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Managing Water in the West

Two-dimensional water temperature modeling of in-channel and hydraulically connected off-channel zones in Reach 1A of the San Joaquin River

Daniel Dombroski (ddombroski@usbr.gov)
Blair Greimann, Yong Lai, Victor Huang

U.S. Department of the Interior
Bureau of Reclamation

Motivation

- ***Water temperature is a critical quality parameter effecting survival of salmonids***
- ***Impacted river systems may experience elevated water temperatures due to flow and vegetation management***
- ***Hydraulically connected off-channel zones complicate river temperature dynamics***

Questions

- *How do reservoir operations effect temperature dynamics within the system?*
- *How do varying water-year types effect temperature dynamics within the system?*
- *How do the presence of hydraulically connected pools from gravel mining operations effect temperature dynamics?*
- *How does vegetation shading effect temperature dynamics within the system?*

SRH-2D Computational Package

Two-dimensional (2D) flow and sediment transport simulation tool developed at USBR and currently in operation. Vegetation and temperature simulation modules currently in development.

- **Solves the depth-averaged Navier-Stokes equations**
- **Computes variables over an unstructured hybrid mesh**
- **Features an automatic wetting-drying algorithm**
- **Uses a spatially distributed Manning's *n* roughness as the primary tuning parameter**

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Approach

Development of two-dimensional (2D) spatially and temporally distributed model for modeling hydraulic and thermal processes

Hydraulics

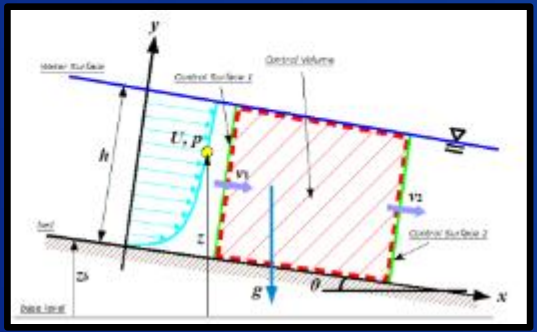

Photo: Wikipedia

Meteorology

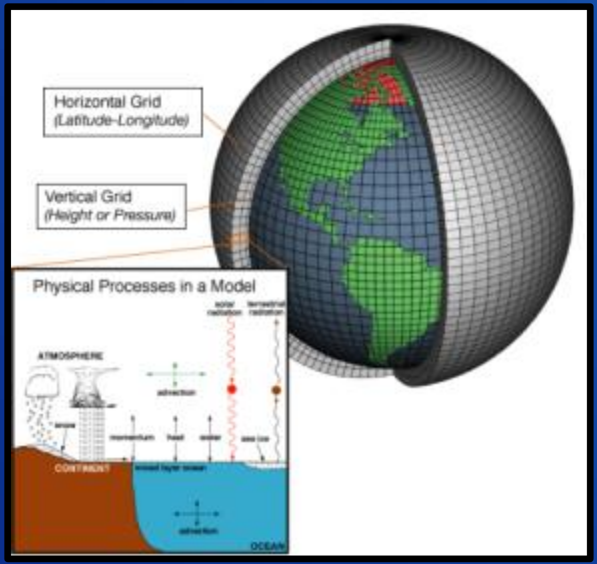

Photo: NOAA

Physical Environment

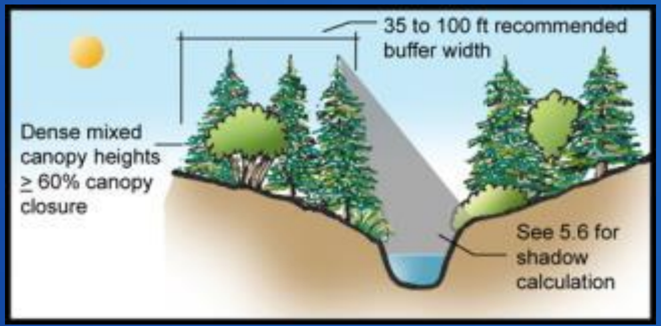

Photo: USDA

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SRH-2D Temperature Model

Two-dimensional, depth-averaged heat equation

$$\frac{\partial hT}{\partial t} + \frac{\partial hUT}{\partial x} + \frac{\partial hVT}{\partial y} = \frac{\partial}{\partial x}\left[\frac{h\nu_t}{\sigma_t}\frac{\partial T}{\partial x}\right] + \frac{\partial}{\partial y}\left[\frac{h\nu_t}{\sigma_t}\frac{\partial T}{\partial y}\right] + \frac{\Phi_{net}}{c_w \rho_w}$$

Net heat exchange

$$\Phi_{net} = \Phi_{ns} + \Phi_{na} + \Phi_{bed} - \Phi_{br} - \Phi_e - \Phi_c$$

Φ_{ns} = incoming solar radiation
Φ_{na} = incoming atmospheric radiation
Φ_{br} = outgoing back radiation
Φ_e = evaporative heat loss
Φ_c = conductive heat loss
Φ_{bed} = heat flux at channel bed

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Data Intensive!

time	Q
hr	cfs
0	740
24	1160
48	1570
72	1950
96	1950
120	1970
144	1930
168	1991
192	3910
216	3210
240	2540
264	2020
288	1980
312	2020
336	2030
360	1939
384	1460
408	1470
432	1440
456	1450
480	1430
504	1310

Q	WSE
cfs	ft
0	190
100	192.4
200	192.9
350	193.6
500	194.2
570	194.4
700	195
1100	196.7
1500	197.2
2000	197.8
2500	198.4
4000	200
7500	202.4

Hydraulics

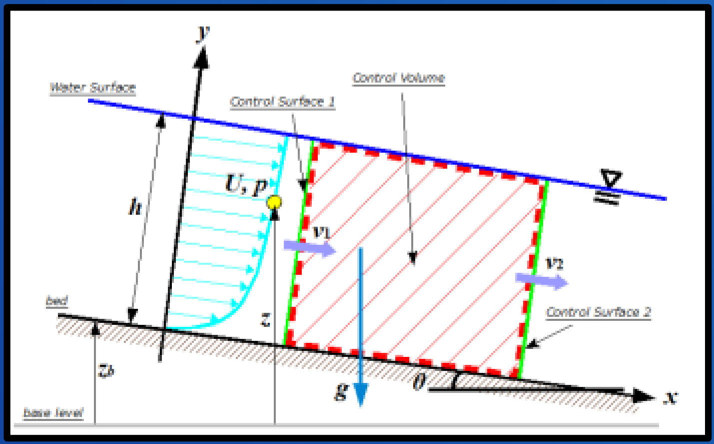

Photo: Wikipedia

Data Intensive!

time	cc	air temp	dew temp	air pressure	wind speed	solar radiation
hr		C	C	mb	m/s	kcal/m2/hr
0	0.24	11.17	7.78	1017.7	2.32	0
0.25	0.24	11.01	7.72	1017.72	2.3	0
0.5	0.23	10.86	7.67	1017.75	2.28	0
0.75	0.23	10.71	7.61	1017.77	2.26	0
1	0.23	10.56	7.56	1017.8	2.24	0
1.25	0.23	10.43	7.51	1017.78	2.22	0
1.5	0.23	10.31	7.47	1017.75	2.21	0
1.75	0.22	10.18	7.43	1017.73	2.2	0
2	0.22	10.06	7.39	1017.7	2.19	0
2.25	0.22	9.93	7.33	1017.63	2.2	0
2.5	0.22	9.81	7.28	1017.55	2.21	0
2.75	0.21	9.68	7.22	1017.48	2.22	0
3	0.21	9.56	7.17	1017.4	2.23	0
3.25	0.21	9.46	7.11	1017.38	2.21	0
3.5	0.22	9.36	7.06	1017.35	2.19	0
3.75	0.23	9.26	7	1017.33	2.17	0
4	0.23	9.17	6.94	1017.3	2.15	0
4.25	0.23	9.08	6.88	1017.35	2.12	0
4.5	0.23	9	6.81	1017.4	2.1	0
4.75	0.22	8.92	6.74	1017.45	2.08	0
5	0.22	8.83	6.67	1017.5	2.06	0
5.25	0.23	8.75	6.63	1017.57	2.03	5.29

Meteorology

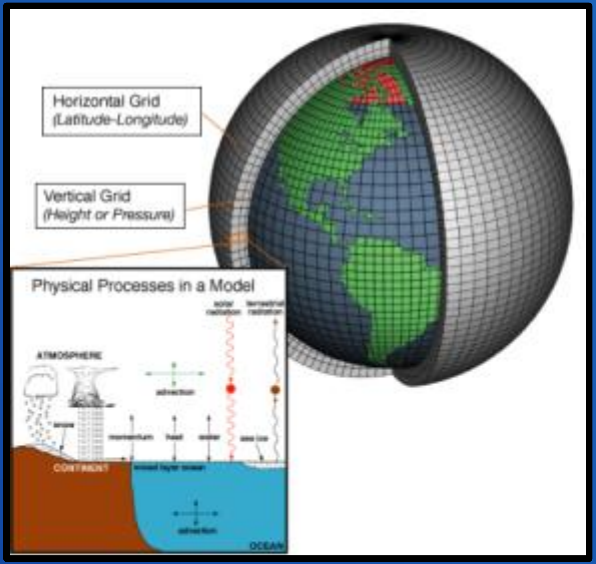

Photo: NOAA

Data Intensive!

longitude	latitude	azimuth	height	buffer	width
ft	ft	deg	ft	ft	ft
6770666	1779908	11	18	0	474
6770541	1779358	17	18	0	470
6770441	1778974	12	15	0	278
6770358	1778697	27	7	0	235
6770207	1778507	45	7	0	238
6769938	1778243	46	18	0	286
6769730	1778050	53	27	0	434
6769620	1778005	83	27	0	333
6769482	1778030	112	27	0	250
6769357	1778082	114	27	0	252
6769220	1778115	98	18	0	190
6769082	1778159	123	18	0	433
6768926	1778171	80	18	0	445
6768597	1778102	78	27	0	166
6768220	1778045	87	28	0	590
6767986	1778077	117	30	0	847
6767850	1778249	156	30	0	797
6767769	1778390	113	30	0	382
6767685	1778306	34	30	0	576
6767545	1778146	49	30	0	296
6767352	1777947	41	7	0	147
6767166	1777744	45	7	0	227

Physical Environment

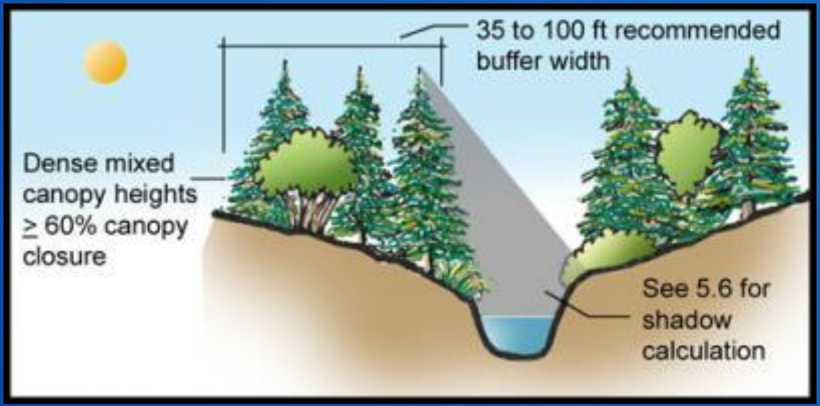

Photo: USDA

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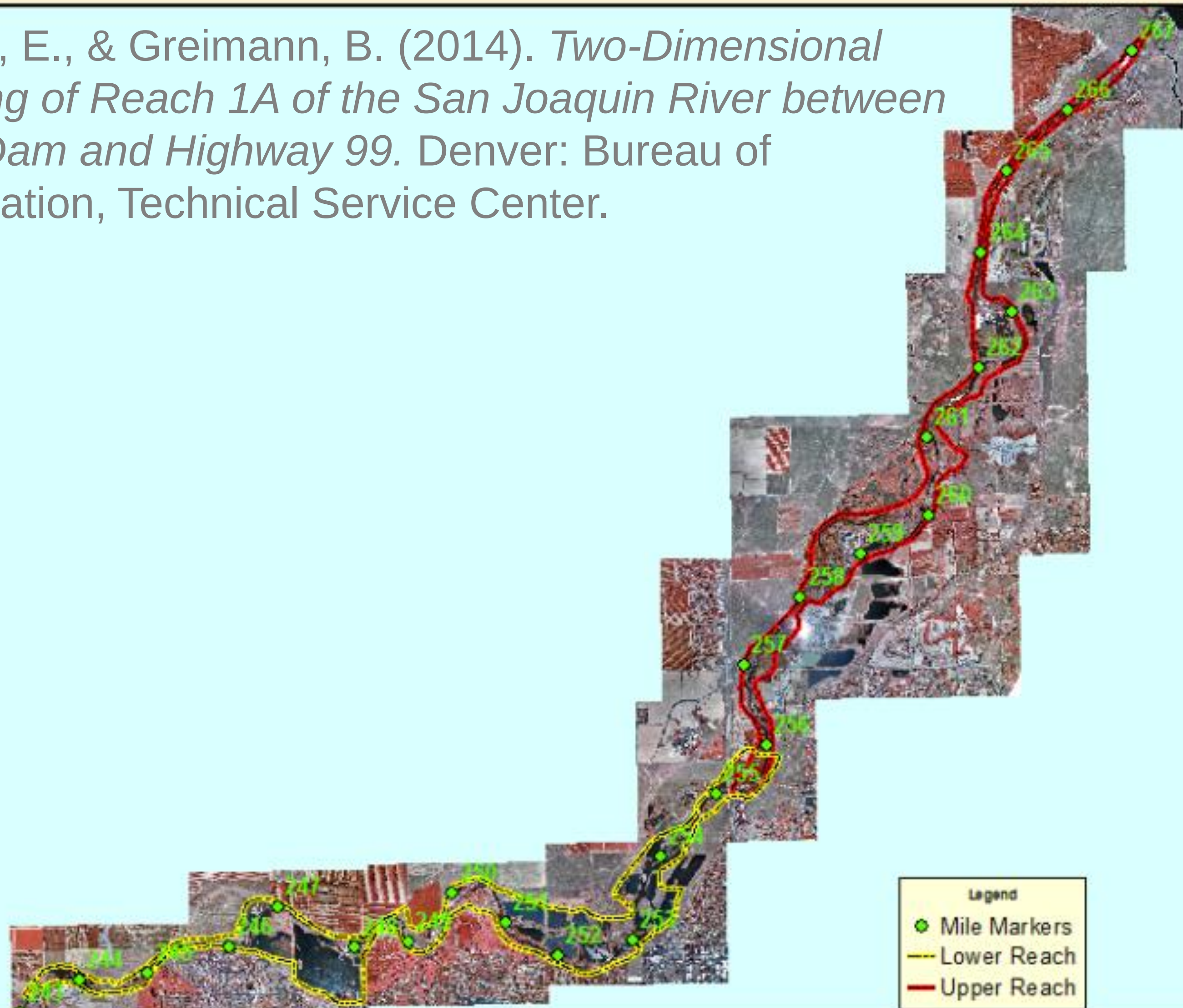
Gordon, E., & Greimann, B. (2014). *Two-Dimensional Modeling of Reach 1A of the San Joaquin River between Friant Dam and Highway 99.* Denver: Bureau of Reclamation, Technical Service Center.



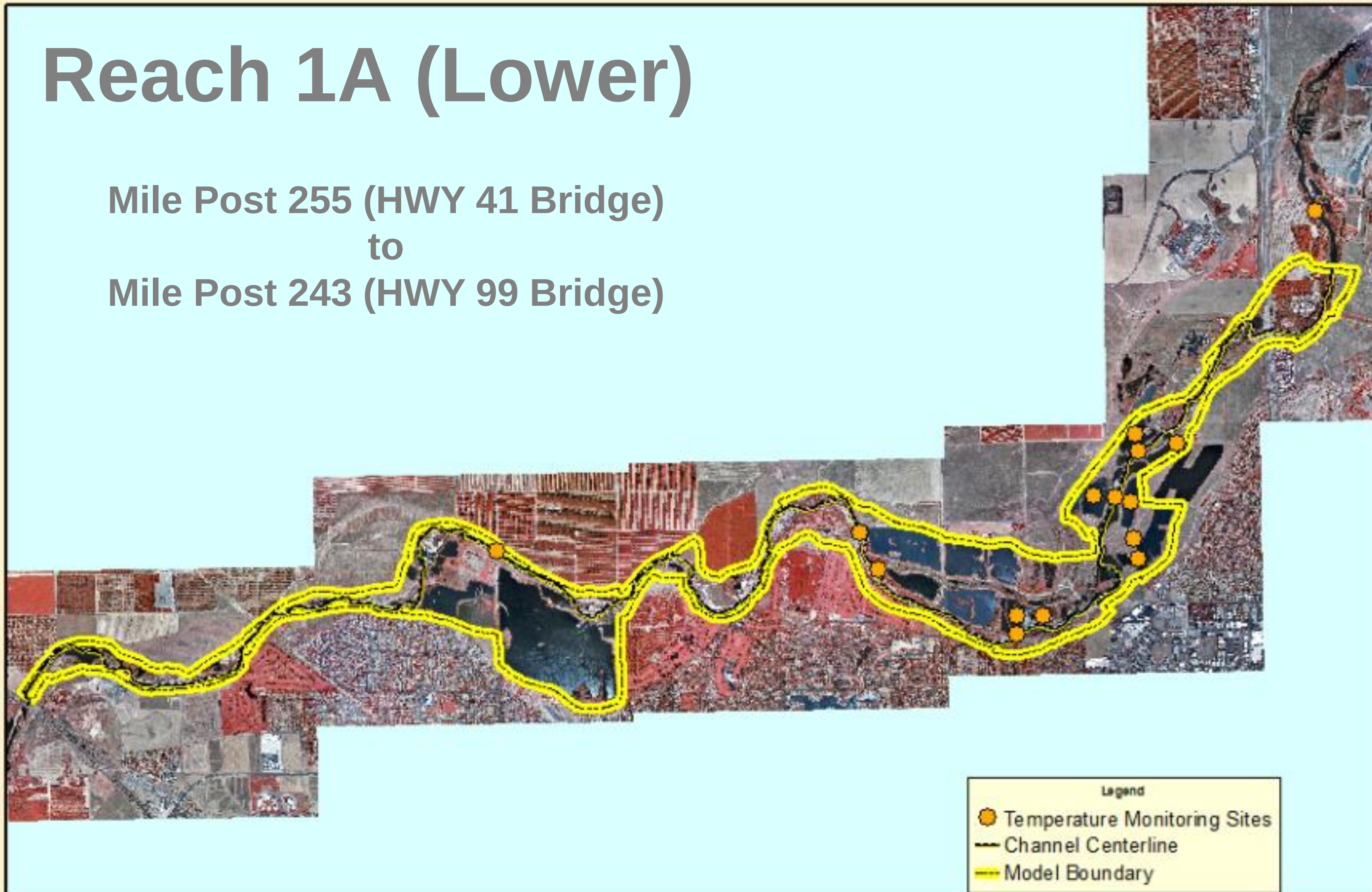
San Joaquin River Reach 1A

0 0.5 1 2 3 4 Miles

Coordinate System: Lambert Conformal Conic
Central Meridian: 120°30'0"W
1st Std Parallel: 37°4'0"N
2nd Std Parallel: 38°26'0"N
Latitude of Origin: 36°30'0"N

Reach 1A (Lower)

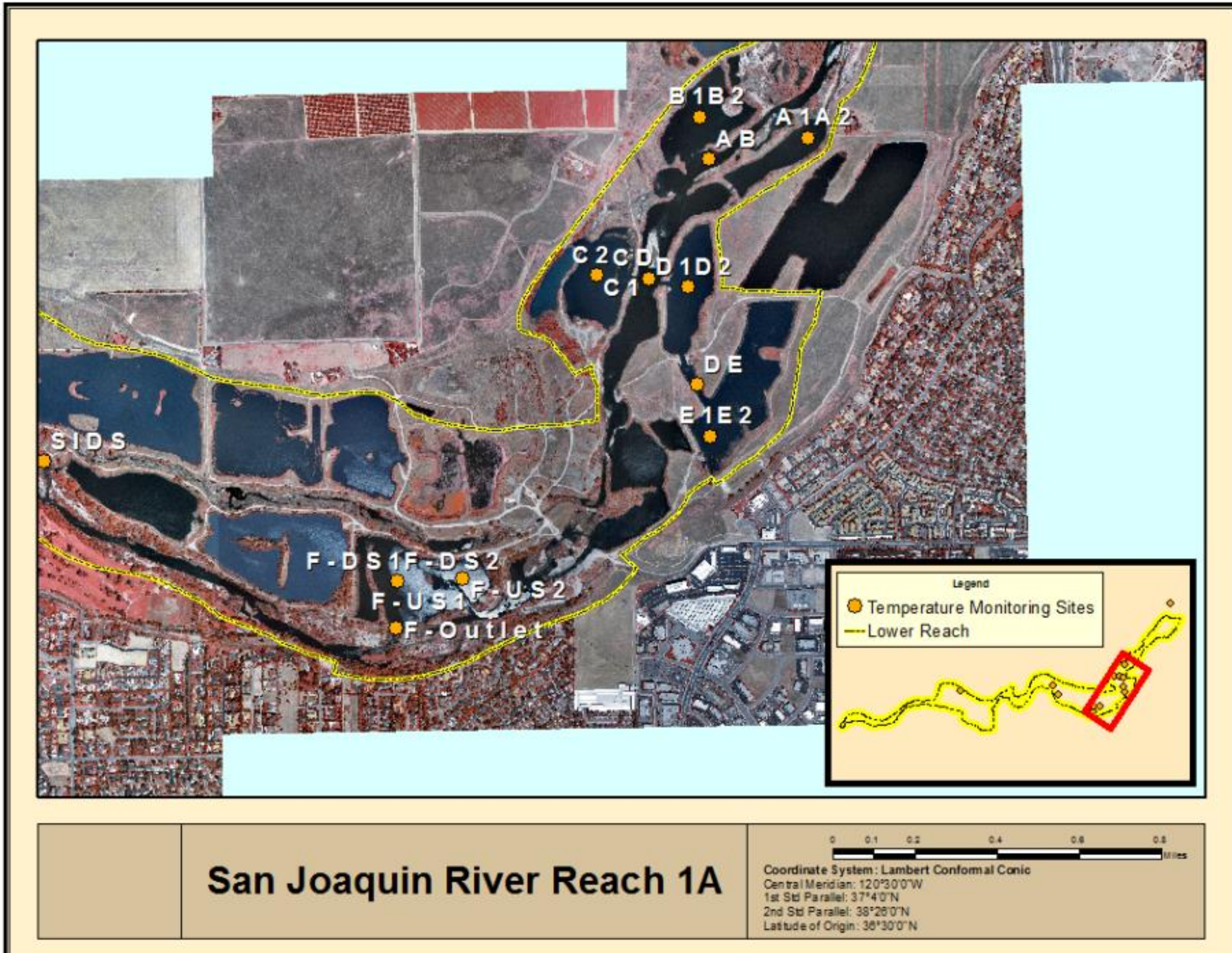
Mile Post 255 (HWY 41 Bridge)
to
Mile Post 243 (HWY 99 Bridge)

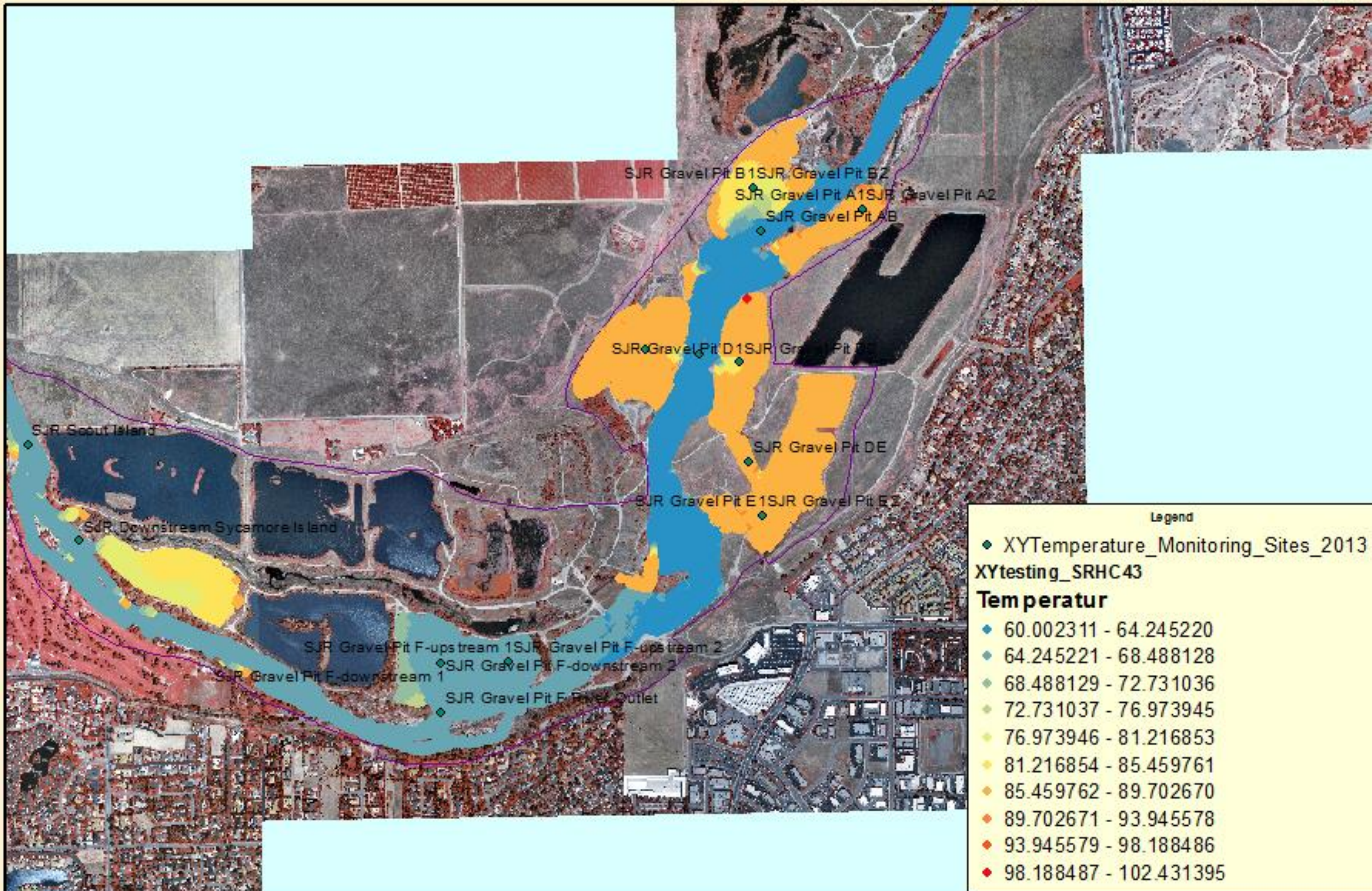


San Joaquin River Reach 1A

0 0.35 0.7 1.4 2.1 2.8 Miles

Coordinate System: Lambert Conformal Conic
Central Meridian: 120°30'0"W
1st Std Parallel: 37°4'0"N
2nd Std Parallel: 38°26'0"N
Latitude of Origin: 36°30'0"N

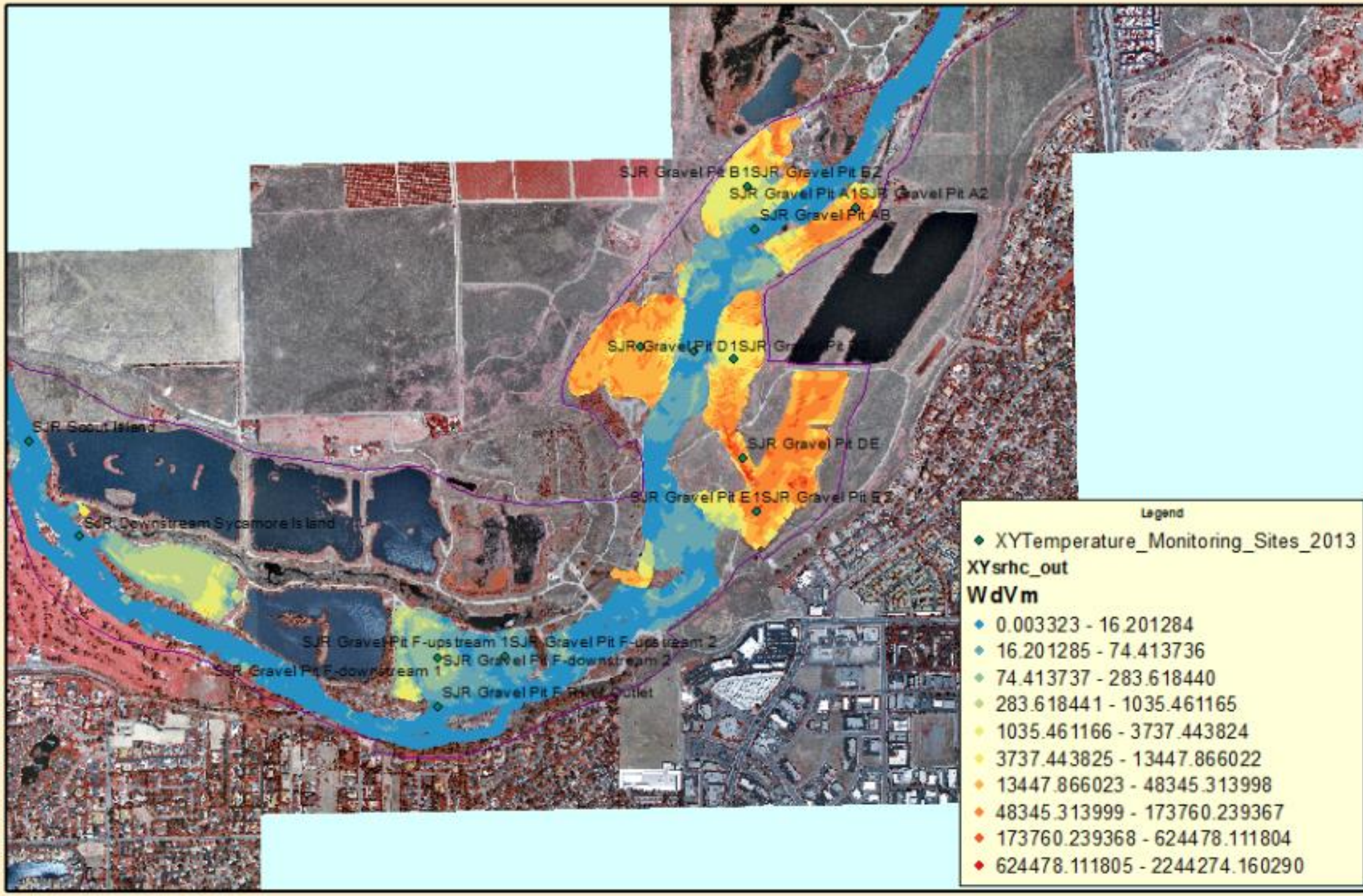

B 1B 2
A 1A 2
A B
C 2C D
D 1D 2
C 1
D E
E 1E 2
S I D S
F - D S 1F - D S 2
F - U S 1
F - U S 2
F - O u t l e t
Legend
Temperature Monitoring Sites
Lower Reach
San Joaquin River Reach 1A
0
0.1
0.2
0.4
0.6
0.8
Miles
Coordinate System: Lambert Conformal Conic
Central Meridian: 120°30'0"W
1st Std Parallel: 37°4'0"N
2nd Std Parallel: 38°26'0"N
Latitude of Origin: 36°30'0"N



San Joaquin River Reach 1A

0 0.125 0.25 0.5 0.75 1 Miles

Coordinate System: Lambert Conformal Conic
Central Meridian: 120°30'0"W
1st Std Parallel: 37°4'0"N
2nd Std Parallel: 38°26'0"N
Latitude of Origin: 36°30'0"N

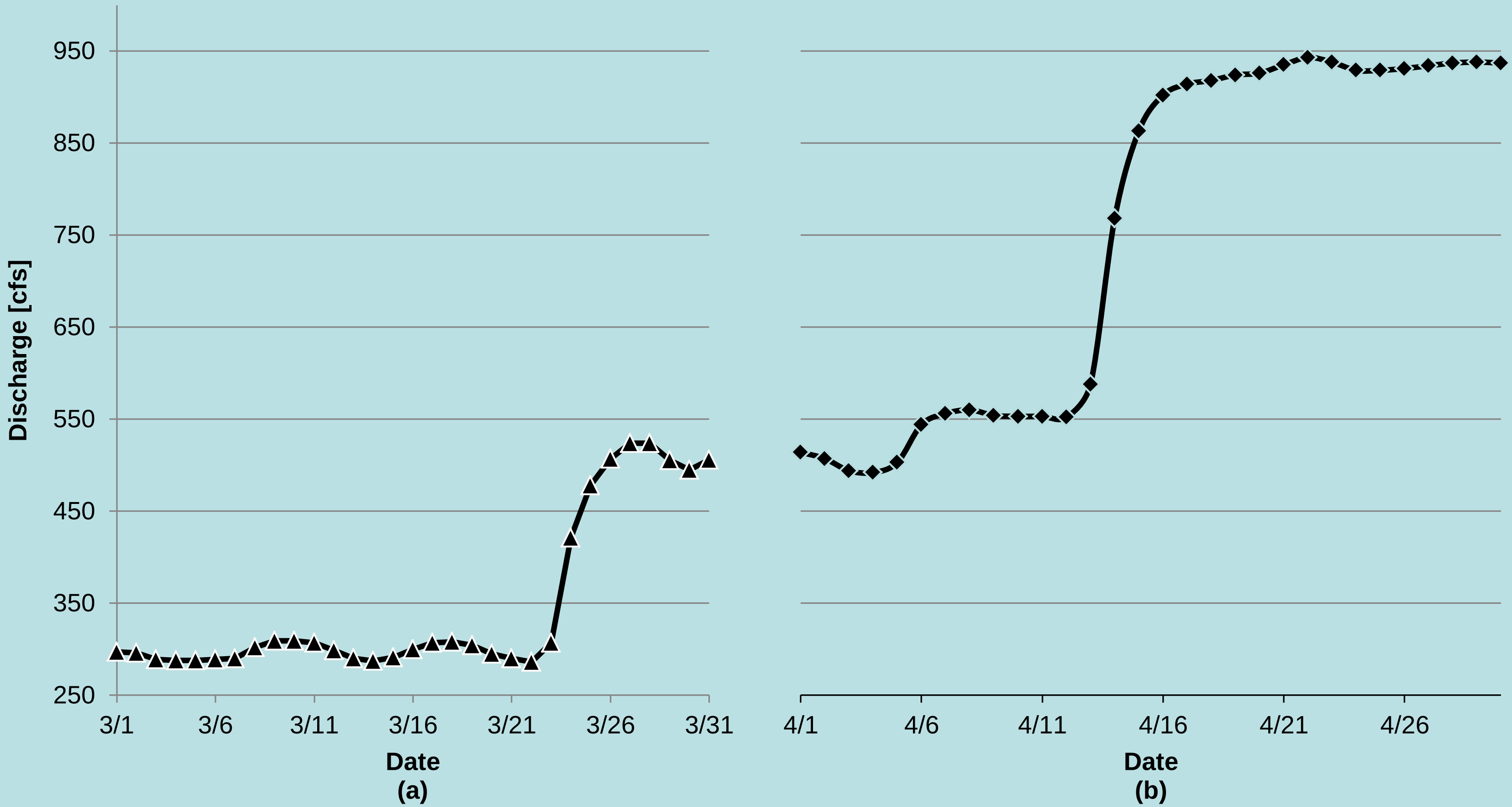


San Joaquin River Reach 1A

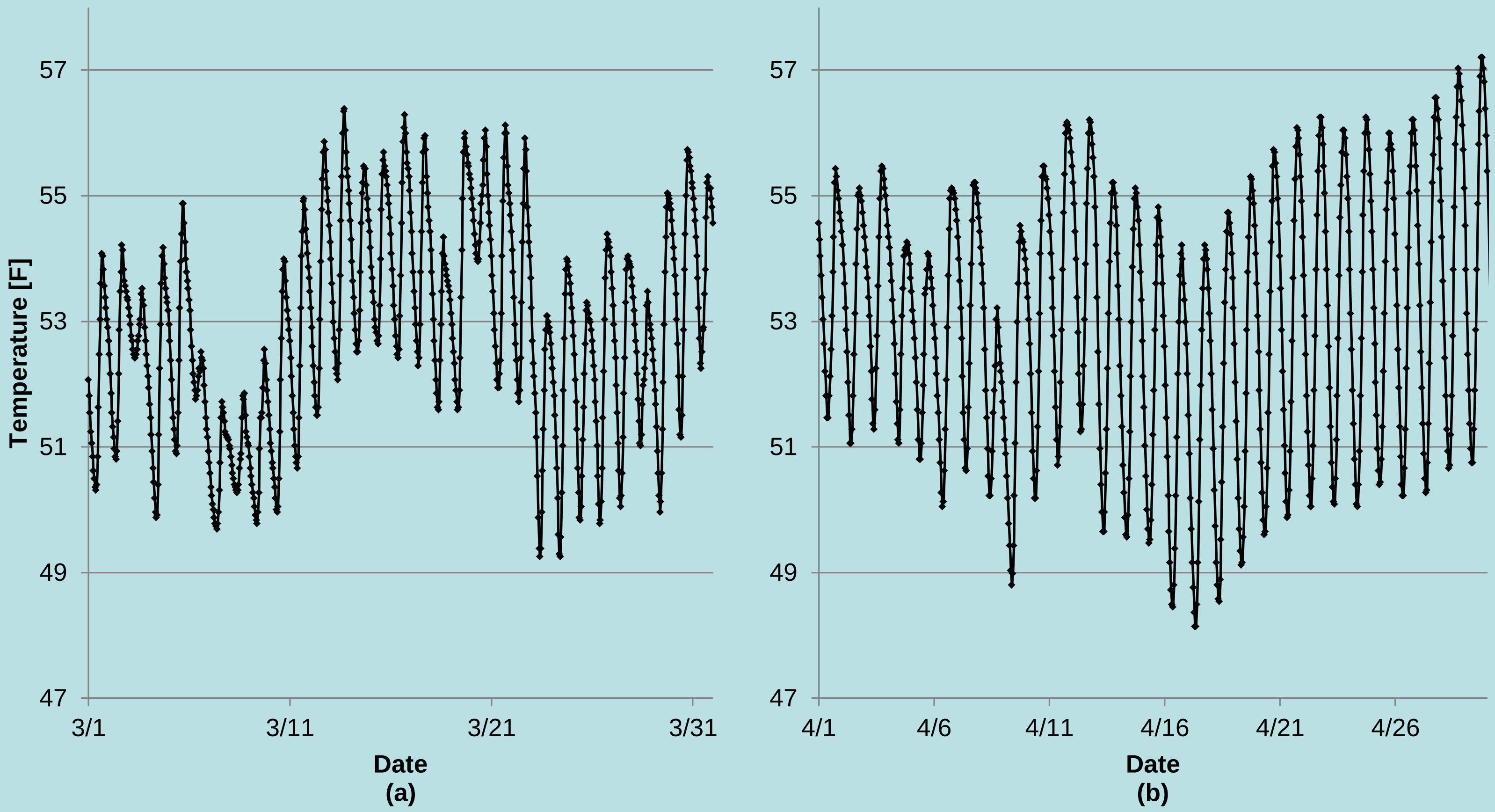
0 0.125 0.25 0.5 0.75 1 Miles

Coordinate System: Lambert Conformal Conic
Central Meridian: 120°30'0"W
1st Std Parallel: 37°4'0"N
2nd Std Parallel: 38°26'0"N
Latitude of Origin: 36°30'0"N

Model "Burn-in" and Validation



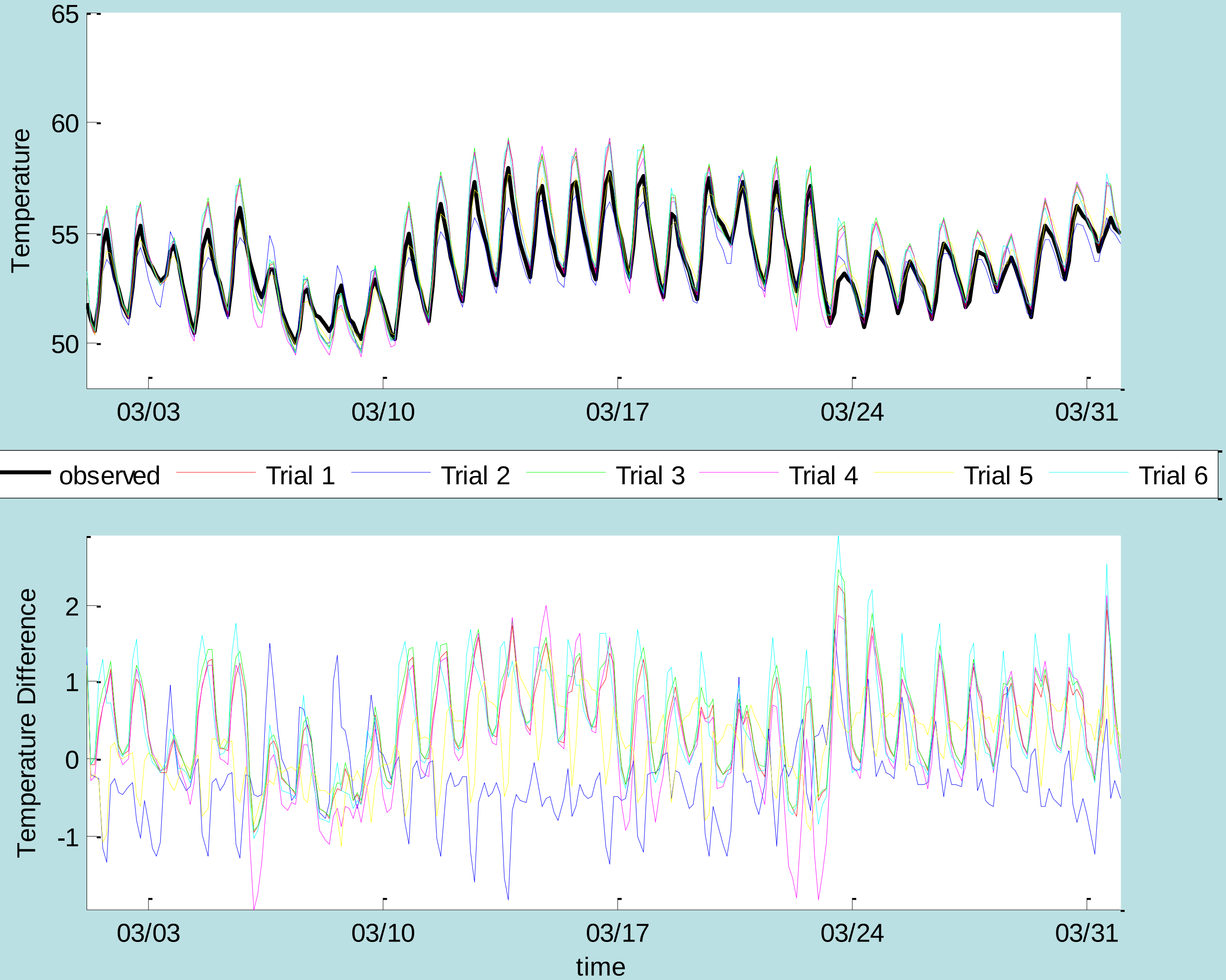
Model "Burn-in" and Validation



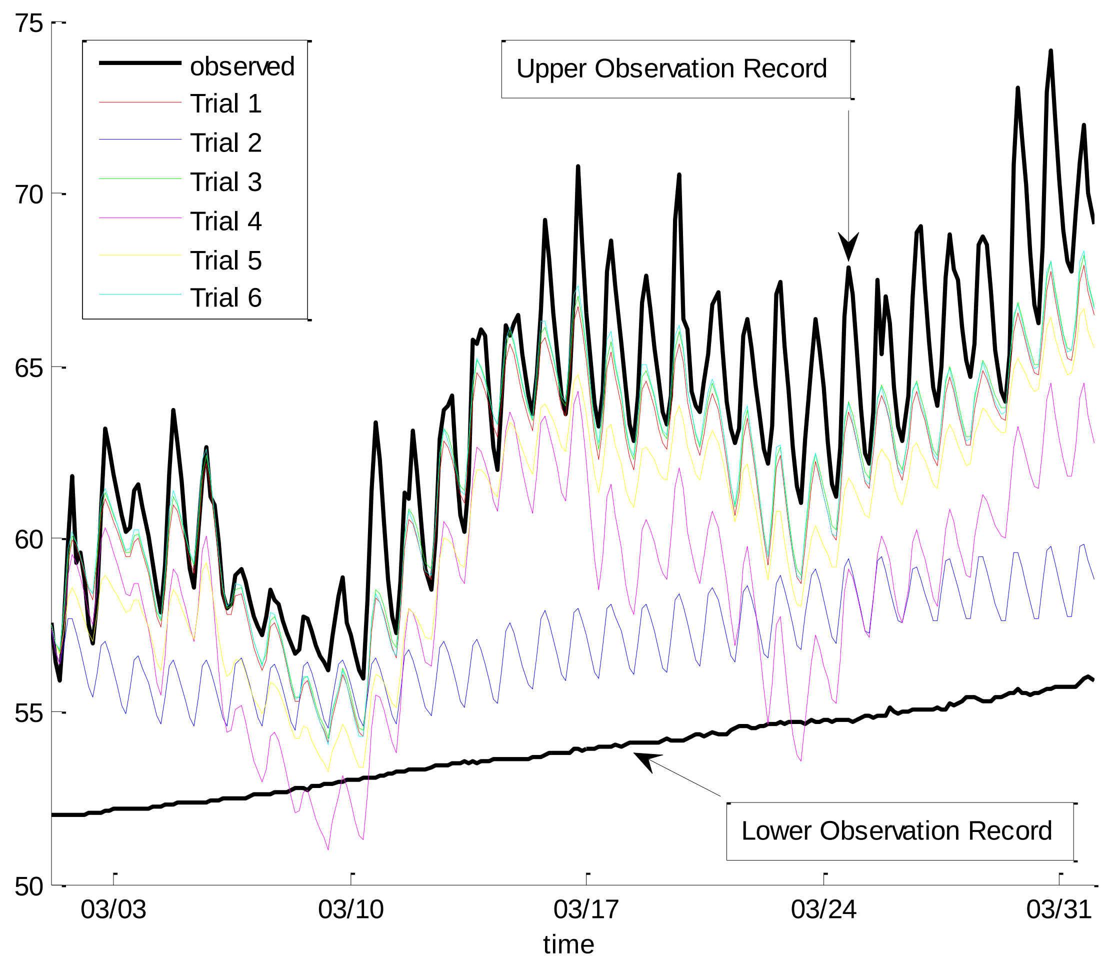
Model Calibration

Trial	Description	Value
Trial 1	Default	----------
Trial 2	Meteorology from NCDC	----------
Trial 3	No solar reduction from shading	E_s= 1.0
Trial 4	Large wind function coefficients	a_1=4x10^{-9} , b_1=3x10^{-9}
Trial 5	Increased substrate thickness	δ_{bed}^{1}=1 m , δ_{bed}^{2}=10 m
Trial 6	Decreased substrate thickness	δ_{bed}^{1}=0.01 m , δ_{bed}^{2}=0.1 m

Model Calibration



Model Calibration



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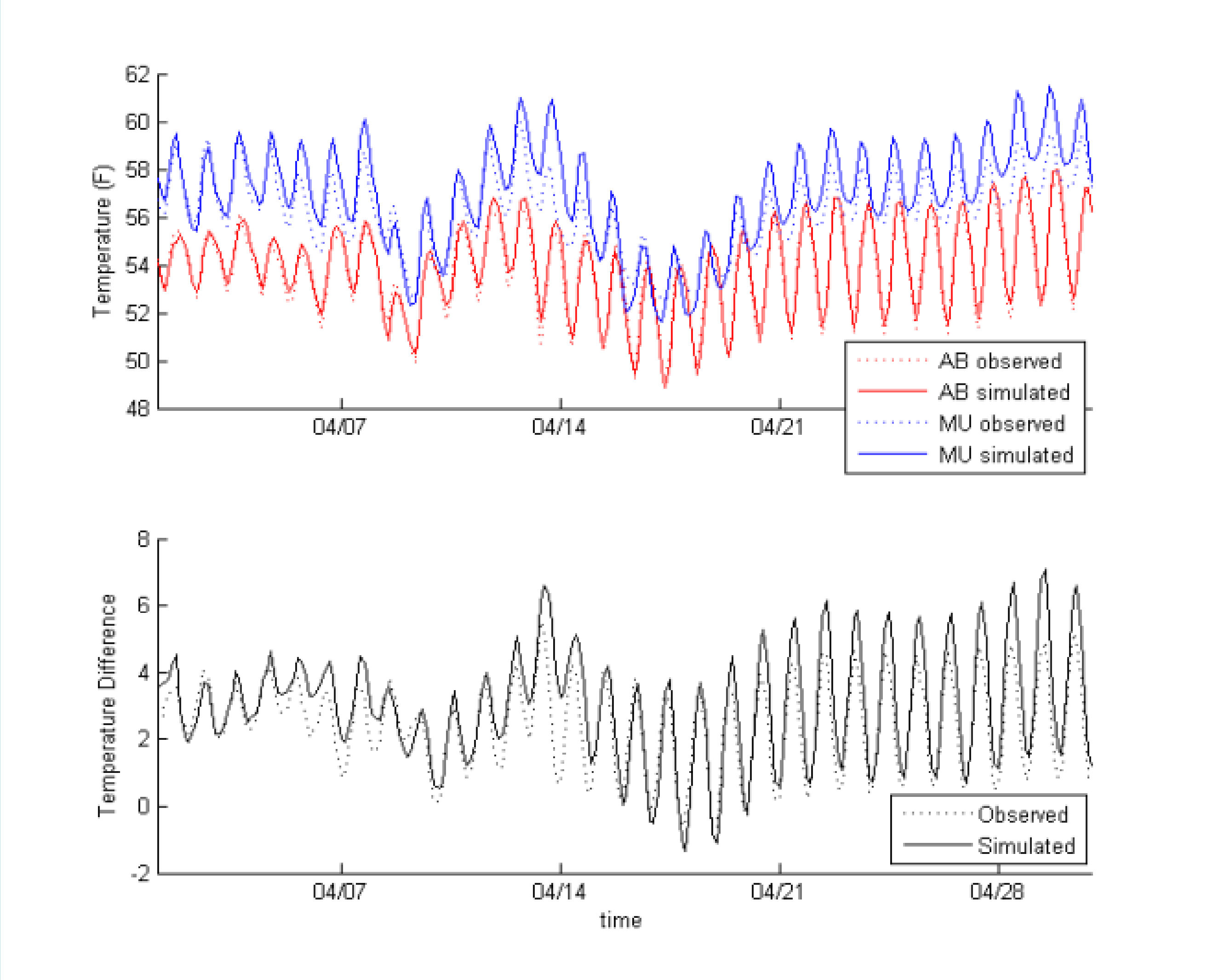
Reach Warming



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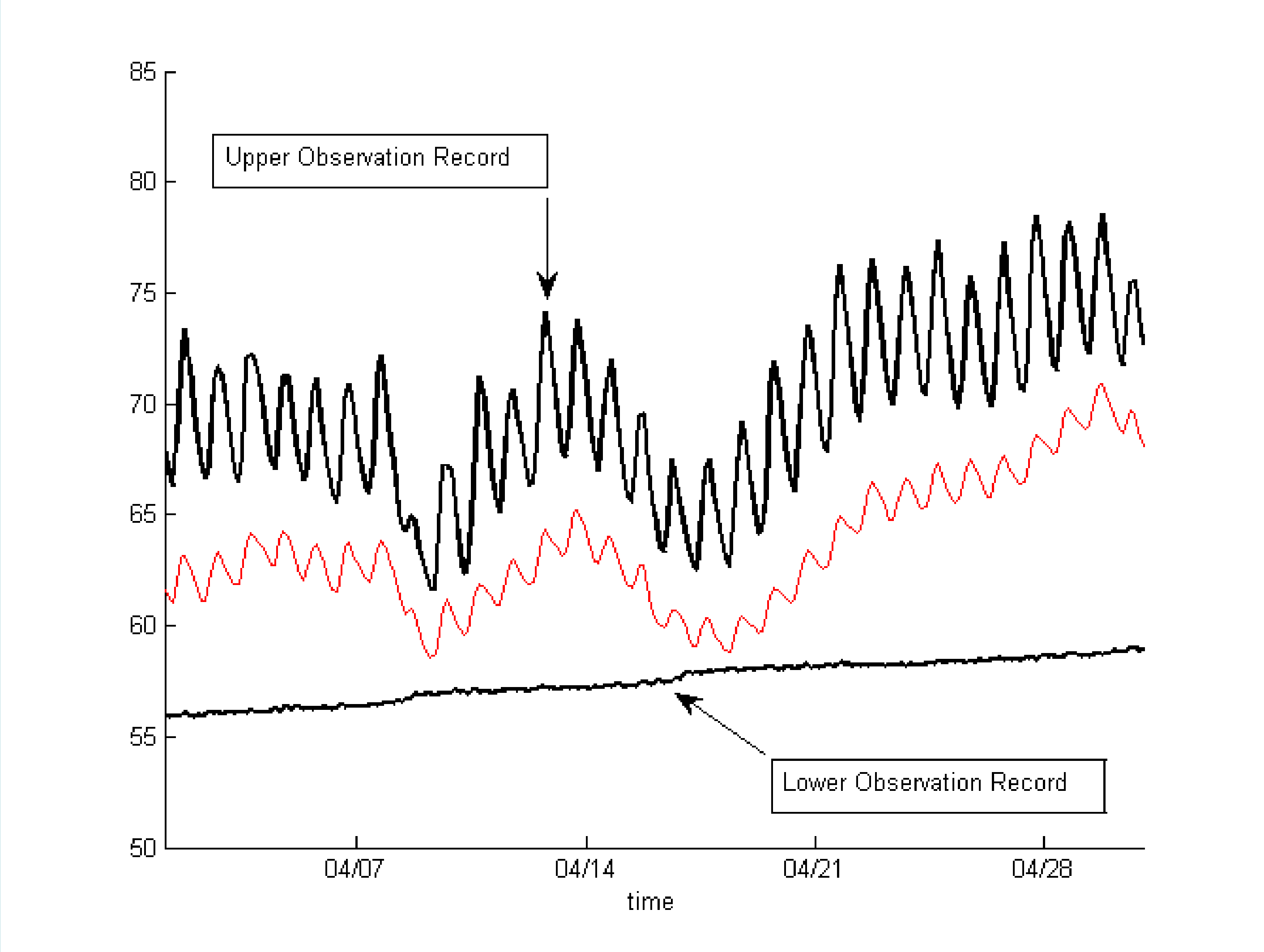
Temperature Stratification



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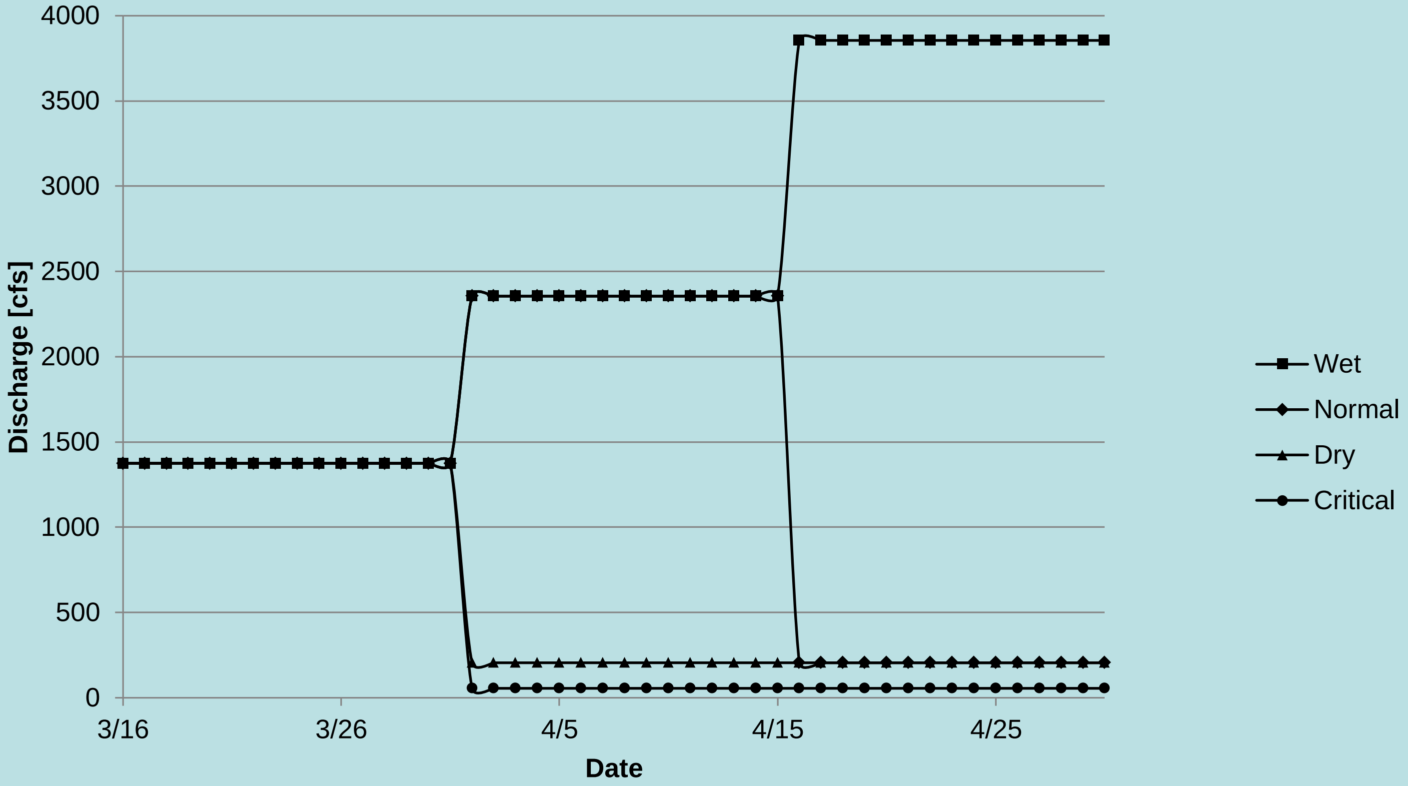
SJRRP Water-year Types



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SJRRP Water-year Types