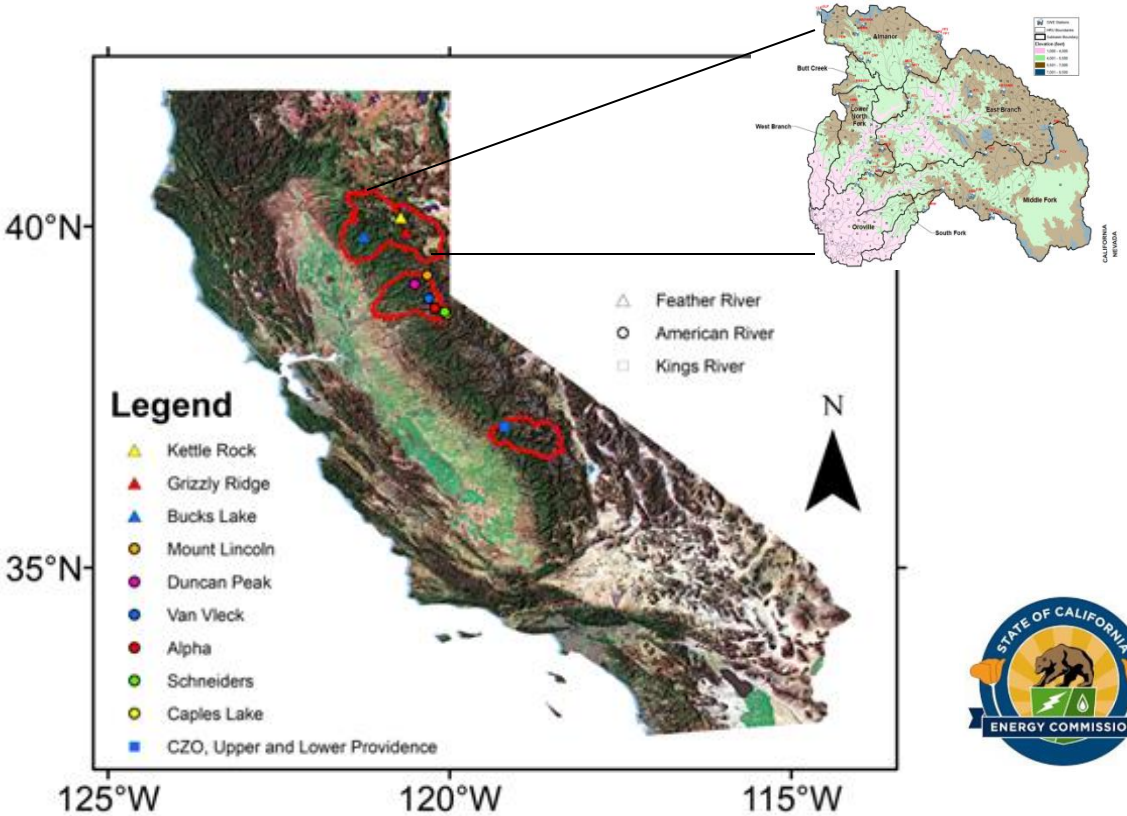
Improving snow & streamflow modeling on the Feather River using intelligent information systems

November 14, 2018



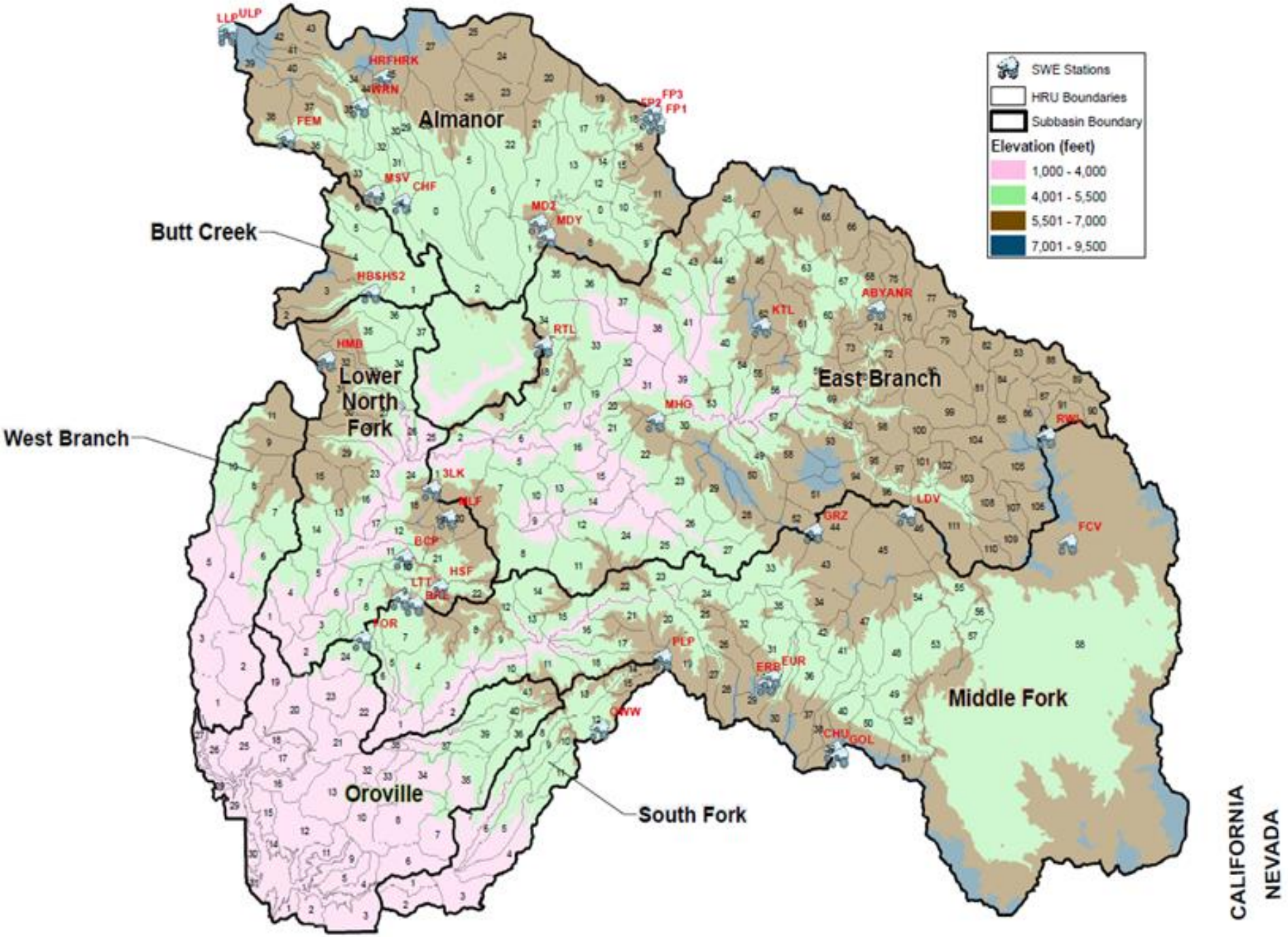
Feather Team:

Tessa Maurer

Francesco Avanzi

Sami Malek

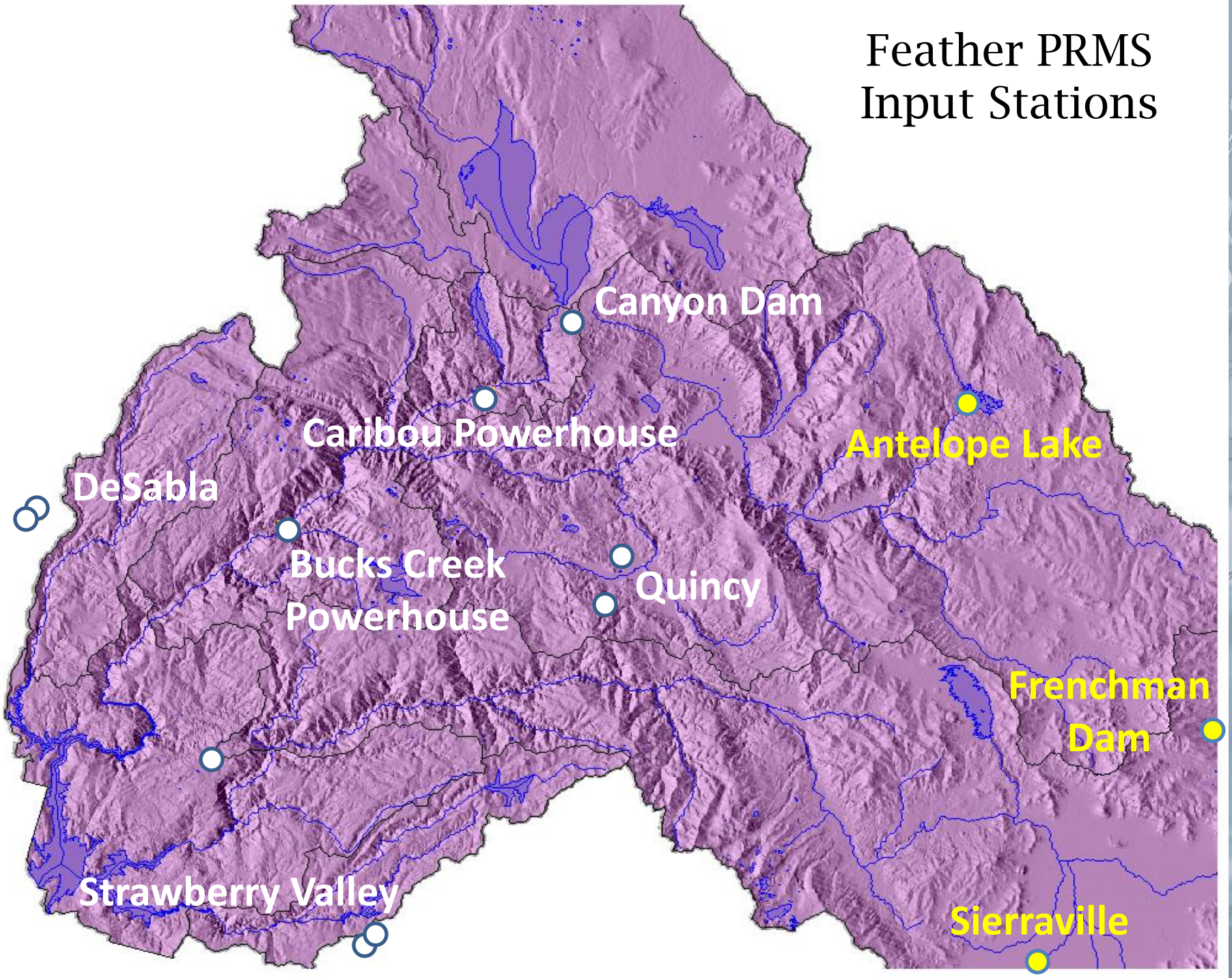
Kevin Richards

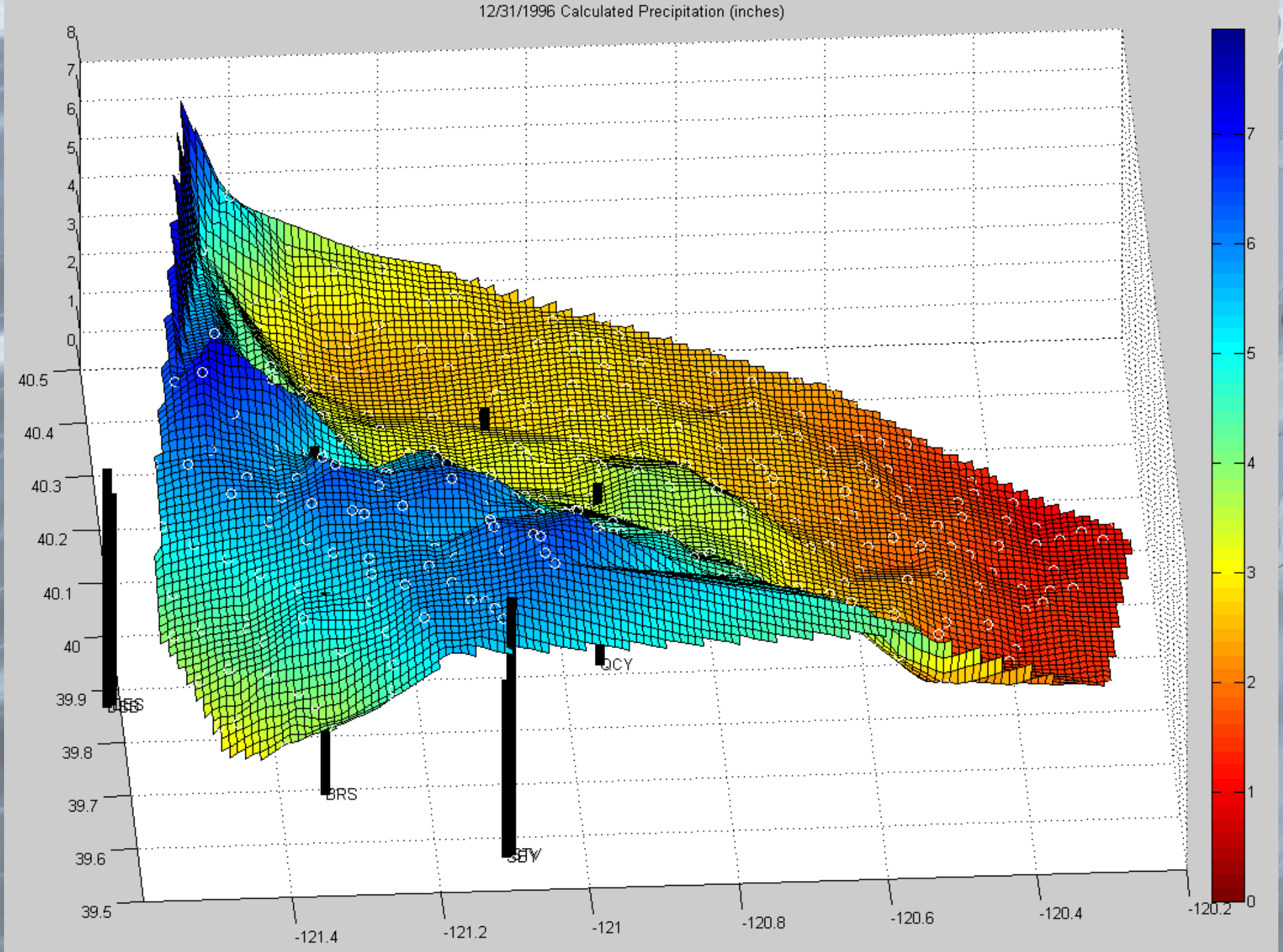


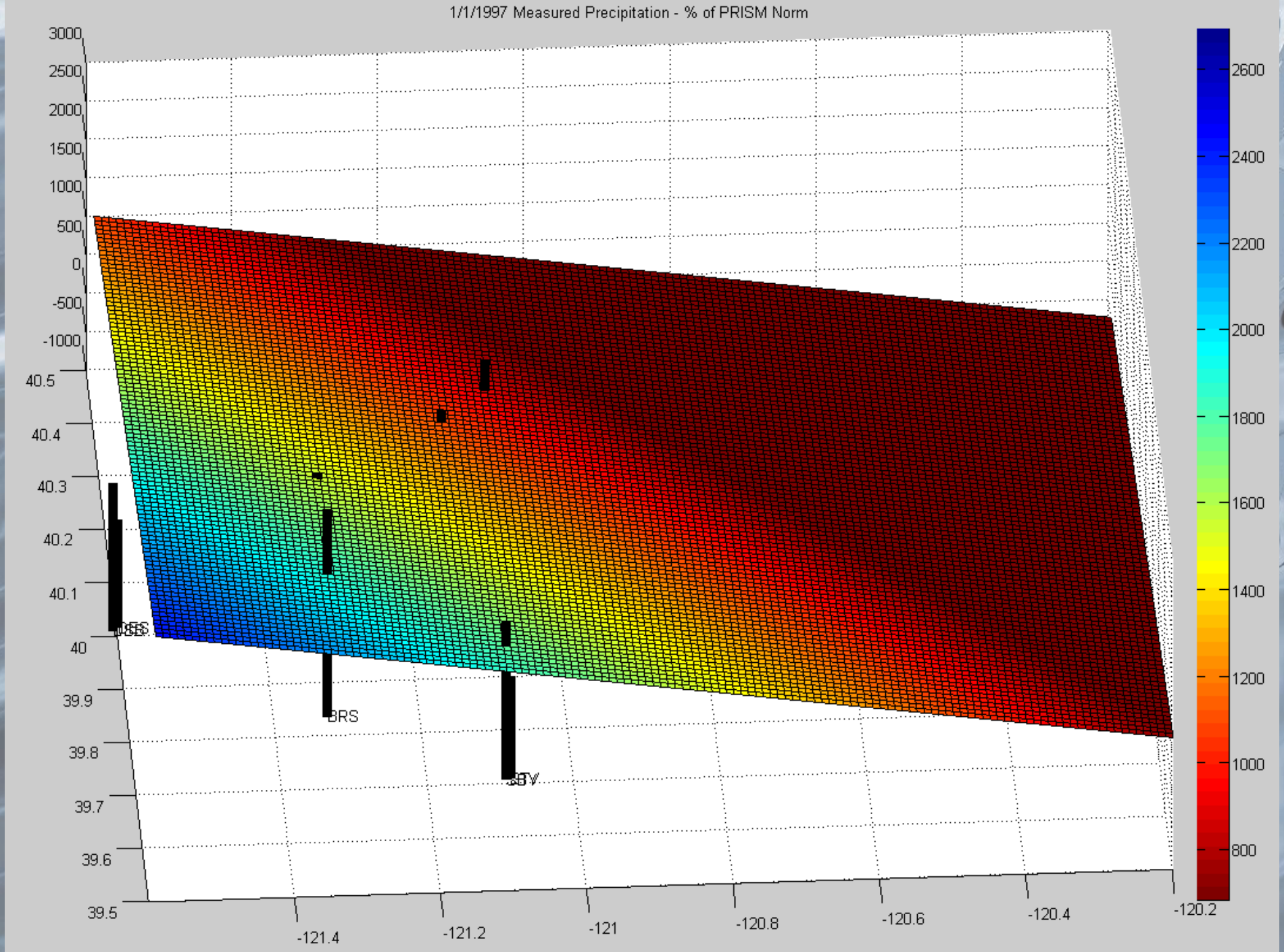
SWE Stations
HRU Boundaries
Subbasin Boundary
Elevation (feet)
1,000 - 4,000
4,001 - 5,500
5,501 - 7,000
7,001 - 9,500
Almanor
Butt Creek
Lower North Fork
West Branch
East Branch
Middle Fork
Oroville
South Fork
LLP
ULP
HRF
HRK
HWRN
FEM
MSV
CHF
FP3
FP2
FP1
MD2
MDY
HBS
HS2
HMB
RTL
KTL
ABY
ANR
MHG
RWI
3LK
MLF
BCP
HSF
LTT
BRL
POR
GRZ
LDV
FCV
PLP
ERB
EUR
CHU
GOL
QWW
CALIFORNIA
NEVADA

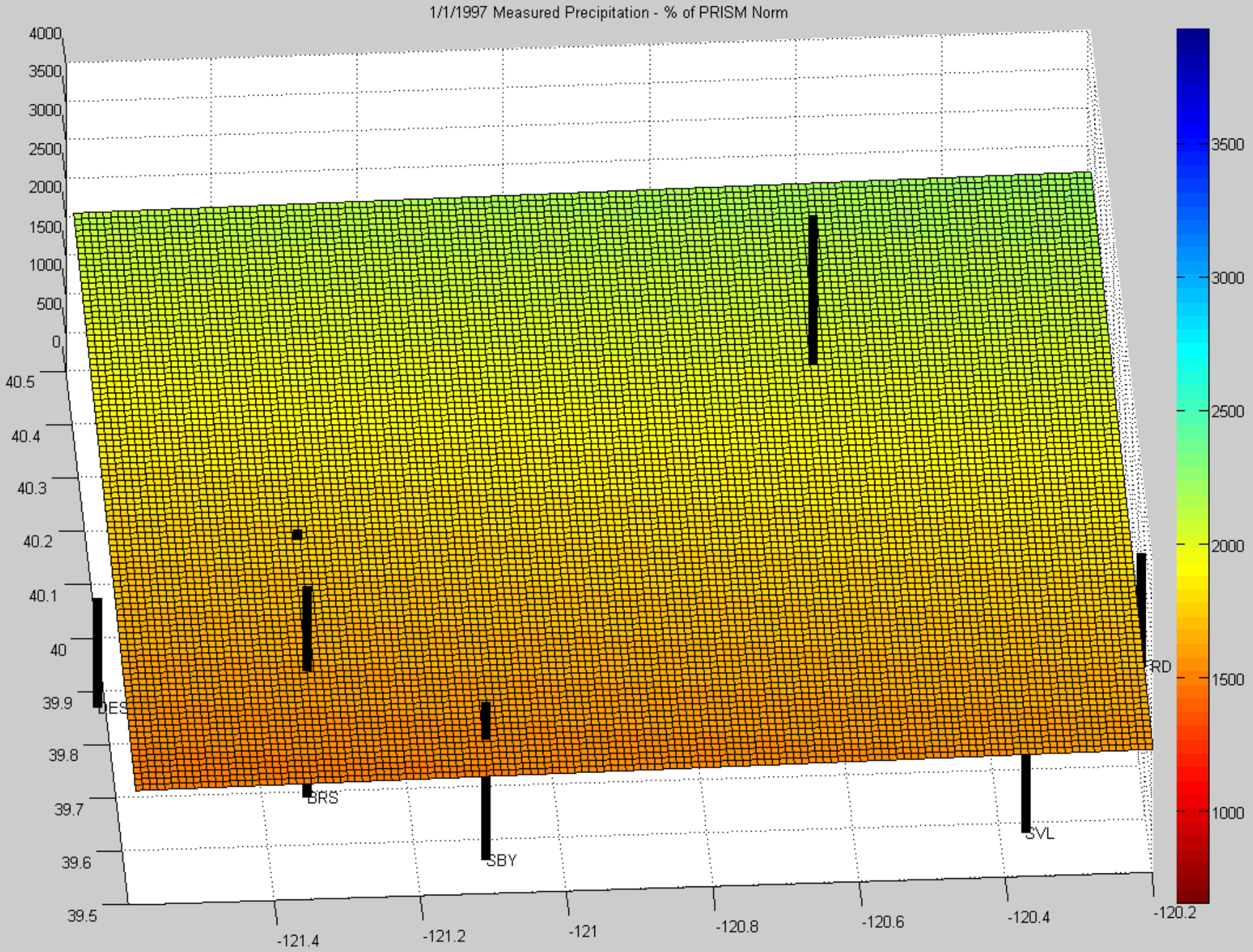
- Motivation and PRMS
- Wireless sensor network
- PRMS calibration
- Model metrics
- Next steps

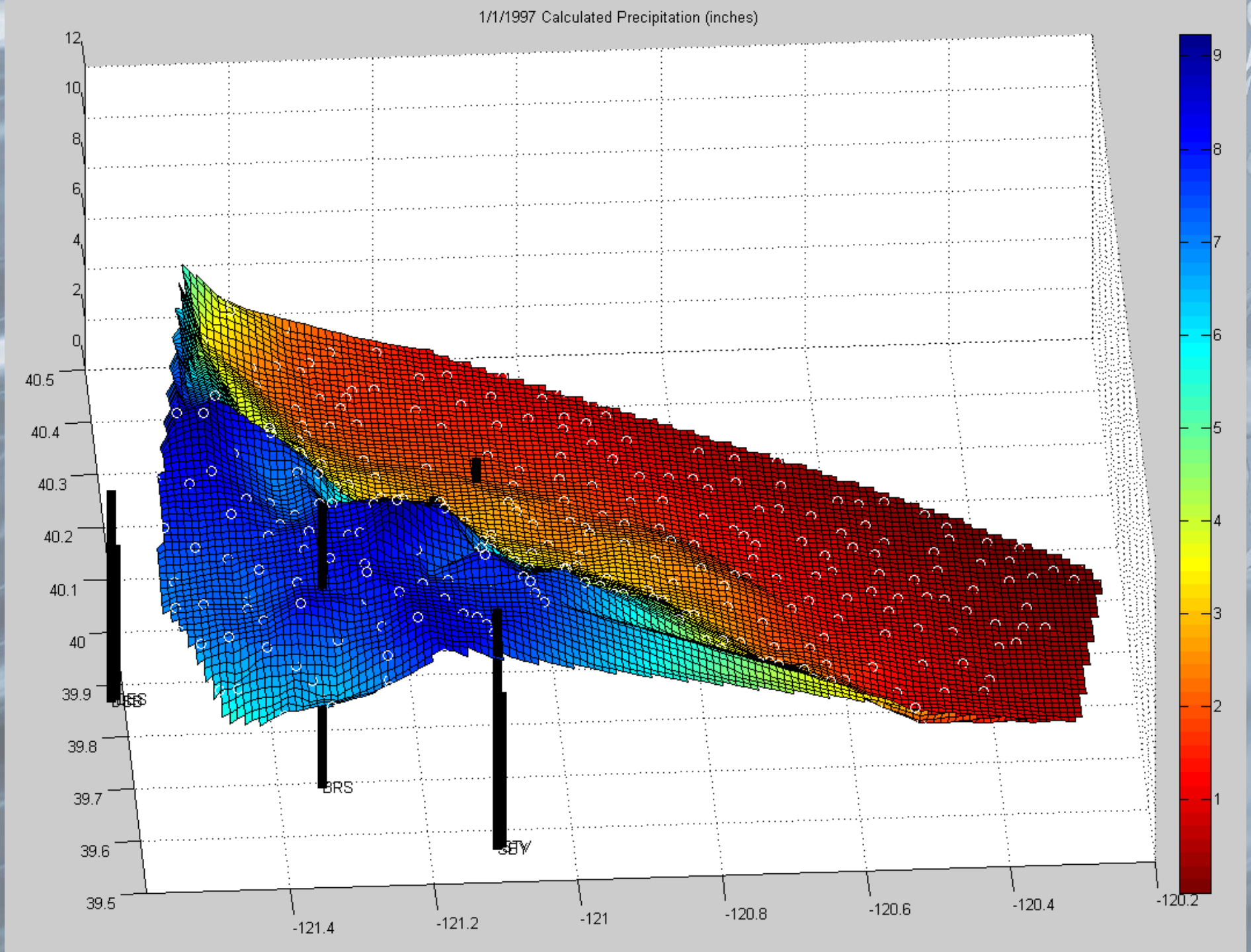
Feather PRMS Input Stations

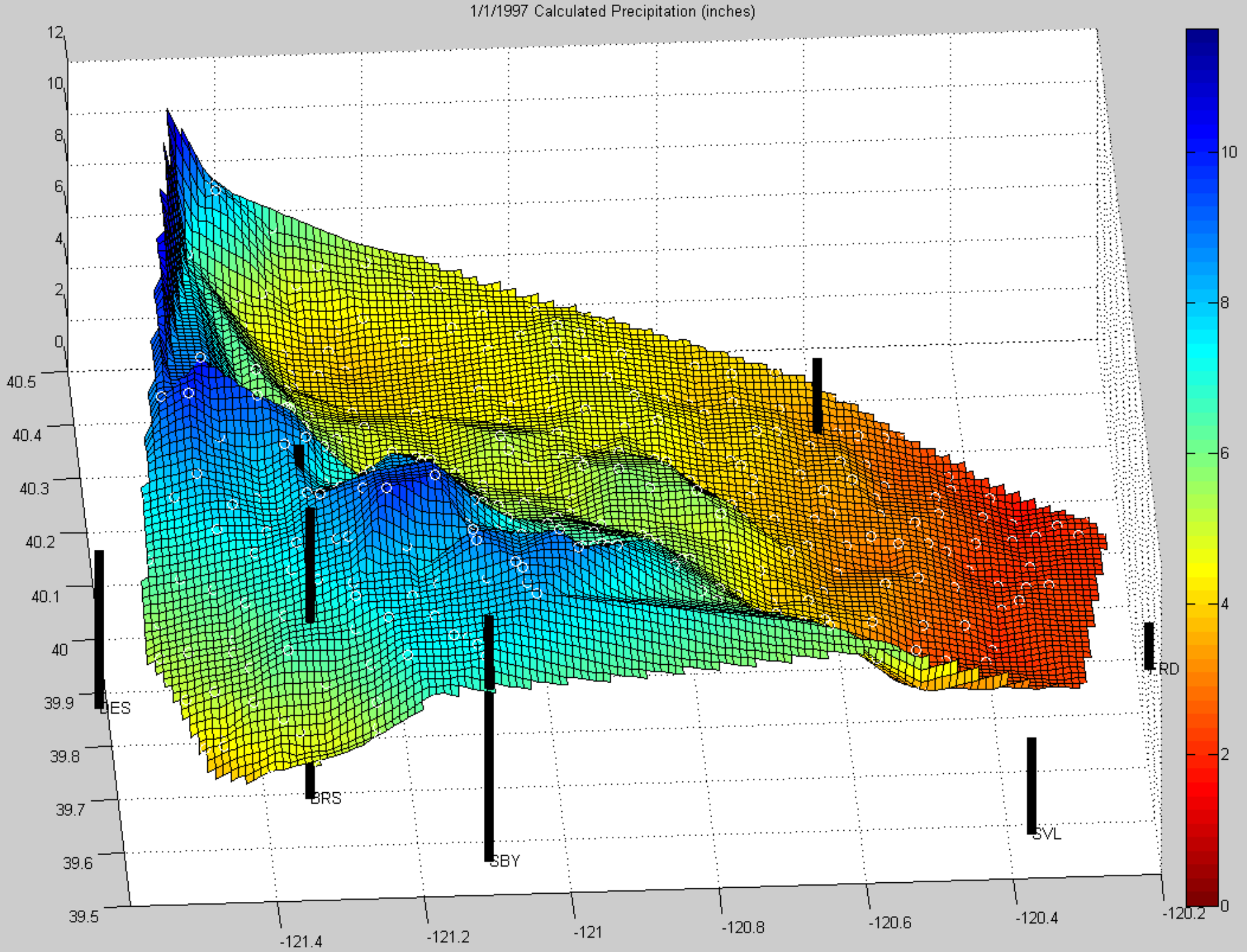



12/31/1996 Calculated Precipitation (inches)
8
7
6
5
4
3
2
1
0
40.5
40.4
40.3
40.2
40.1
40
39.9
39.8
39.7
39.6
39.5
-121.4
-121.2
-121
-120.8
-120.6
-120.4
-120.2
7
6
5
4
3
2
1
0
BRS
SBY
SCY


1/1/1997 Measured Precipitation - % of PRISM Norm
3000
2500
2000
1500
1000
500
0
-500
-1000
40.5
40.4
40.3
40.2
40.1
40
39.9
39.8
39.7
39.6
39.5
-121.4
-121.2
-121
-120.8
-120.6
-120.4
-120.2
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
BRS

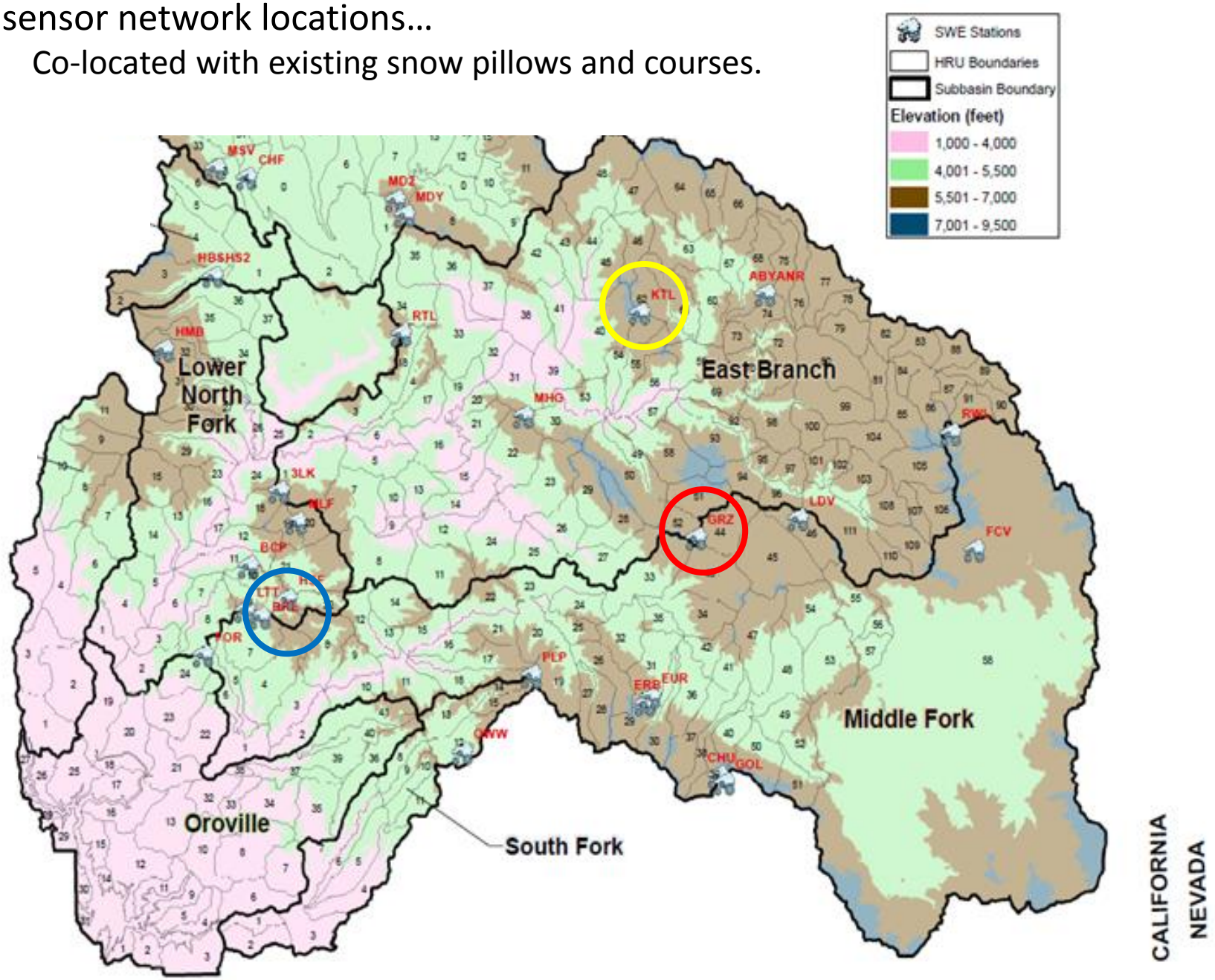

1/1/1997 Measured Precipitation - % of PRISM Norm
4000
3500
3000
2500
2000
1500
1000
500
0
40.5
40.4
40.3
40.2
40.1
40
39.9
39.8
39.7
39.6
39.5
-121.4
-121.2
-121
-120.8
-120.6
-120.4
-120.2
3500
3000
2500
2000
1500
1000
DES
BRS
SBY
SVL
RD


1/1/1997 Calculated Precipitation (inches)
12
10
8
6
4
2
0
40.5
40.4
40.3
40.2
40.1
40
39.9
39.8
39.7
39.6
39.5
-121.4
-121.2
-121
-120.8
-120.6
-120.4
-120.2
9
8
7
6
5
4
3
2
1
BRS
SBV

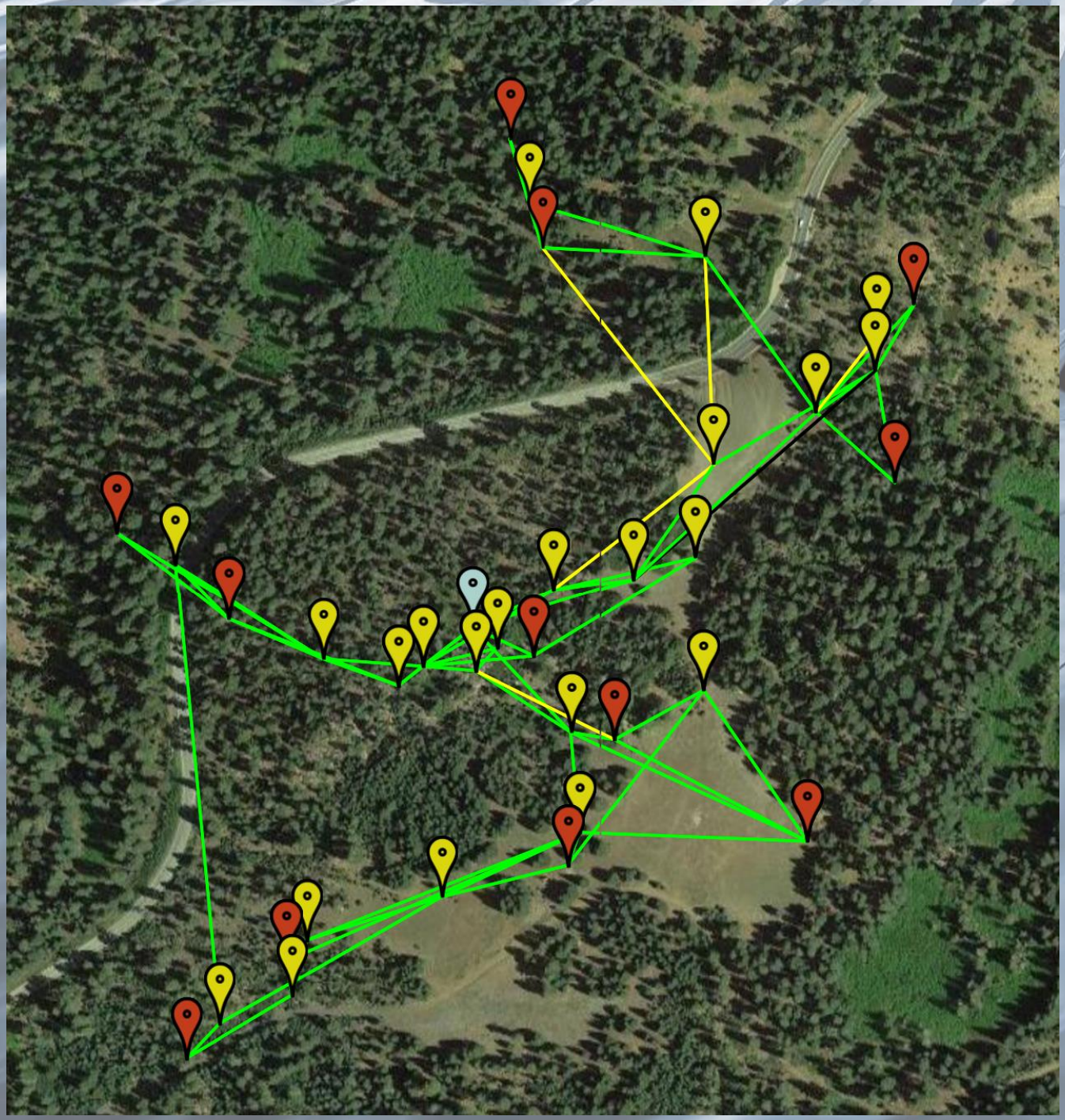

1/1/1997 Calculated Precipitation (inches)
12
10
8
6
4
2
0
40.5
40.4
40.3
40.2
40.1
40
39.9
39.8
39.7
39.6
39.5
-121.4
-121.2
-121
-120.8
-120.6
-120.4
-120.2
10
8
6
4
2
0
ES
BRS
SBY
SVL
RD

Wireless sensor network locations…

Co-located with existing snow pillows and courses.



Bucks Lake Wireless Sensor Network (WSN)



Node

Repeater

Base station

Good connection

Moderate connection

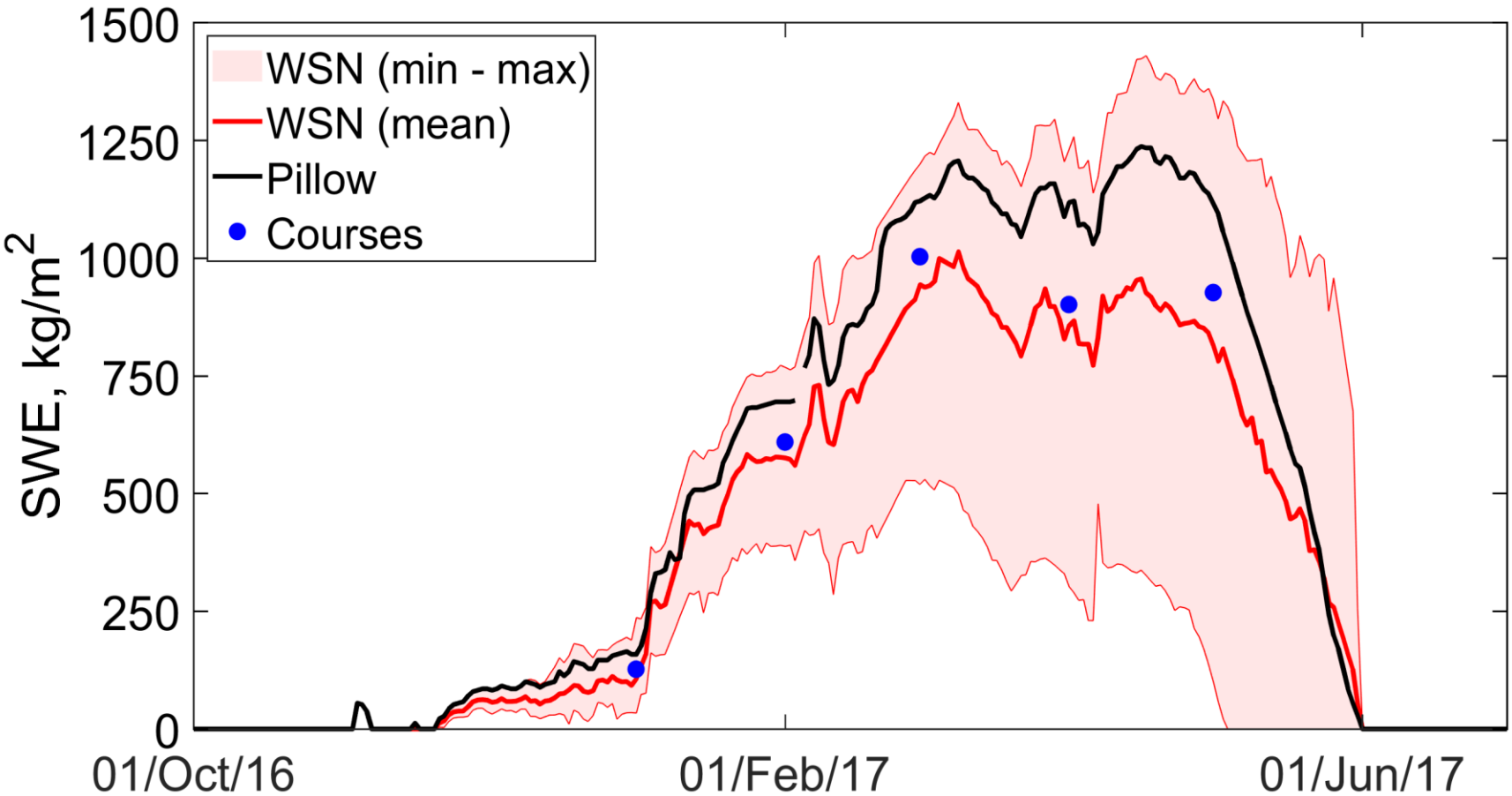
The Sensor Node

Solar radiation

Snow depth

Temperature & relative humidity

Soil moisture & temp



Malek, S.A.; Avanzi, F.; Brun-Laguna, K.; Maurer, T.; Oroza, C.A.; Hartsough, P.C.; Watteyne, T.; Glaser, S.D. Real-Time Alpine Measurement System Using Wireless Sensor Networks. Sensors 2017, 17, 2583.

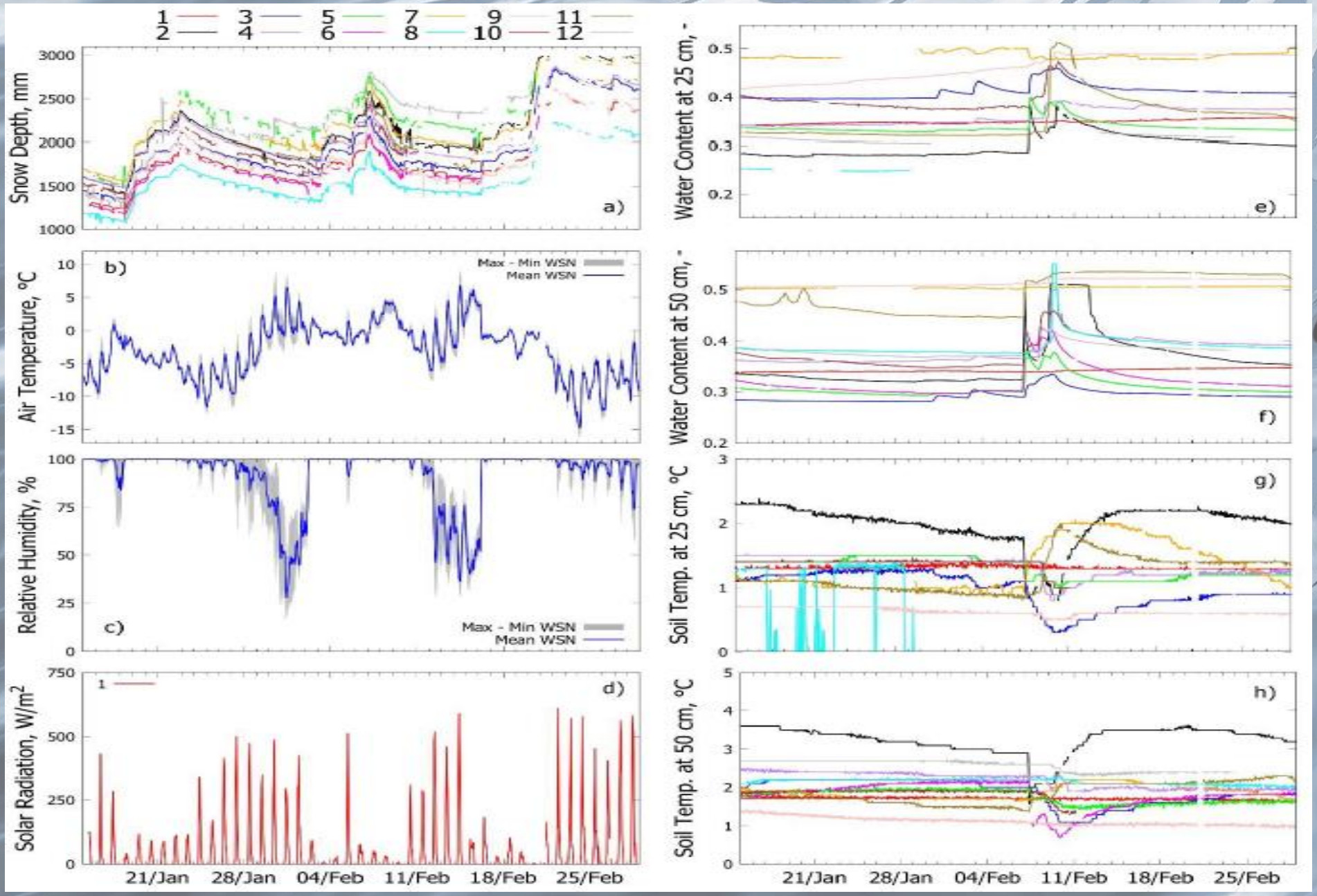


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Figure 1: Time series, simulated versus observed

File Edit View Insert Tools Desktop Window Help

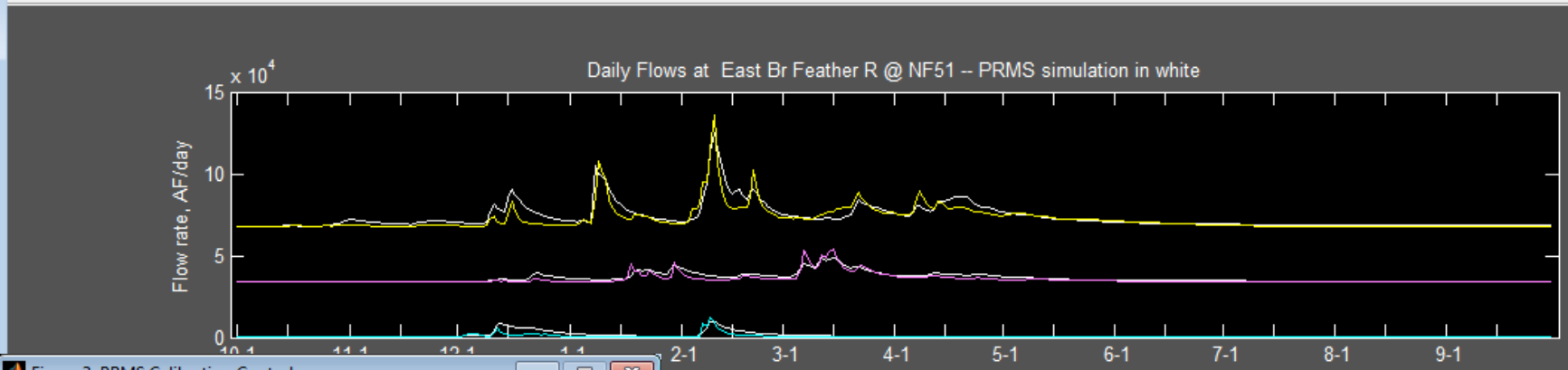

Figure 3: PRMS Calibration Control

File Edit View Insert Tools Desktop Window Help

Plot from: Oct 1 to: Sep 30

Run
Residuals
SWE Plots
Optimize
Save/Copy
Exit

Forecast Site

EB NF903 8100 East Br Feather R ...

tmax_adj	0
tmin_adj	0
tmax_lapse	2.5
tmin_lapse	2.5
tmax_allrain	42
tmax_allsnow	34
adjmix_rain	0.75
dday_intcp	-10
jh_coef_hru	14
hru_percent_imp	0.03
carea_max	0.001
smidx_exp	0.3
soil_moist_max	5.94
soil_rechr_max	1.5
ssrmax_coef	1
gwflow_coef	0.005
gwsink_coef	0.005

Available years

Sort by year flow

✓ 2017	1696.665
1995	1557.488
2006	1349.685
1997	1183.694
1998	1071.149
2011	975.607
1993	939.483
1996	783.970
1999	761.858
2003	613.056
✓ 2016	596.592
2005	568.442
2000	528.060
1989	483.409
2004	434.863
2010	411.542
2009	396.127
2002	367.516
2013	363.981
2012	298.755
2007	259.960
1990	252.523
2008	239.718
1991	226.235
✓ 2015	197.174
1994	177.231
2001	166.559
1992	154.764
1988	145.424
2014	127.293

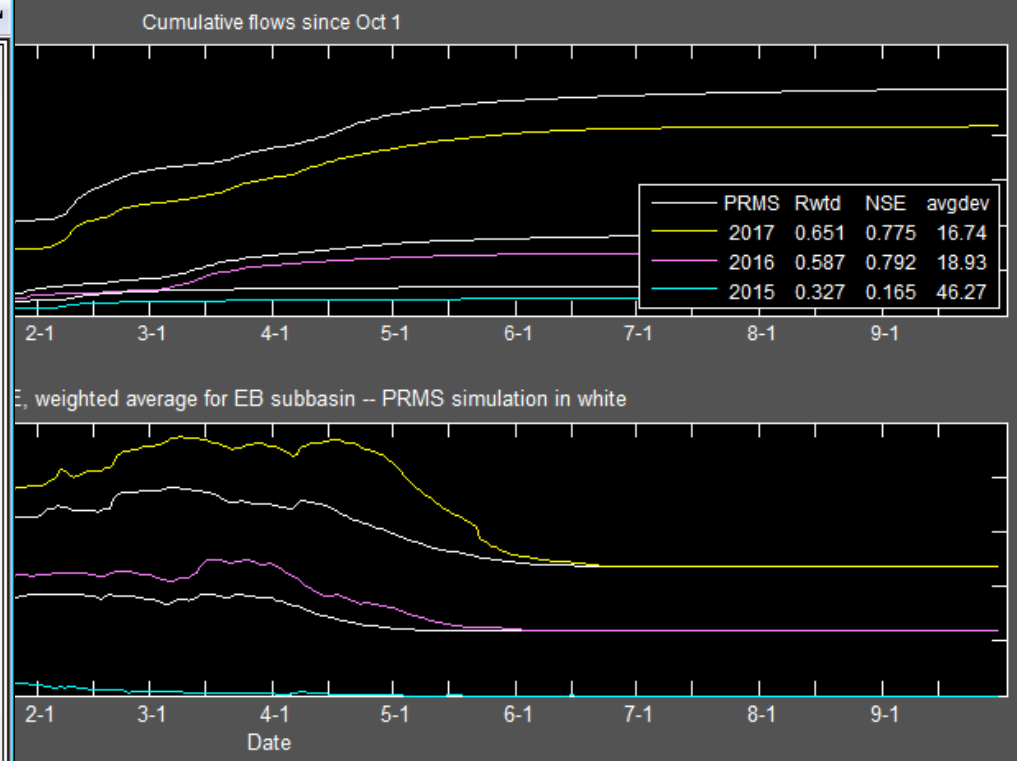

Figure 1: Time series, simulated versus observed

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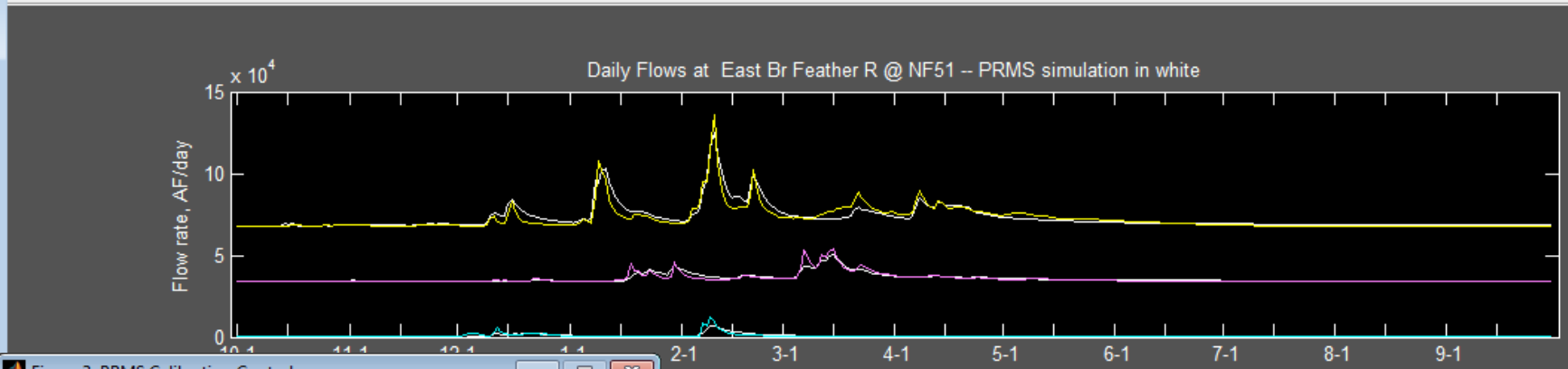

Figure 3: PRMS Calibration Control

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Plot from: Oct 1 to: Sep 30

Run
Residuals
SWE Plots
Optimize
Save/Copy
Exit

Forecast Site

EB NF903 8100 East Br Feather R ...

tmax_adj	0
tmin_adj	0
tmax_lapse	2.5
tmin_lapse	2.5
tmax_allrain	52
tmax_allsnow	30
adjmix_rain	0.75
dday_intcp	-10
jh_coef_hru	12
hru_percent_imp	0.03
carea_max	0.01
smidx_exp	0.3
soil_moist_max	10
soil_rechr_max	1.5
ssrmax_coef	0.4
gwflow_coef	0.005
gwsink_coef	0.005

Available years

Sort by year flow

☑	2017	1696.665
☐	1995	1557.488
☐	2006	1349.685
☐	1997	1183.694
☐	1998	1071.149
☐	2011	975.607
☐	1993	939.483
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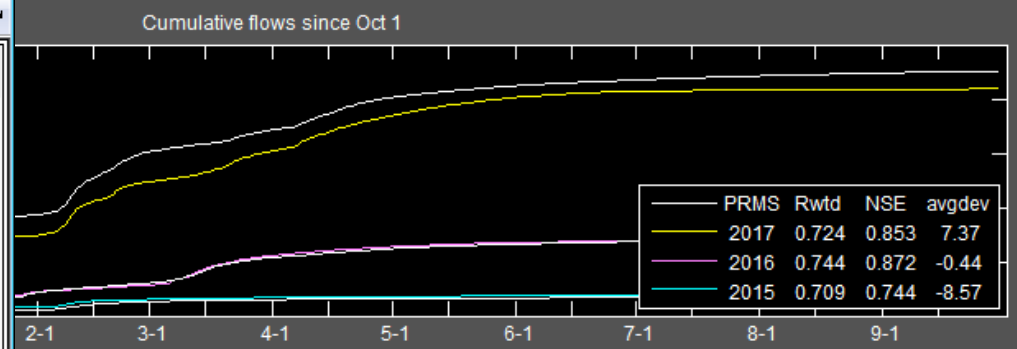
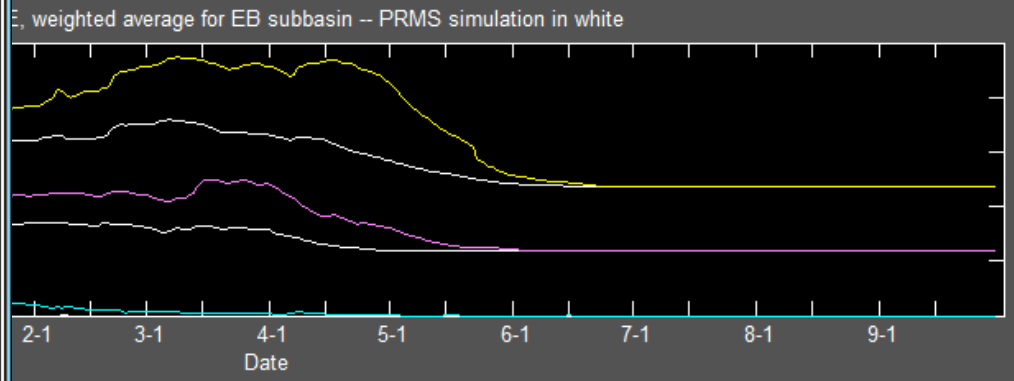
☐	1991	226.235
☑	2015	197.174
☐	1994	177.231
☐	2001	166.559
☐	1992	154.764
☐	1988	145.424
☐	2014	127.293





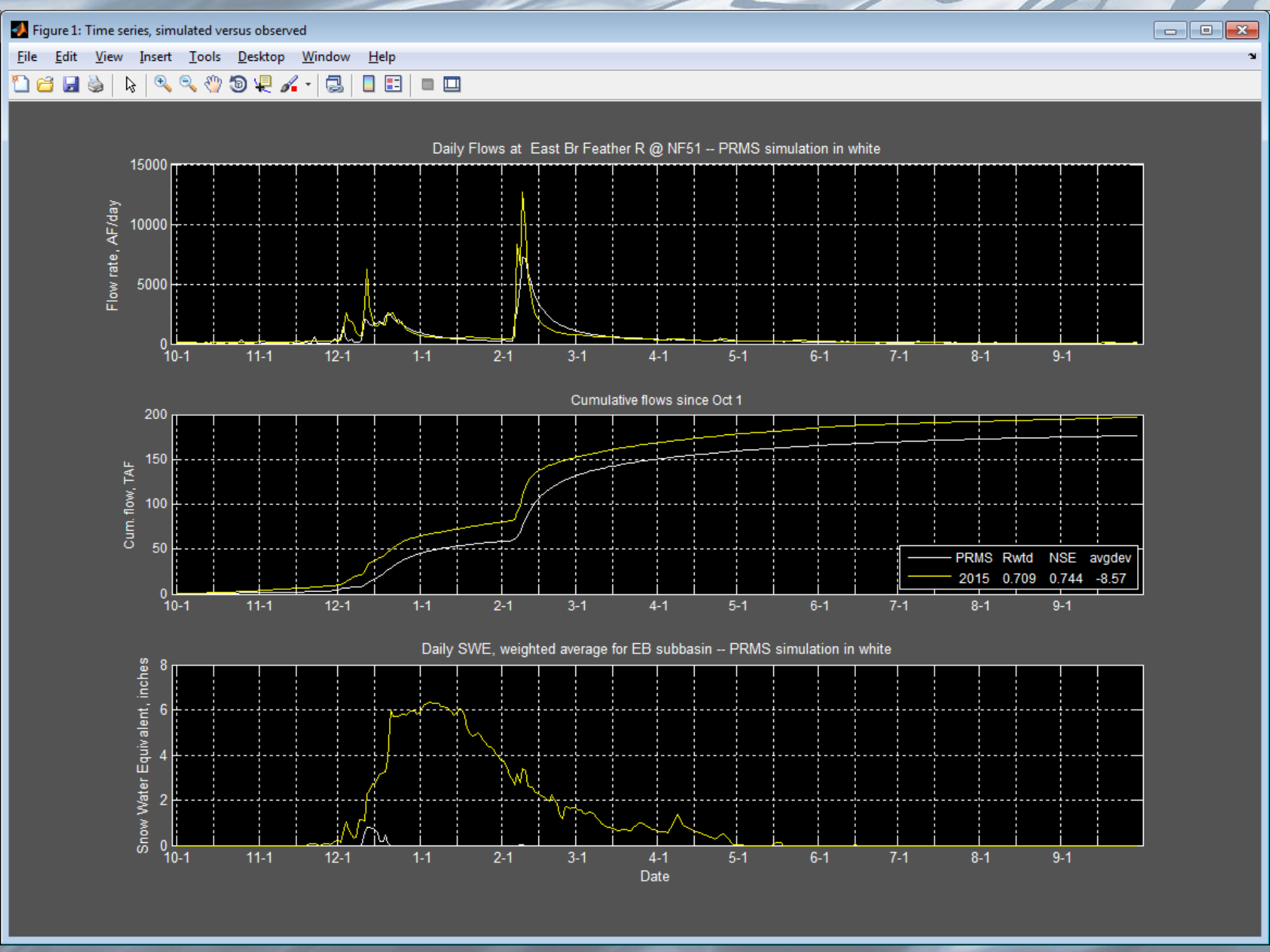


Figure 1: Time series, simulated versus observed
File Edit View Insert Tools Desktop Window Help
Daily Flows at East Br Feather R @ NF51 -- PRMS simulation in white
Flow rate, AF/day
15000
10000
5000
0
10-1 11-1 12-1 1-1 2-1 3-1 4-1 5-1 6-1 7-1 8-1 9-1
Cumulative flows since Oct 1
Cum. flow, TAF
200
150
100
50
0
PRMS Rwtd NSE avgdev
2015 0.709 0.744 -8.57
10-1 11-1 12-1 1-1 2-1 3-1 4-1 5-1 6-1 7-1 8-1 9-1
Daily SWE, weighted average for EB subbasin -- PRMS simulation in white
Snow Water Equivalent, inches
8
6
4
2
0
10-1 11-1 12-1 1-1 2-1 3-1 4-1 5-1 6-1 7-1 8-1 9-1
Date

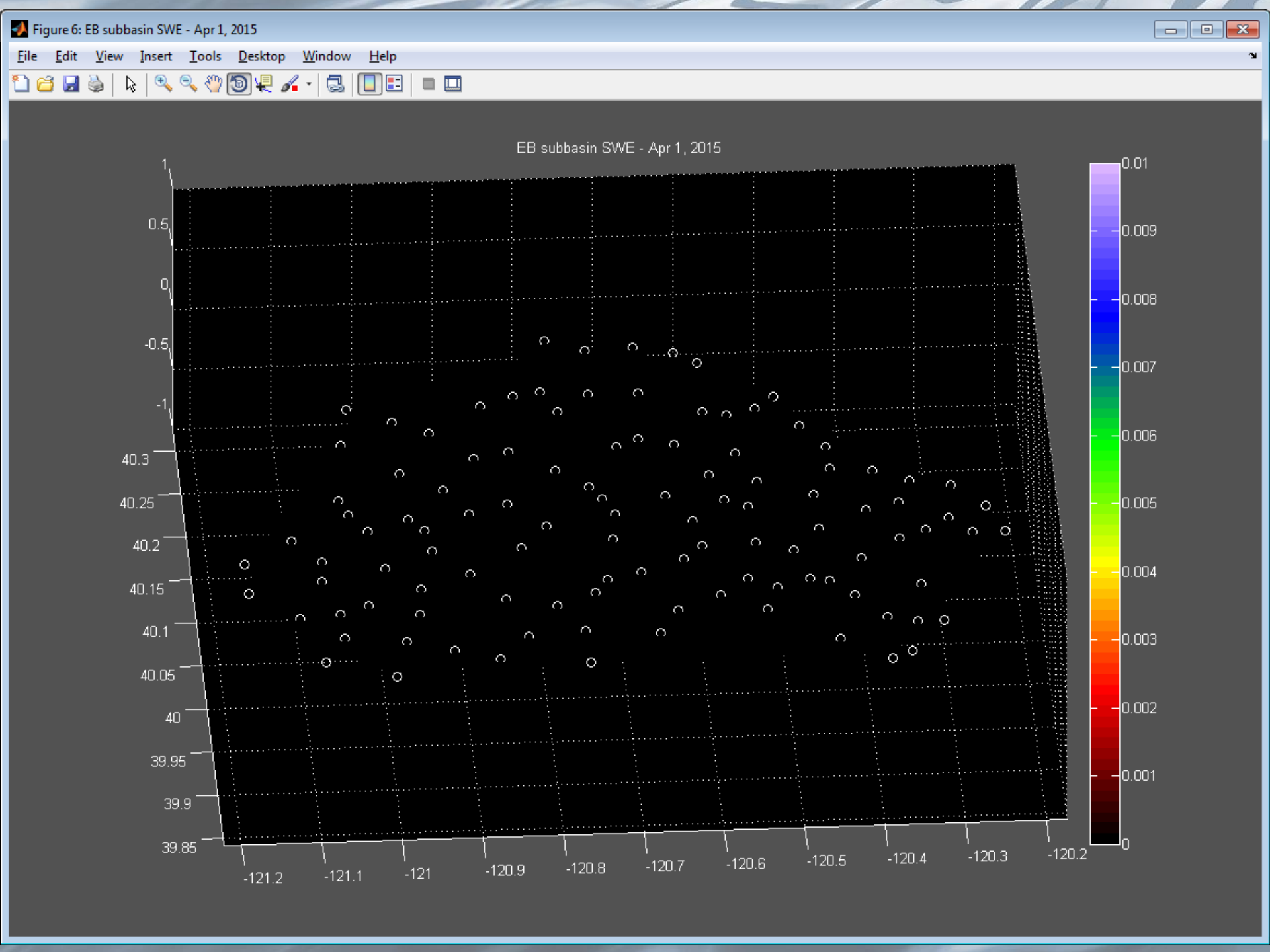


Figure 6: EB subbasin SWE - Apr 1, 2015
File Edit View Insert Tools Desktop Window Help
EB subbasin SWE - Apr 1, 2015
1
0.5
0
-0.5
-1
40.3
40.25
40.2
40.15
40.1
40.05
40
39.95
39.9
39.85
-121.2
-121.1
-121
-120.9
-120.8
-120.7
-120.6
-120.5
-120.4
-120.3
-120.2
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0

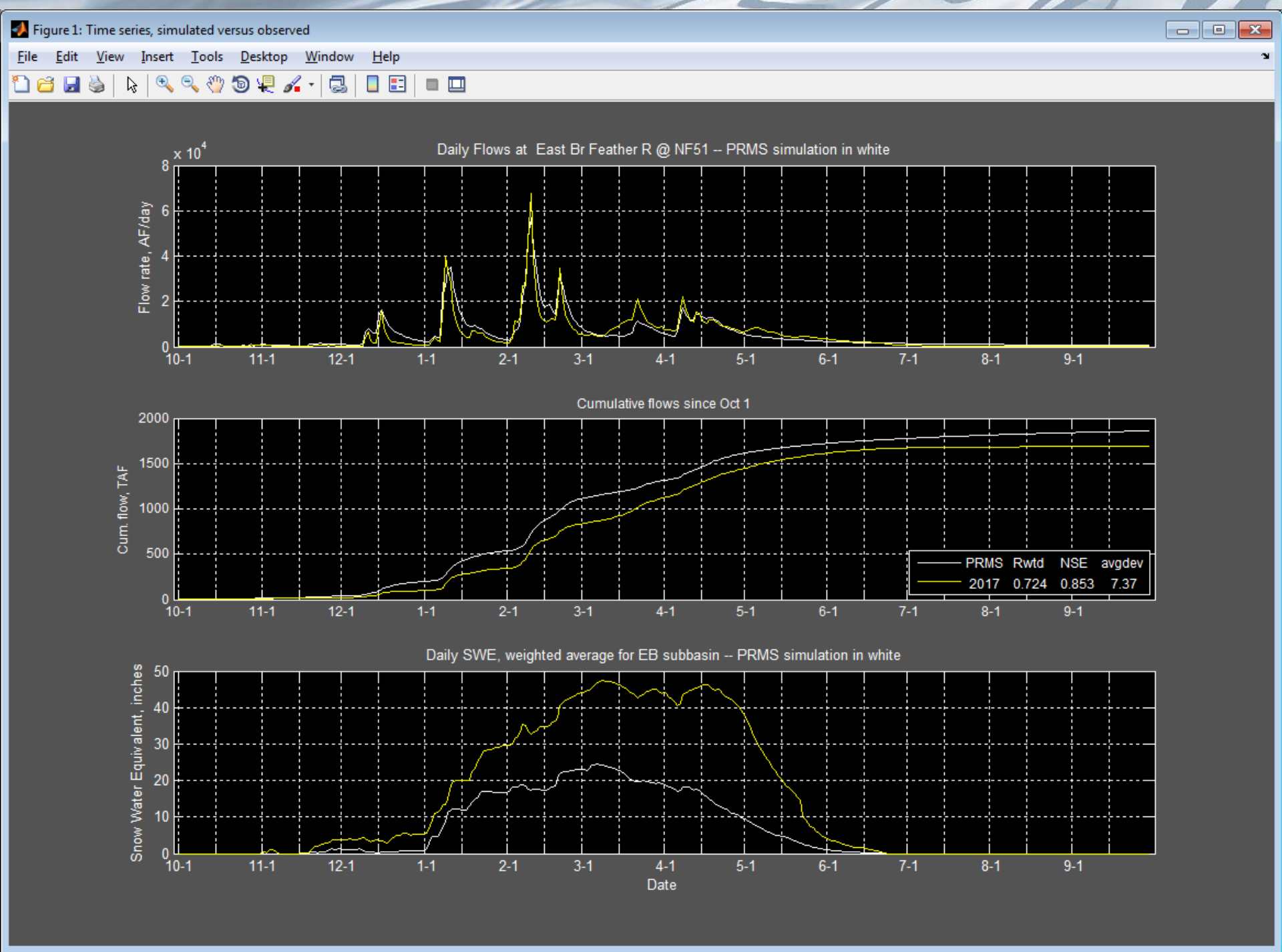


Figure 1: Time series, simulated versus observed
File Edit View Insert Tools Desktop Window Help
Daily Flows at East Br Feather R @ NF51 -- PRMS simulation in white
x 10^4
Flow rate, AF/day
0 2 4 6 8
10-1 11-1 12-1 1-1 2-1 3-1 4-1 5-1 6-1 7-1 8-1 9-1
Cumulative flows since Oct 1
Cum. flow, TAF
0 500 1000 1500 2000
PRMS Rwtd NSE avgdev
2017 0.724 0.853 7.37
Daily SWE, weighted average for EB subbasin -- PRMS simulation in white
Snow Water Equivalent, inches
0 10 20 30 40 50
Date

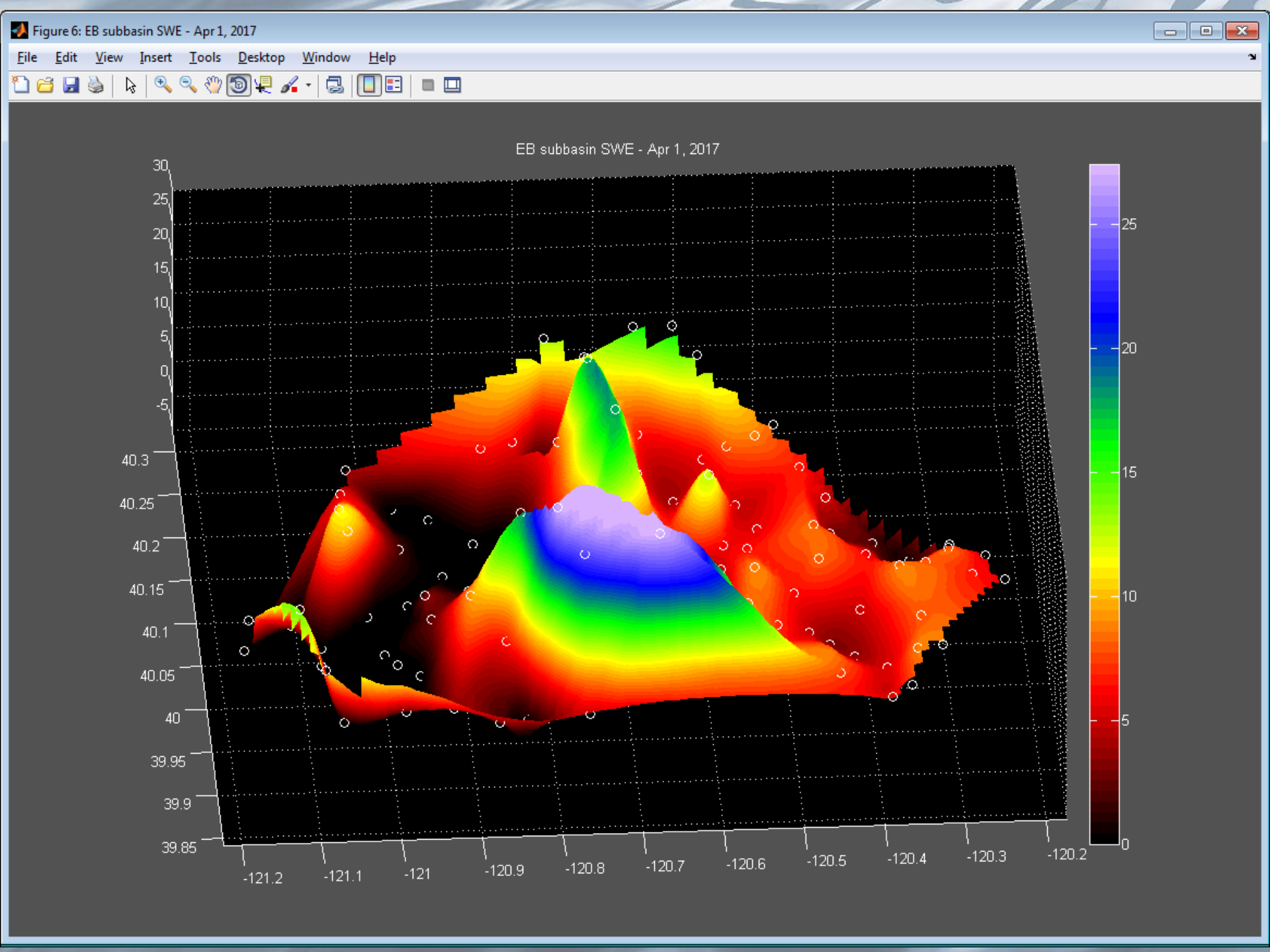
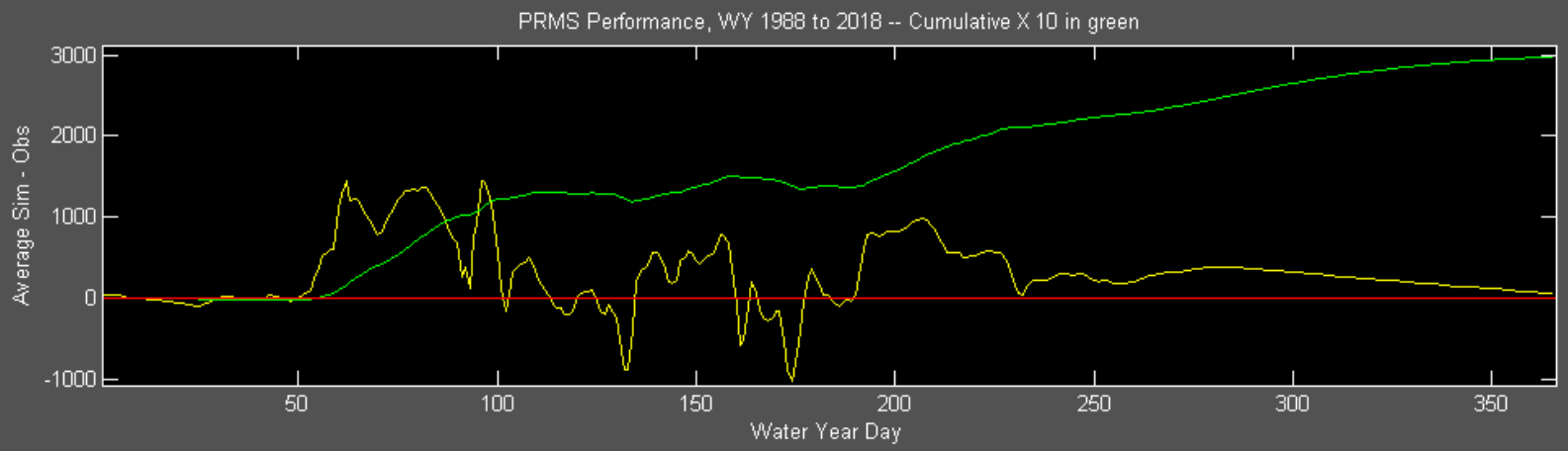


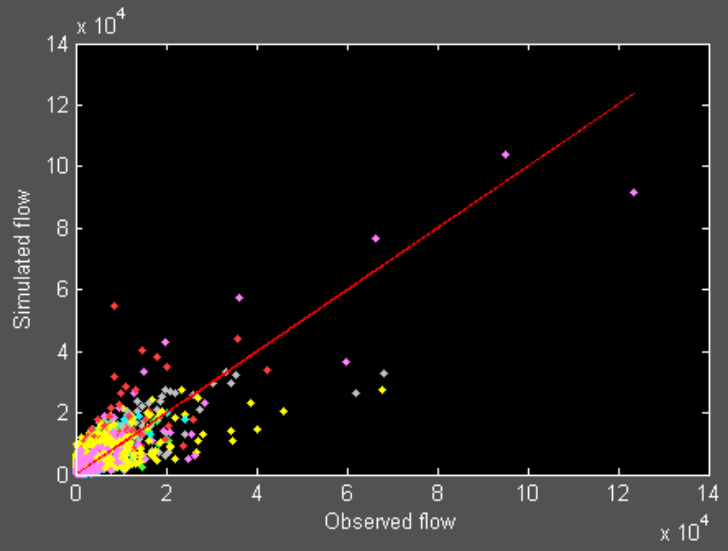
Figure 6: EB subbasin SWE - Apr 1, 2017
File Edit View Insert Tools Desktop Window Help
EB subbasin SWE - Apr 1, 2017
30
25
20
15
10
5
0
-5
40.3
40.25
40.2
40.15
40.1
40.05
40
39.95
39.9
39.85
-121.2
-121.1
-121
-120.9
-120.8
-120.7
-120.6
-120.5
-120.4
-120.3
-120.2
25
20
15
10
5
0

Figure 3: Period of record metrics

File Edit View Insert Tools Desktop Window Help



	Rwtd	NSE	LogNSE	KGE	RMSE	Bias
Total Water Year:	0.595	0.442	0.775	0.737	1724.5	298.5
November - March:	0.531	0.383	0.629	0.738	2260.2	339.2
April - July:	0.592	0.301	0.752	0.749	1325.9	392.8



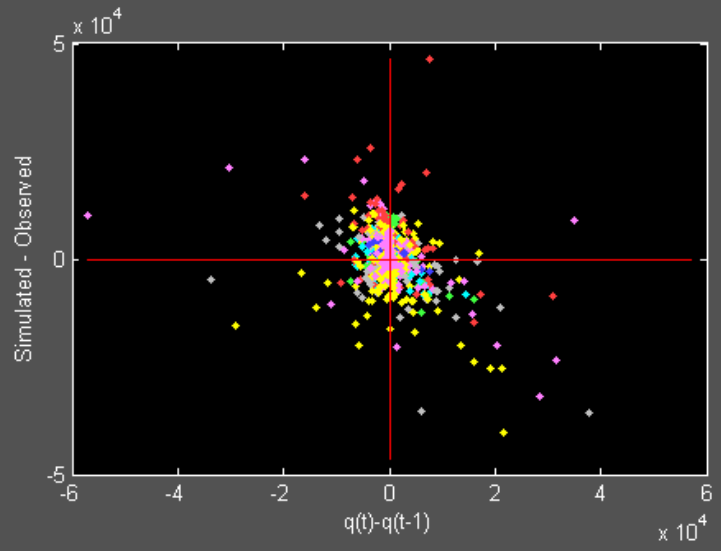


Figure 3: Period of record metrics

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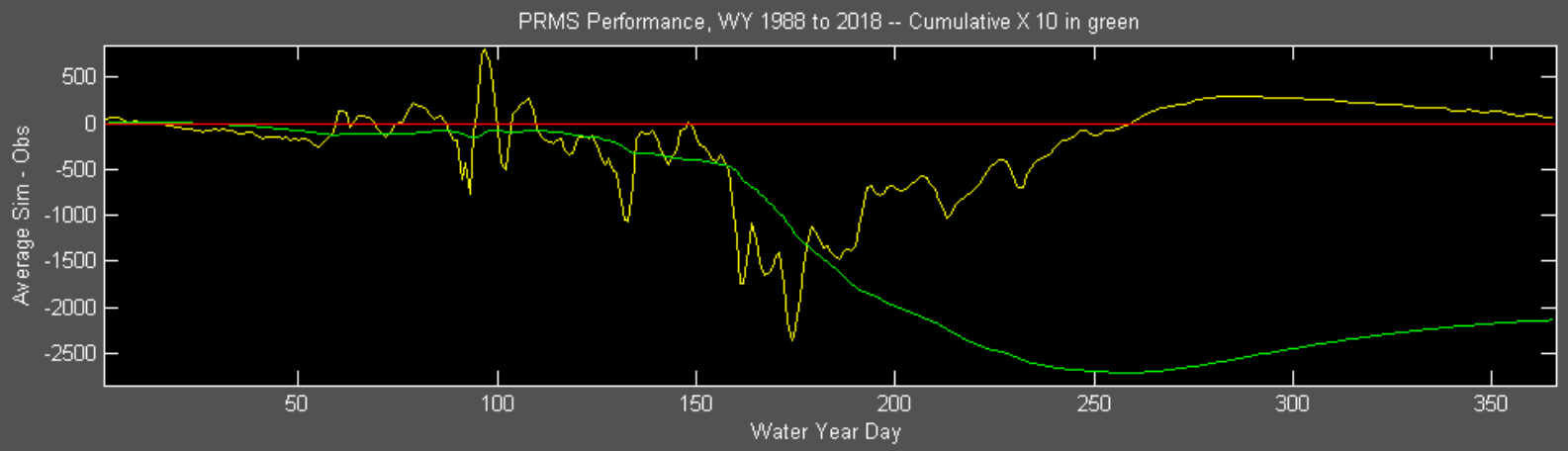
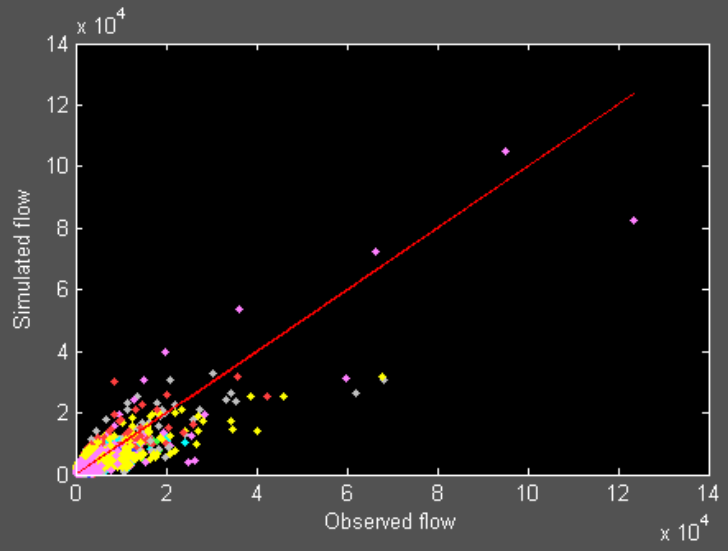
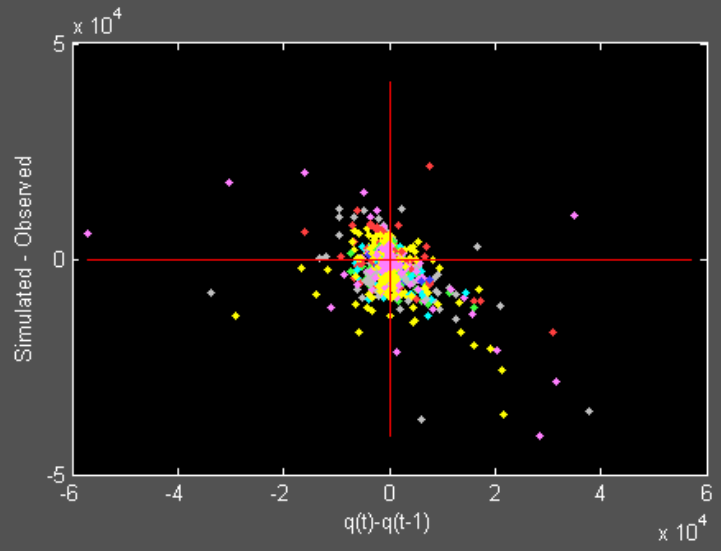


	Rwtd	NSE	LogNSE	KGE	RMSE	Bias
Total Water Year:	0.684	0.693	0.730	0.796	1403.5	-214.3
November - March:	0.661	0.682	0.463	0.800	1851.7	-353.0
April - July:	0.674	0.670	0.774	0.688	1105.1	-285.2



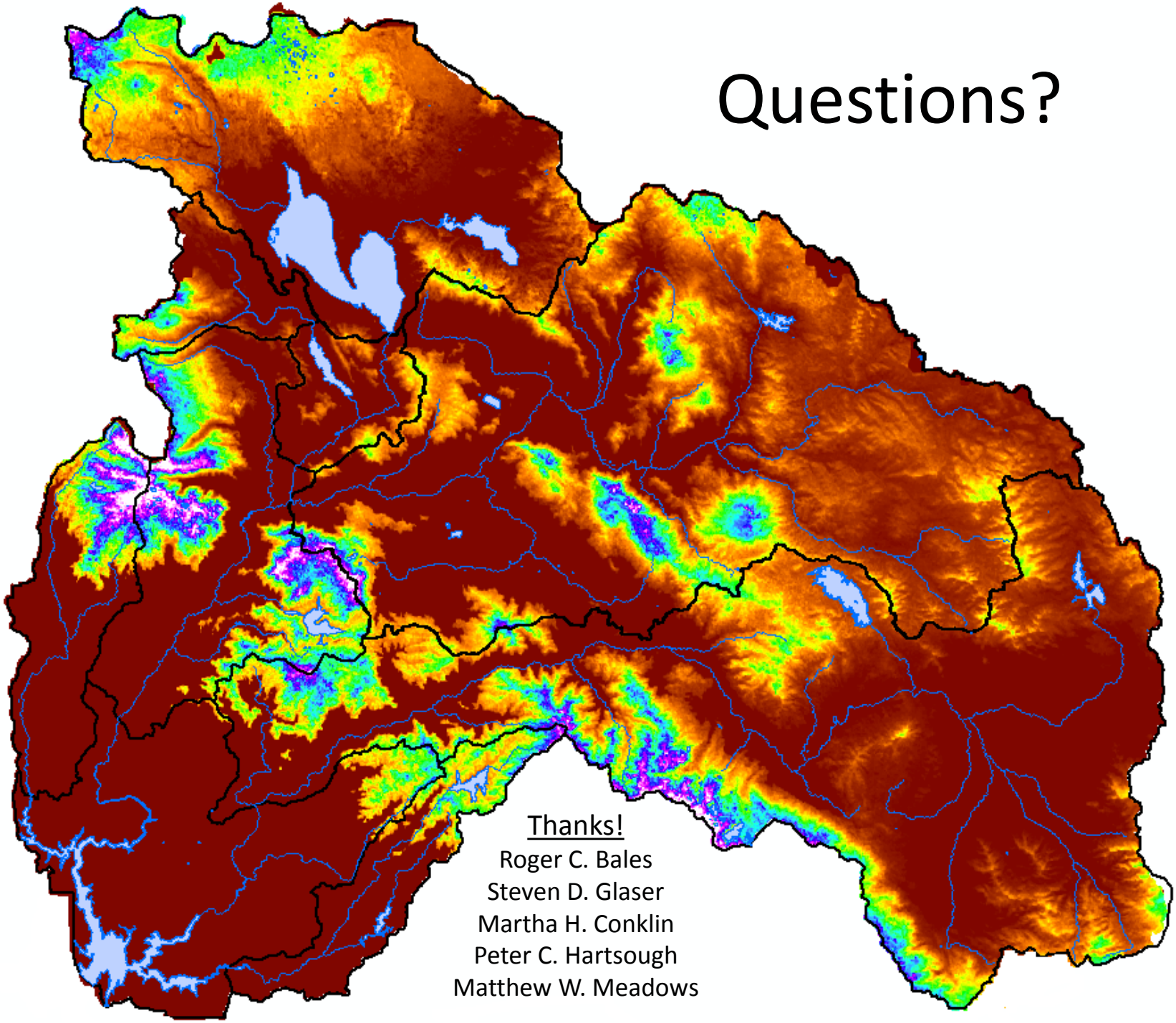


Next Steps

- **Compute SWE metrics & refine calibration**
- **Apply to other basins (Kings, Yuba, ?)**
- **Gridded input rather than Draper?**

Presentation by
Kevin Richards (K1Ra@pge.com)
PG&E Water Management
November 14, 2018

Questions?



<u>Thanks!</u>

Roger C. Bales
Steven D. Glaser
Martha H. Conklin
Peter C. Hartsough
Matthew W. Meadows