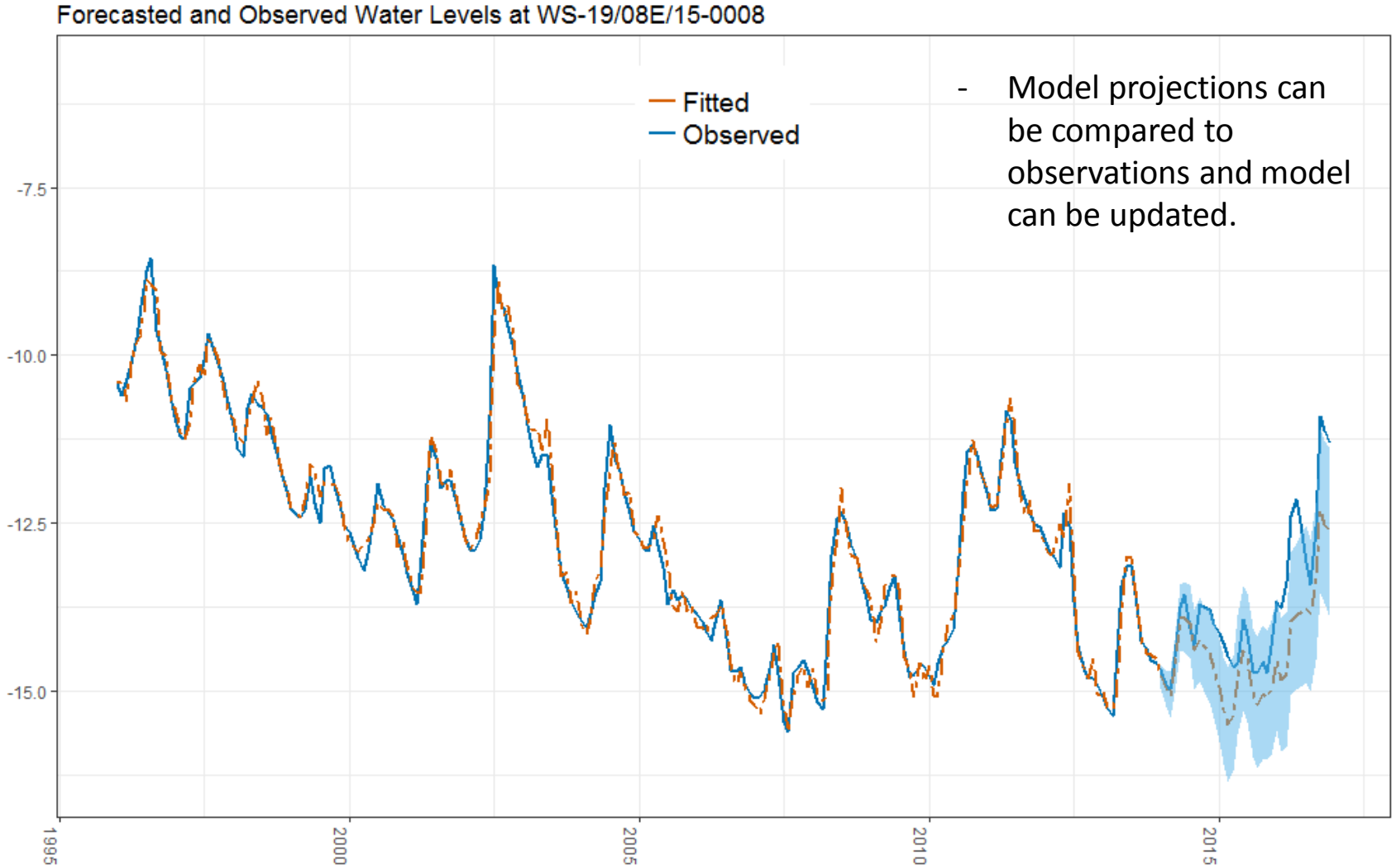
- Time series model is estimated though 100's or 1000's of iterations where each point represents a probable levels given the history of the monitoring point and a seasonal cycle.

Understanding and Forecasting Variation on Water Levels



- Model can be projected into the future and a credible range can be estimated.

Understanding and Forecasting Variation on Water Levels

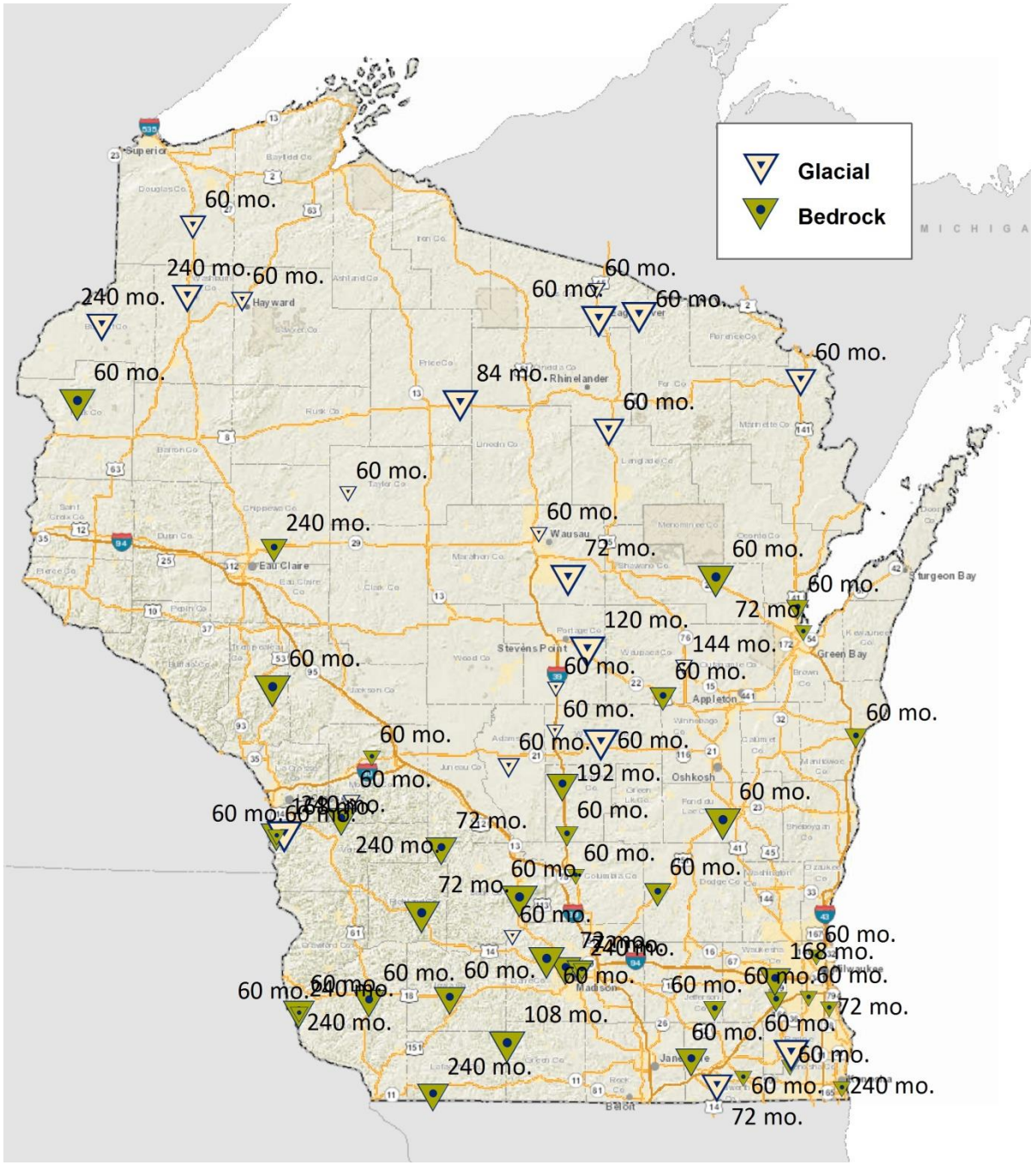


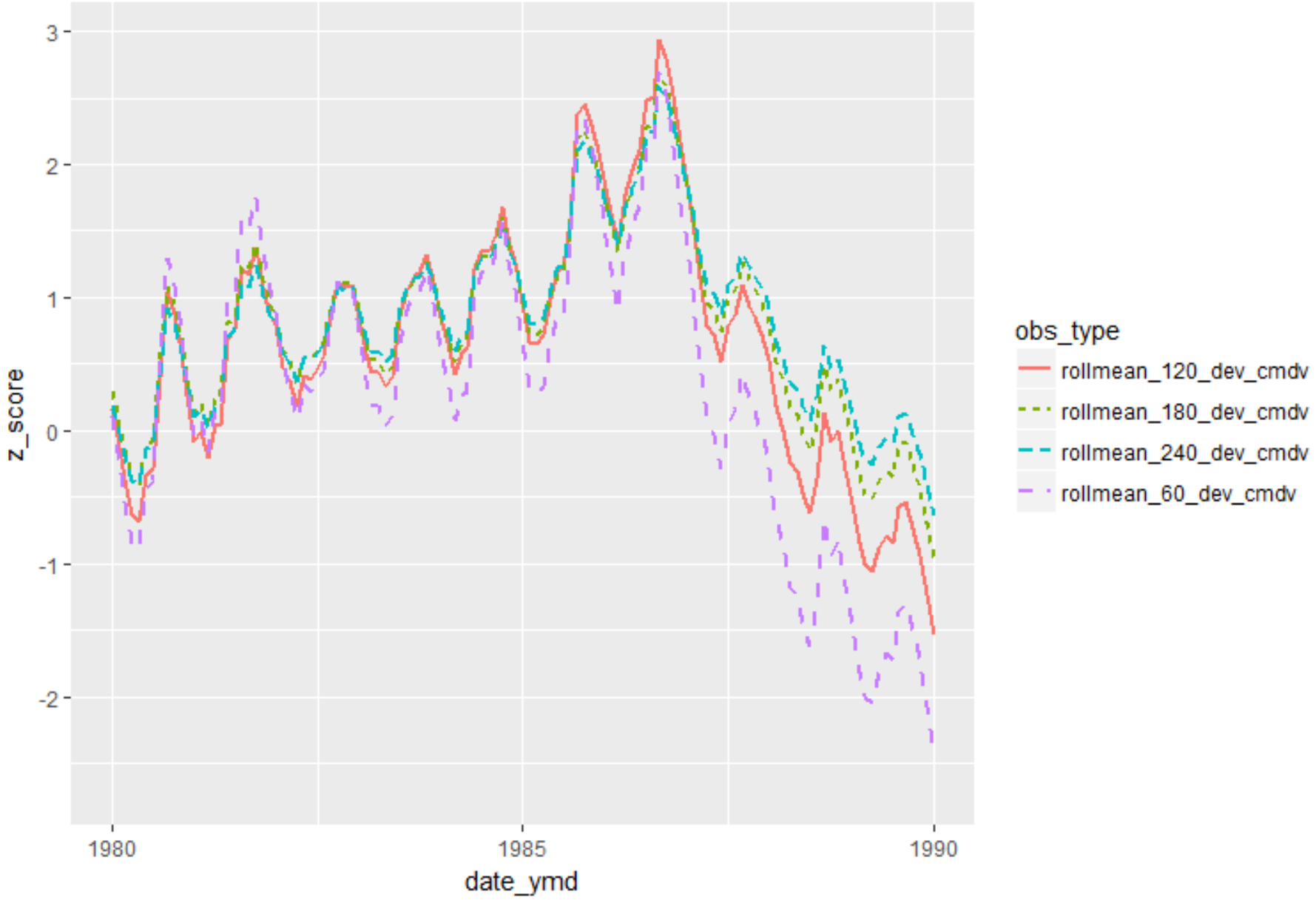
- Model projections can be compared to observations and model can be updated.

Thank You

For more information, contact

Bob Smail
608-267-3581
Robert.smail@wisconsin.gov


Glacial
Bedrock
60 mo.
240 mo.
84 mo.
72 mo.
120 mo.
144 mo.
192 mo.
108 mo.
168 mo.
Superior
Hayward
Rhinelander
Wausau
Eau Claire
Stevens Point
Appleton
Oshkosh
Green Bay
Madison
Beloit


3
2
1
0
-1
-2
z_score
1980
1985
1990
date_ymd
obs_type
rollmean_120_dev_cmdv
rollmean_180_dev_cmdv
rollmean_240_dev_cmdv
rollmean_60_dev_cmdv