Columbia/Snake River Temperature Modeling Preliminary Results

Bill Perkins, Marshall Richmond, Greg Guensch
Pacific Northwest National Laboratory

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Contents

1 1977 Conditions Scenario

The simulation period was limited to April 1, 1977 to October 31, 1977. The heat exchange component of MASS1 was recalibrated for this period and the conditions listed below. Simulated temperatures were compared to observed at several locations. Table 1 summarizes the comparison for the period. Several figures follow showing graphical comparisons.

This simulation was performed using the following conditions:

- Observed 1977 flows for model boundaries:
  - Columbia River at Grand Coulee (hourly),
  - Snake River at Anatone (daily),
  - North Fork Clearwater River at Dworshak (hourly), and
  - Clearwater River at Orofino (daily)
- Observed 1977 flows at all gaged tributaries;
- Constant project forebay stages (normal pool elevation);
- Observed 1977 daily water temperatures at Grand Coulee;
- Observed 1977 daily water temperatures at Anatone;
- Dworshak and Orofino temperatures set to that observed at Spalding;
- Water temperatures at tributaries were set to observed 1977 daily values when available, long term monthly averages when observed data not available;
- Gas levels were assumed to be 100% saturated in the Grand Coulee and Dworshak forebays, and at all tributaries;
- At all projects, spill was assumed to occur only if the powerhouse capacity was exceeded[1]; and
- Meteorology data was used from the following stations (see Figures 135 and 136):
  - Pranghorn Airport, Wenatchee,
  - Hanford Meteorological Station, and
  - Portland International Airport.

[1]The application of this rule resulted in zero spill at all projects for the entire season.

Table 1: Statistical comparison of simulated and observed temperatures from April through September (RMS and AME units are degrees Celsius)

	N	R^2	Bias	RMS	AME
LMN Scroll Case	128	0.89	-0.36	1.52	1.17
LGS Scroll Case	124	0.89	-0.30	1.49	1.18
IHR Scroll Case	200	0.94	-0.17	1.31	1.02
RIS Scroll Case	212	0.98	-0.30	0.59	0.49
MCN Scroll Case	151	0.97	-0.94	1.26	1.06
BON Scroll Case	85	0.97	-1.25	1.56	1.35
Snake R. @ Burbank	210	0.95	-0.33	1.27	0.95
Columbia R. @ Vernita Bridge	214	0.98	-0.29	0.62	0.51
Columbia R. @ Richland	214	0.98	-0.57	0.82	0.68
Columbia R. @ Umatilla	201	0.98	-0.47	0.77	0.62
Columbia R. @ Warrendale	214	0.98	-0.37	1.26	0.95
Columbia R. @ Vancouver	191	0.97	-0.69	1.46	1.10
Columbia R. @ Kalama	214	0.98	-0.75	1.28	1.01

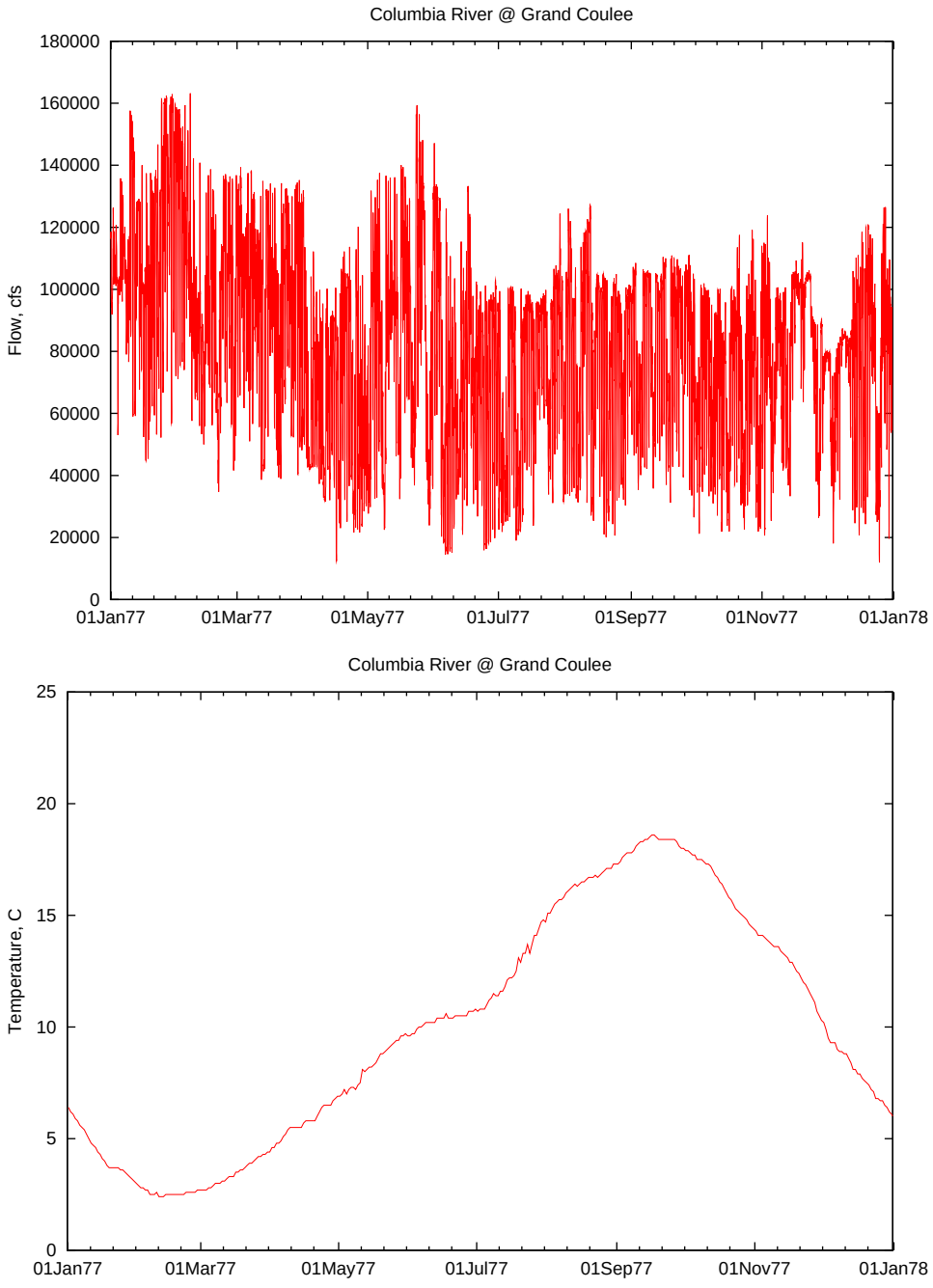

Figure 1: Flow and temperature boundary conditions at Grand Coulee dam.

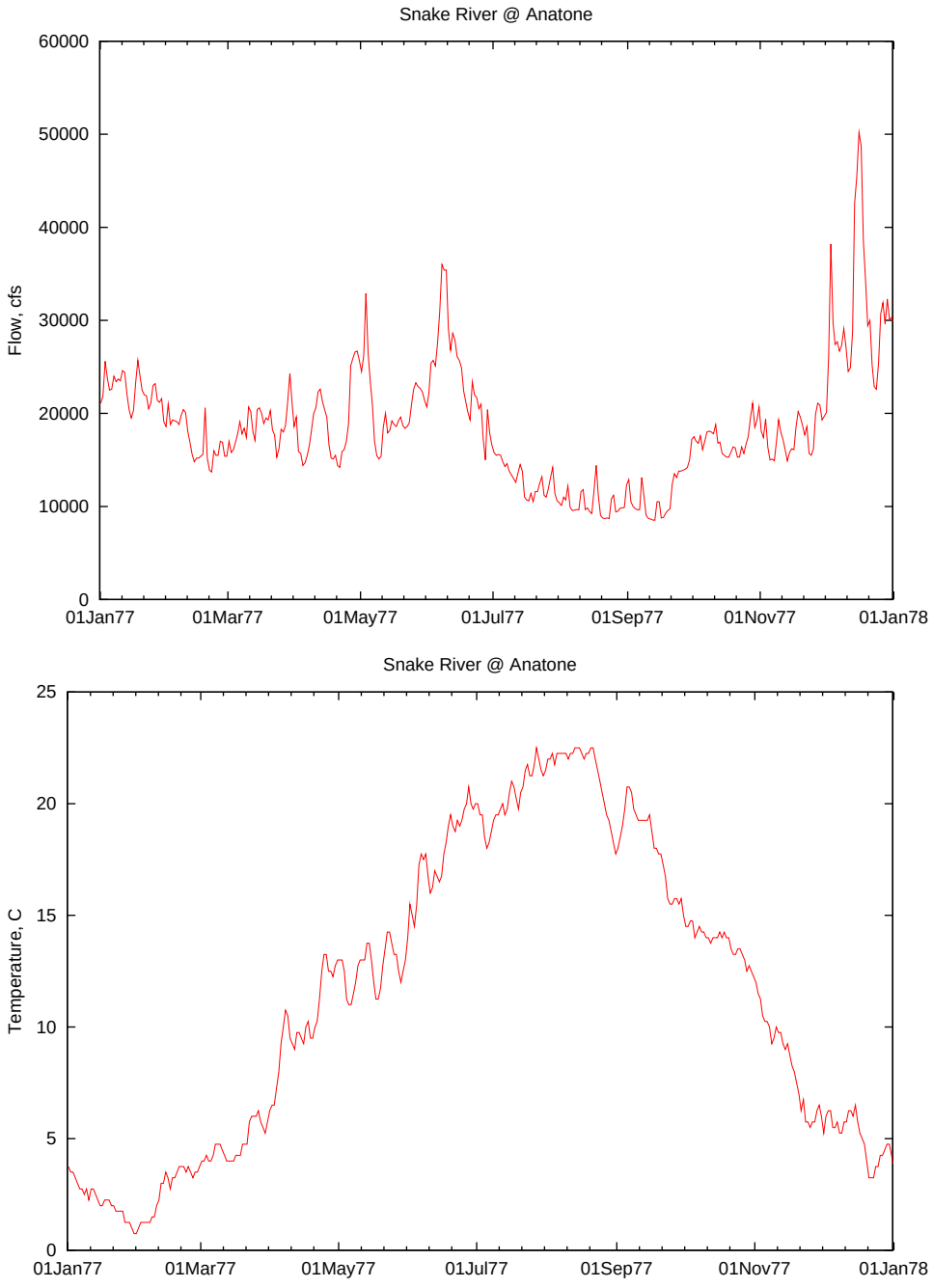

Figure 2: 1977 Snake River flow and temperature boundary conditions at Anatone.

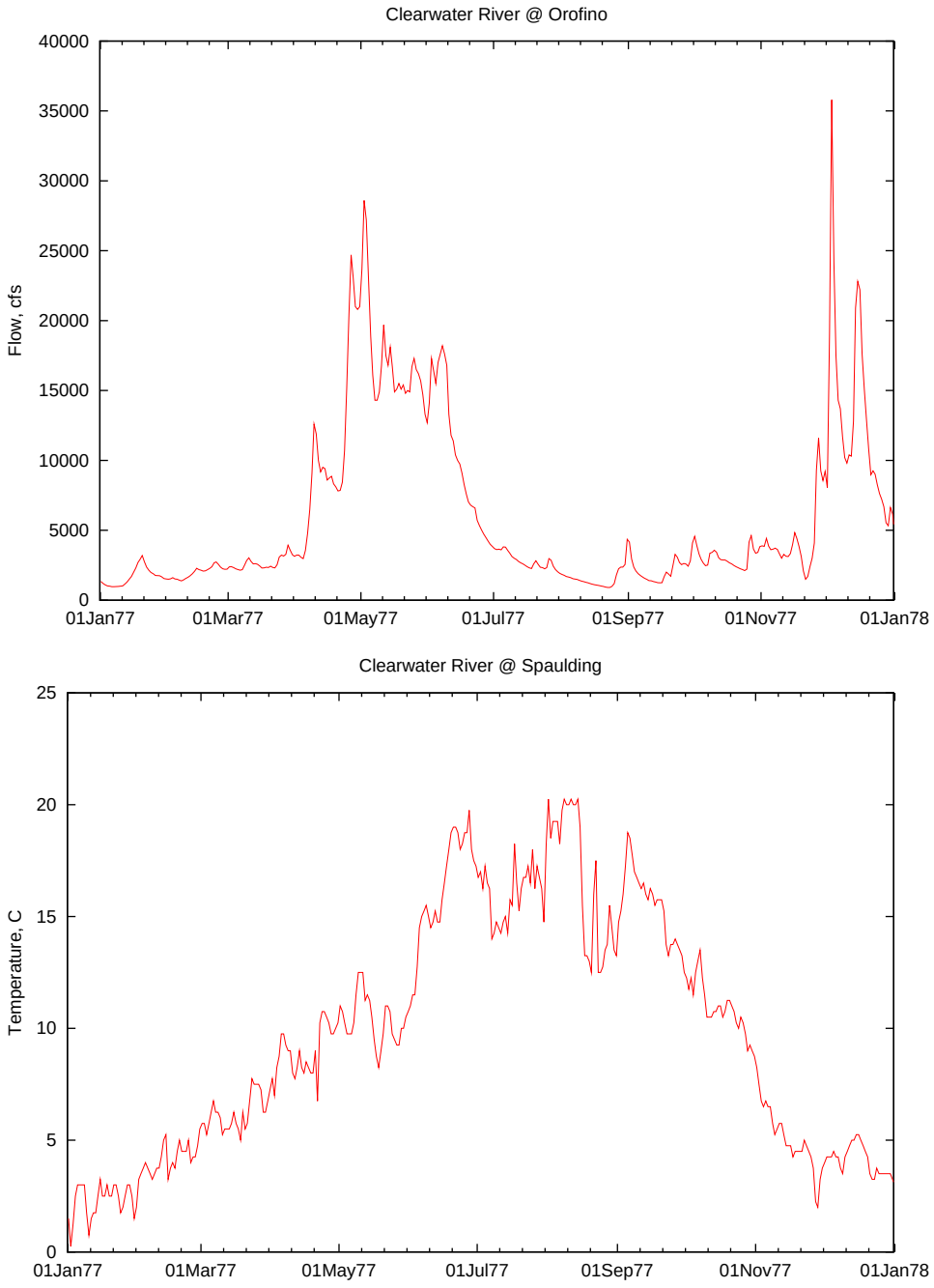

Figure 3: 1977 Clearwater River flow and temperature boundary conditions at Orofino. Temperature is taken from the Spaulding gage downstream.

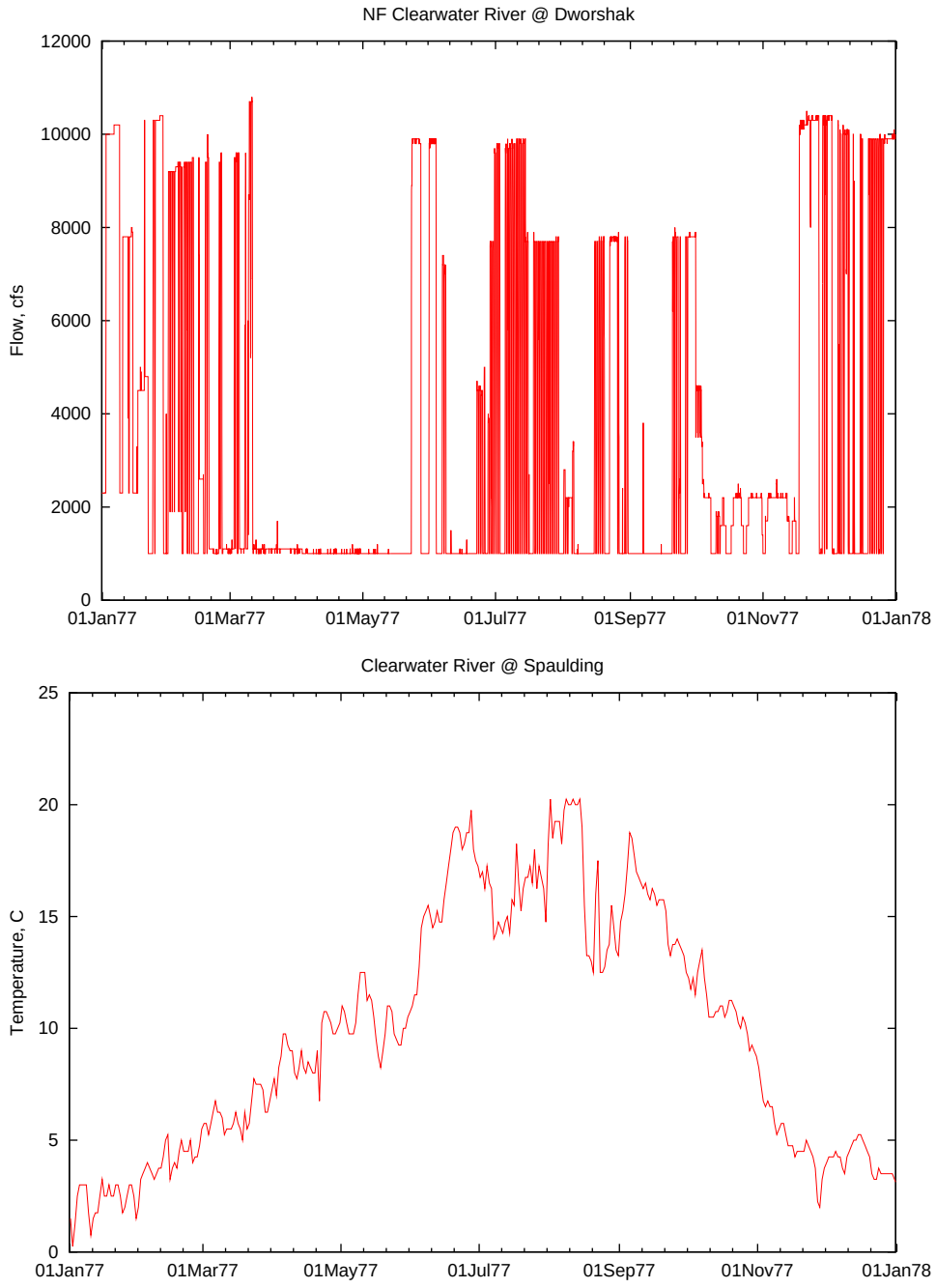

Figure 4: 1977 North Fork Clearwater River flow and temperature boundary conditions at Dworshak dam. Temperature is taken from the Spaulding gage downstream.

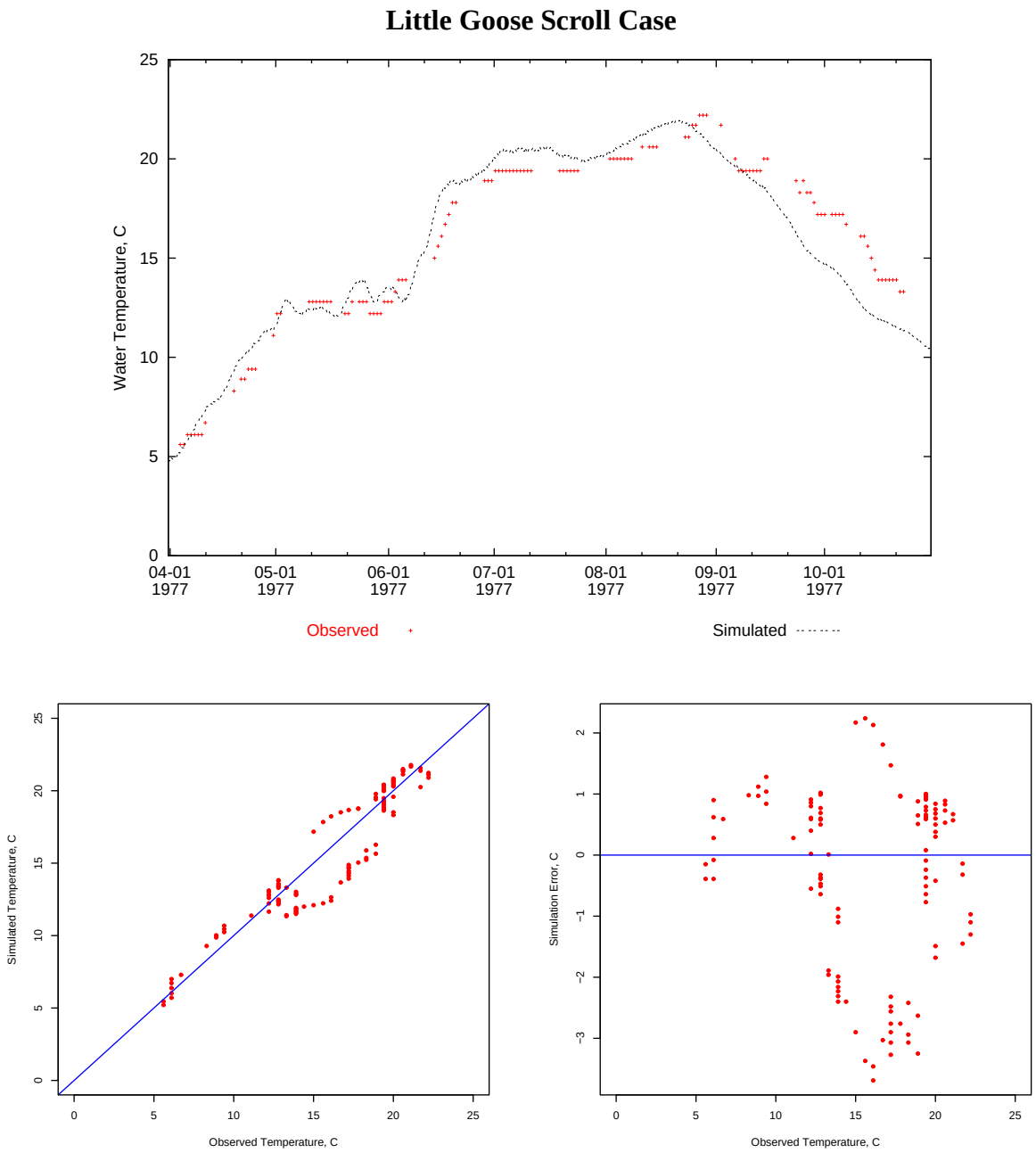

Figure 5: Comparison of simulated temperature and observed scroll case temperature (instantaneous) at Little Goose dam.

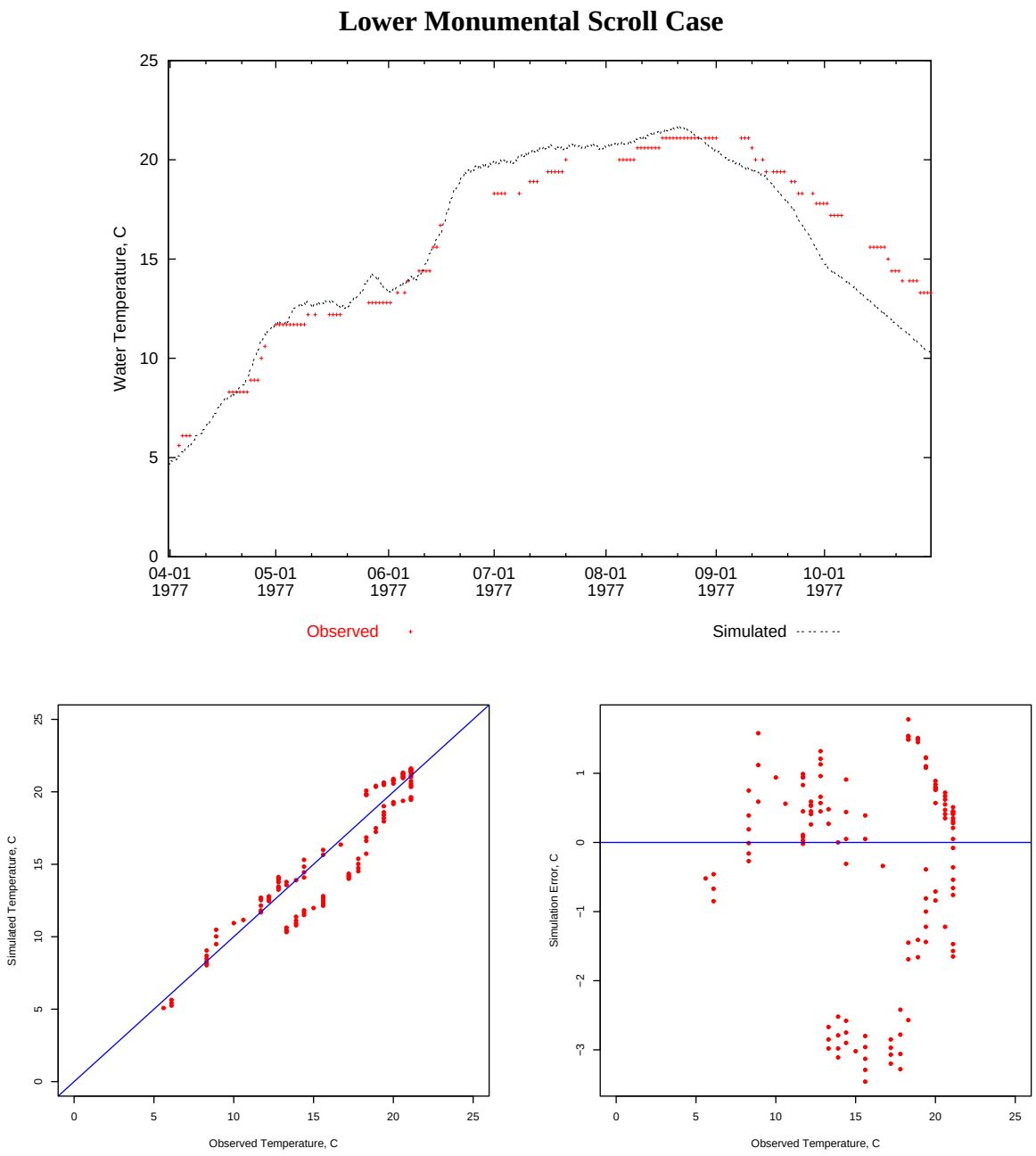

Figure 6: Comparison of simulated temperature and observed scroll case temperature (instantaneous) at Lower Monumental dam.

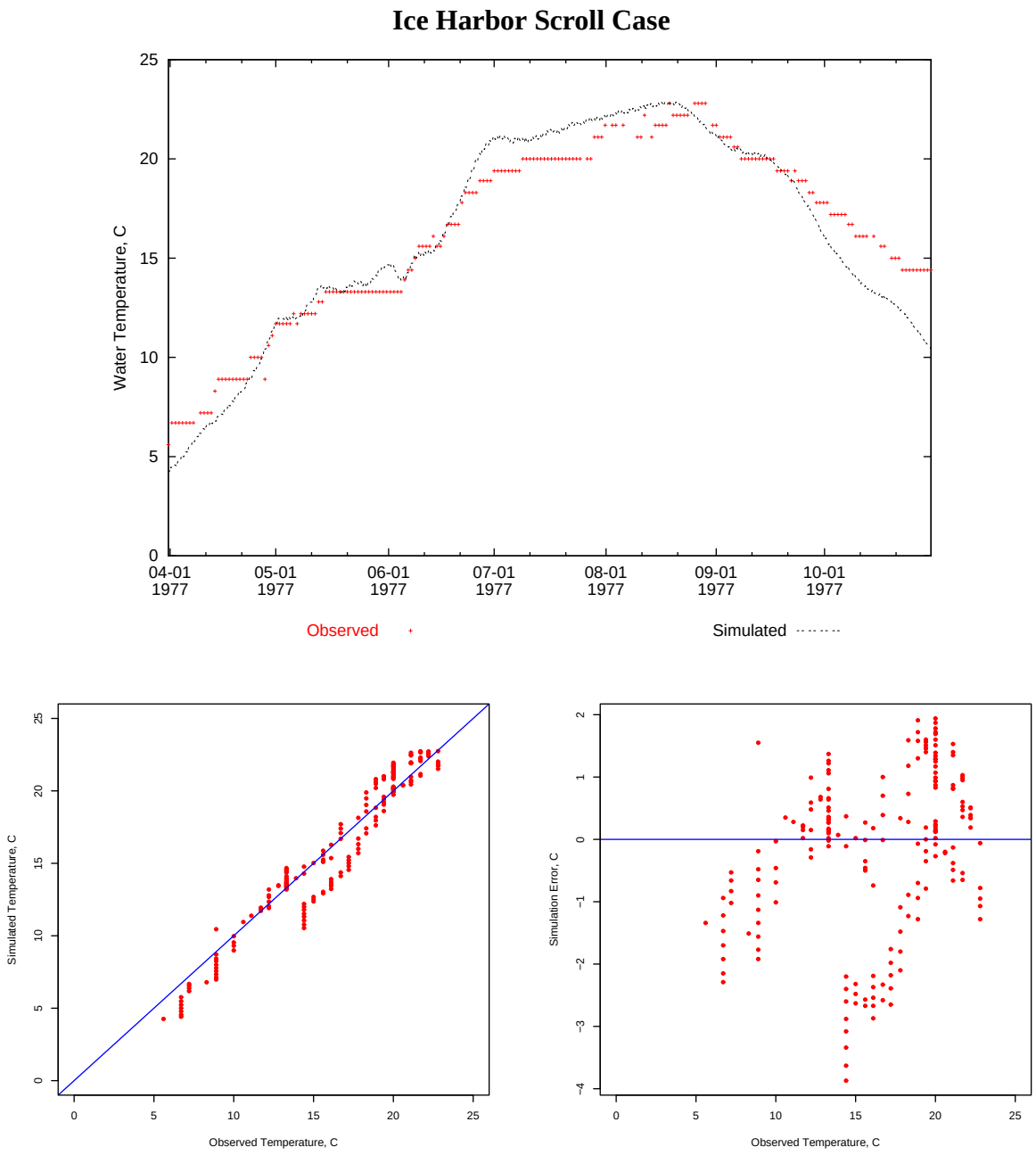

Figure 7: Comparison of simulated temperature and observed scroll case temperature (instantaneous) at Ice Harbor dam.

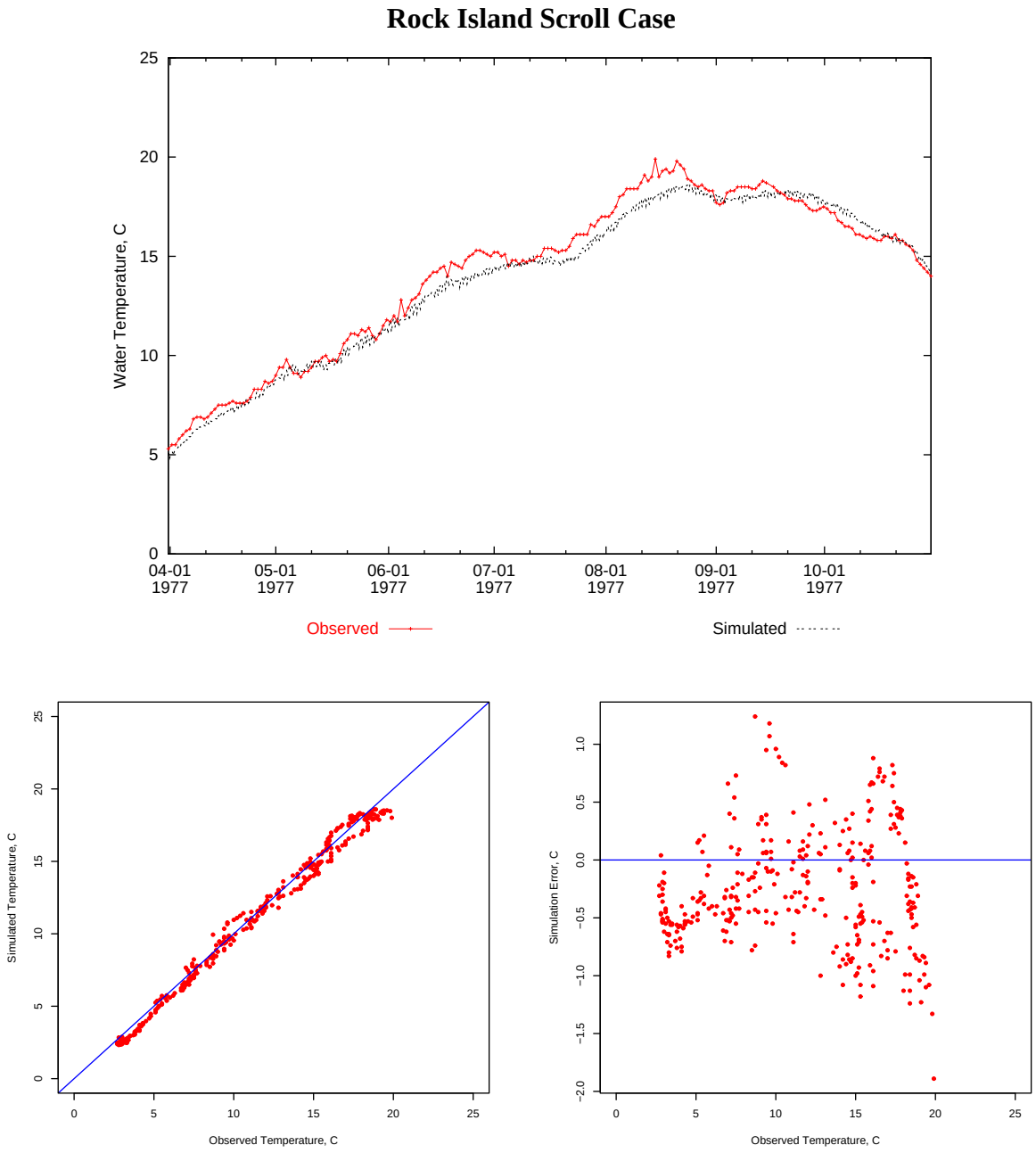

Figure 8: Comparison of simulated temperature and observed scroll case temperature (instantaneous) at Rock Island dam.

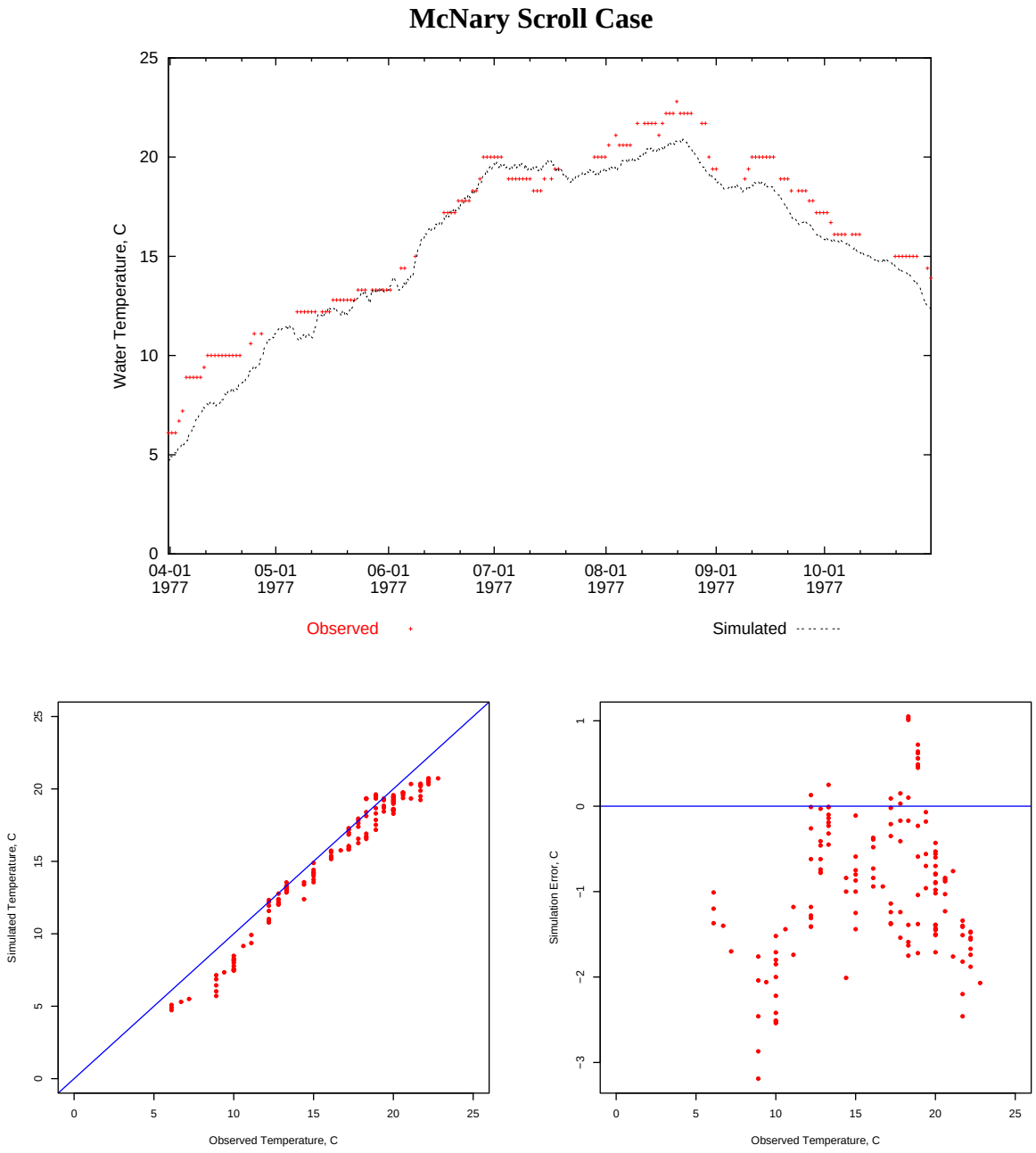

Figure 9: Comparison of simulated temperature and observed scroll case temperature (instantaneous) at McNary dam.

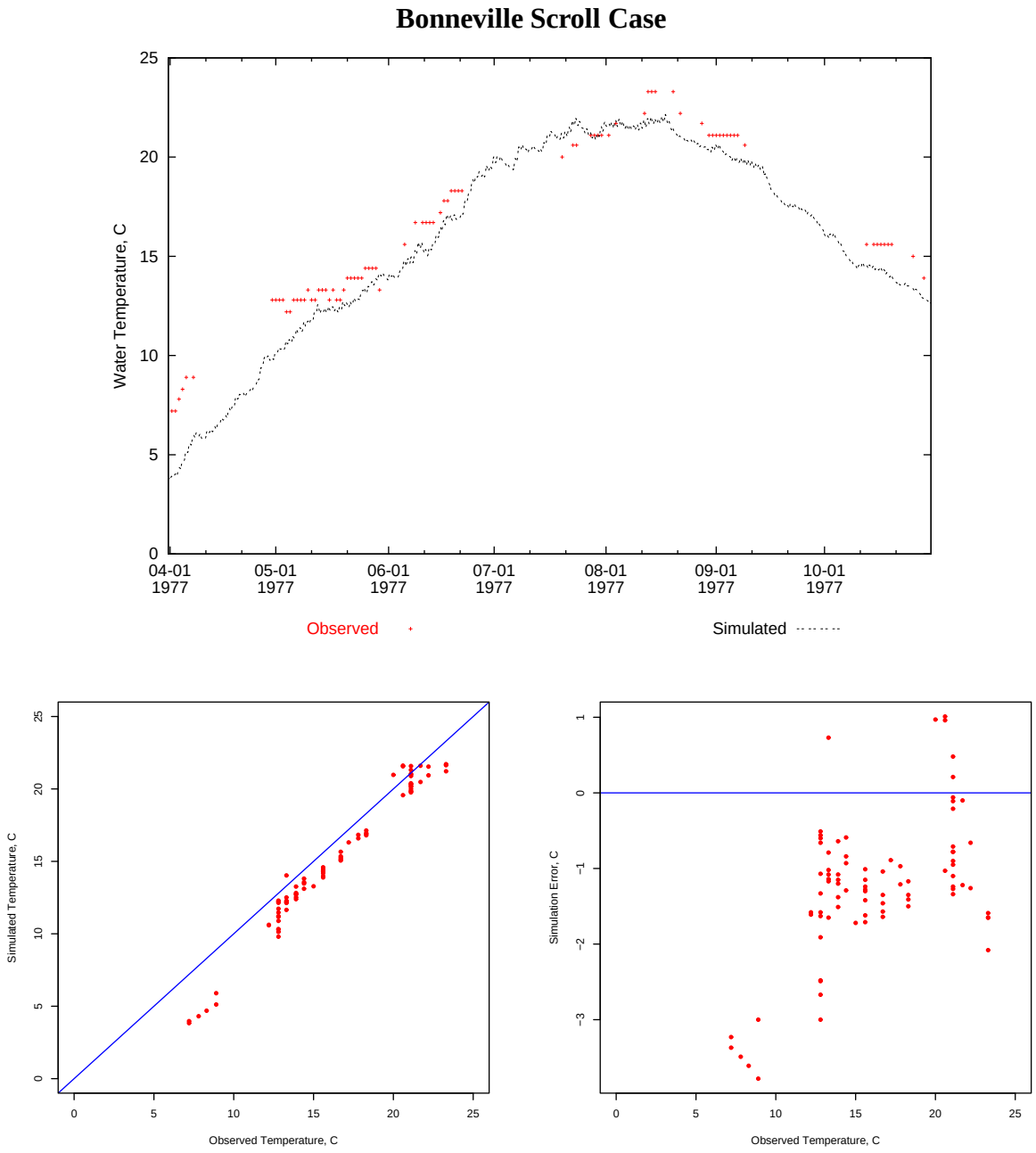

Figure 10: Comparison of simulated temperature observed scroll case temperature (instantaneous) at Bonneville dam.

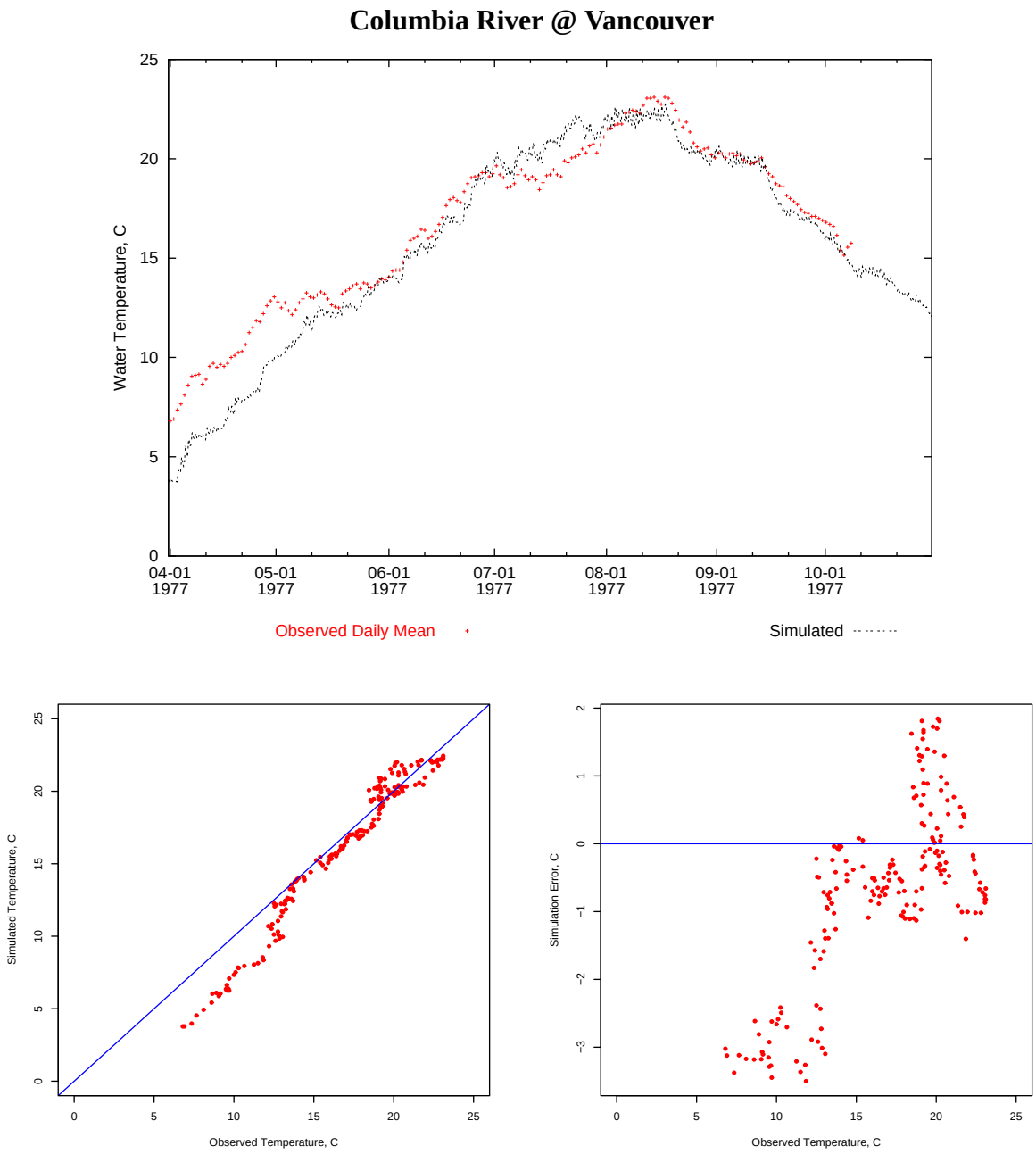

Figure 11: Comparison of simulated and observed daily mean Columbia River temperature at the USGS gage near Vancouver, Washington.

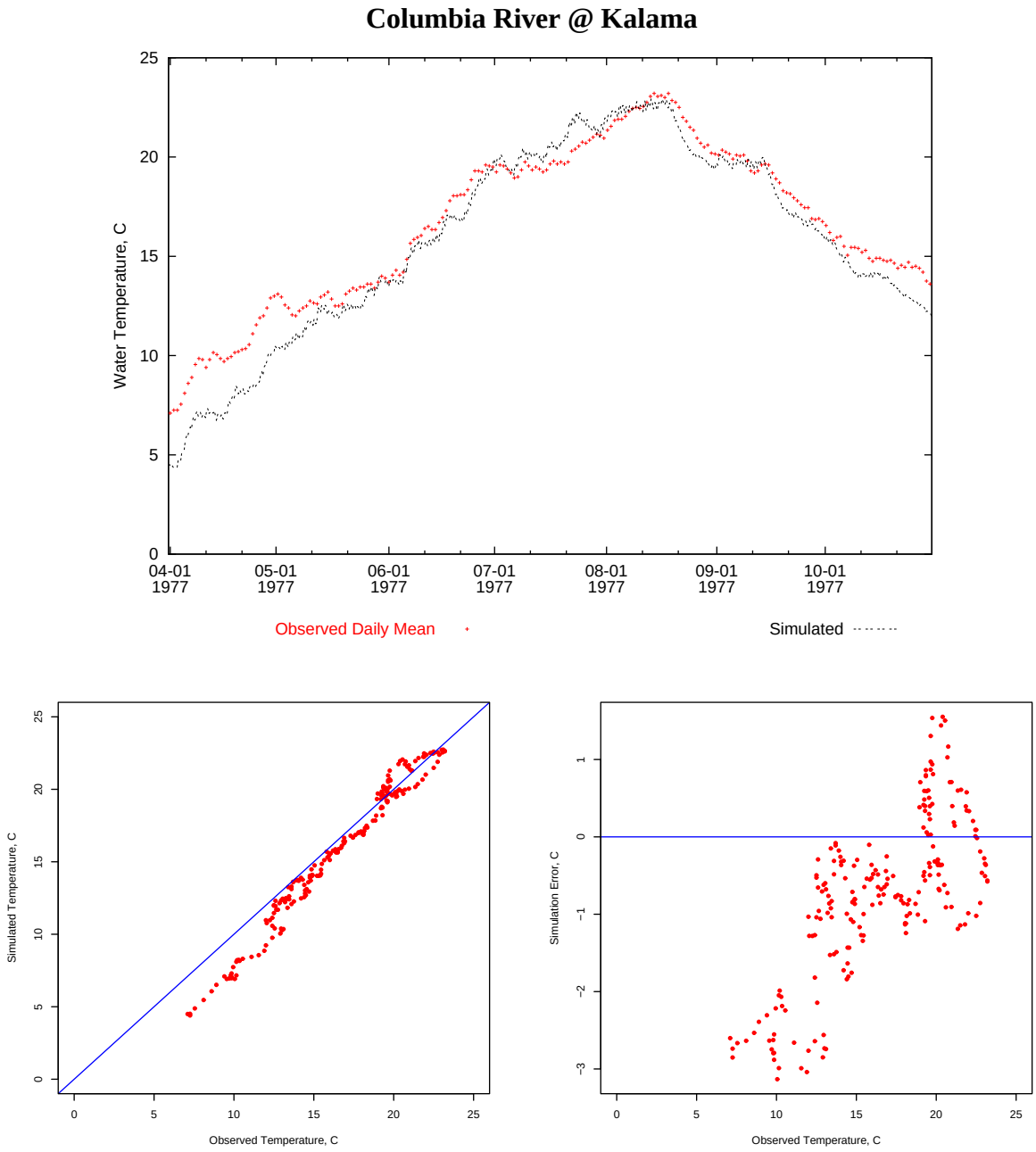

Figure 12: Comparison of simulated and observed daily mean Columbia River temperature at the USGS gage near Kalama, Washington.

2 77H/94M Scenario

This scenario is the same as the 1977 conditions scenario, except that 1994 weather, from the same stations (Wenatchee, Hanford, Portland), was used. This means that the same water temperatures were used at the boundaries (Grand Coulee and Clearwater and Snake Rivers).

3 77H/94M/DWR10 Scenario

Simulation of this scenario was the same as the 77H/94M Scenario, with the following modifications:

- Dworshak discharge was increased to 10.0 kcfs from July 1 to September 30, with 1977 flows for remainder of the season;
- Dworshak temperature during that period was assumed to be 8.89°C (48°F) July 1 to September 30, with temperatures the same as the 1994 Weather Scenario for the remainder of the season;
- Clearwater main stem temperature during the July 1 to September 30 were estimated using the method described in Appendix A; and
- Flow is augmented on the Columbia in order to maintain flows at Priest Rapids above 65 kcfs.

Figure 13 compares the Clearwater River boundary conditions used in the 77H/94M/DWR10 scenario to those used in the 77H/94M scenario. When the Priest Rapids discharge (in the 77H/94M scenario) dropped below 65 kcfs, the amount required to bring it to 65 kcfs was lagged 6 hours (the approximate wave travel time from Grand Coulee to Priest Rapids) and added to the original (1977) Grand Coulee discharge. Figure 14 compares the discharge used at Grand Coulee with the 77H/94M scenario, and also shows the result change in flow at Priest Rapids. In general, this augmentation had the desired effect – Priest Rapids minimum flows were raised, but minimum flows were closer to 60 kcfs than 65 kcfs. This is probably because the wave travel time between Grand Coulee was not precisely 6 hours. Any augmentation done in this fashion in going to be imprecise.

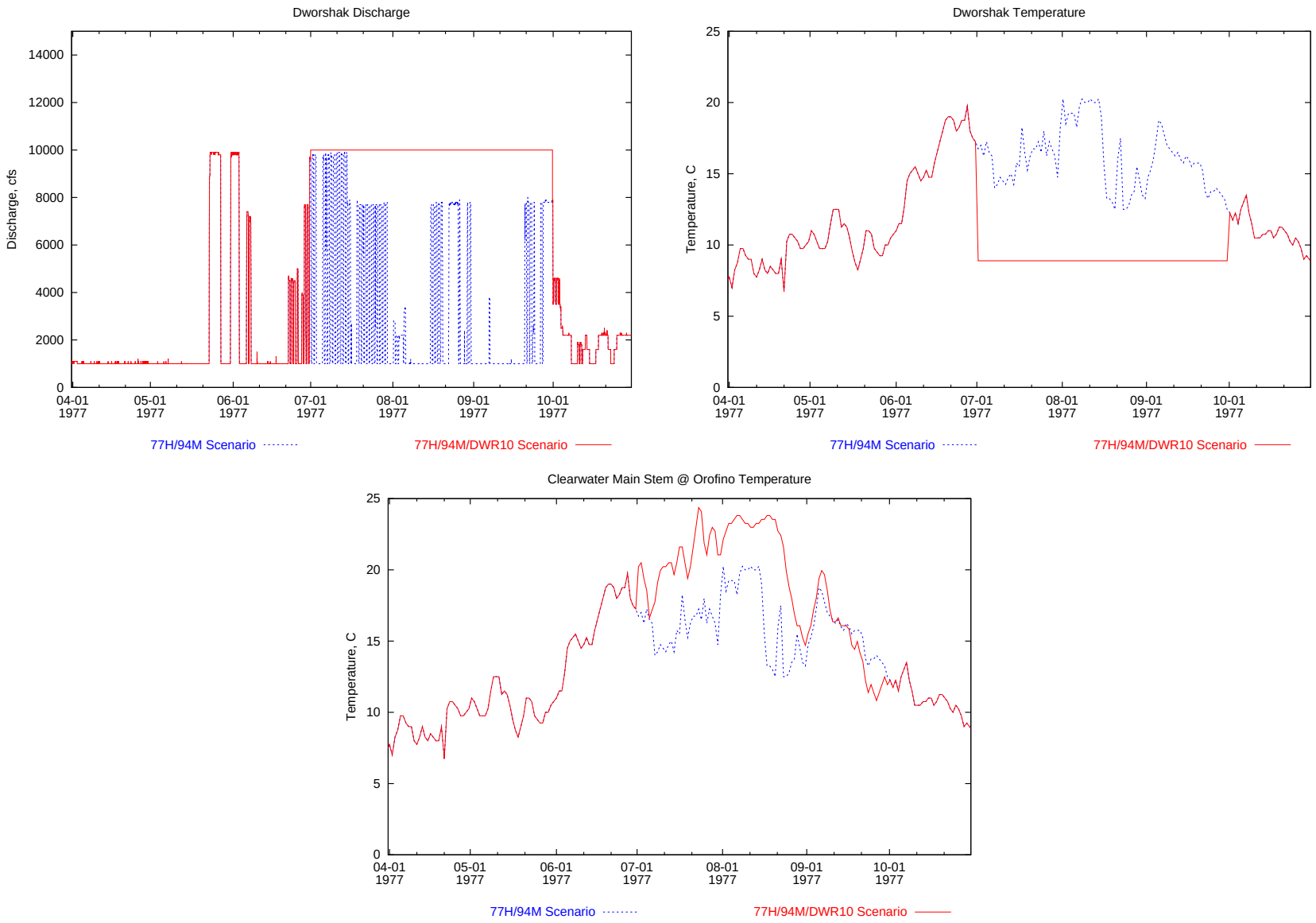

Figure 13: Altered Clearwater River boundary conditions for the 77H/94M/DWR10 scenario.

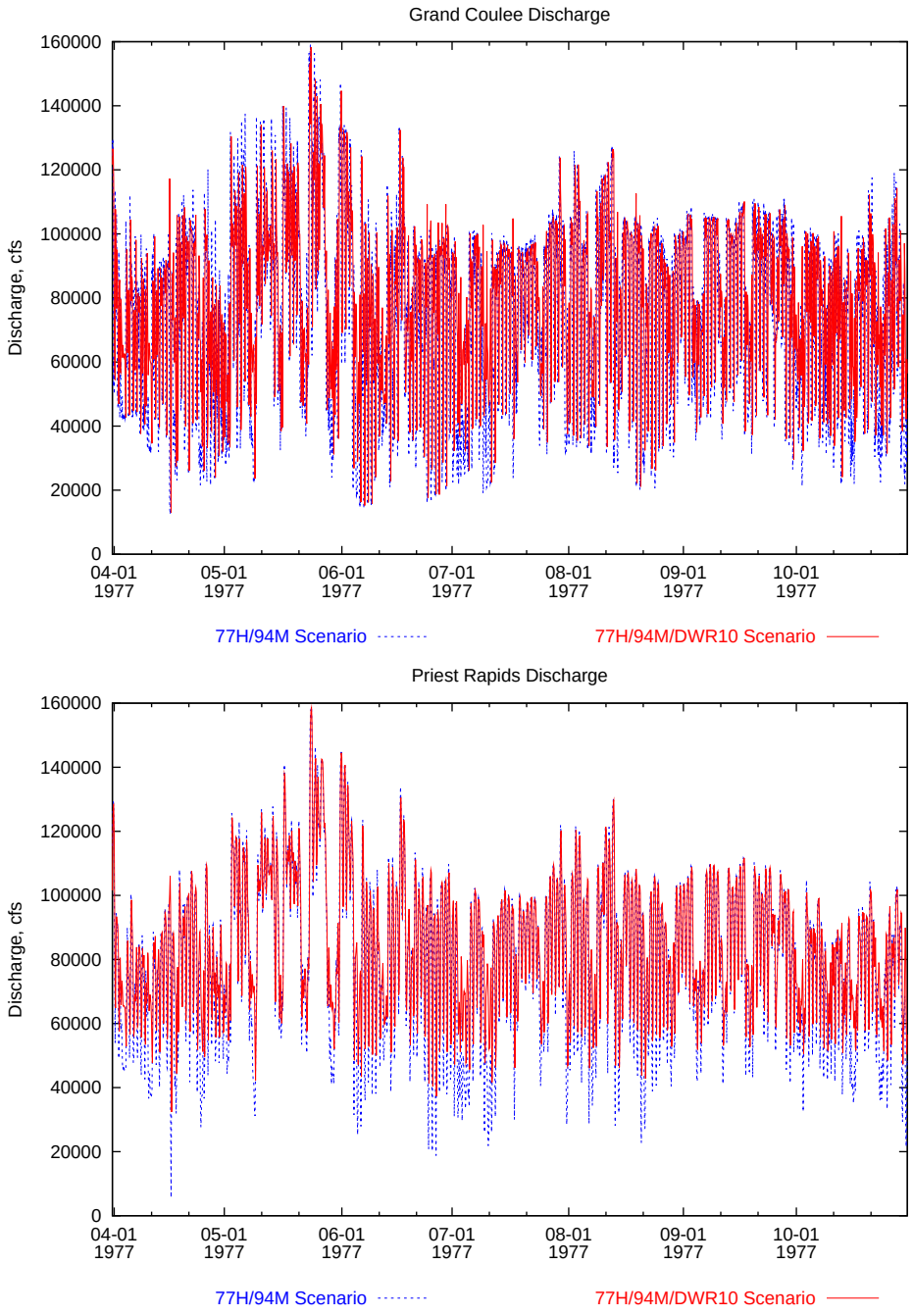

Figure 14: Altered flow boundary conditions at Grand Coulee and comparison of resulting flow at Priest Rapids.

4 77H/94M/DWR.V/7/8/10/8/4.5 Scenario

This senario differs from the base scenario (77H/94M, Section 2) in two ways: (1) discharge at Grand Coulee is manipulated in an attempt to meet minimum flow targets at Priest Rapids, and (2) Dworshak discharge and temperature is manipulated as shown in Table 2. Figures 15 and 16 show differences in boundary conditions, from the 77H/94M scenario, used at Dworshak Grand Coulee.

For this scenario, the observed, hourly 1977 flows at Grand Coulee were modified in an attempt to meet a target minimum flow at Priest Rapids. This target varied through the simulated season, as shown in Table 3. To produce the target minimum flow at PRD, the flow at Grand Coulee was not allowed to go below the Priest Rapids target minimum less 5 kcfs. This was a rough approximation to account for tributary inflow and discharge wave attenuation, but seemed to have the desired effect, as shown in Figure 16.

Table 2: Discharge and water temperature used at Dworshak in the 77H/94M/DWR.V/7/8/10/8/4.5 Scenario.

Start Date	**End Date**	**Discharge** (kcfs)	**Temperature** (°C)
01 Jan	30 Jun	(1977 cond.)	(1977 cond.)
01 Jul	15 Jul	7.0	8.89
16 Jul	31 Jul	8.0	8.89
01 Aug	15 Aug	10.0	8.89
16 Aug	31 Aug	8.0	8.89
01 Sep	16 Sep	4.5	8.89
15 Sep	31 Dec	(1977 cond.)	(1977 cond.)

Table 3: Priest Rapids target minimum flows and Grand Coulee minimum flows used in the 77H/94M/DWR.V/7/8/10/8/4.5 Scenario.

Start Date	**End Date**	**PRD Target Minimum Flow (kcfs)**	**GCL Minimum Flow (kcfs)**
01 Jan	07 May	65.0	60.0
08 May	08 May	60.0	55.0
09 May	09 May	55.0	50.0
10 May	10 May	50.0	45.0
11 May	11 May	45.0	40.0
12 May	31 Dec	36.0	31.0

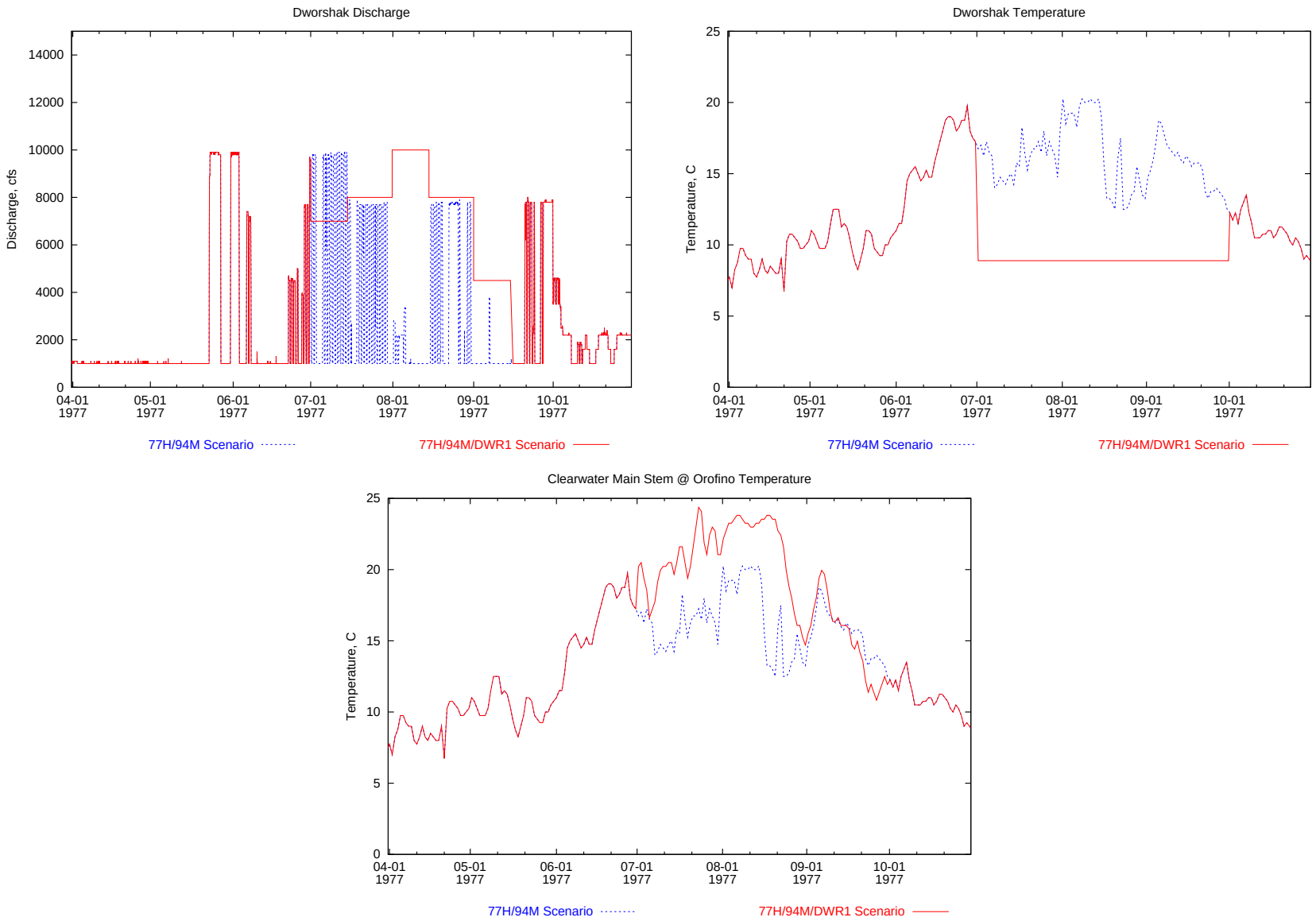

Figure 15: Altered Clearwater River boundary conditions for the 77H/94M/DWR.V/7/8/10/8/4.5 scenario.

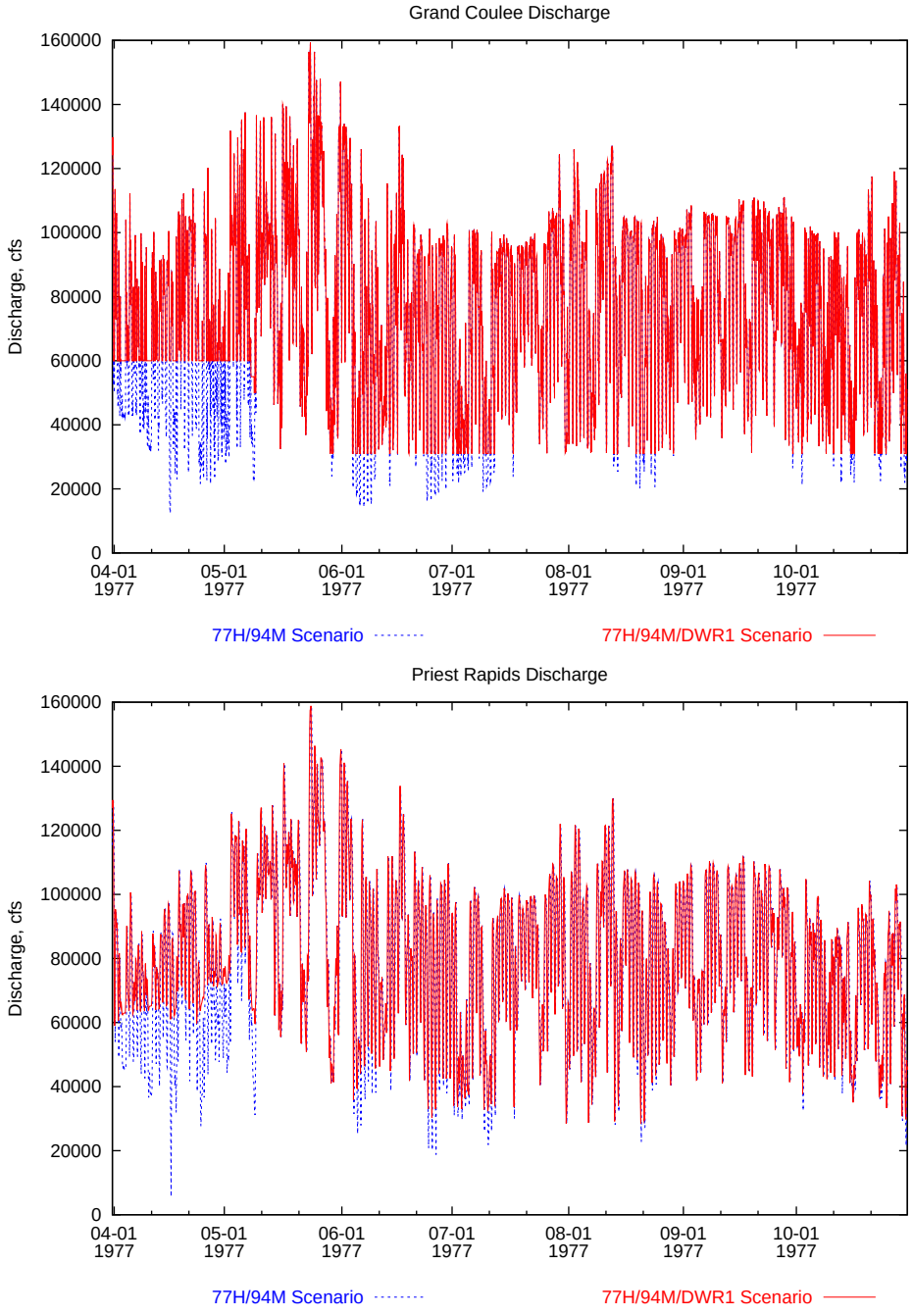

Figure 16: Altered flow boundary conditions at Grand Coulee and comparison of resulting flow at Priest Rapids in the 77H/94M/DWR.V/7/8/10/8/4.5 scenario.

5 77H/94M/DWR.V/1.5/5.5/6/7/8/10/8/7/5/4/1.4/BRN.V Scenario

In this scenario, boundary conditions are modified from the base (Section 2) as follows:

- Grand Coulee discharges are manipulated to achieve a target minimum discharge at Priest Rapids. The changes are identical to those used in the 77H/94M/DWR.V/7/8/10/8/4.5 scenario (Section 4 – refer to Table 3 and Figure 16)
- Dworshak discharges and temperature are set to those shown in Table 4 and Figure 17.
- Snake River discharge was set to that shown in Table 5 and Figure 18.

Table 4: Discharge and water temperature used at Dworshak in the 77H/94M/DWR.V/7/8/10/8/4.5 Scenario.

		NF Clearwater at Dworshak	
Start Date	**End Date**	**Discharge** (kcfs)	**Temperature** (°C)
01 Jan	02 Jun	(1977 cond.)	(1977 cond.)
03 Jun	07 Jul	1.5	8.89
08 Jul	14 Jul	5.5	8.89
15 Jul	21 Jul	6.0	8.89
22 Jul	28 Jul	7.0	8.89
29 Jul	04 Aug	8.0	8.89
05 Aug	15 Aug	10.0	8.89
26 Aug	01 Sep	8.0	8.89
02 Sep	08 Sep	7.0	8.89
09 Sep	15 Sep	5.0	8.89
16 Sep	22 Sep	4.0	8.89
23 Sep	30 Sep	1.4	8.89
01 Oct	31 Dec	(1977 cond.)	(1977 cond.)

Figure 17: Altered Clearwater River boundary conditions for the 77H/94M/DWR.V/1.5/5.5/6/7/8/10/8/7/5/4/1.4/BRN.V scenario.

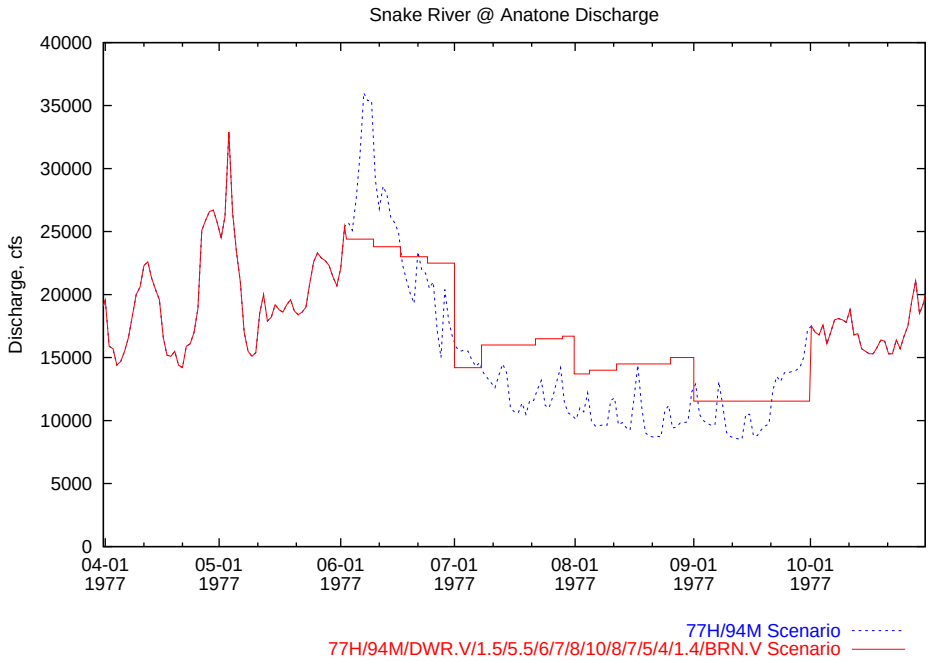

Figure 18: Altered flow boundary condition for the Snake River at Anatone in the 77H/94M/DWR.V/1.5/5.5/6/7/8/10/8/7/5/4/1.4/BRN.V scenario.

Table 5: Discharge and water temperature used for the Snake River at Anatone in the 77H/94M/DWR.V/7/8/10/8/4.5 Scenario.

		Snake River at Anatone	
Start Date	**End Date**	**Discharge** (kcfs)	**Temperature** (°C)
01 Jan	02 Jun	(1977 cond.)	(1977 cond.)
03 Jun	09 Jun	24.4	(1977 cond.)
10 Jun	16 Jun	23.8	(1977 cond.)
17 Jun	23 Jun	23.0	(1977 cond.)
24 Jun	30 Jun	22.5	(1977 cond.)
01 Jul	07 Jul	14.2	(1977 cond.)
08 Jul	14 Jul	16.0	(1977 cond.)
15 Jul	21 Jul	16.0	(1977 cond.)
22 Jul	28 Jul	16.5	(1977 cond.)
29 Jul	31 Jul	16.7	(1977 cond.)
01 Aug	04 Aug	13.7	(1977 cond.)
05 Aug	11 Aug	14.0	(1977 cond.)
12 Aug	25 Aug	14.5	(1977 cond.)
26 Aug	31 Aug	15.0	(1977 cond.)
01 Sep	30 Sep	11.6	(1977 cond.)
01 Oct	31 Dec	(1977 cond.)	(1977 cond.)

6 Scenario Temperature Comparisons

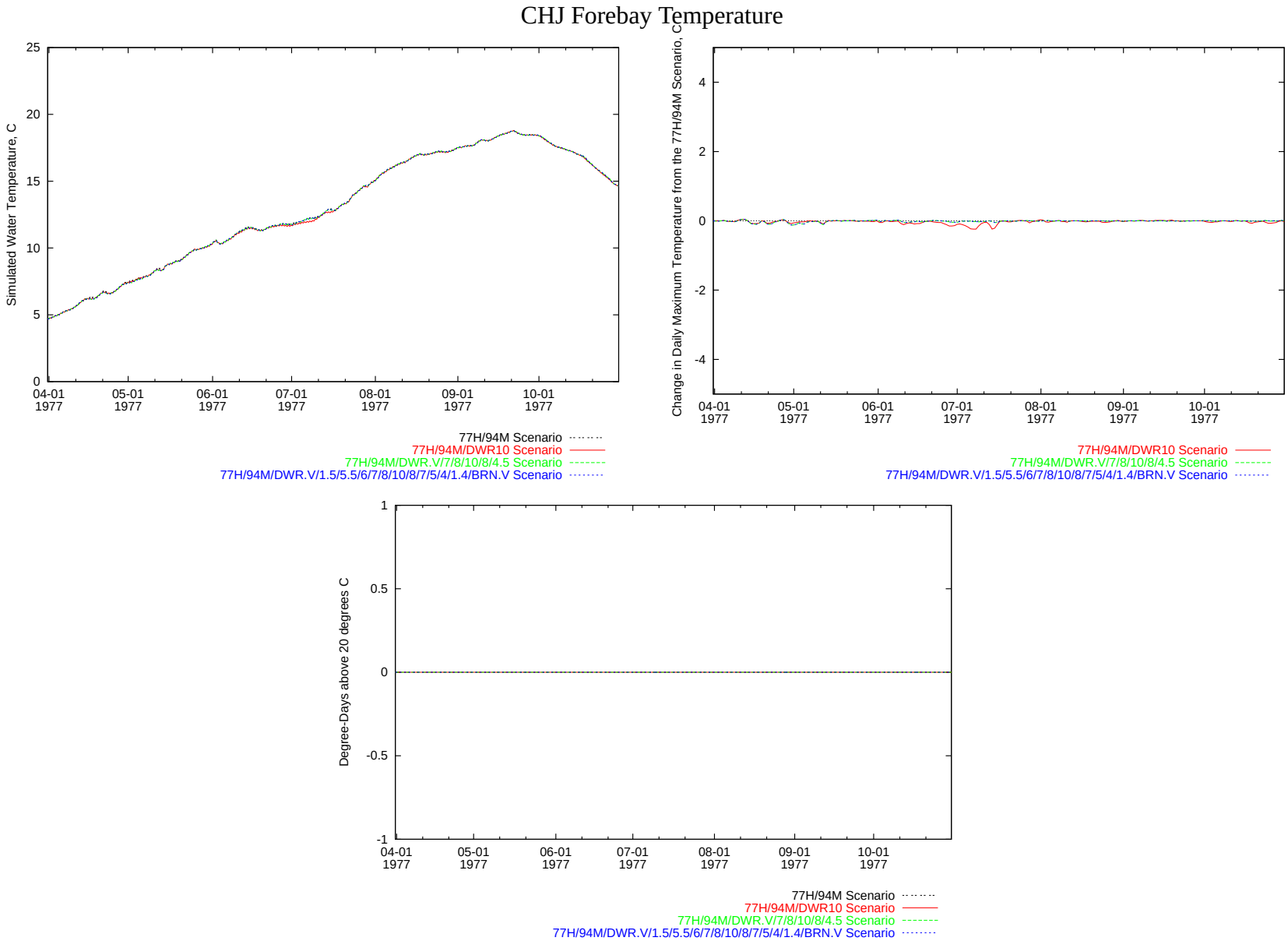

Figure 19: Time series comparison of simulated temperature at the CHJ Forebay.

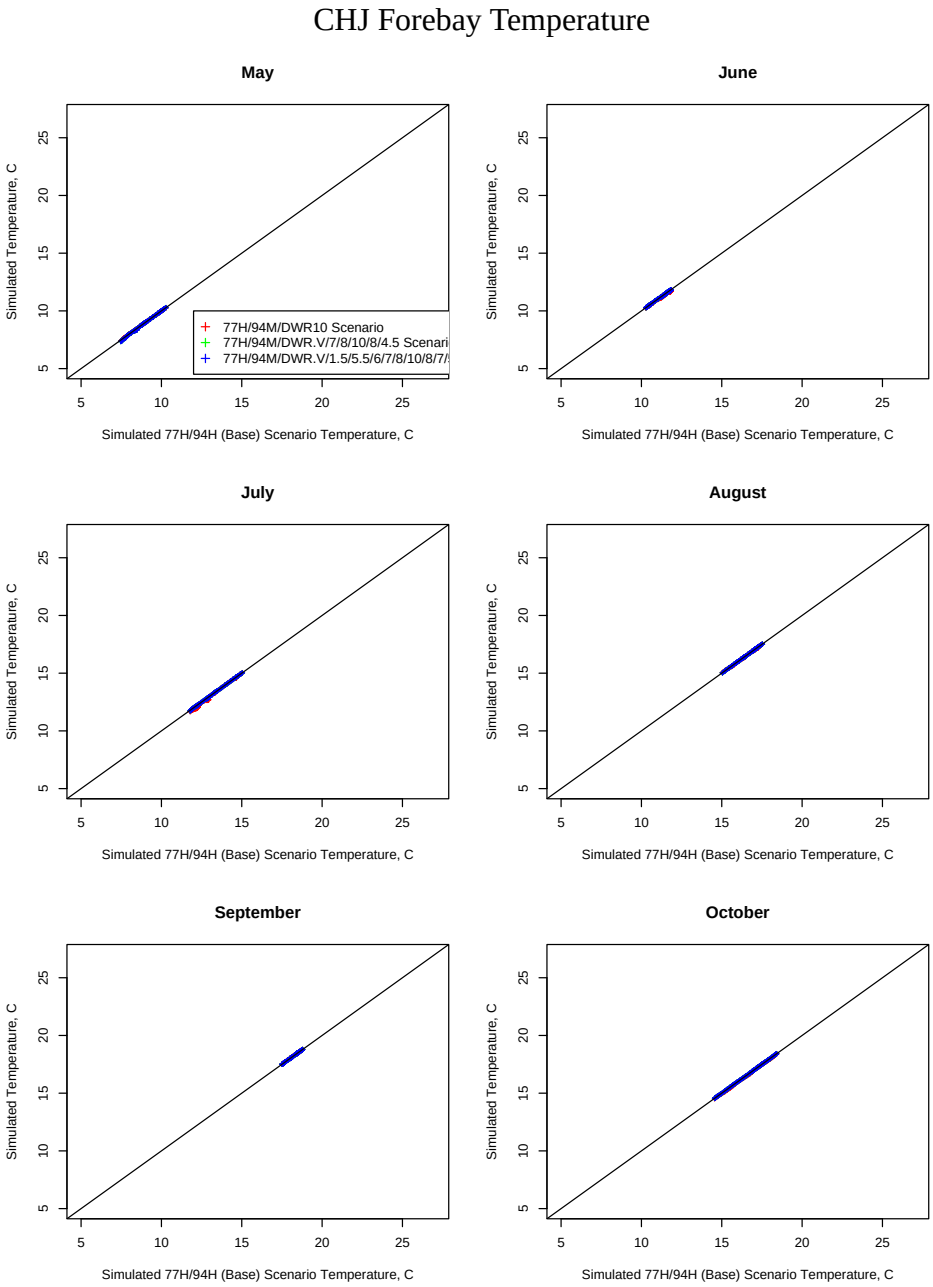

Figure 20: Scatter plot comparison, by month, of simulated temperature at the CHJ Forebay.

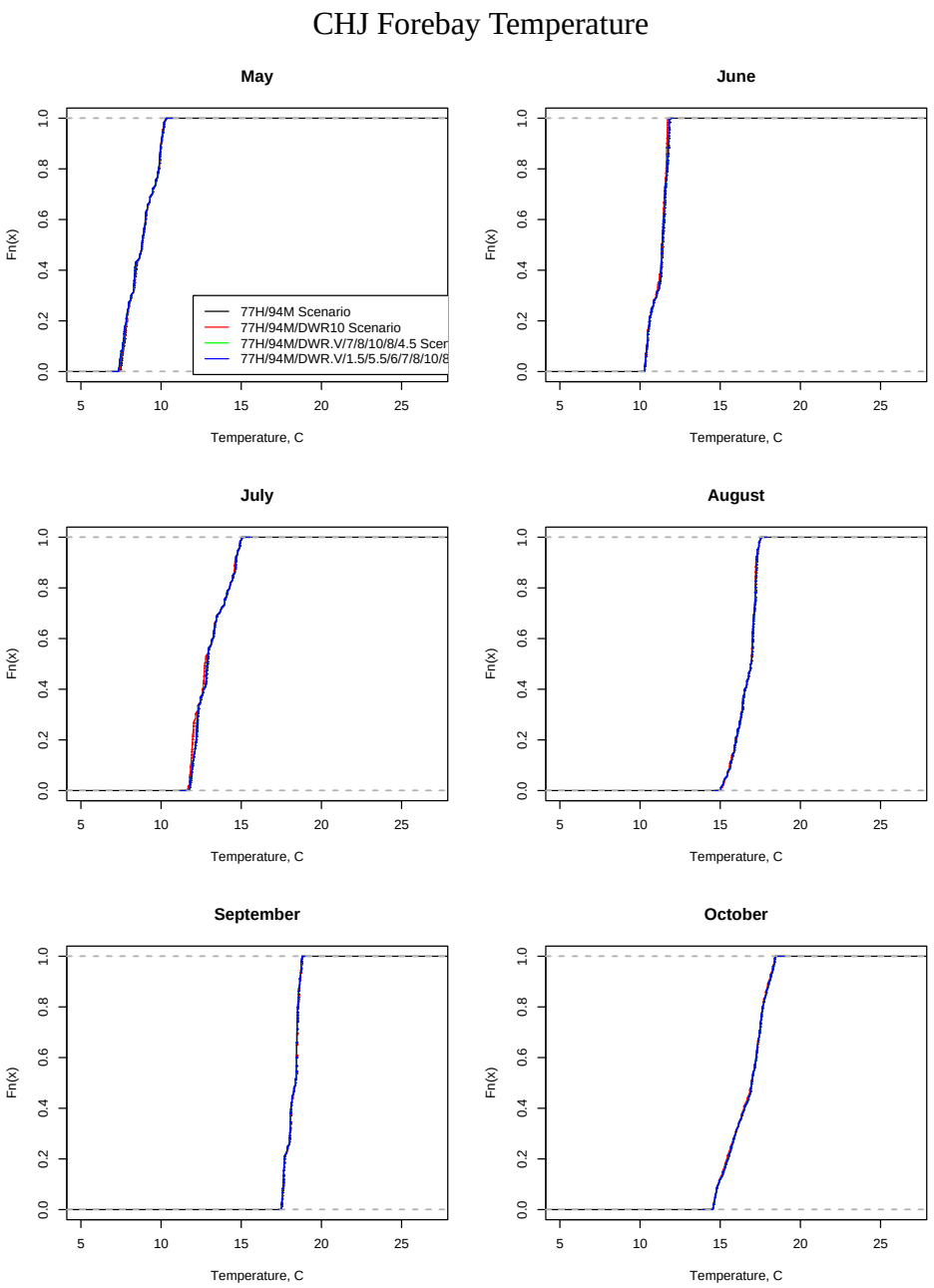

Figure 21: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the CHJ Forebay.

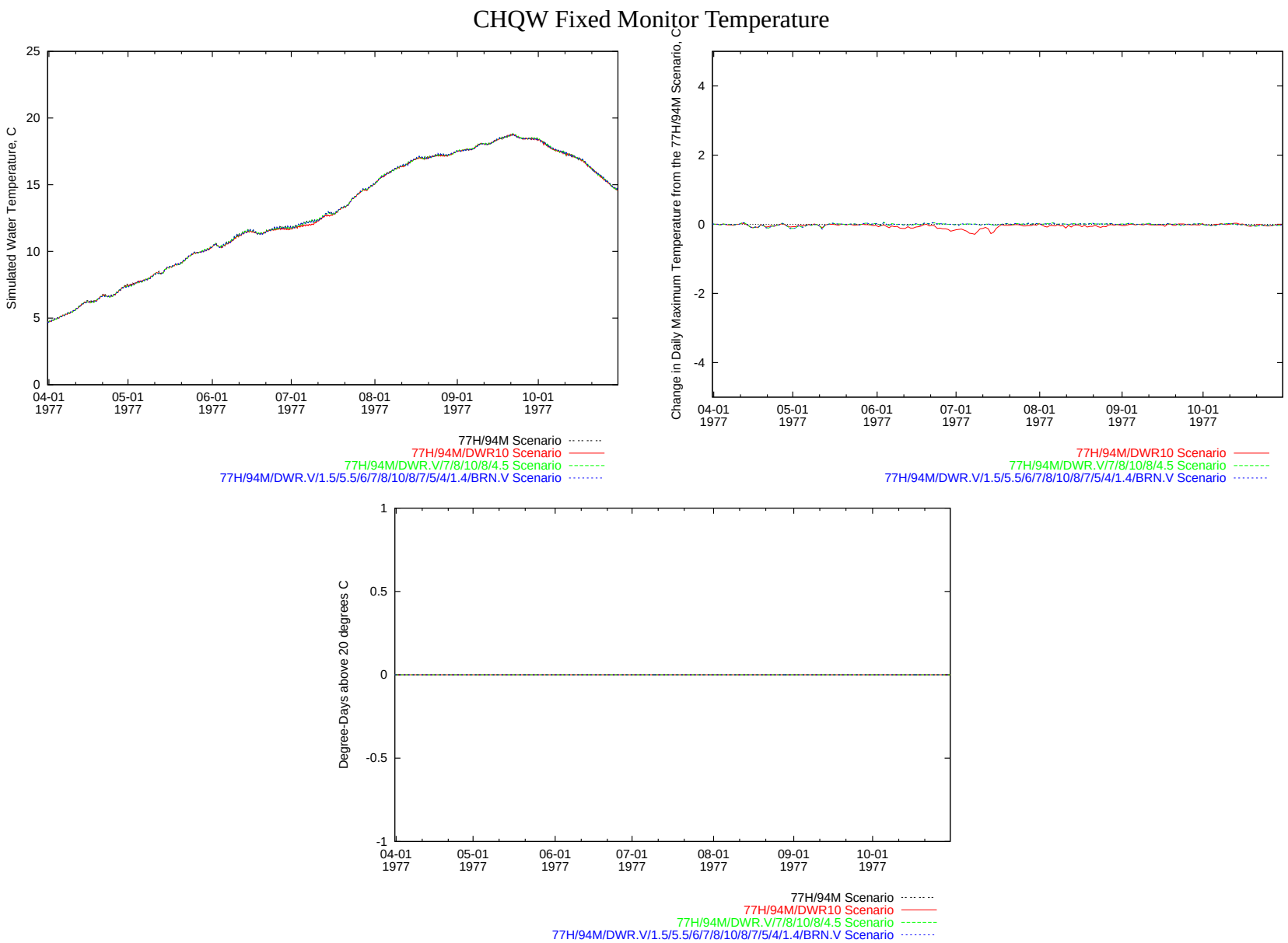

Figure 22: Time series comparison of simulated temperature at the CHQW Fixed Monitor.

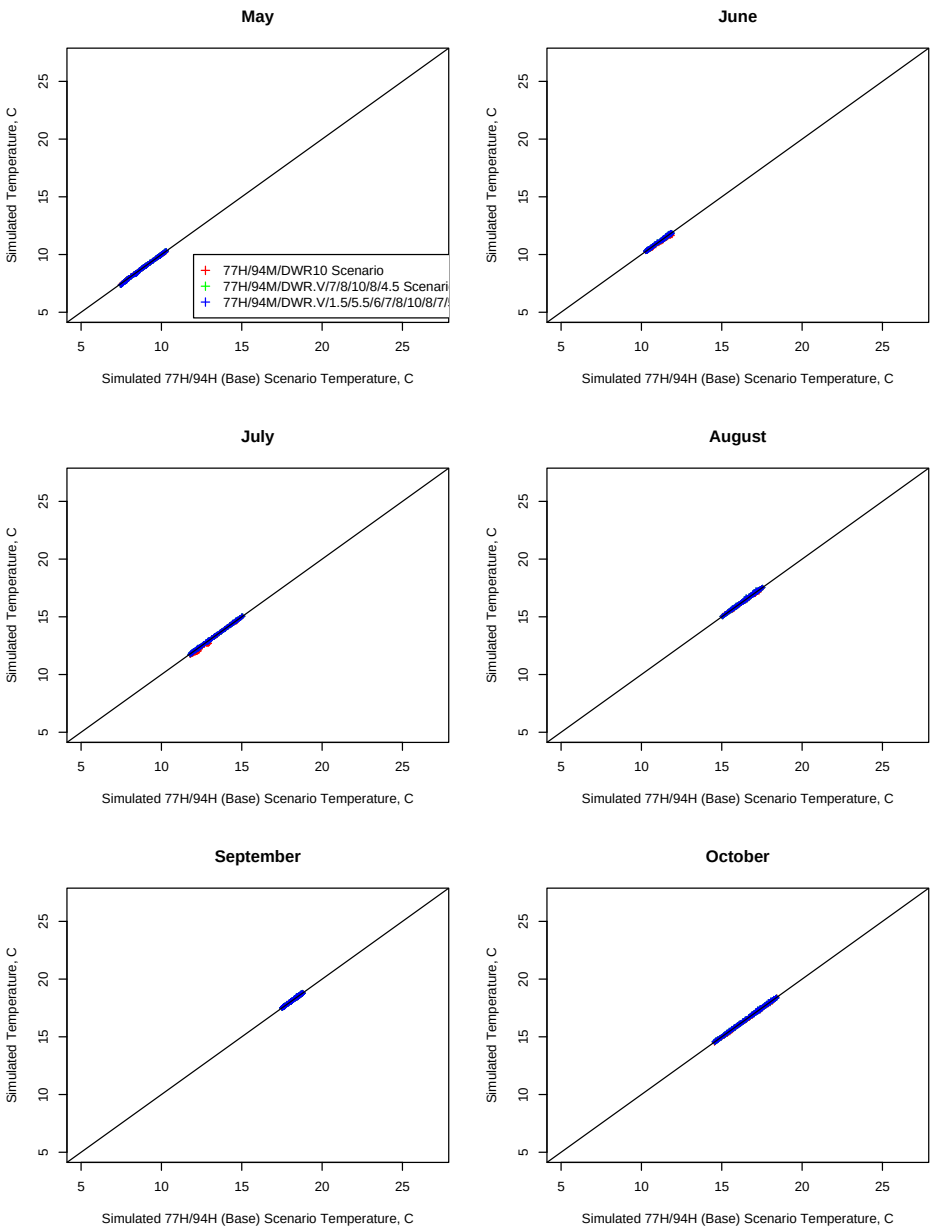

Figure 23: Scatter plot comparison, by month, of simulated temperature at the CHQW Fixed Monitor.

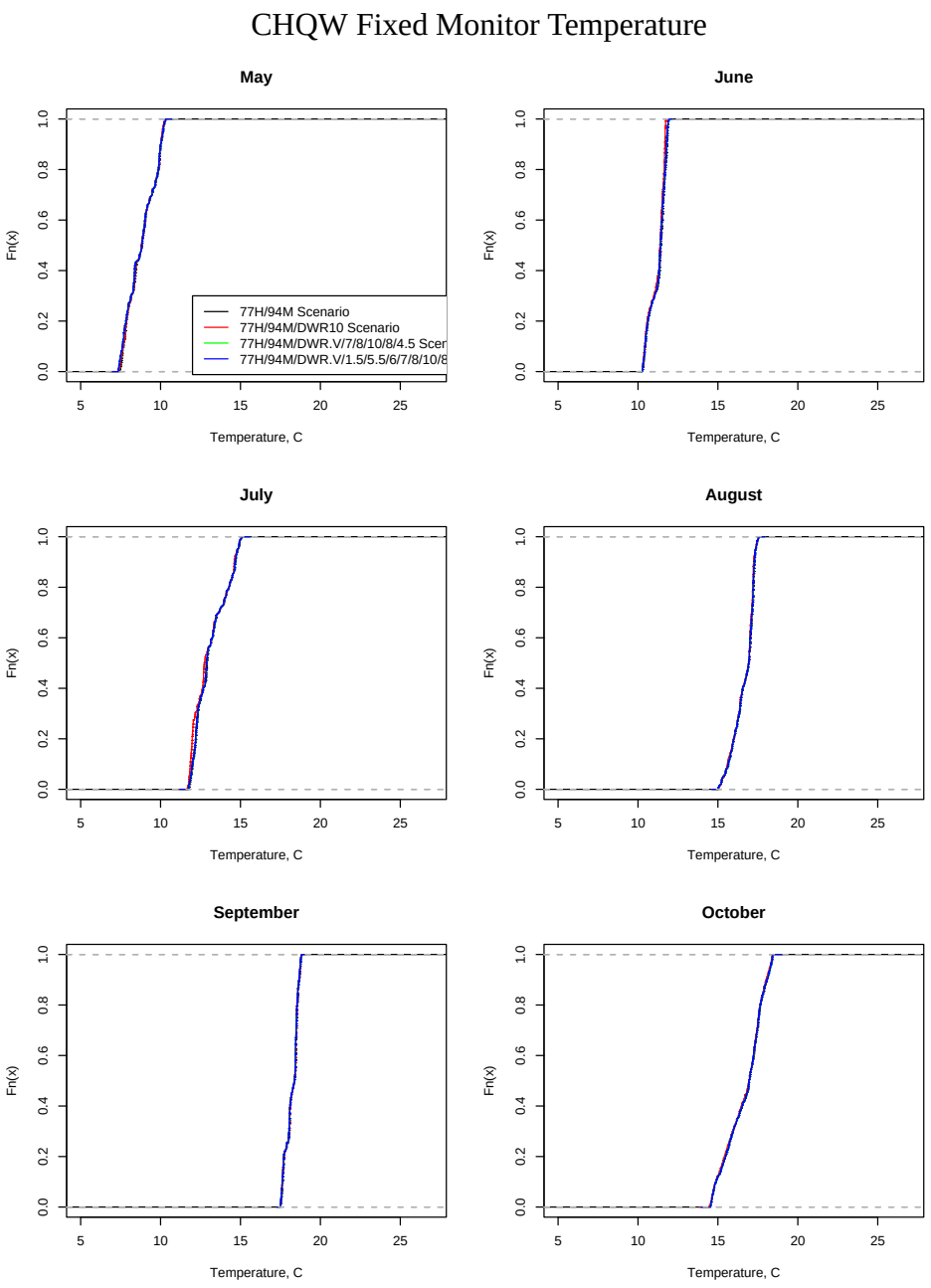

Figure 24: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the CHQW Fixed Monitor.

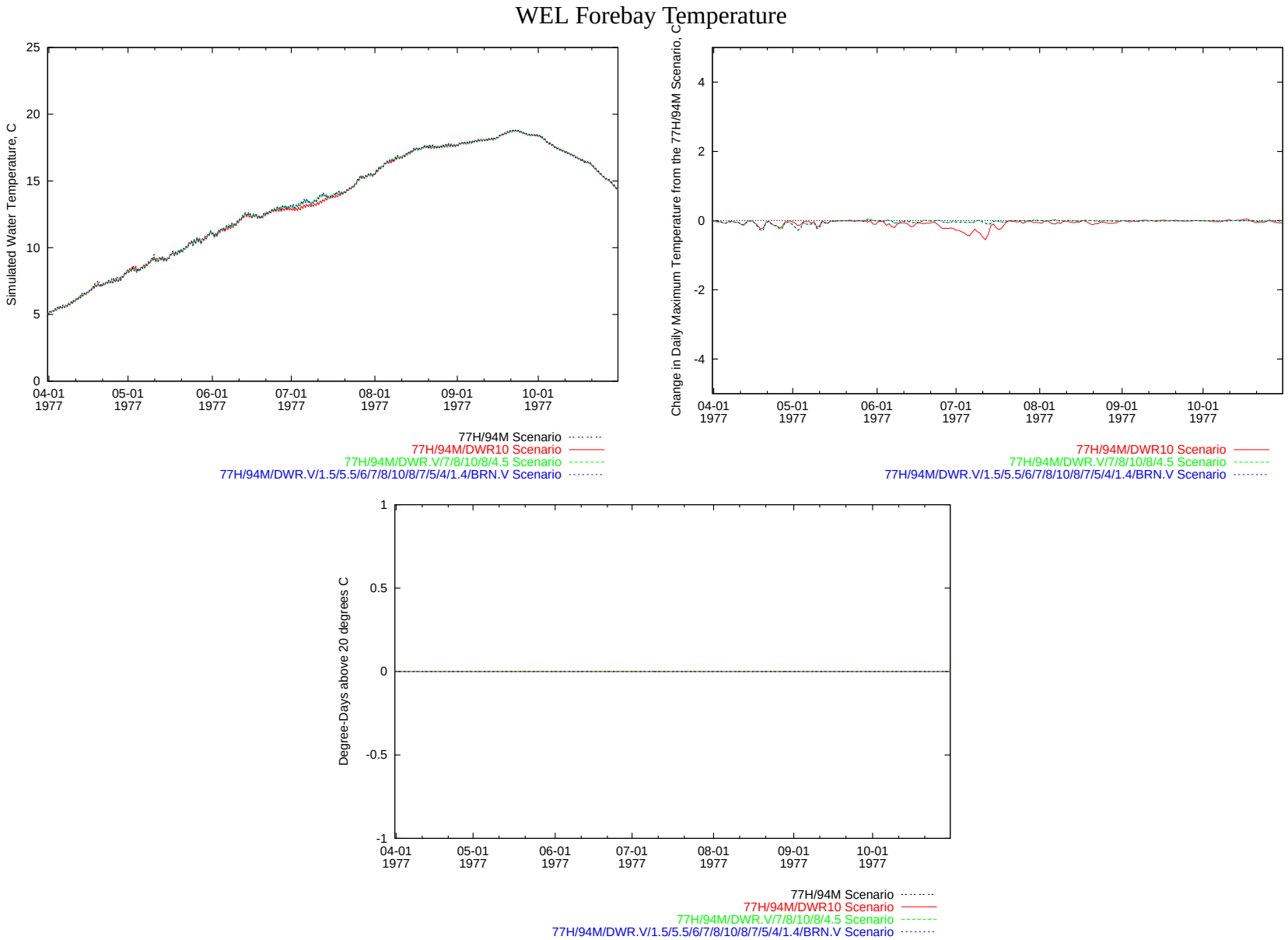

Figure 25: Time series comparison of simulated temperature at the WEL Forebay.

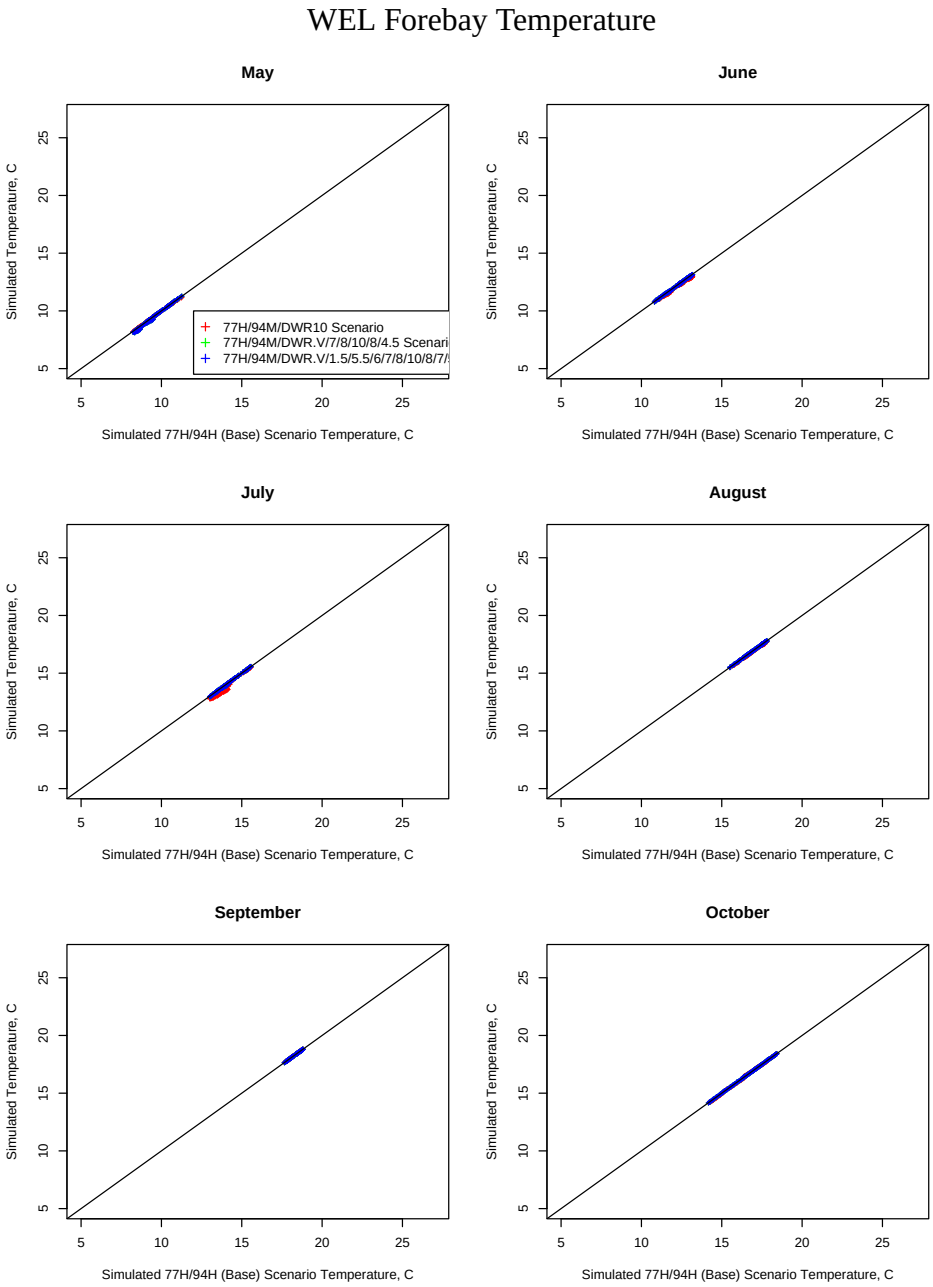

Figure 26: Scatter plot comparison, by month, of simulated temperature at the WEL Forebay.

WEL Forebay Temperature

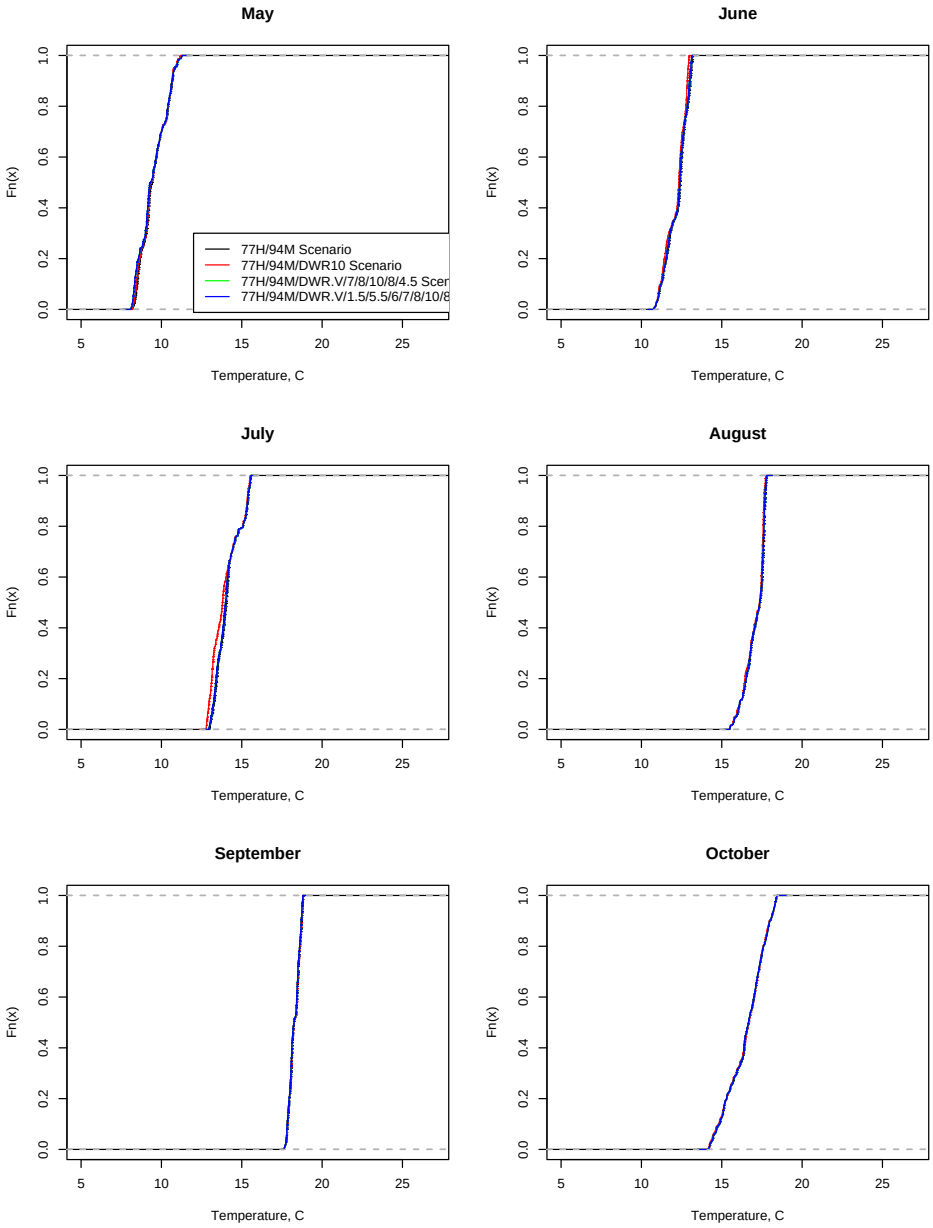

Figure 27: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the WEL Forebay.

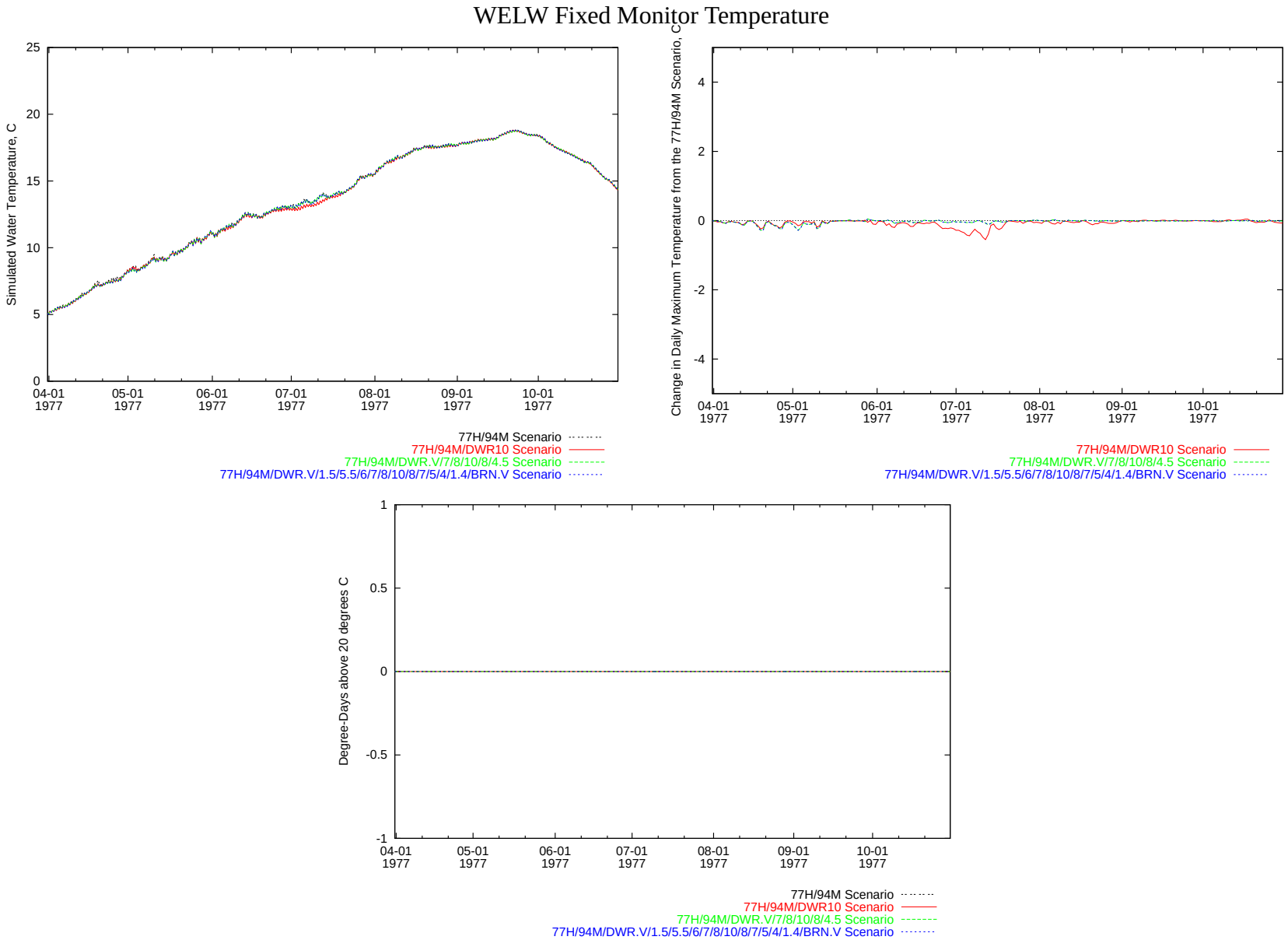

Figure 28: Time series comparison of simulated temperature at the WELW Fixed Monitor.

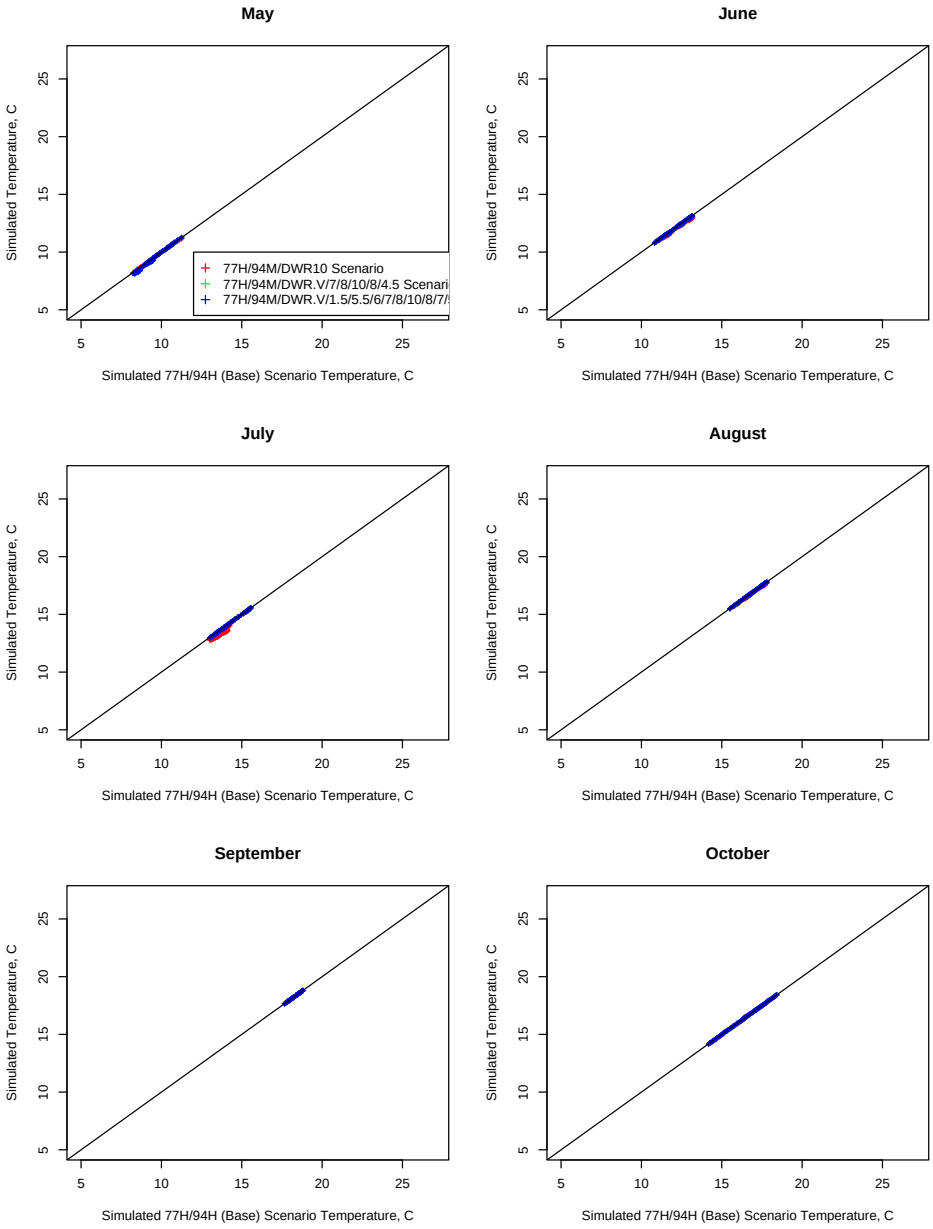

Figure 29: Scatter plot comparison, by month, of simulated temperature at the WELW Fixed Monitor.

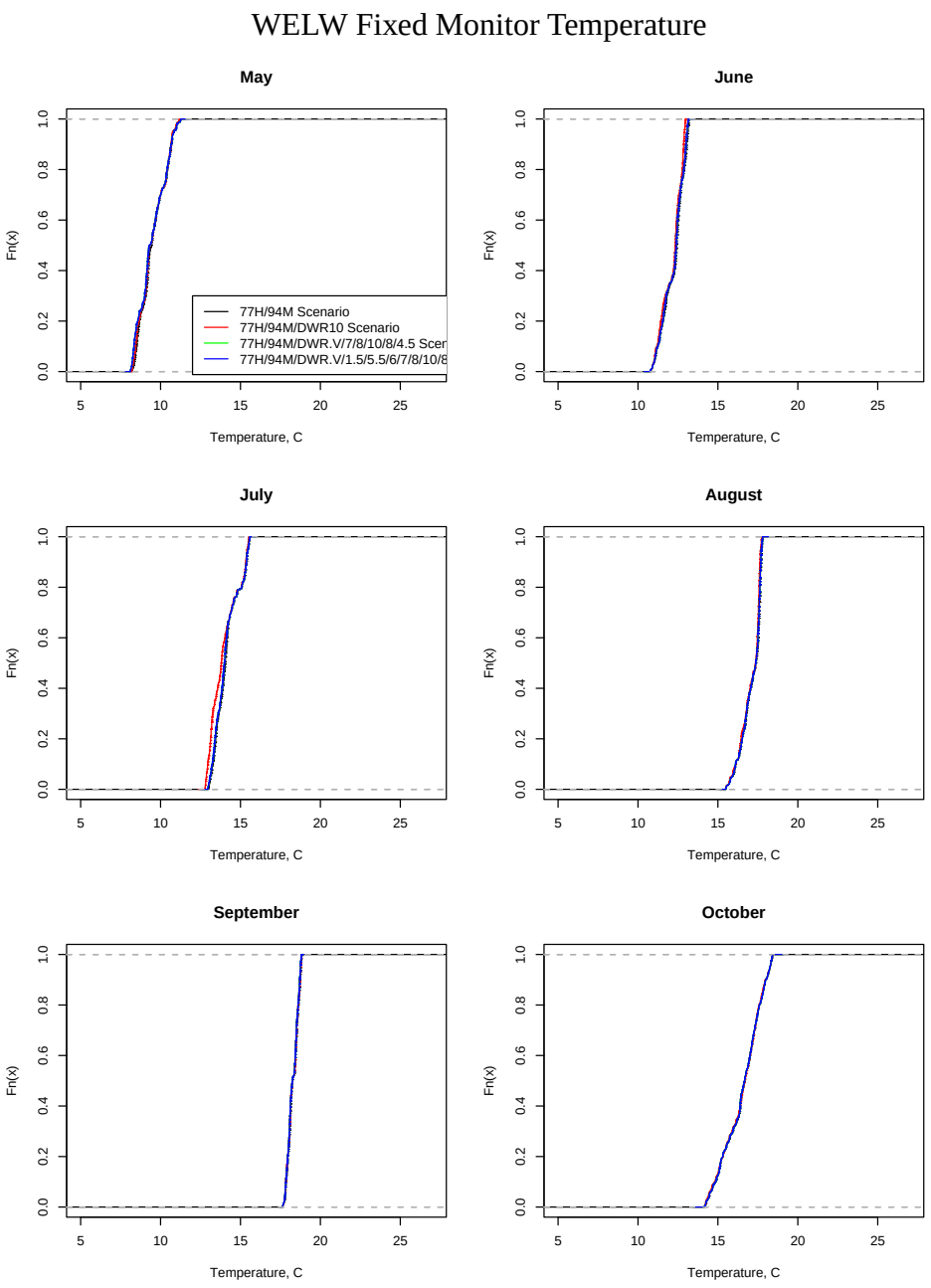

Figure 30: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the WELW Fixed Monitor.

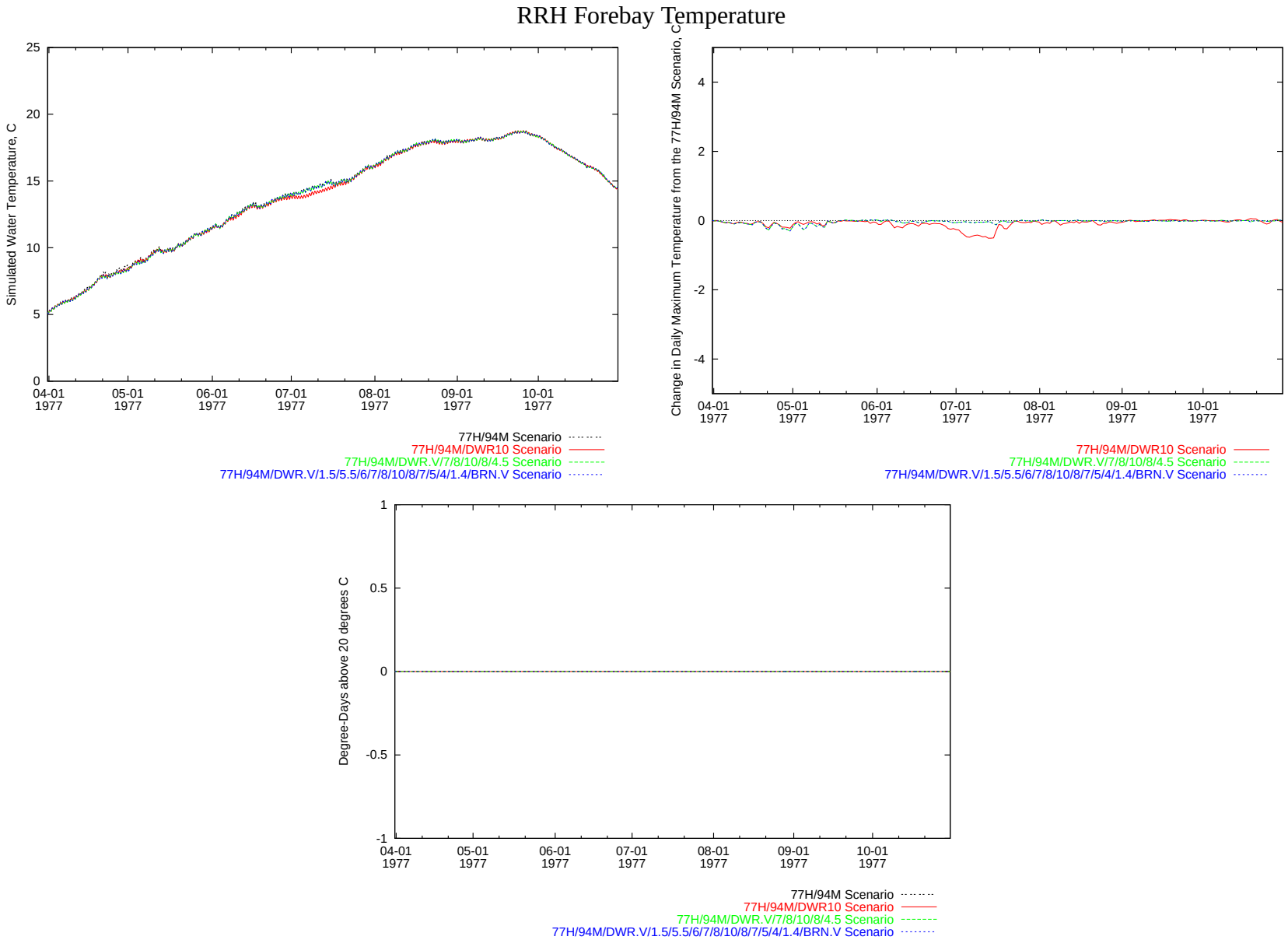

Figure 31: Time series comparison of simulated temperature at the RRH Forebay.

RRH Forebay Temperature

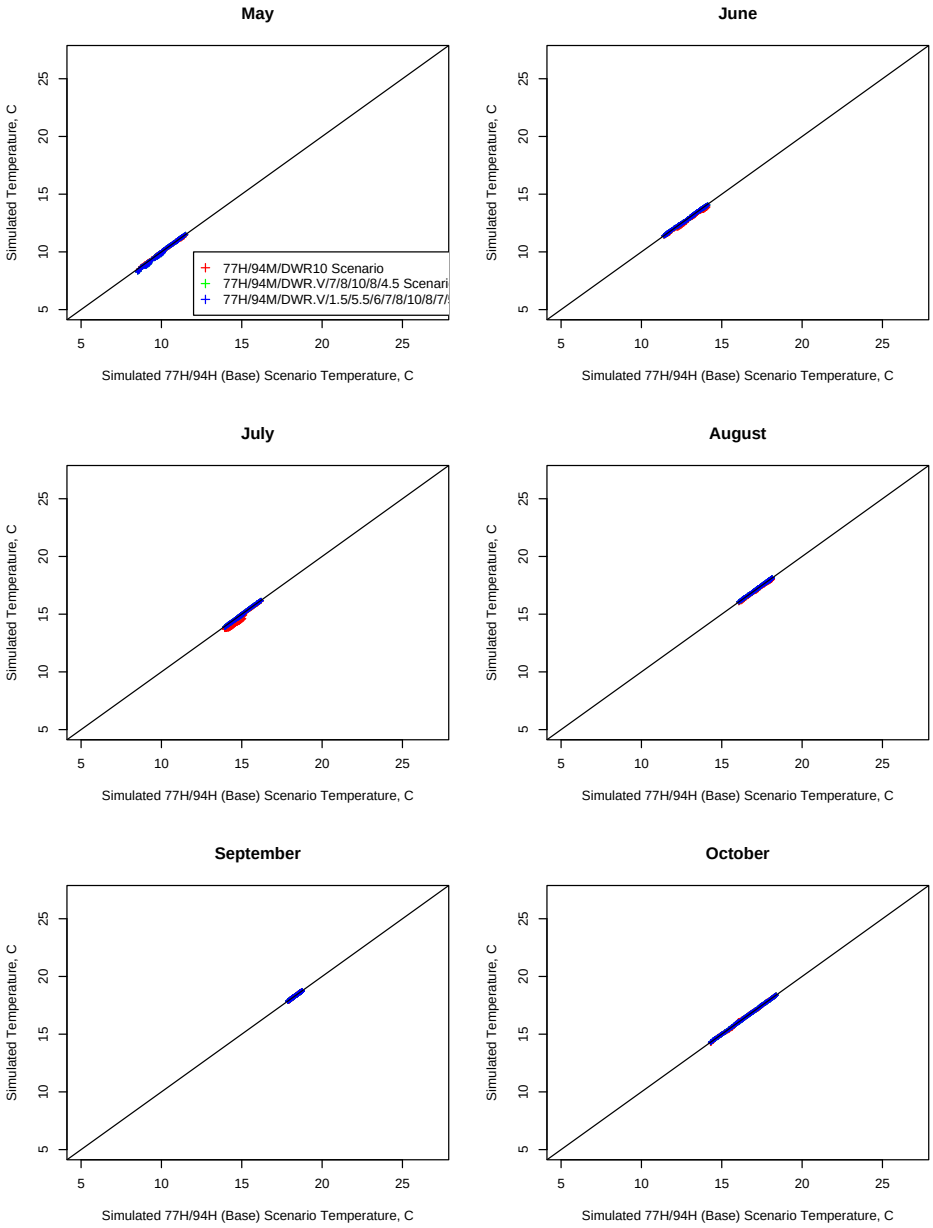

Figure 32: Scatter plot comparison, by month, of simulated temperature at the RRH Forebay.

RRH Forebay Temperature

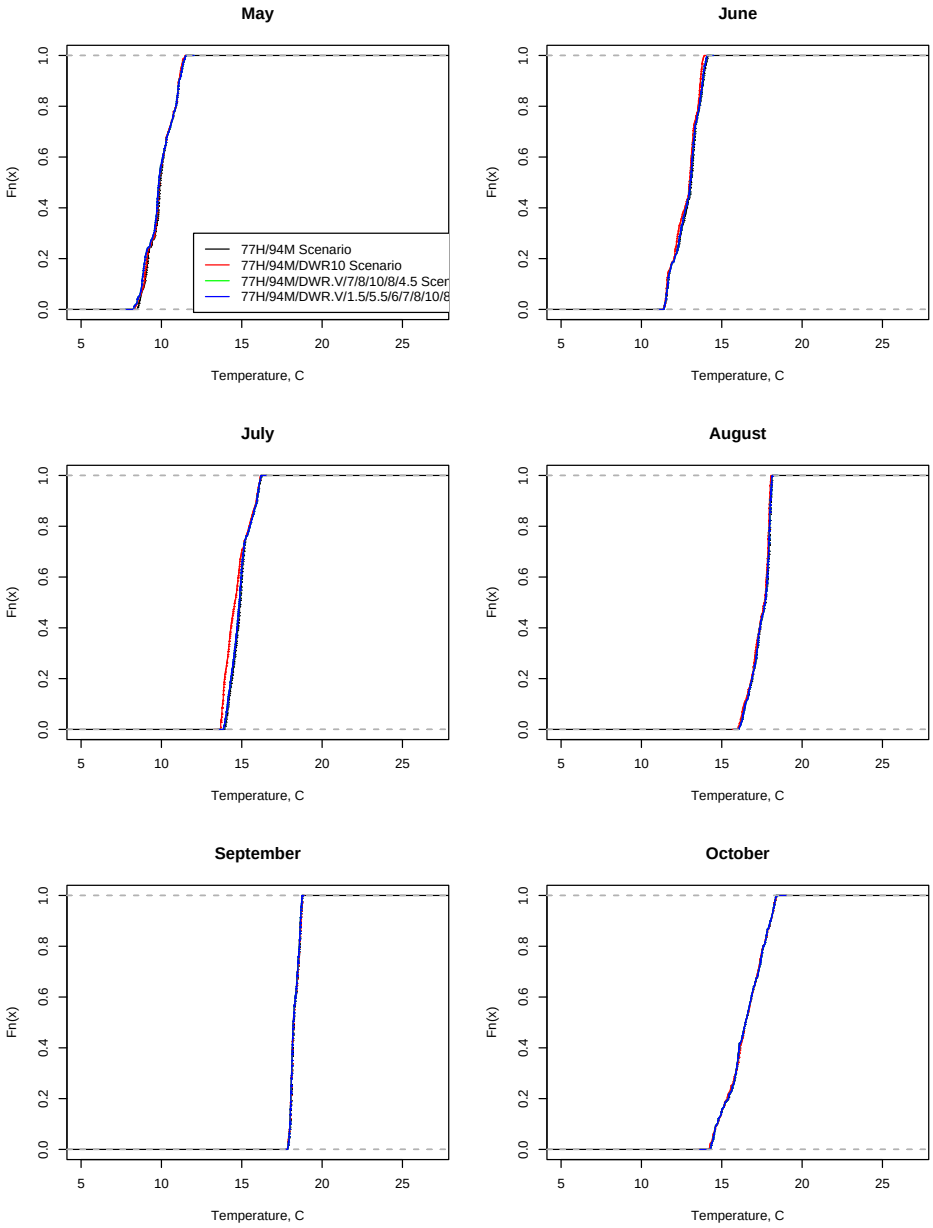

Figure 33: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the RRH Forebay.

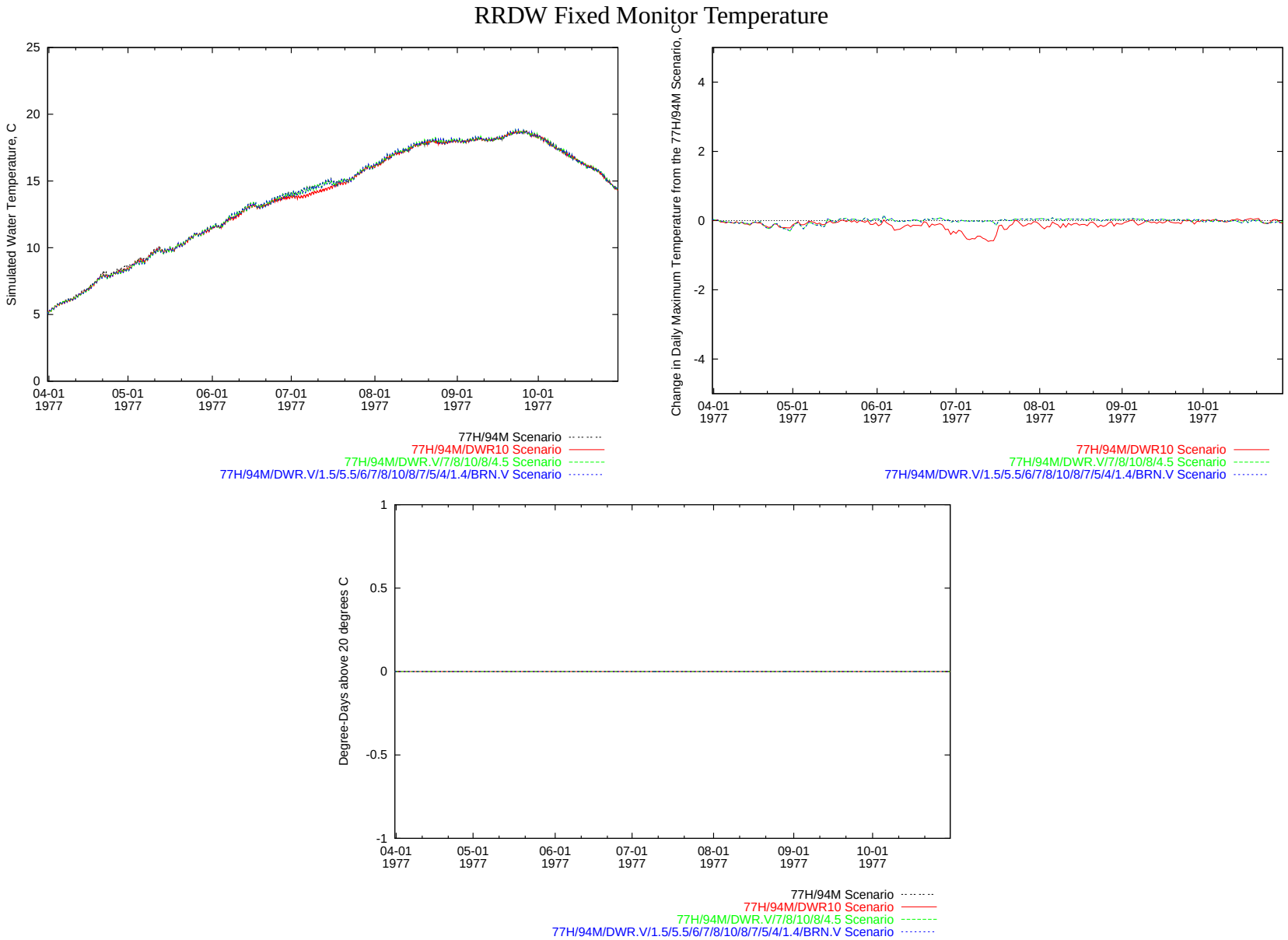

Figure 34: Time series comparison of simulated temperature at the RRDW Fixed Monitor.

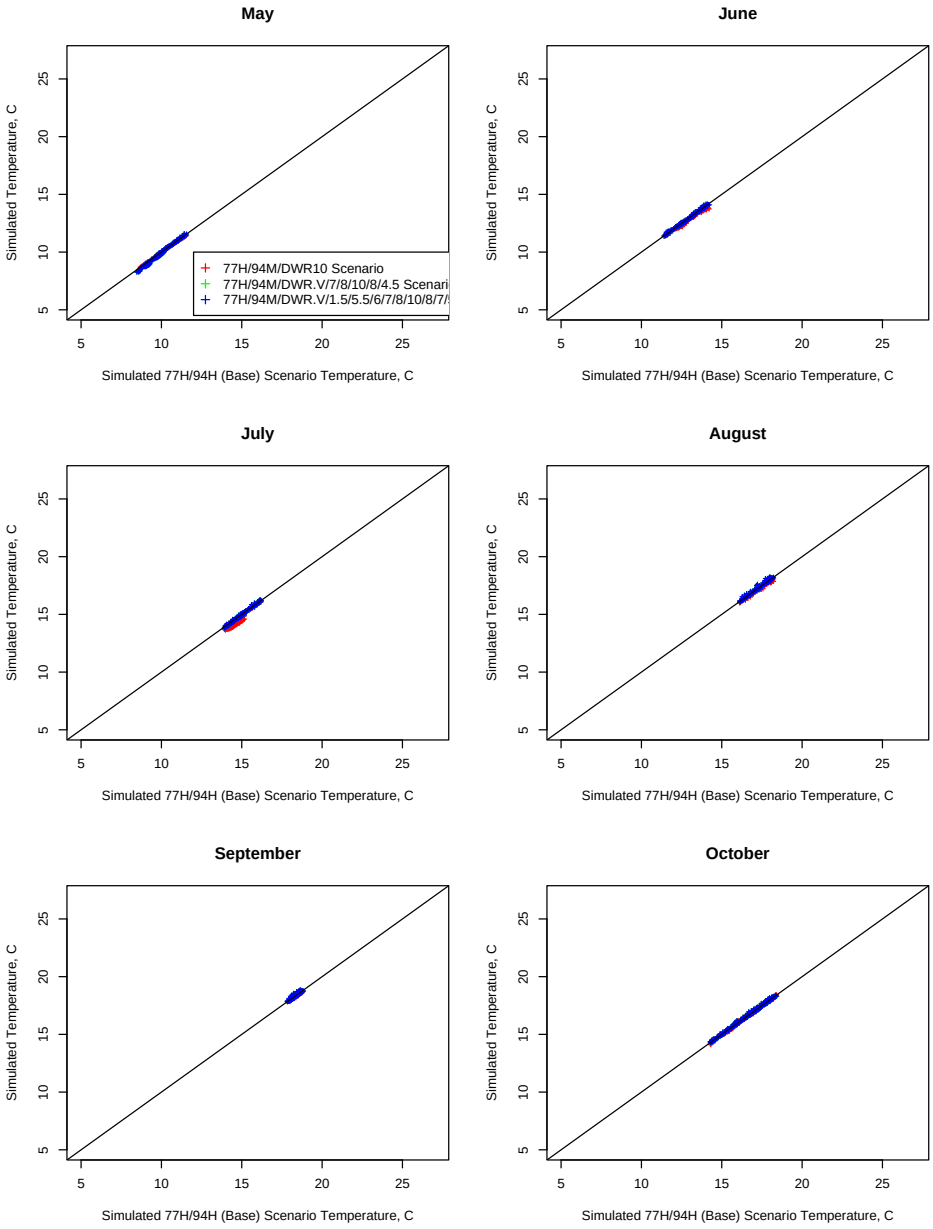

Figure 35: Scatter plot comparison, by month, of simulated temperature at the RRDW Fixed Monitor.

RRDW Fixed Monitor Temperature

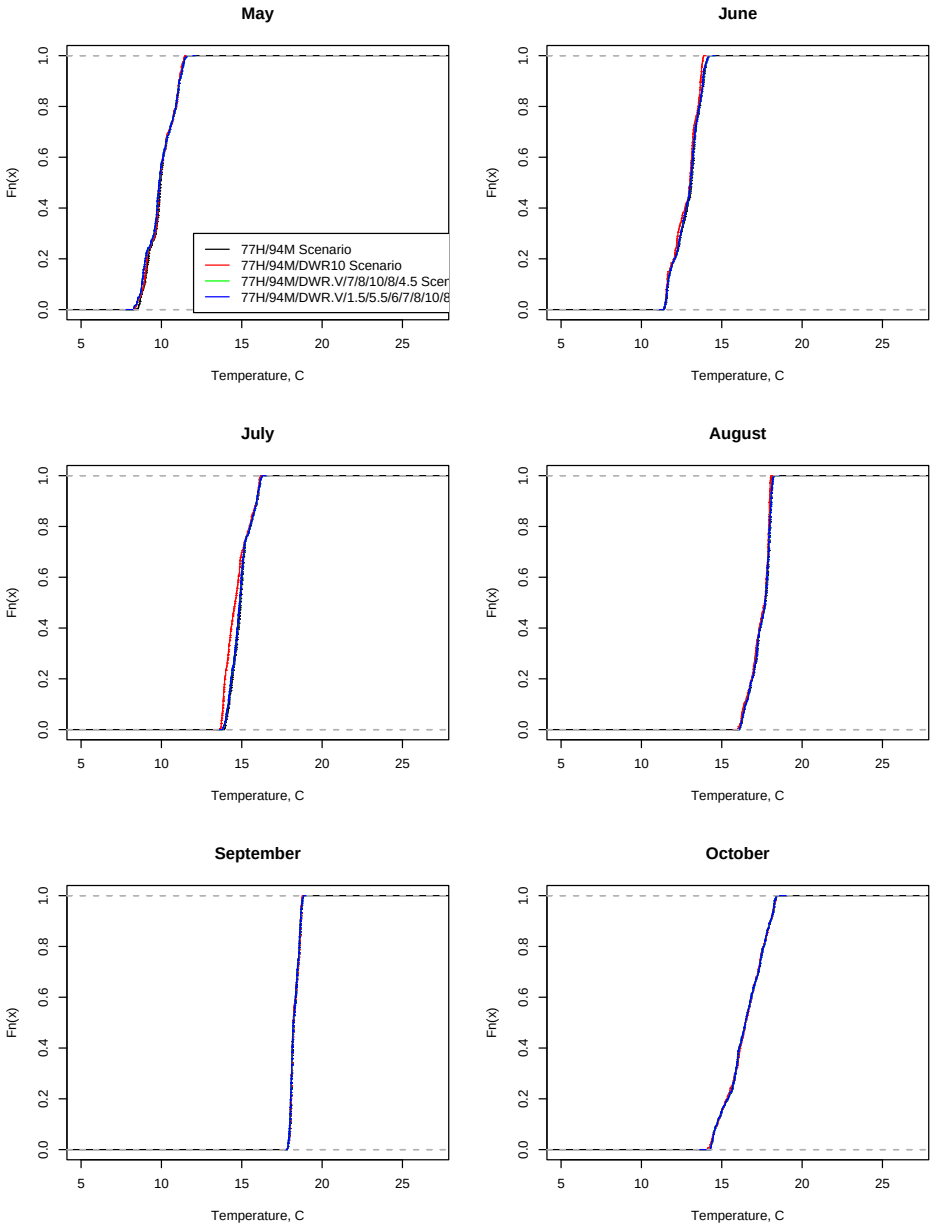

Figure 36: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the RRDW Fixed Monitor.

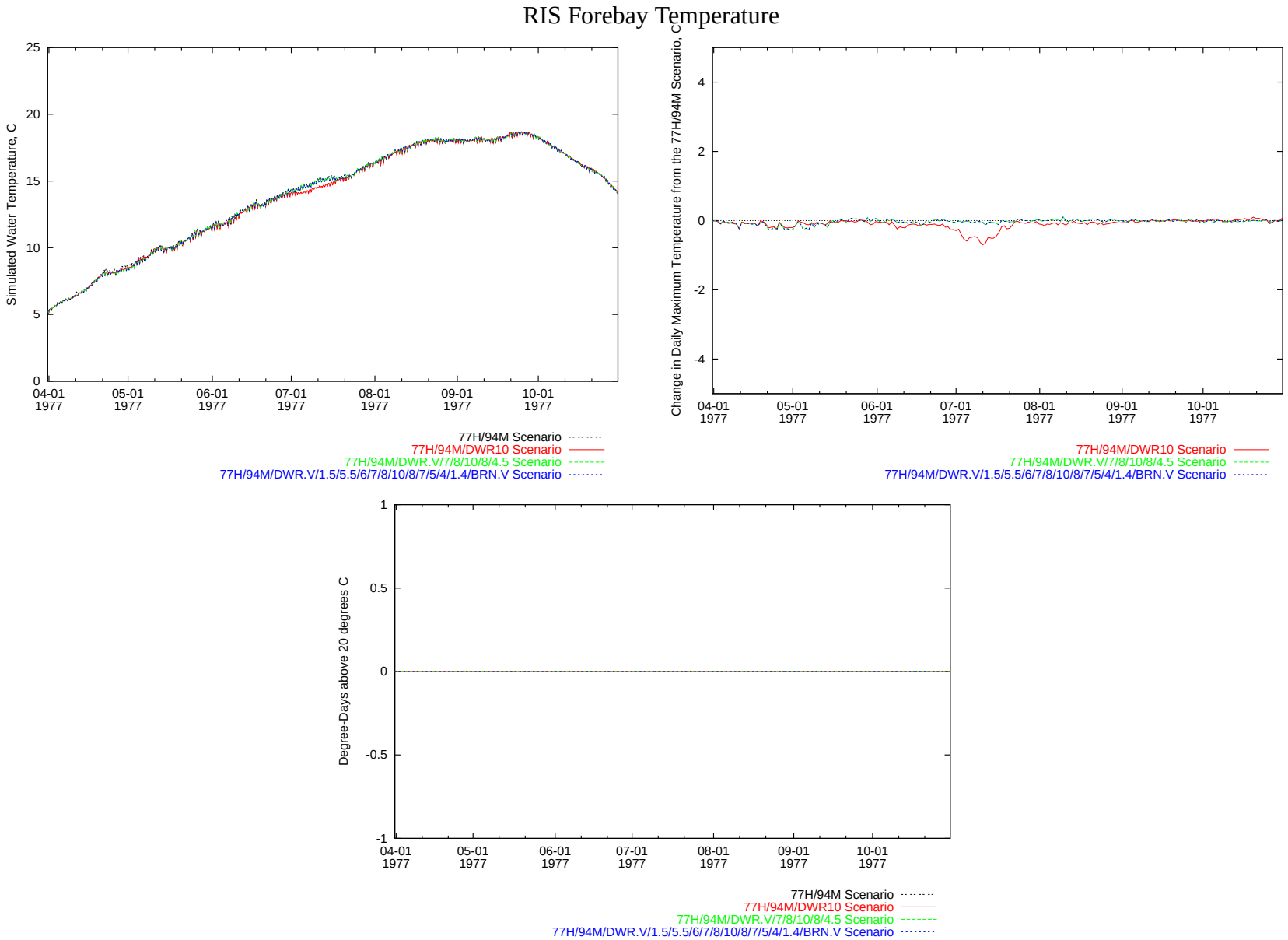

Figure 37: Time series comparison of simulated temperature at the RIS Forebay.

RIS Forebay Temperature

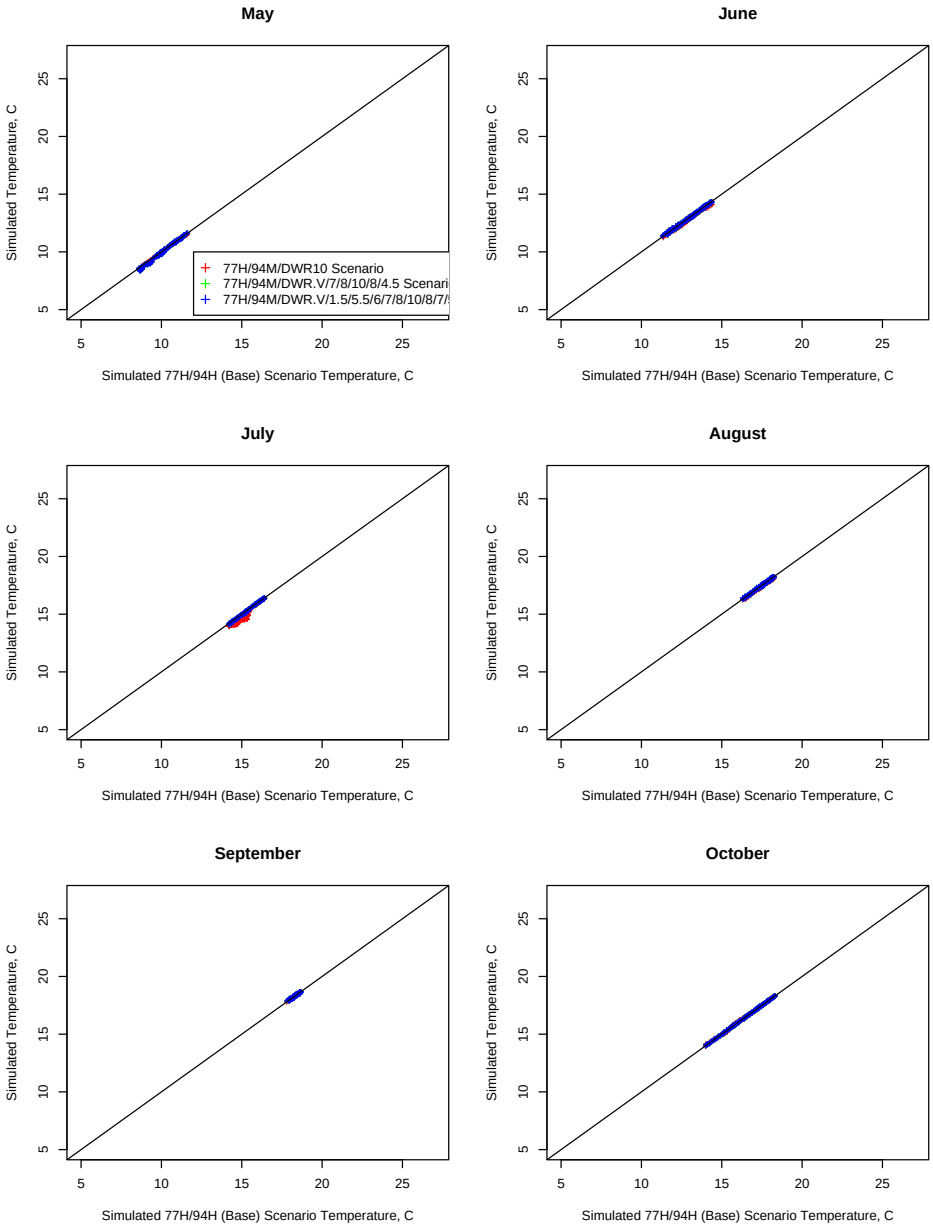

Figure 38: Scatter plot comparison, by month, of simulated temperature at the RIS Forebay.

RIS Forebay Temperature

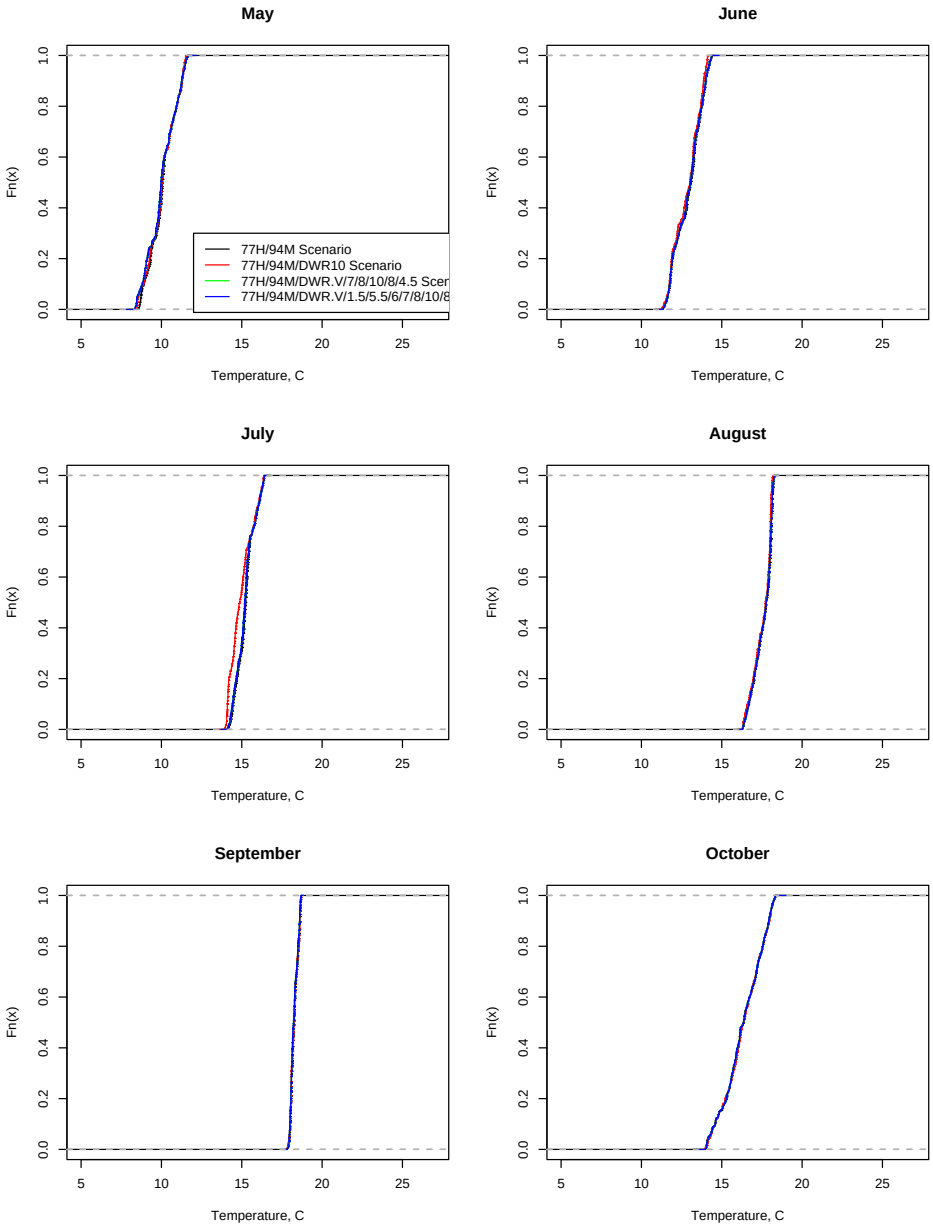

Figure 39: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the RIS Forebay.

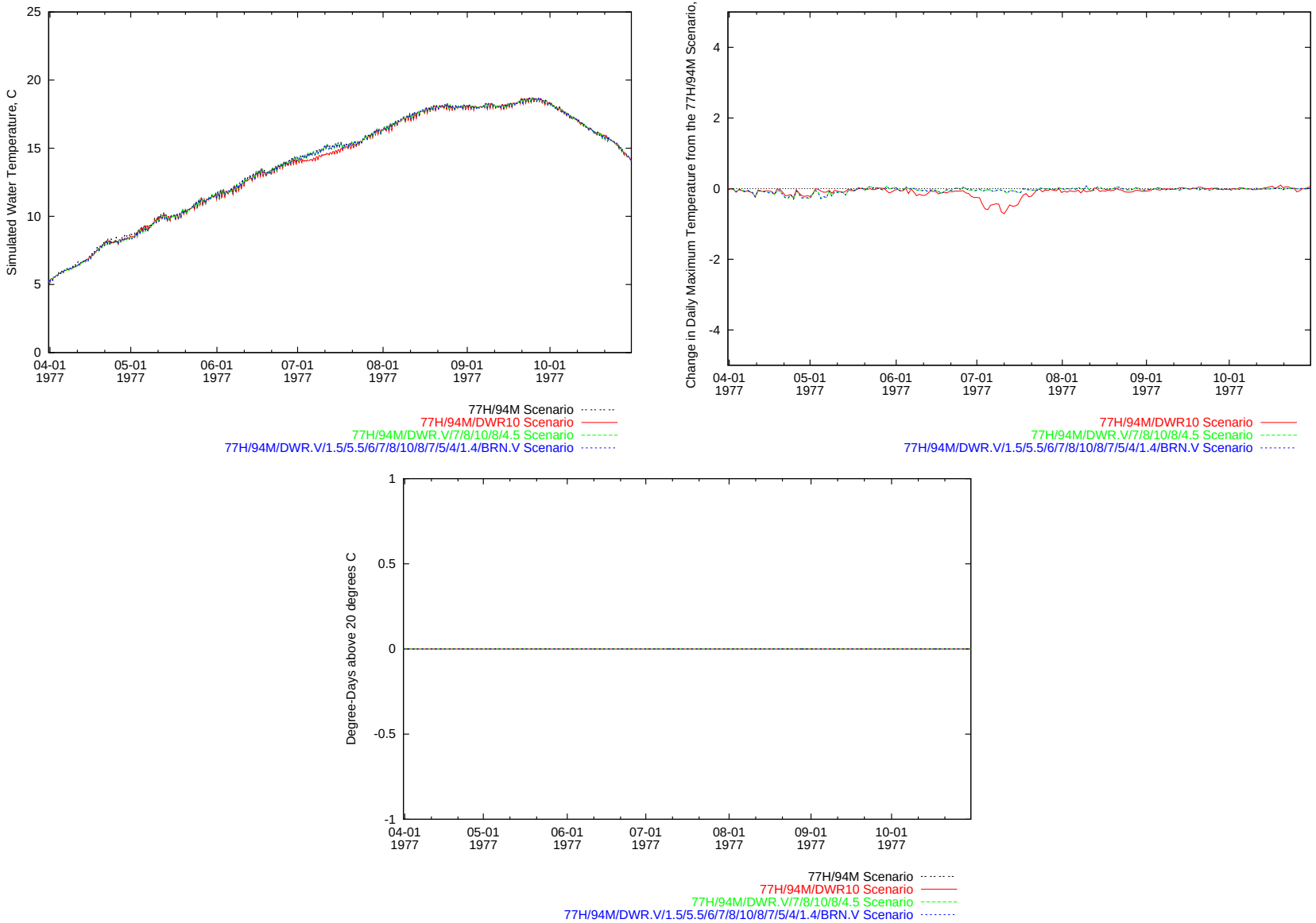

Figure 40: Time series comparison of simulated temperature at the RIGW Fixed Monitor.

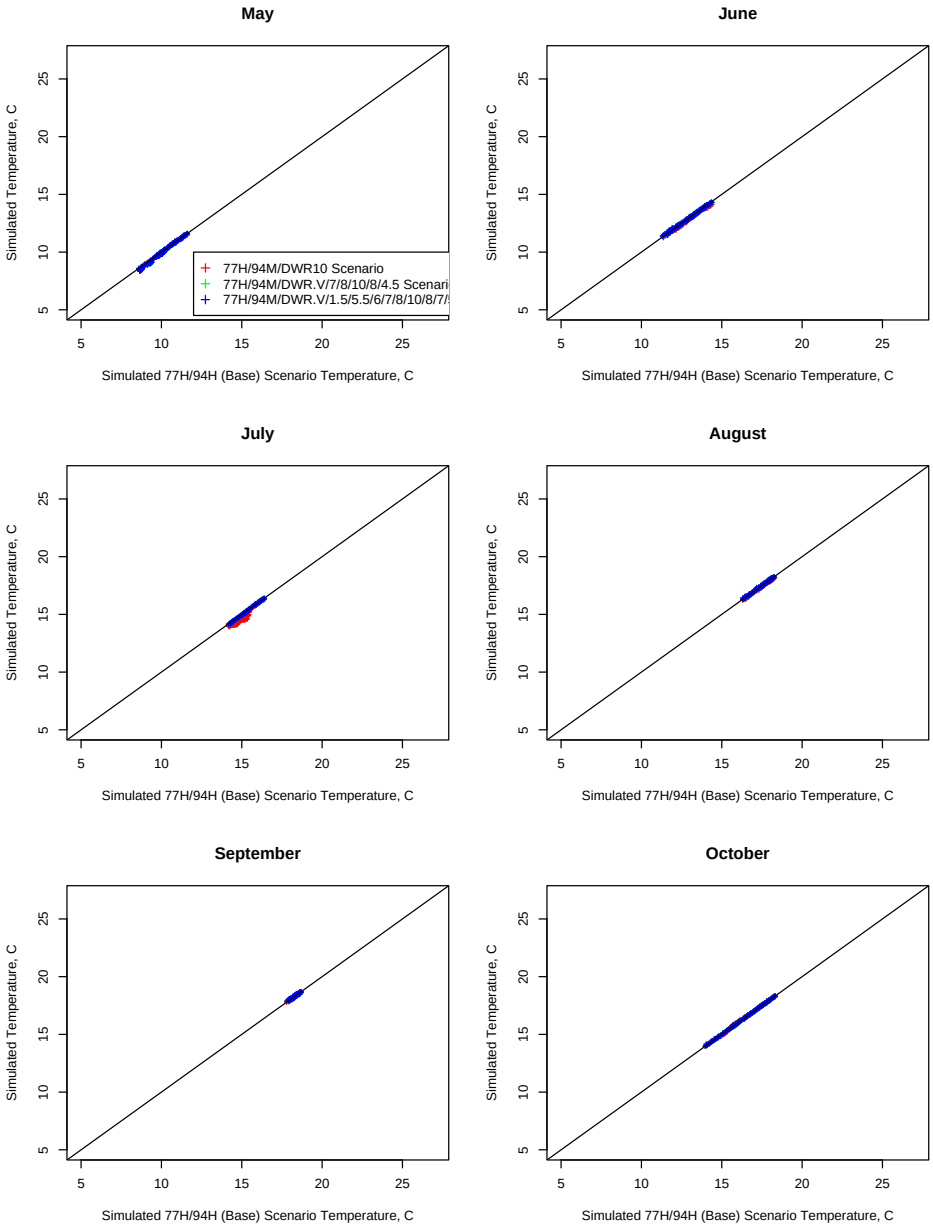

Figure 41: Scatter plot comparison, by month, of simulated temperature at the RIGW Fixed Monitor.

RIGW Fixed Monitor Temperature

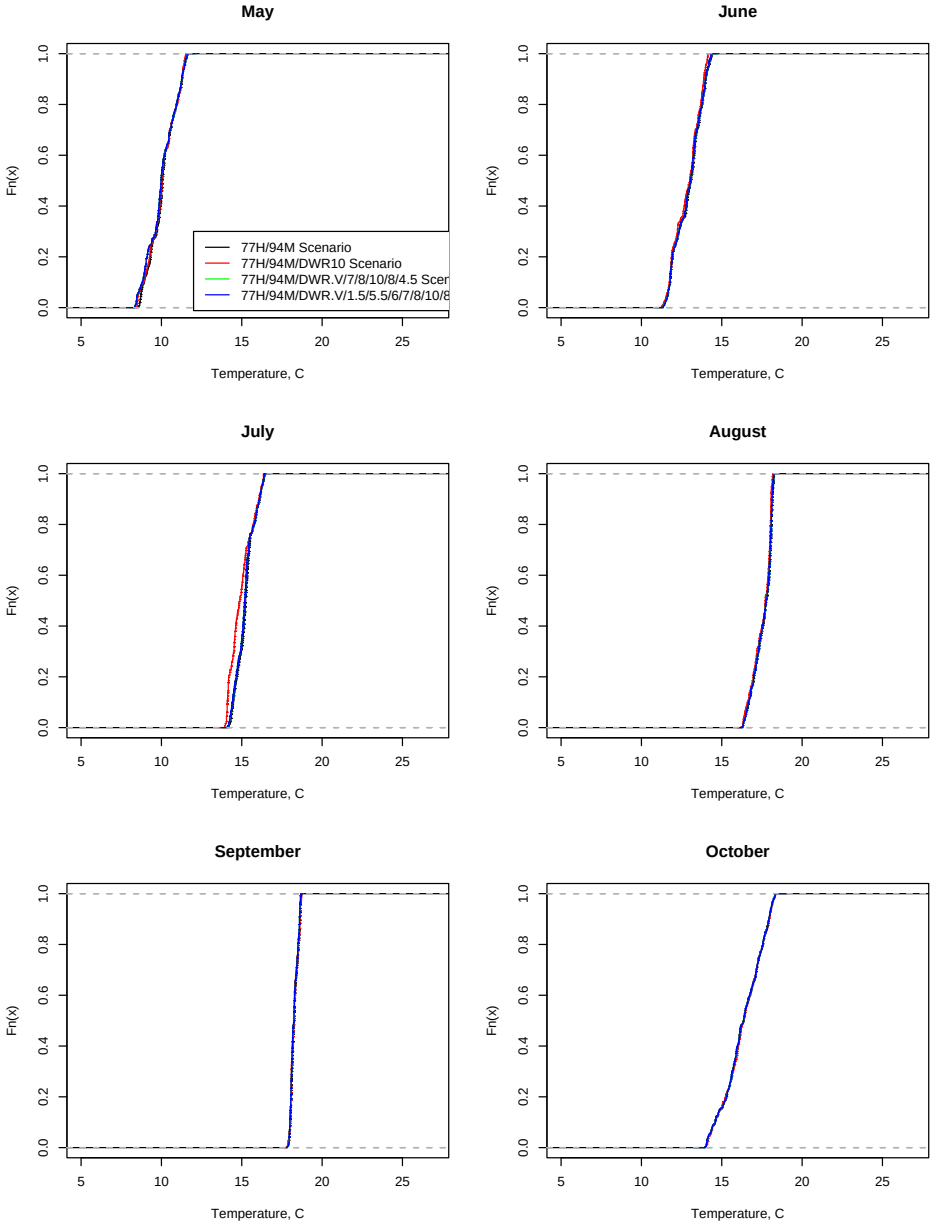

Figure 42: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the RIGW Fixed Monitor.

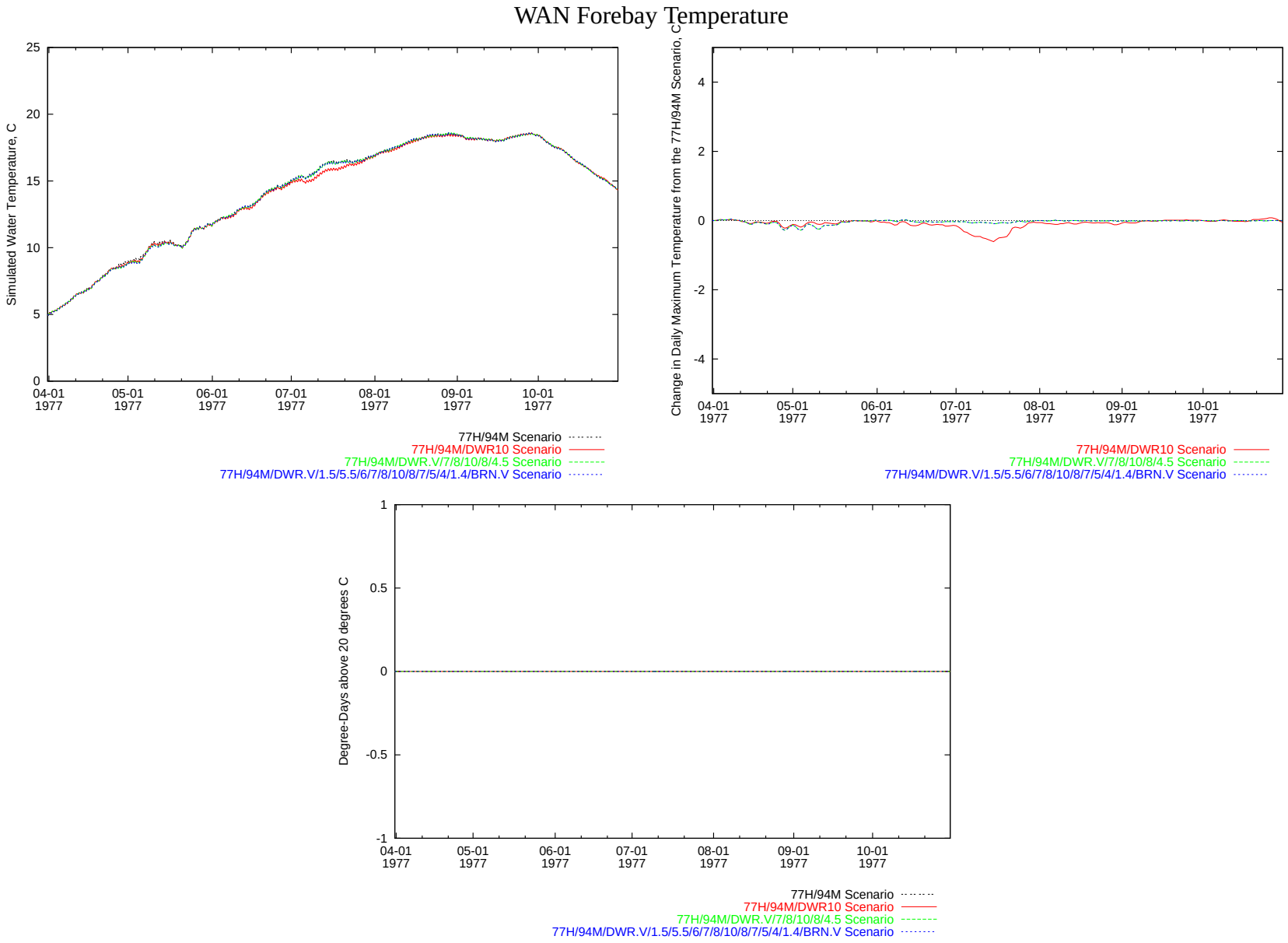

Figure 43: Time series comparison of simulated temperature at the WAN Forebay.

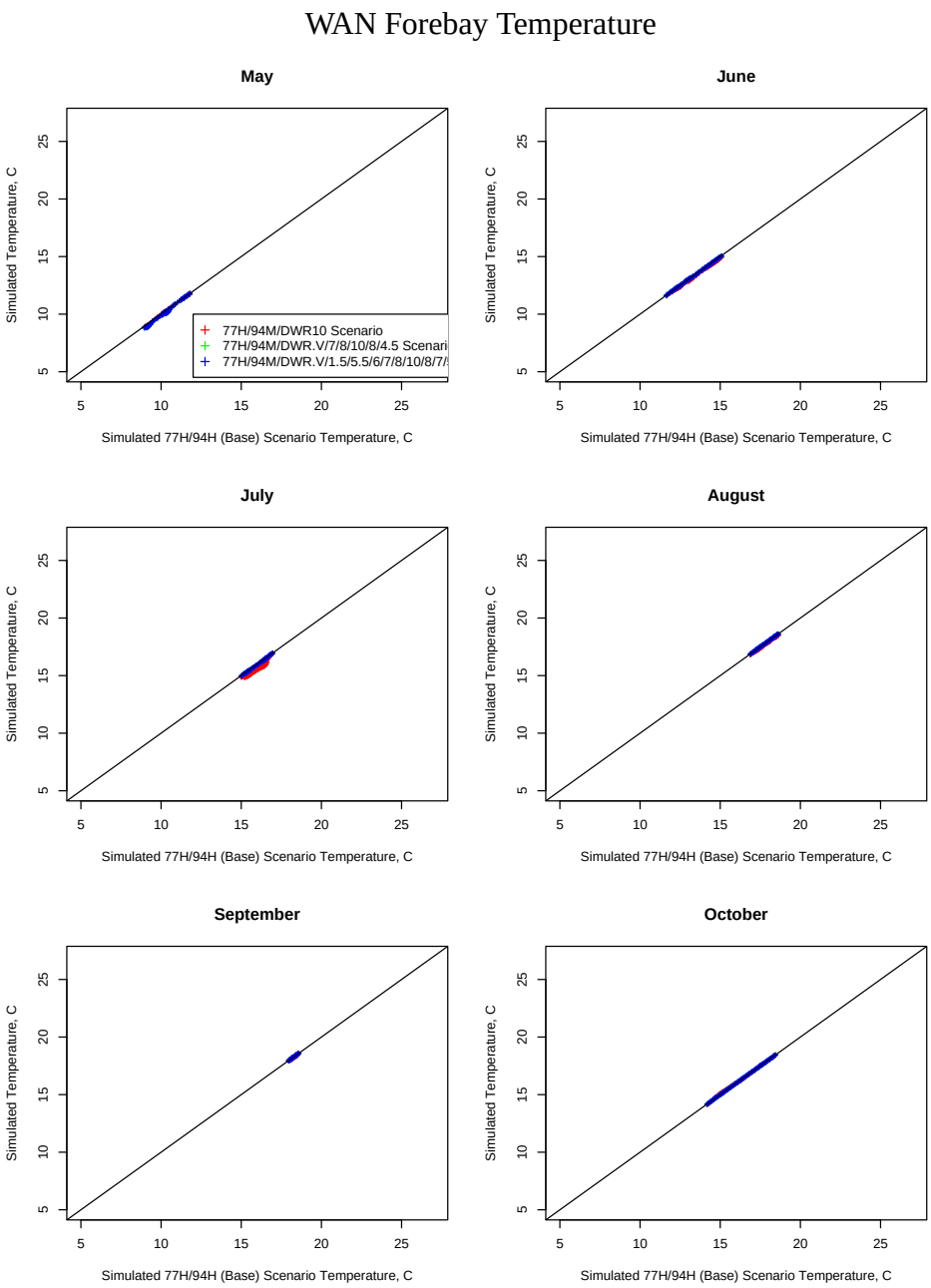

Figure 44: Scatter plot comparison, by month, of simulated temperature at the WAN Forebay.

WAN Forebay Temperature

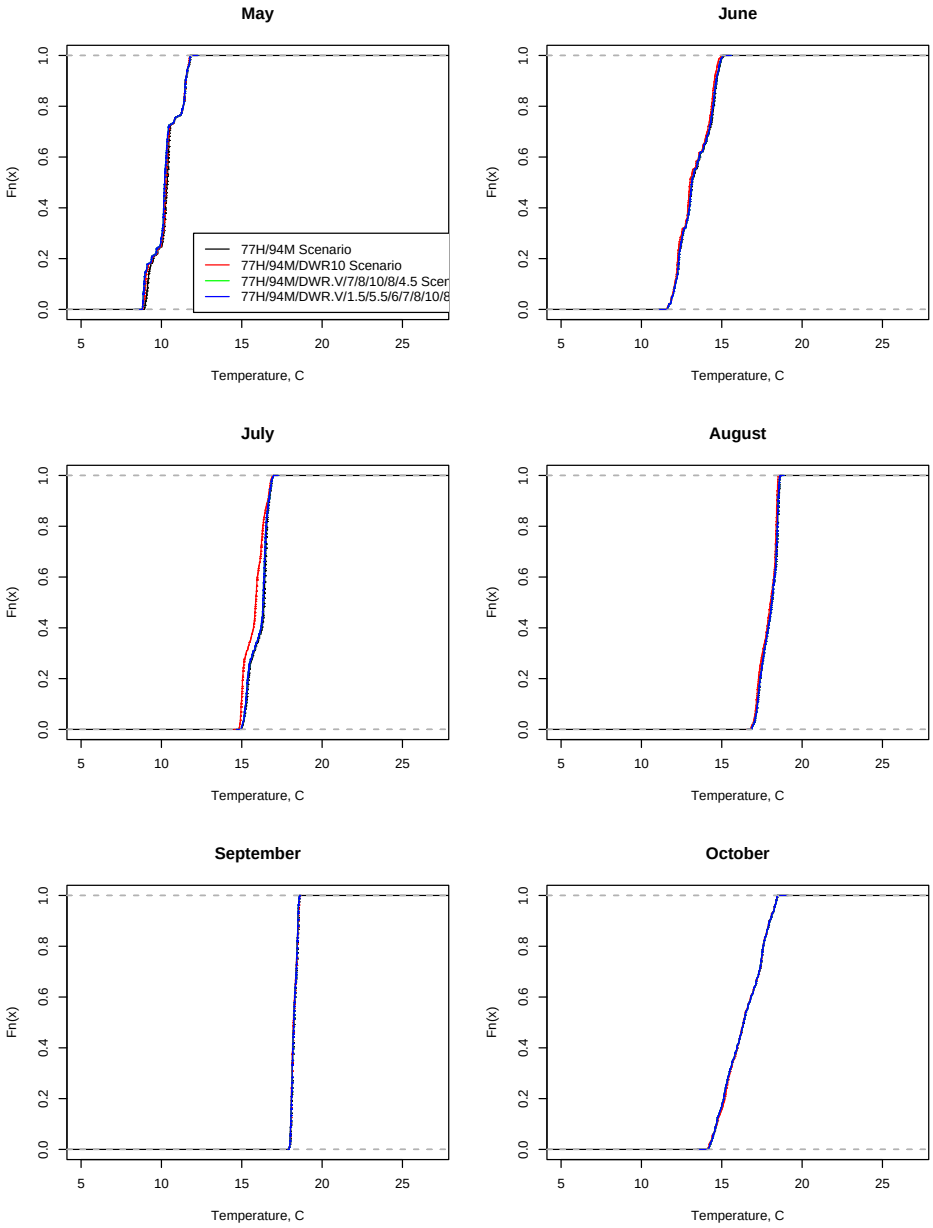

Figure 45: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the WAN Forebay.

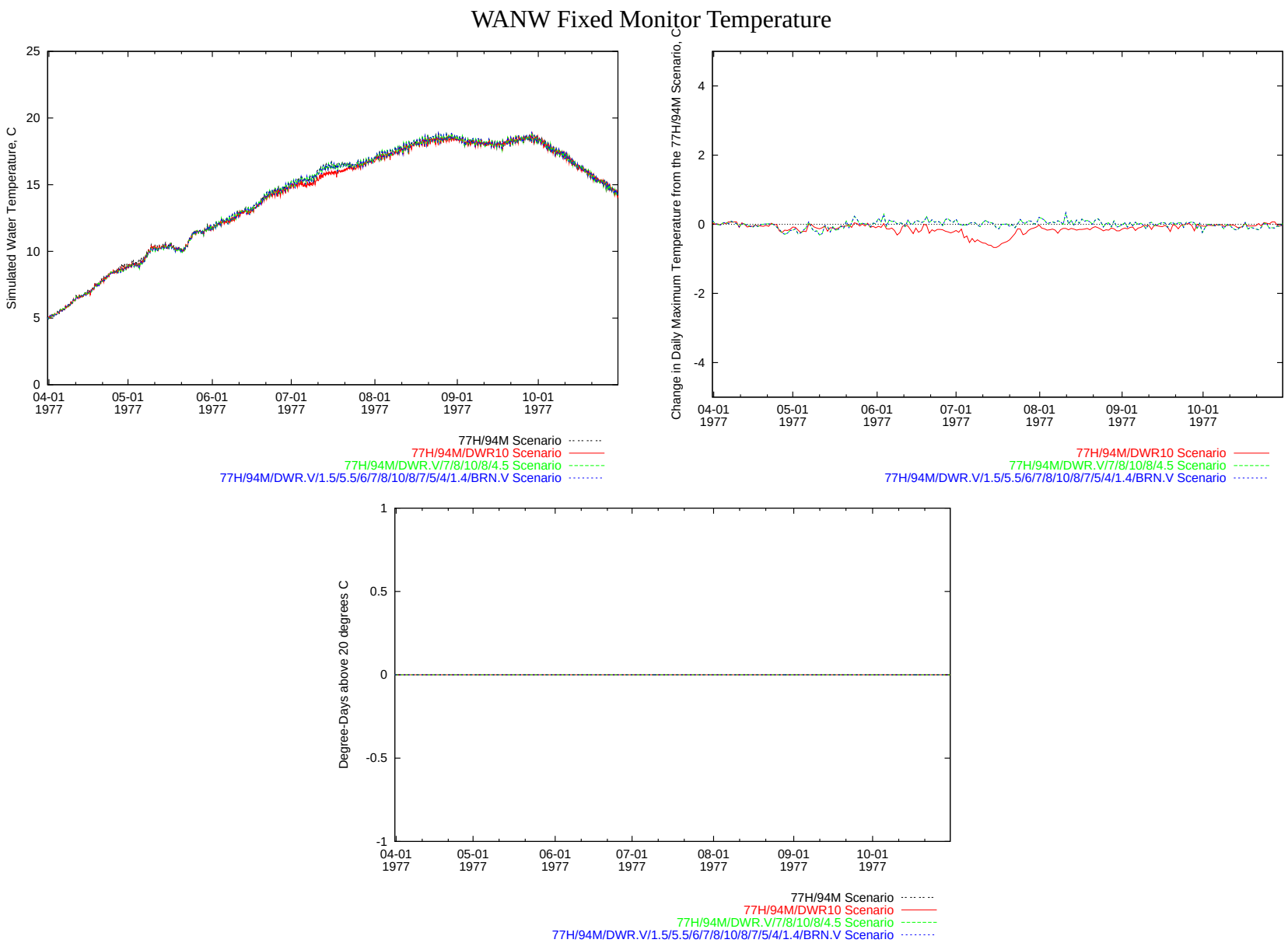

Figure 46: Time series comparison of simulated temperature at the WANW Fixed Monitor.

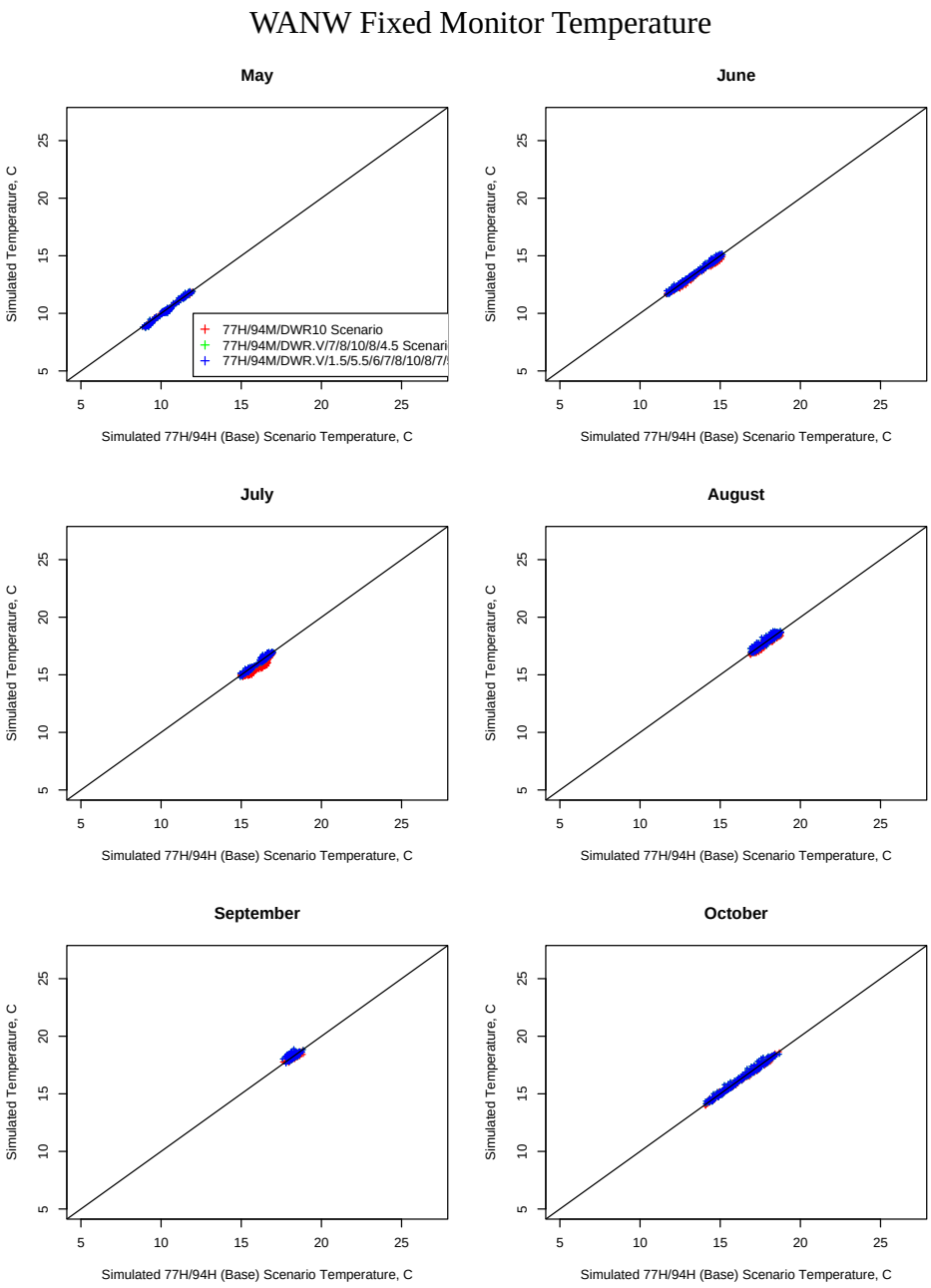

Figure 47: Scatter plot comparison, by month, of simulated temperature at the WANW Fixed Monitor.

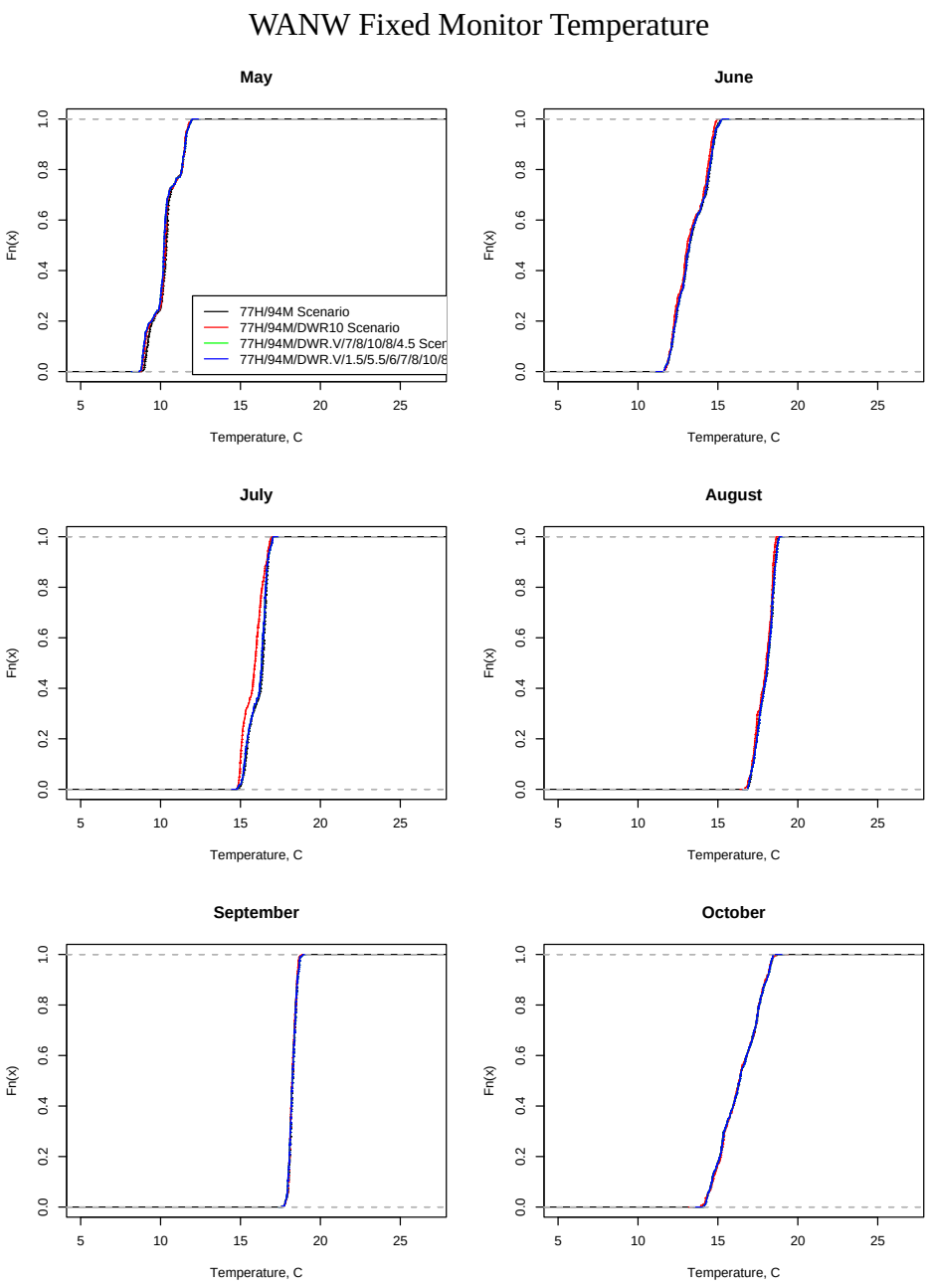

Figure 48: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the WANW Fixed Monitor.

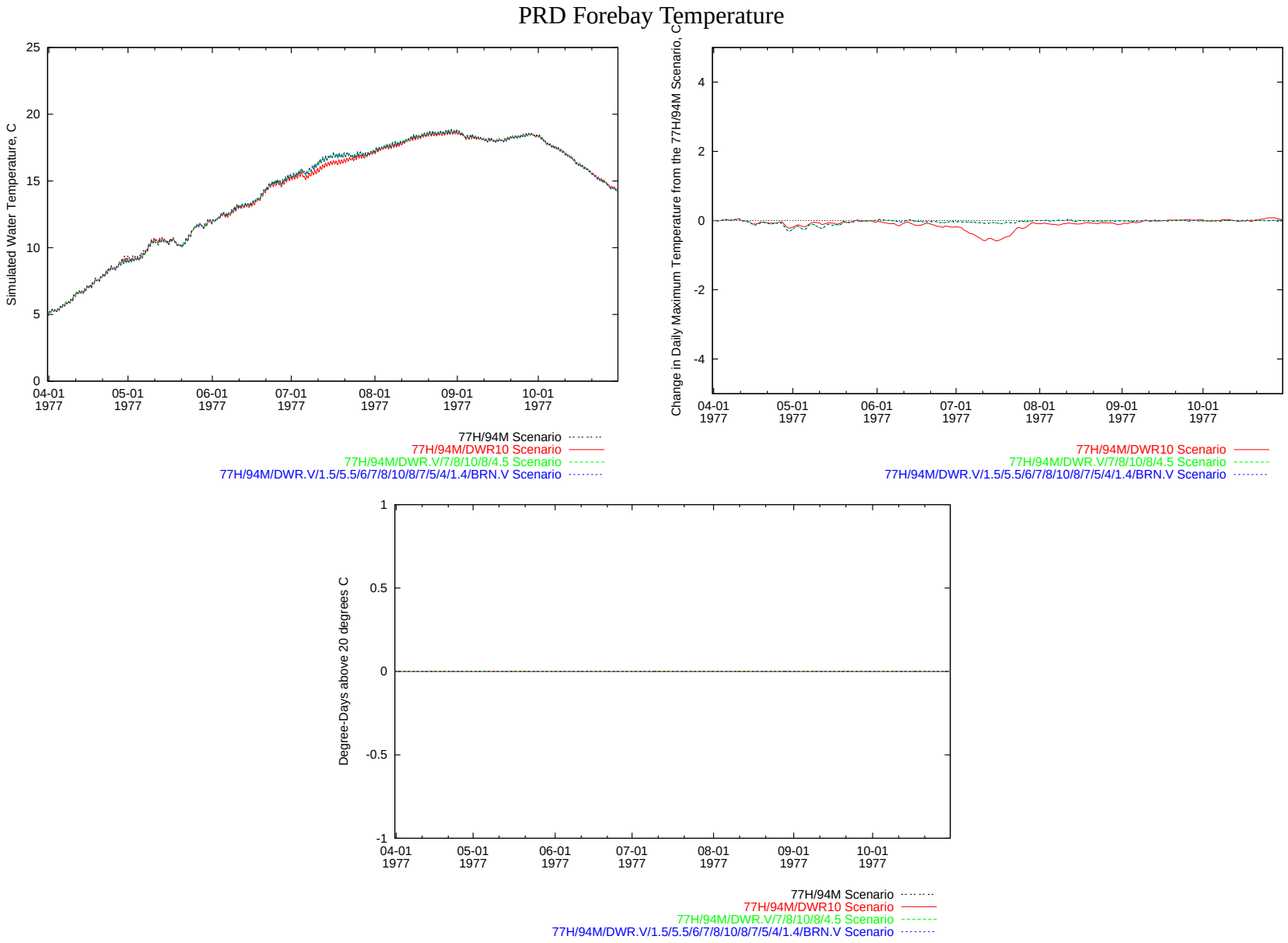

Figure 49: Time series comparison of simulated temperature at the PRD Forebay.

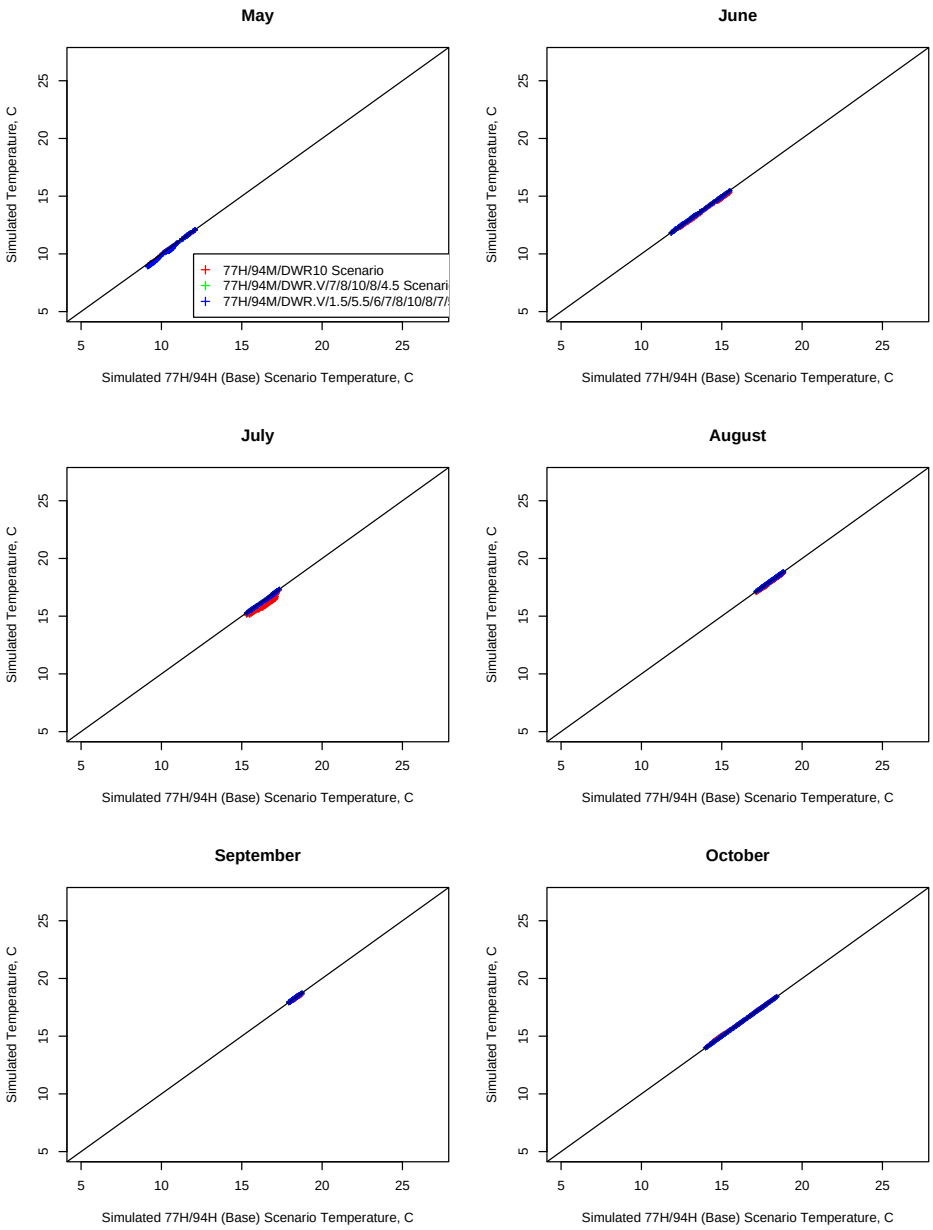

Figure 50: Scatter plot comparison, by month, of simulated temperature at the PRD Forebay.

PRD Forebay Temperature

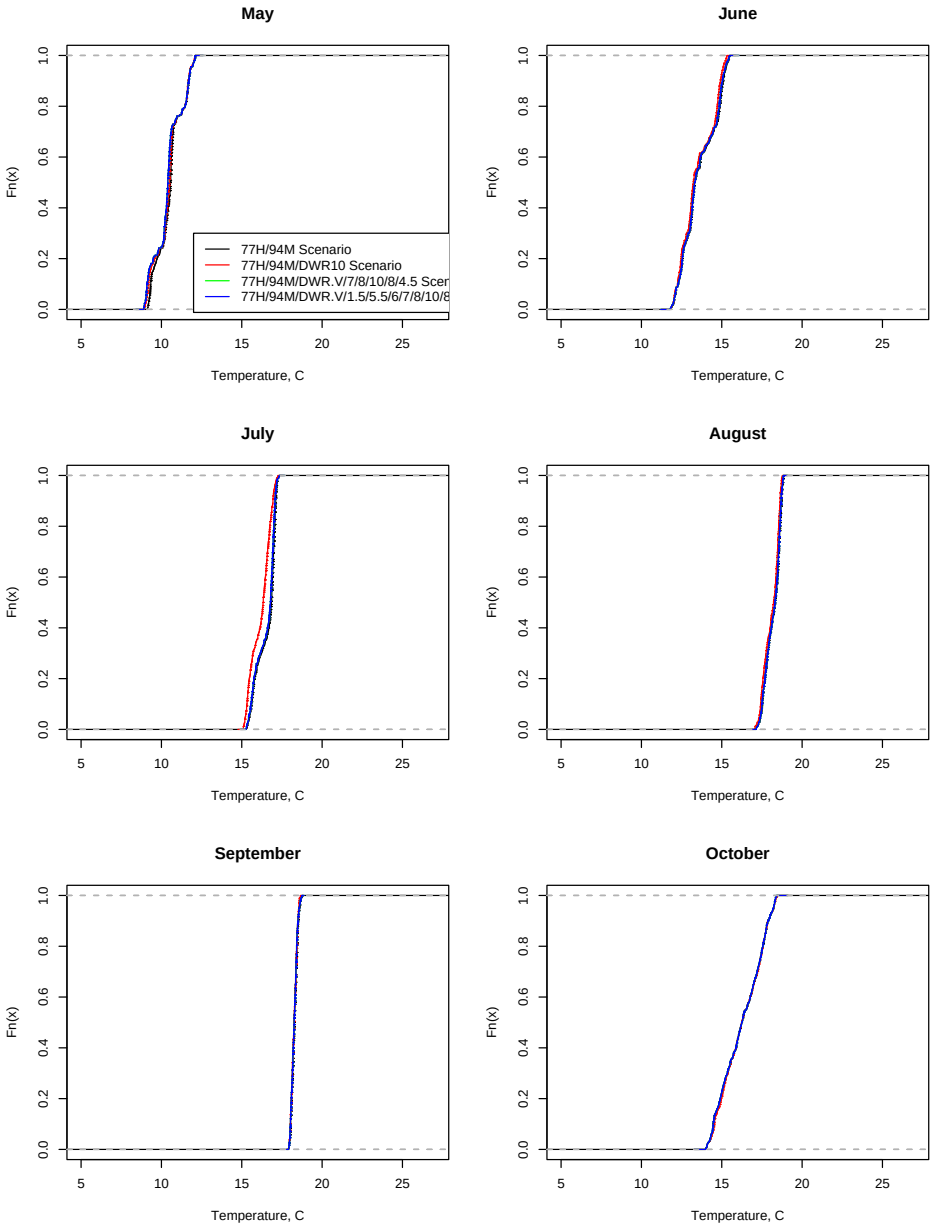

Figure 51: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the PRD Forebay.

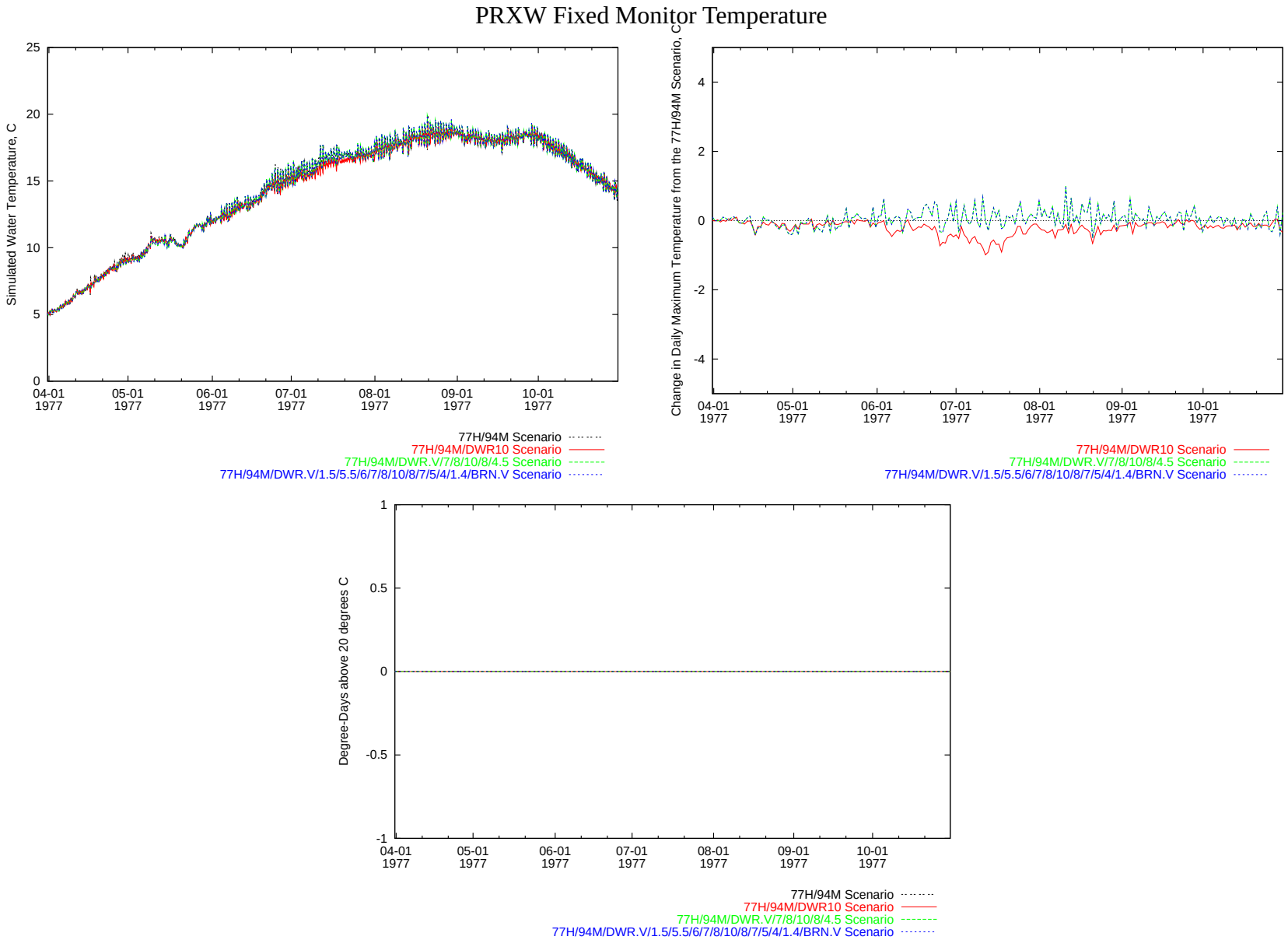

Figure 52: Time series comparison of simulated temperature at the PRXW Fixed Monitor.

PRXW Fixed Monitor Temperature

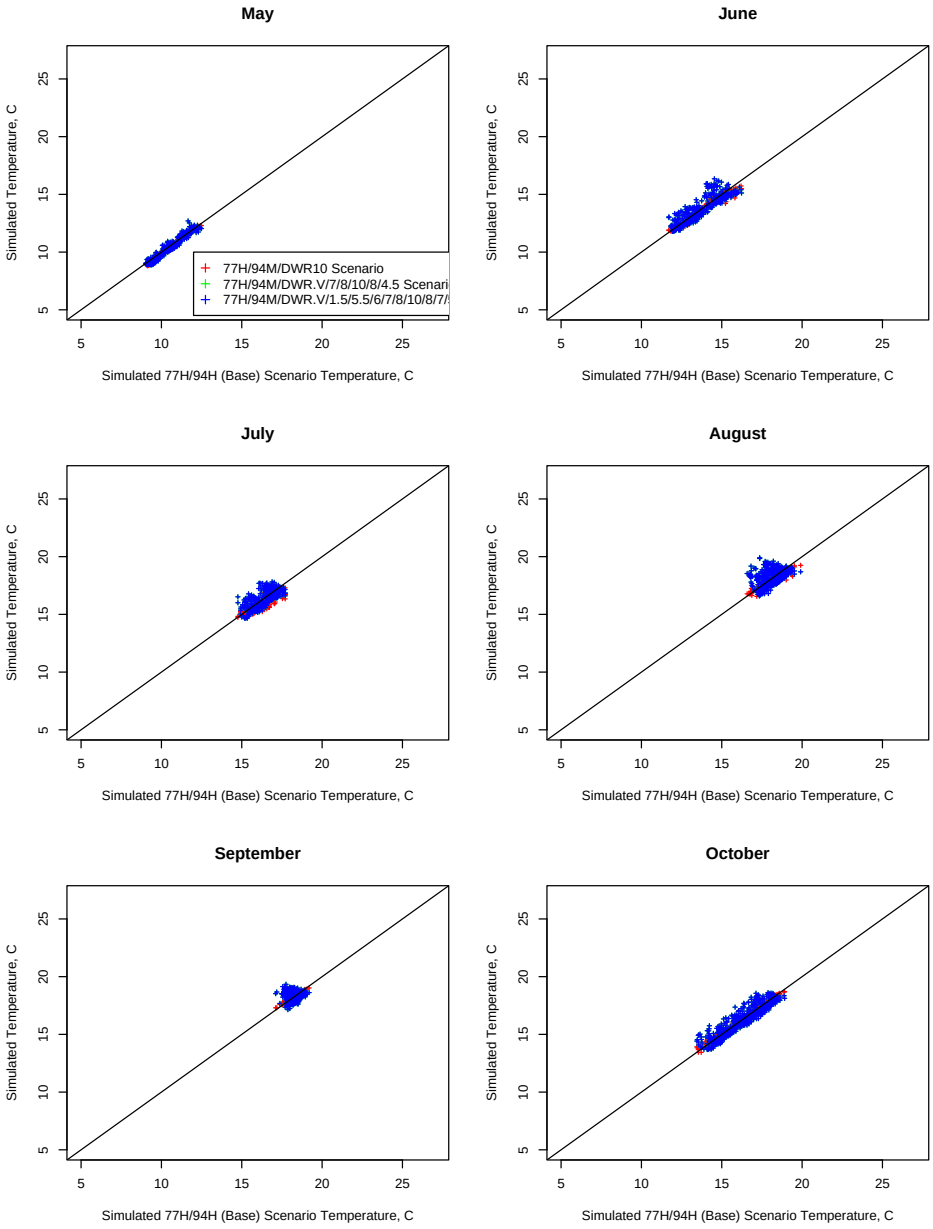

Figure 53: Scatter plot comparison, by month, of simulated temperature at the PRXW Fixed Monitor.

PRXW Fixed Monitor Temperature

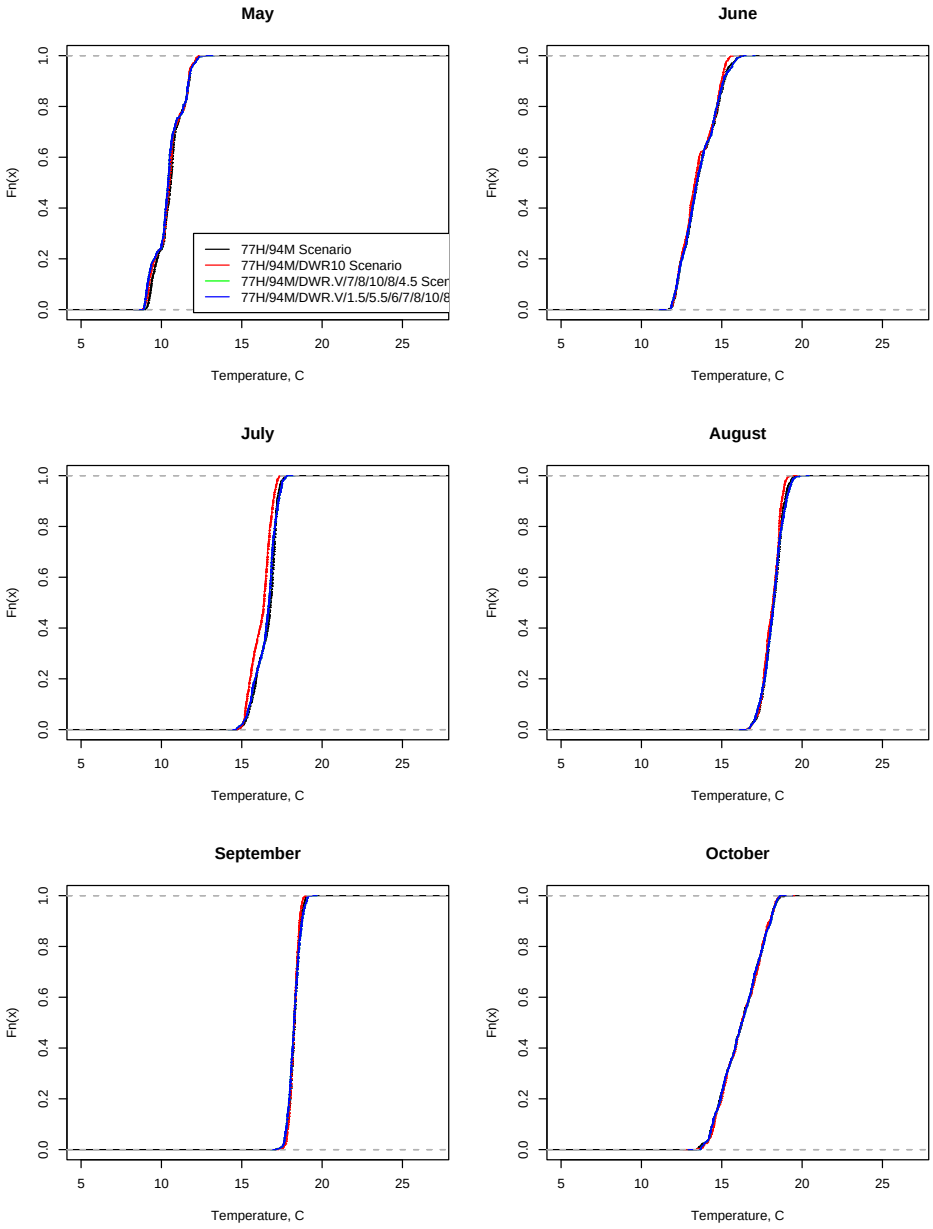

Figure 54: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the PRXW Fixed Monitor.

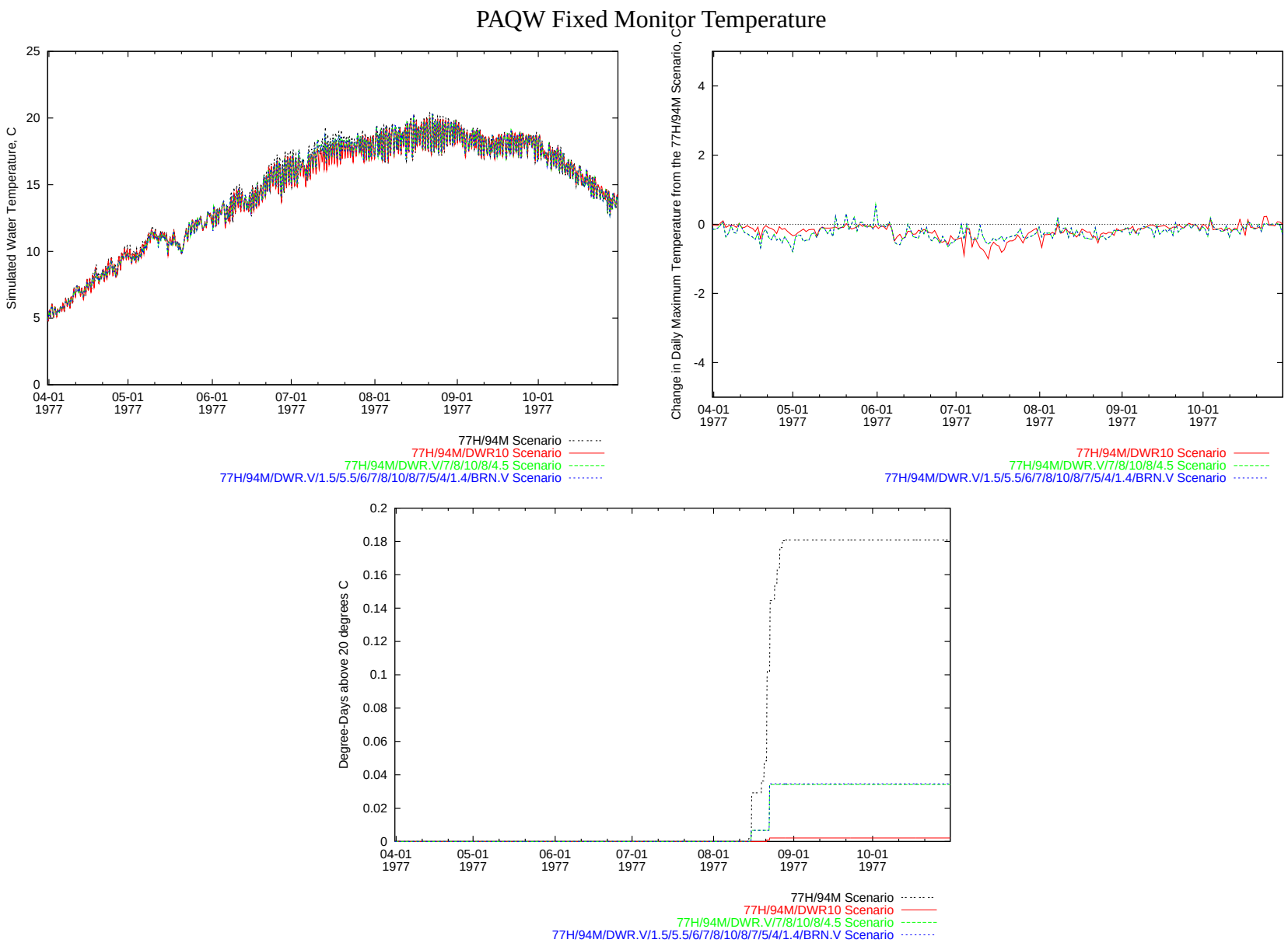

Figure 55: Time series comparison of simulated temperature at the PAQW Fixed Monitor.

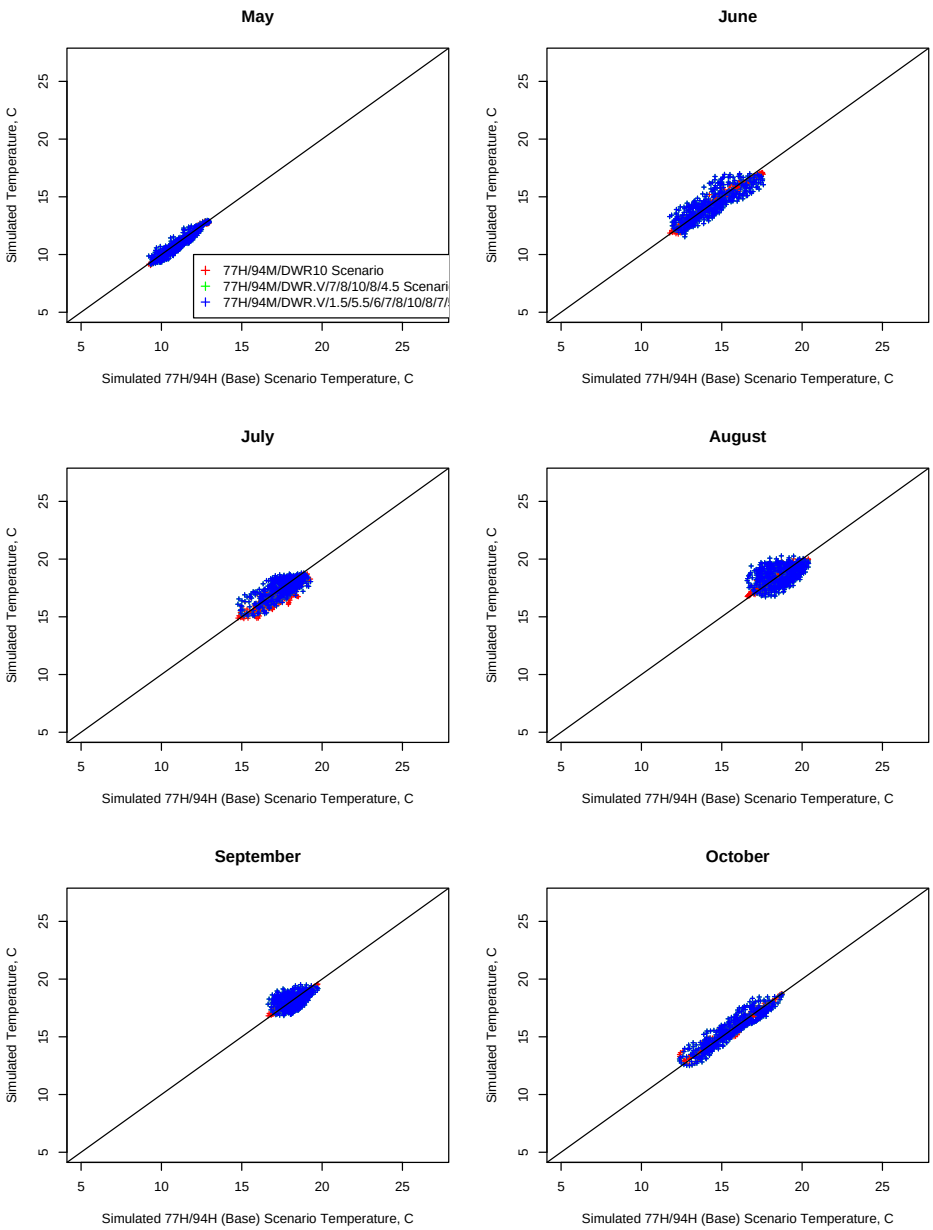

Figure 56: Scatter plot comparison, by month, of simulated temperature at the PAQW Fixed Monitor.

PAQW Fixed Monitor Temperature

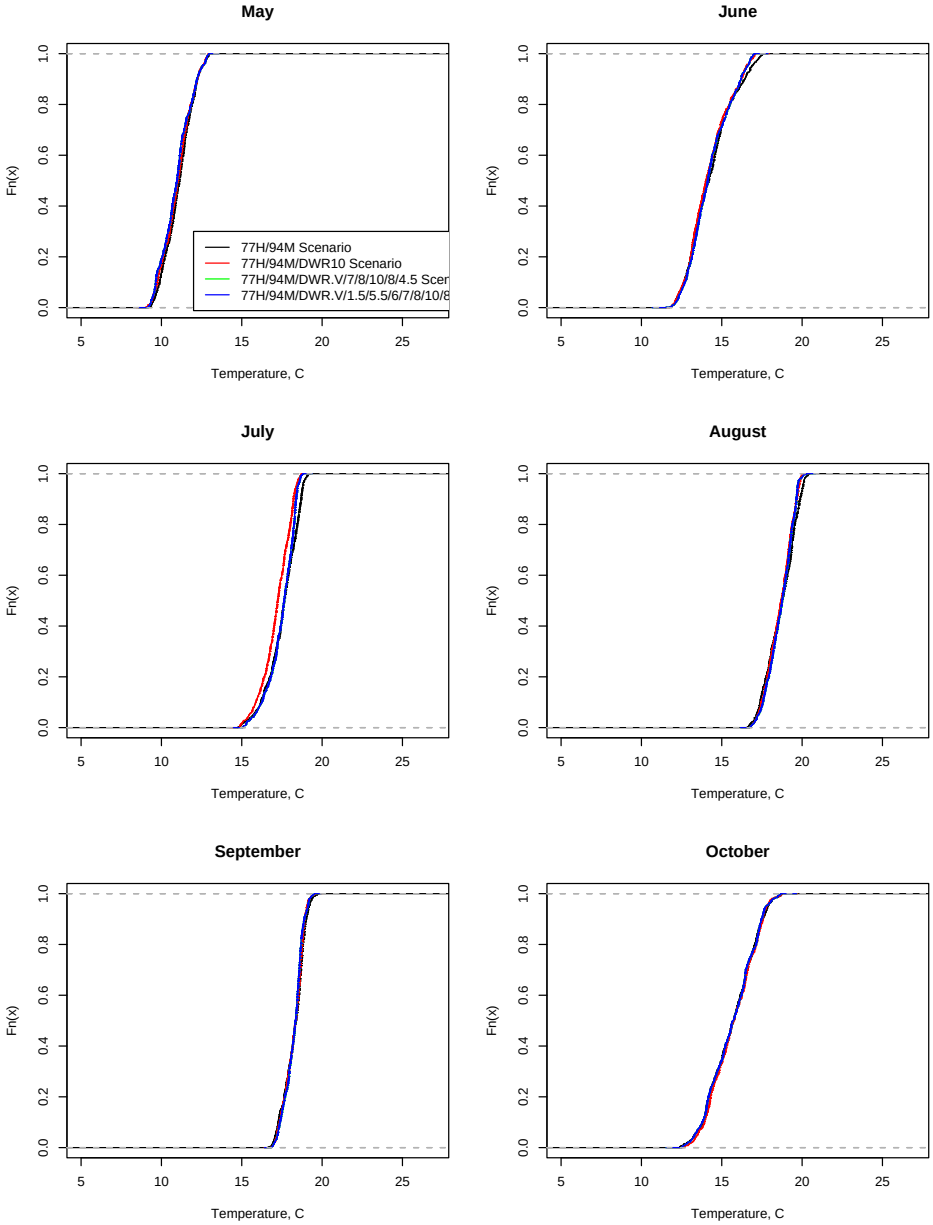

Figure 57: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the PAQW Fixed Monitor.

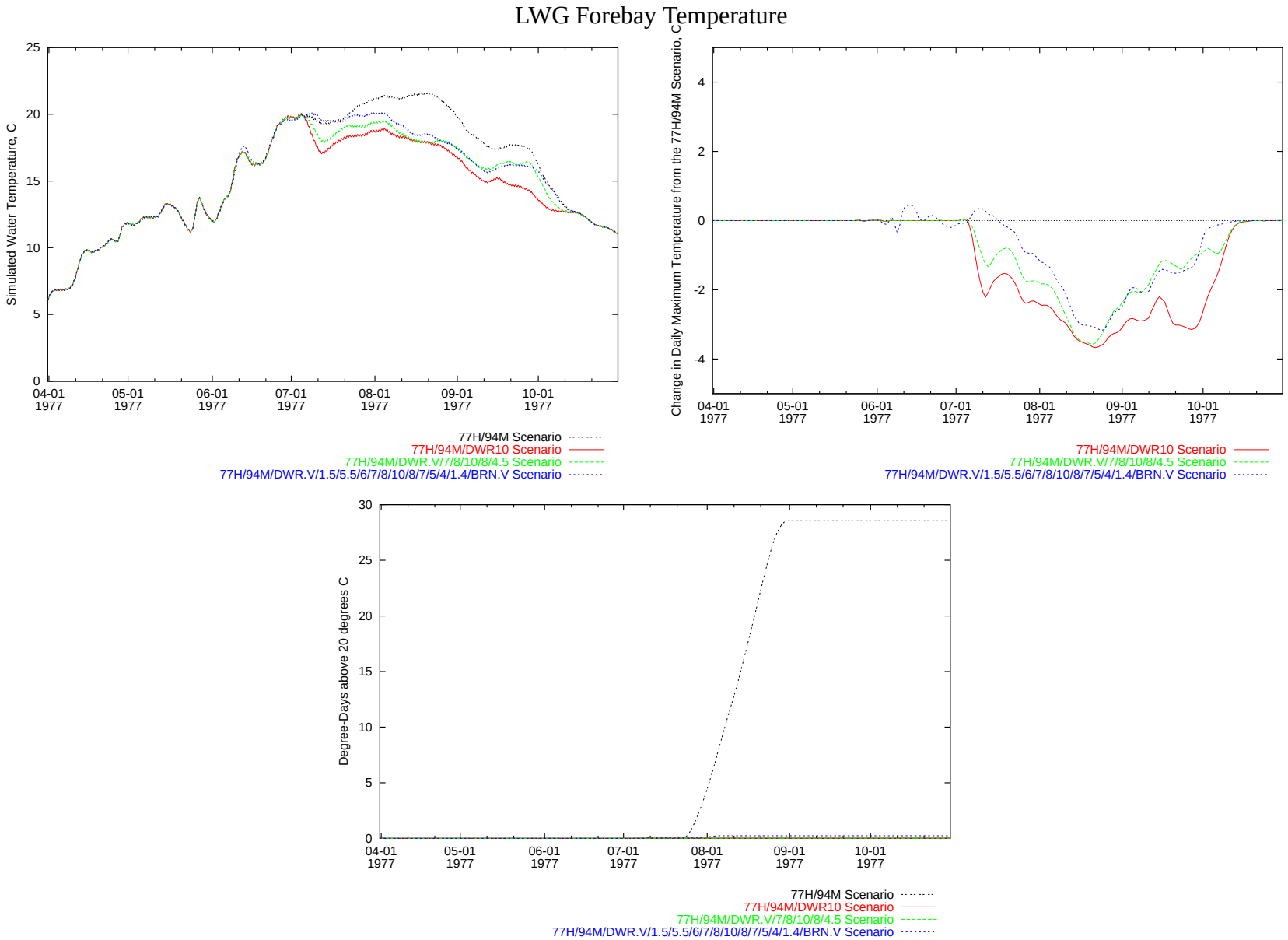

Figure 58: Time series comparison of simulated temperature at the LWG Forebay.

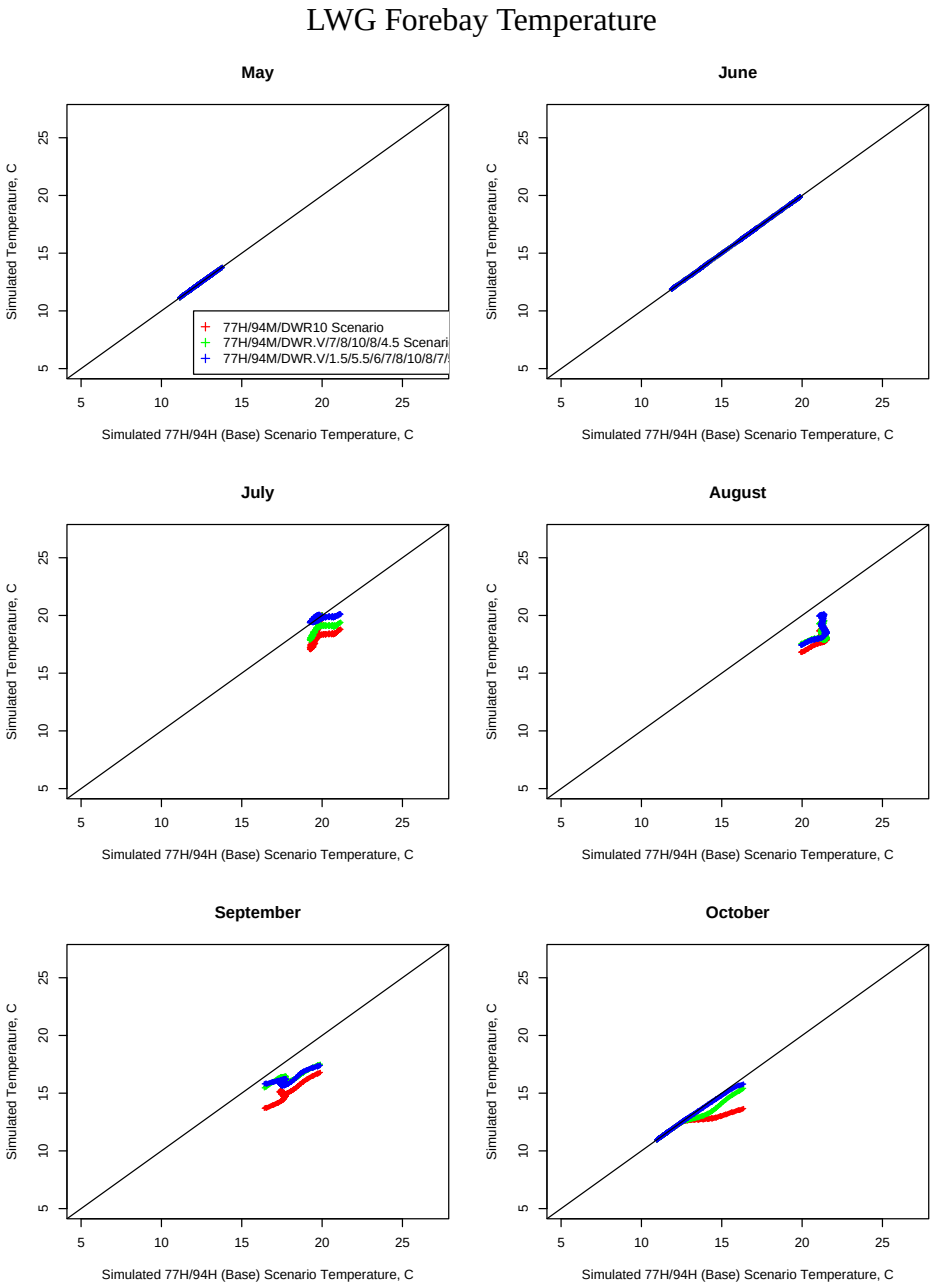

Figure 59: Scatter plot comparison, by month, of simulated temperature at the LWG Forebay.

LWG Forebay Temperature

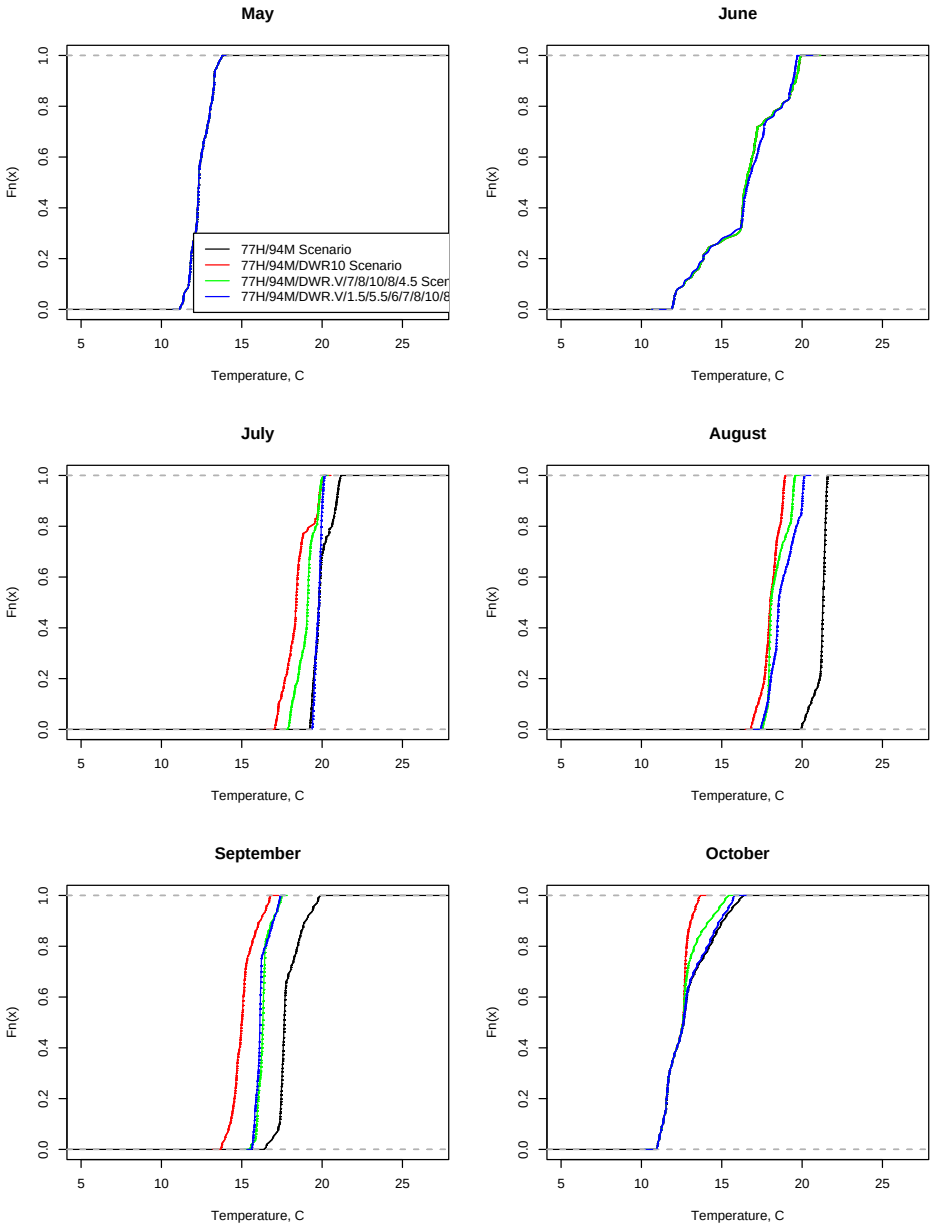

Figure 60: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the LWG Forebay.

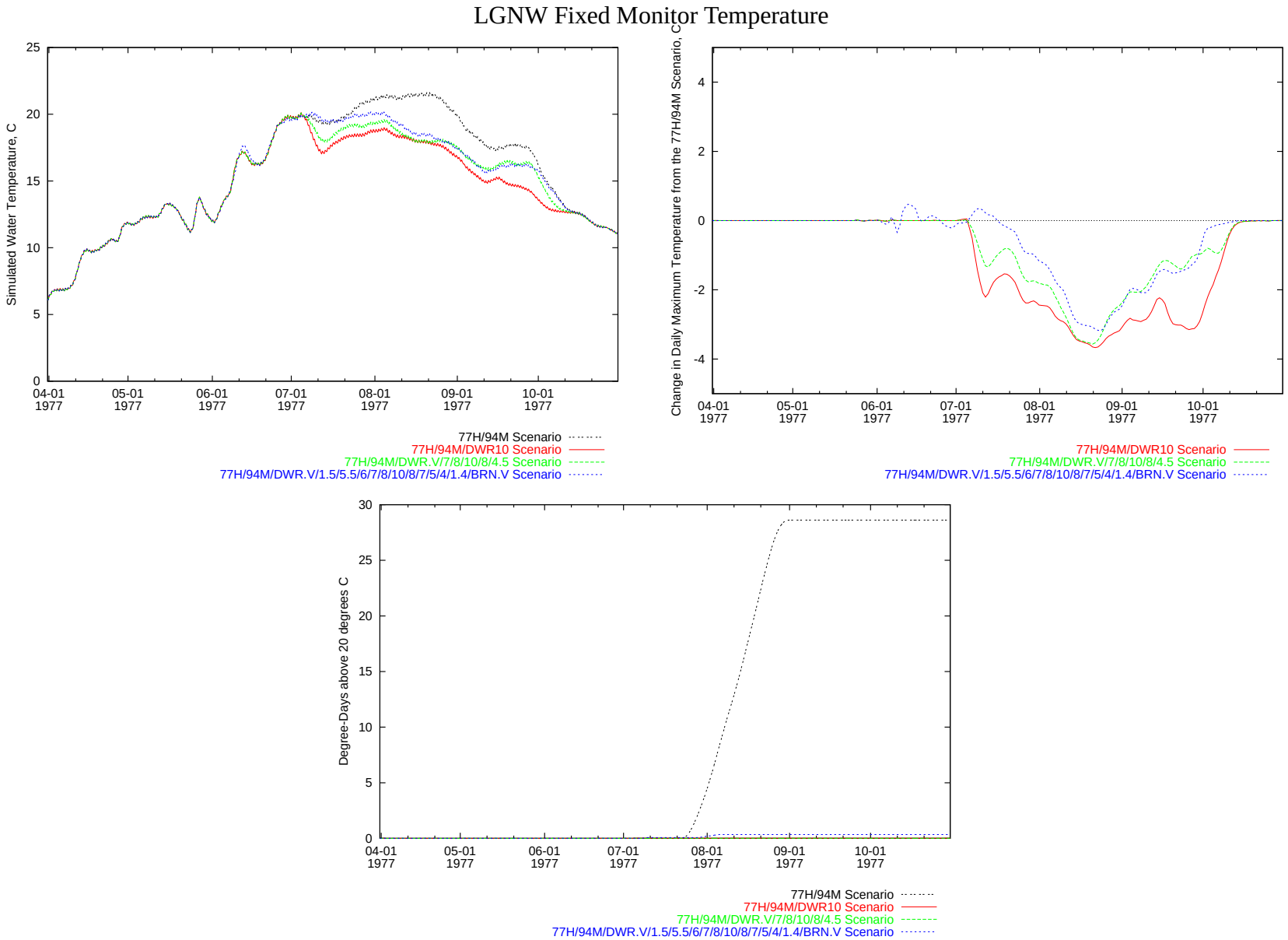

Figure 61: Time series comparison of simulated temperature at the LGNW Fixed Monitor.

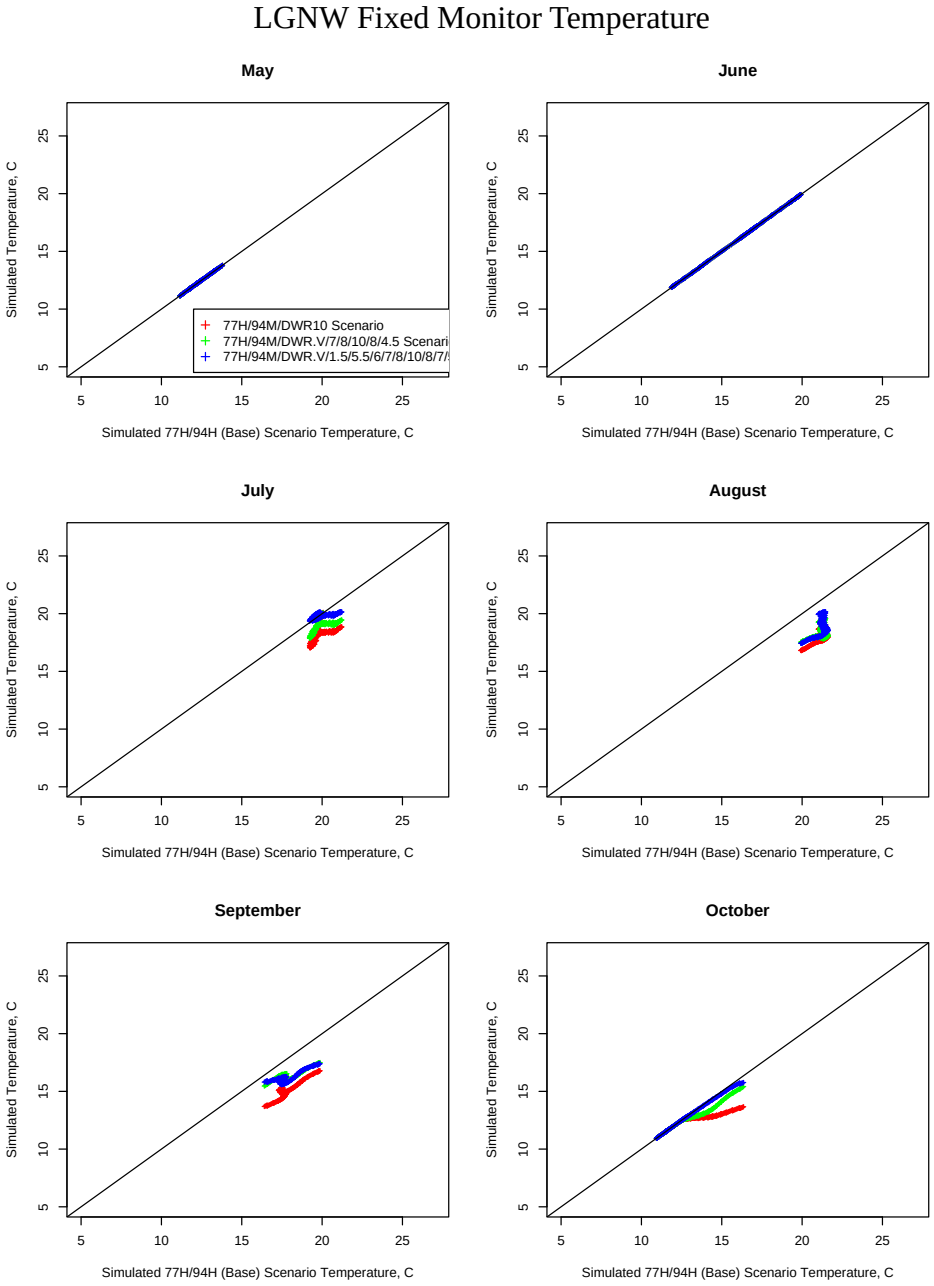

Figure 62: Scatter plot comparison, by month, of simulated temperature at the LGNW Fixed Monitor.

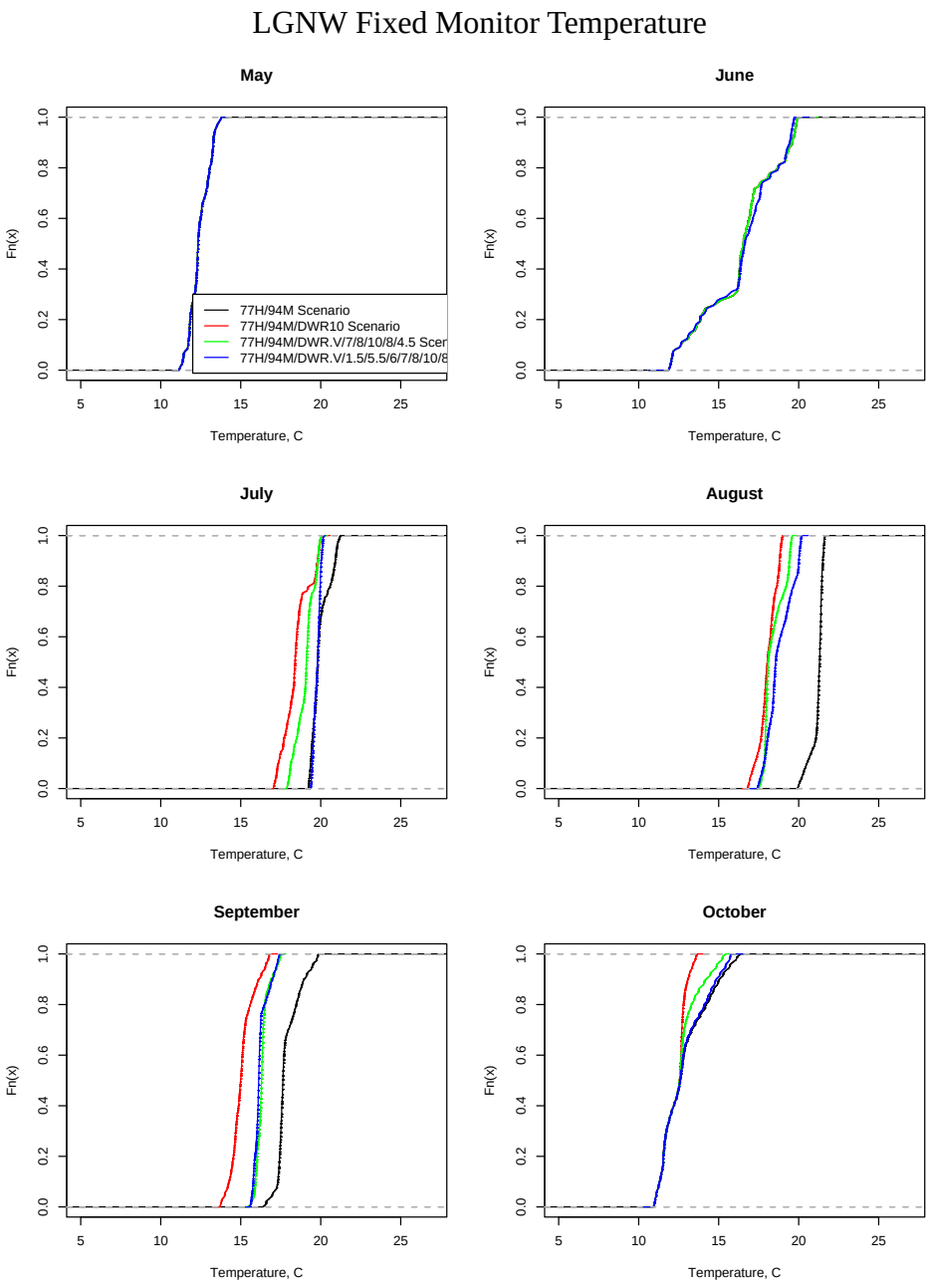

Figure 63: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the LGNW Fixed Monitor.

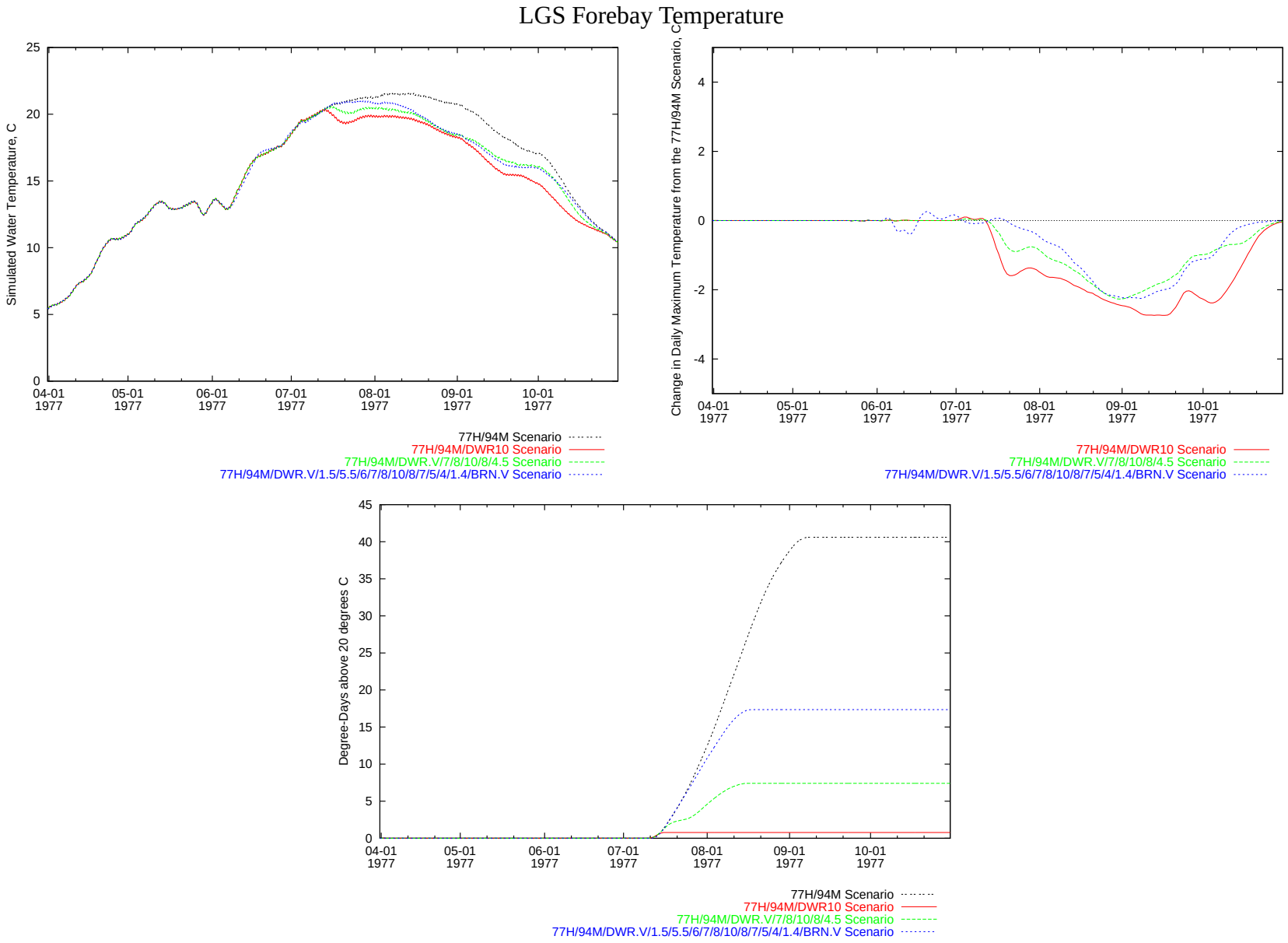

Figure 64: Time series comparison of simulated temperature at the LGS Forebay.

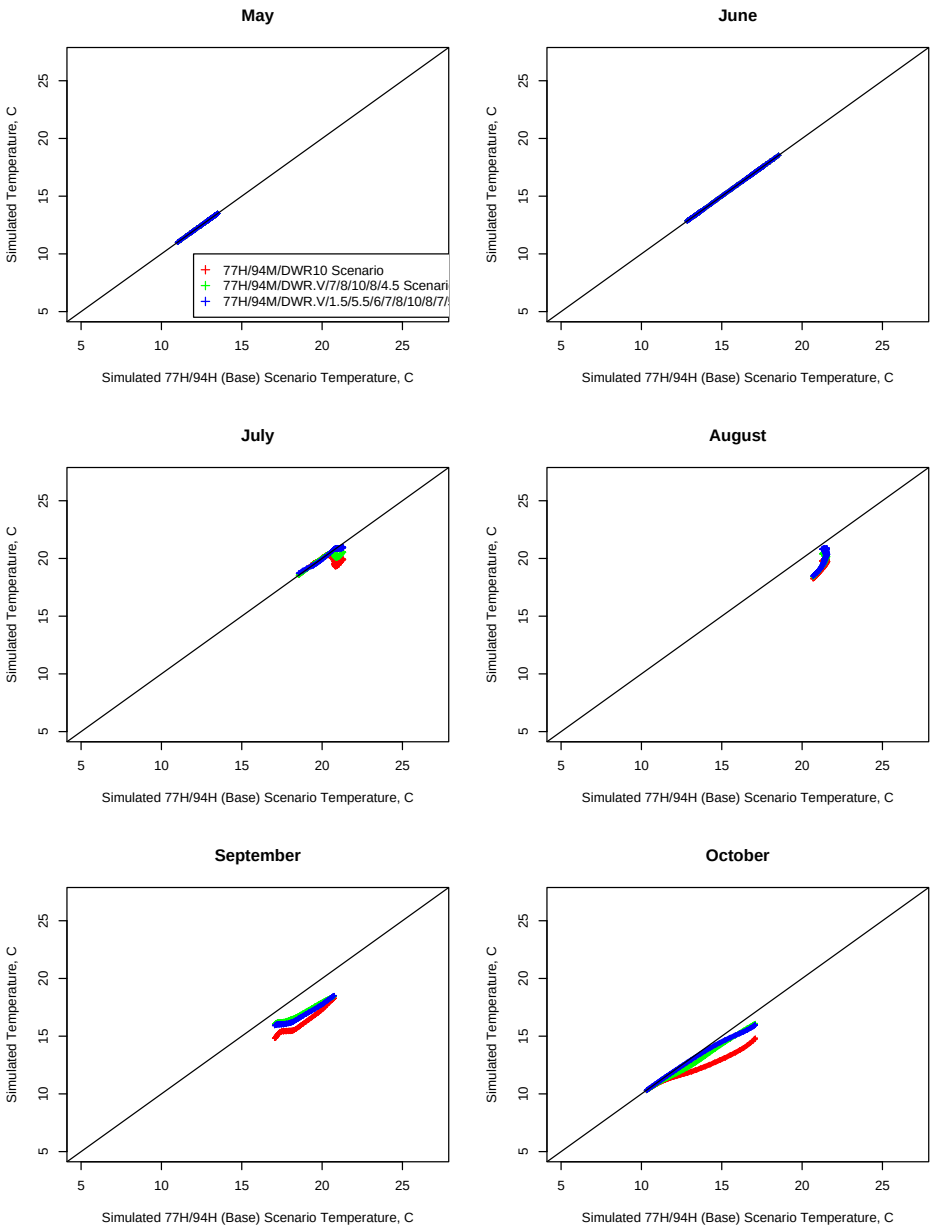

Figure 65: Scatter plot comparison, by month, of simulated temperature at the LGS Forebay.

LGS Forebay Temperature

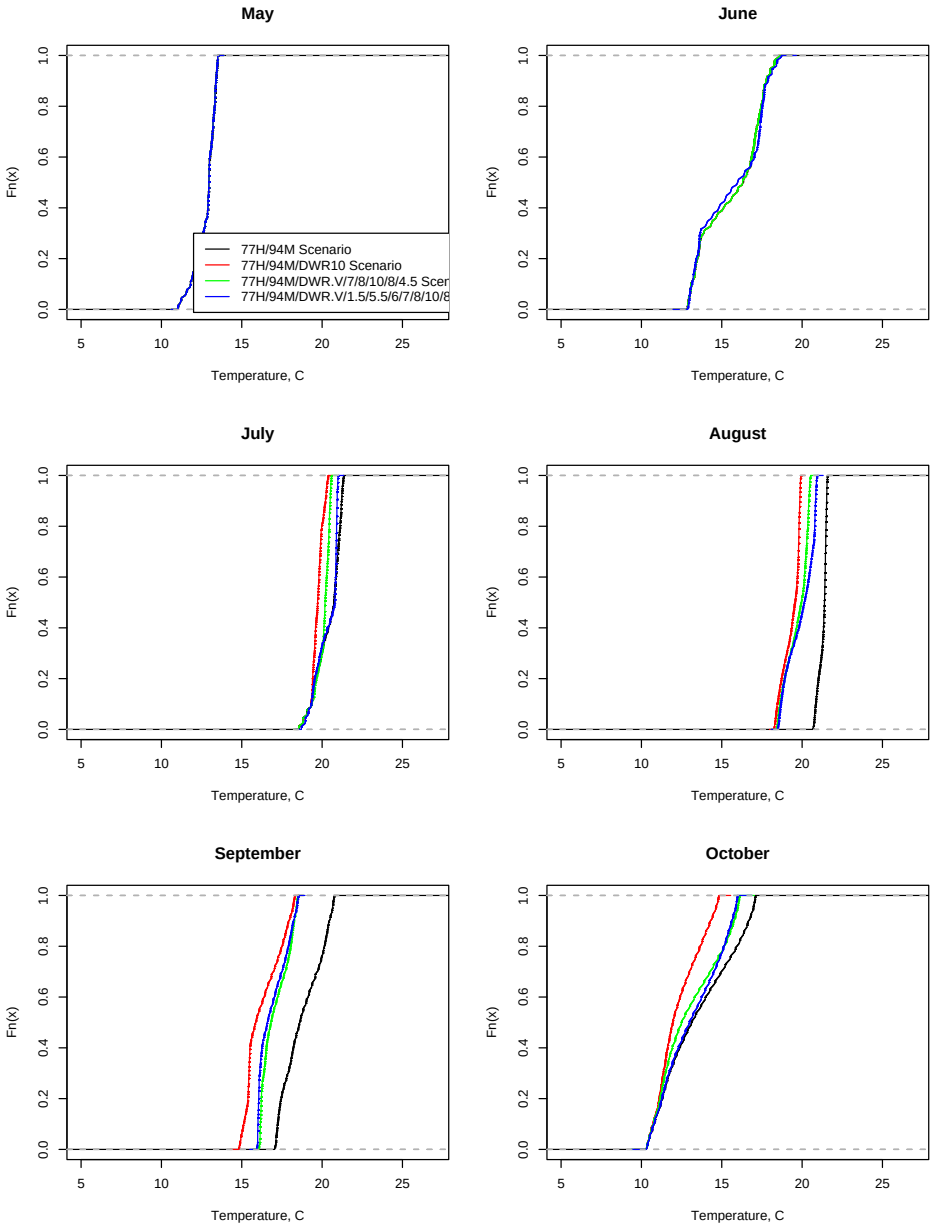

Figure 66: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the LGS Forebay.

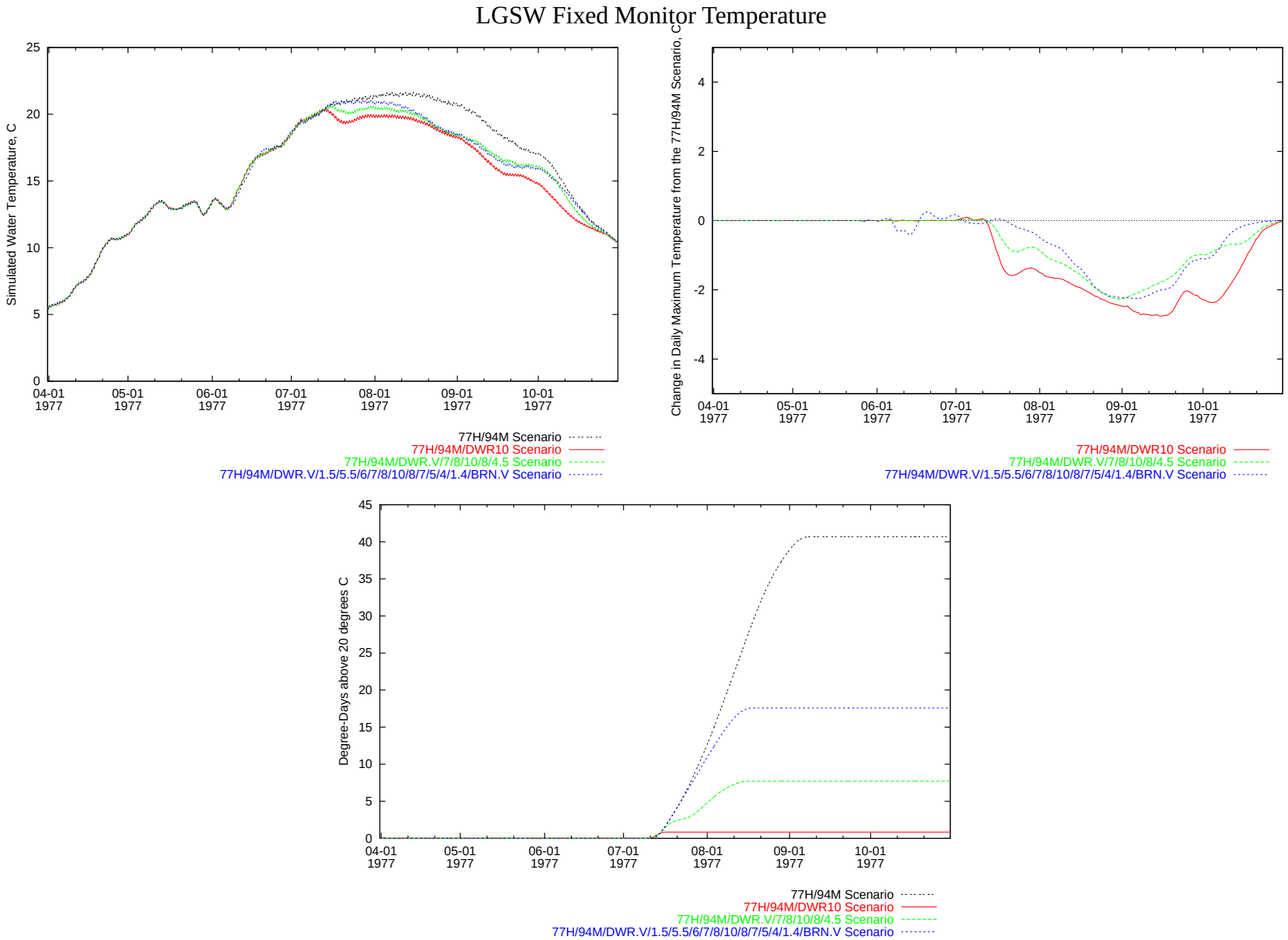

Figure 67: Time series comparison of simulated temperature at the LGSW Fixed Monitor.

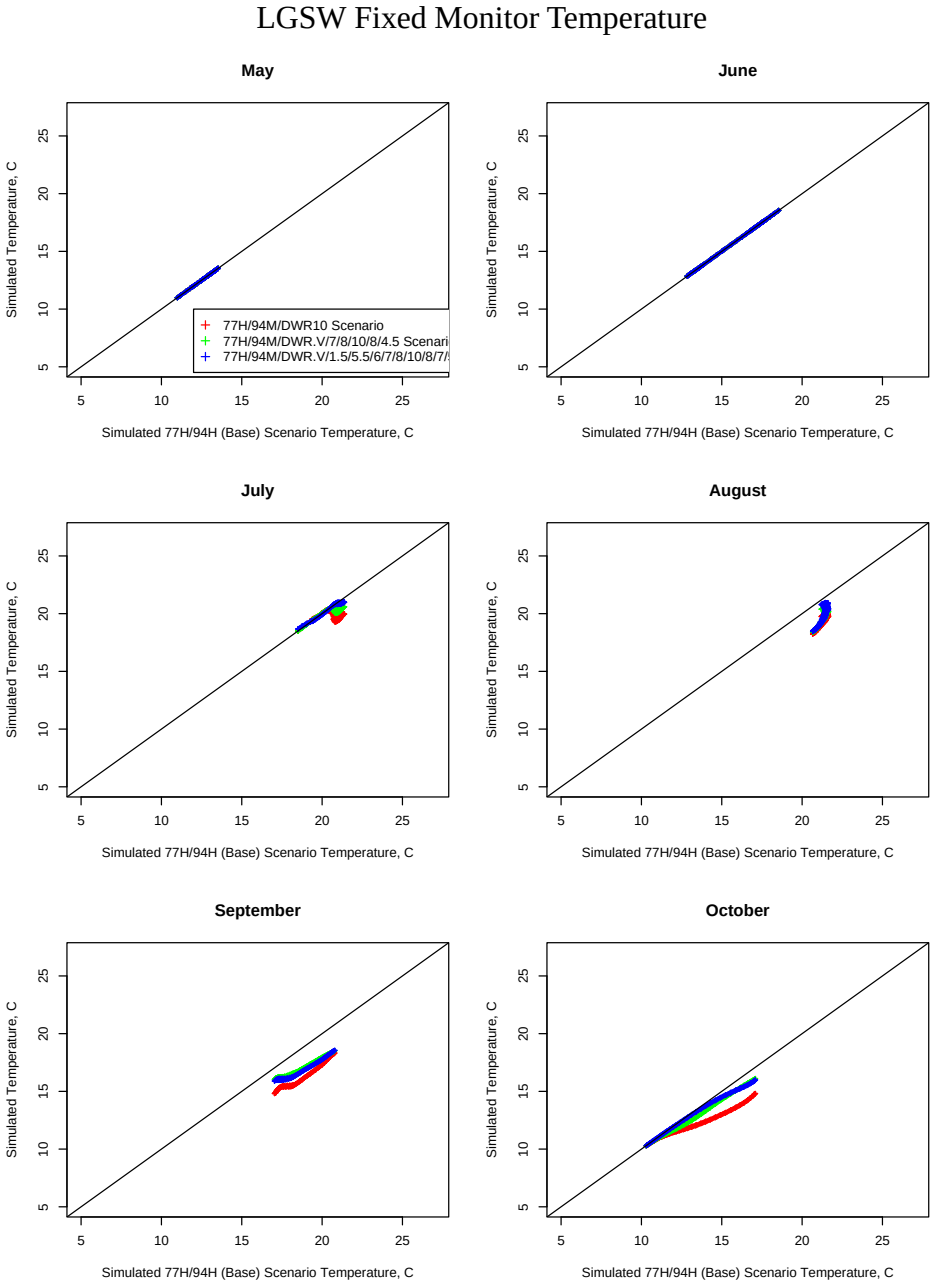

Figure 68: Scatter plot comparison, by month, of simulated temperature at the LGSW Fixed Monitor.

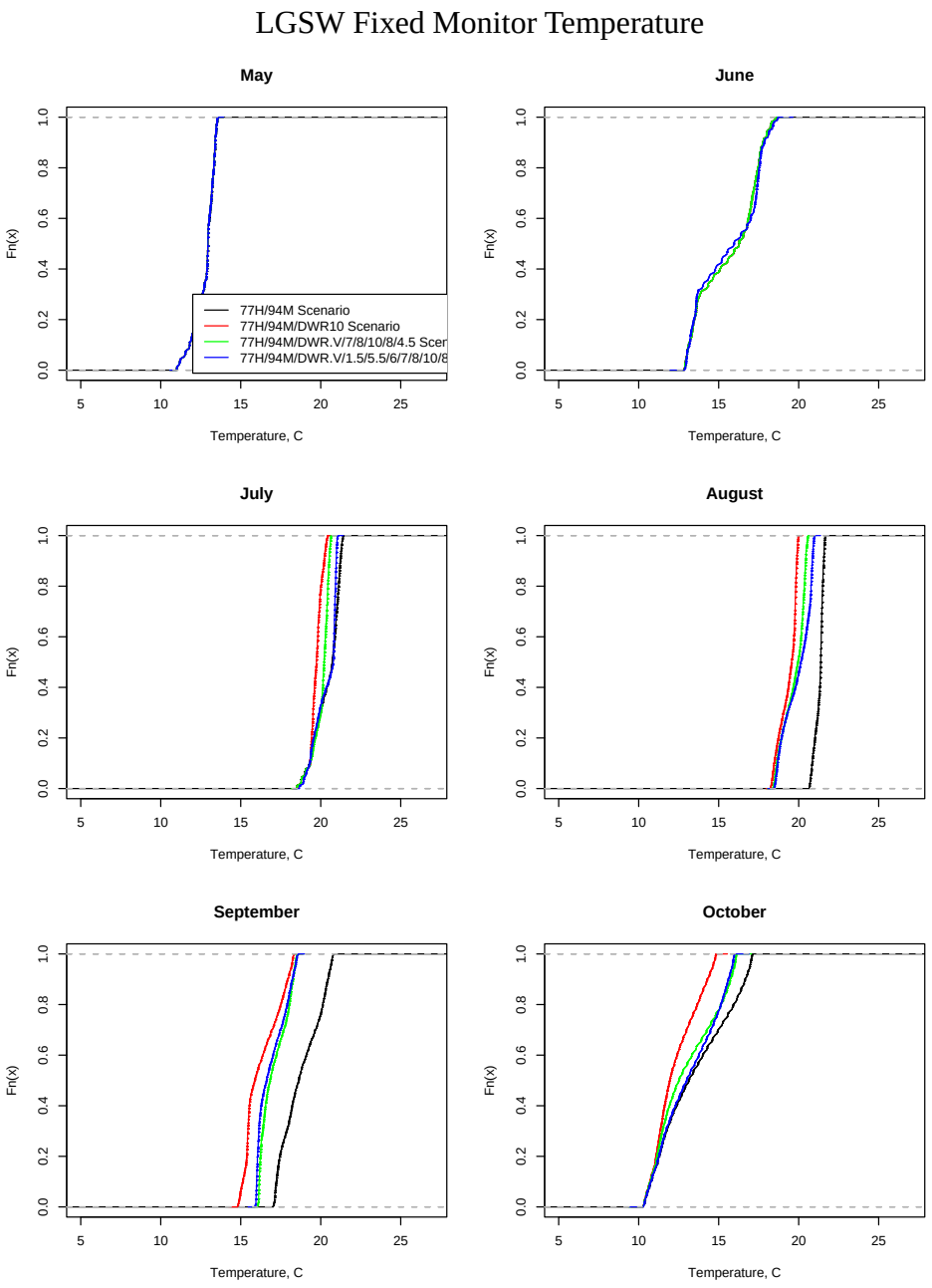

Figure 69: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the LGSW Fixed Monitor.

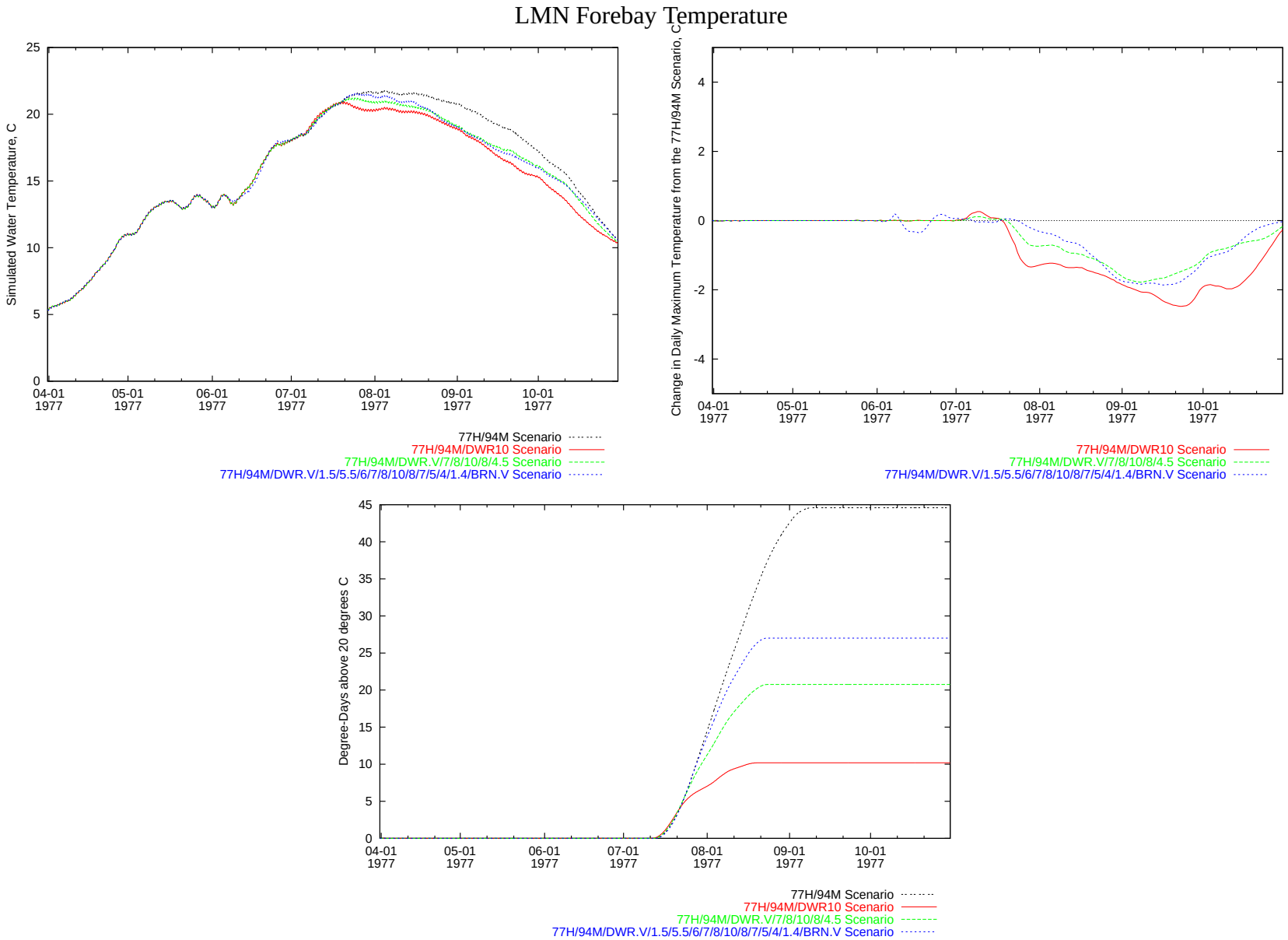

Figure 70: Time series comparison of simulated temperature at the LMN Forebay.

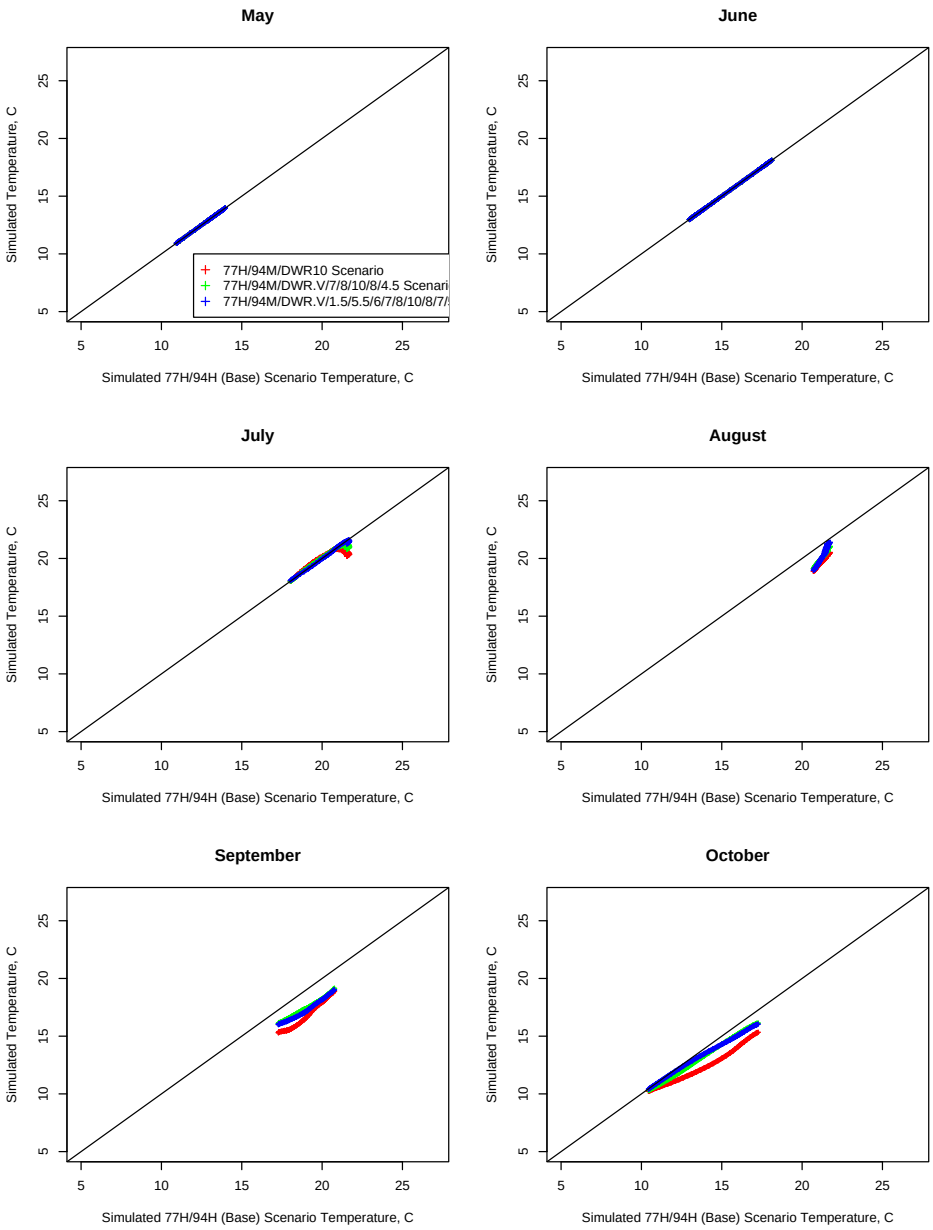

Figure 71: Scatter plot comparison, by month, of simulated temperature at the LMN Forebay.

LMN Forebay Temperature

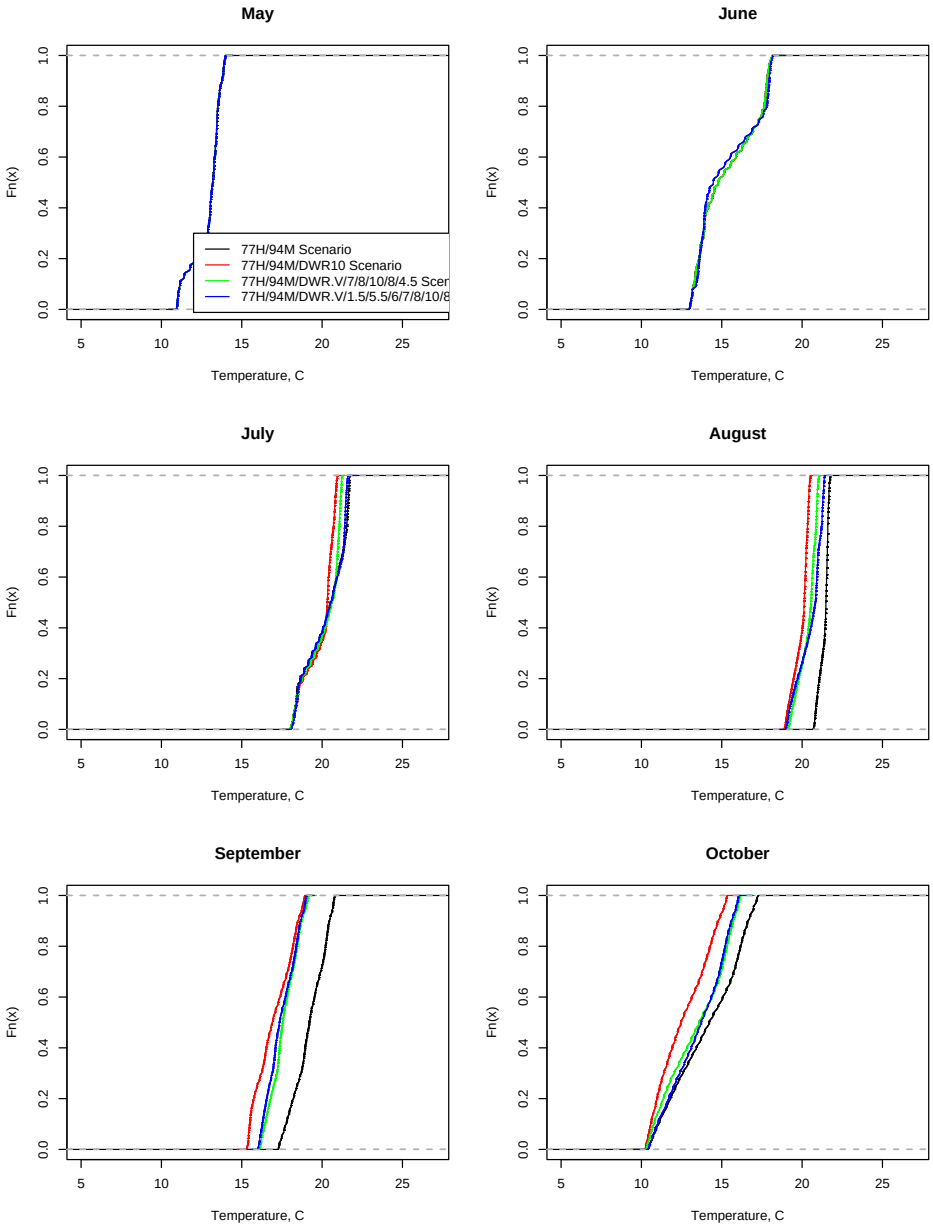

Figure 72: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the LMN Forebay.

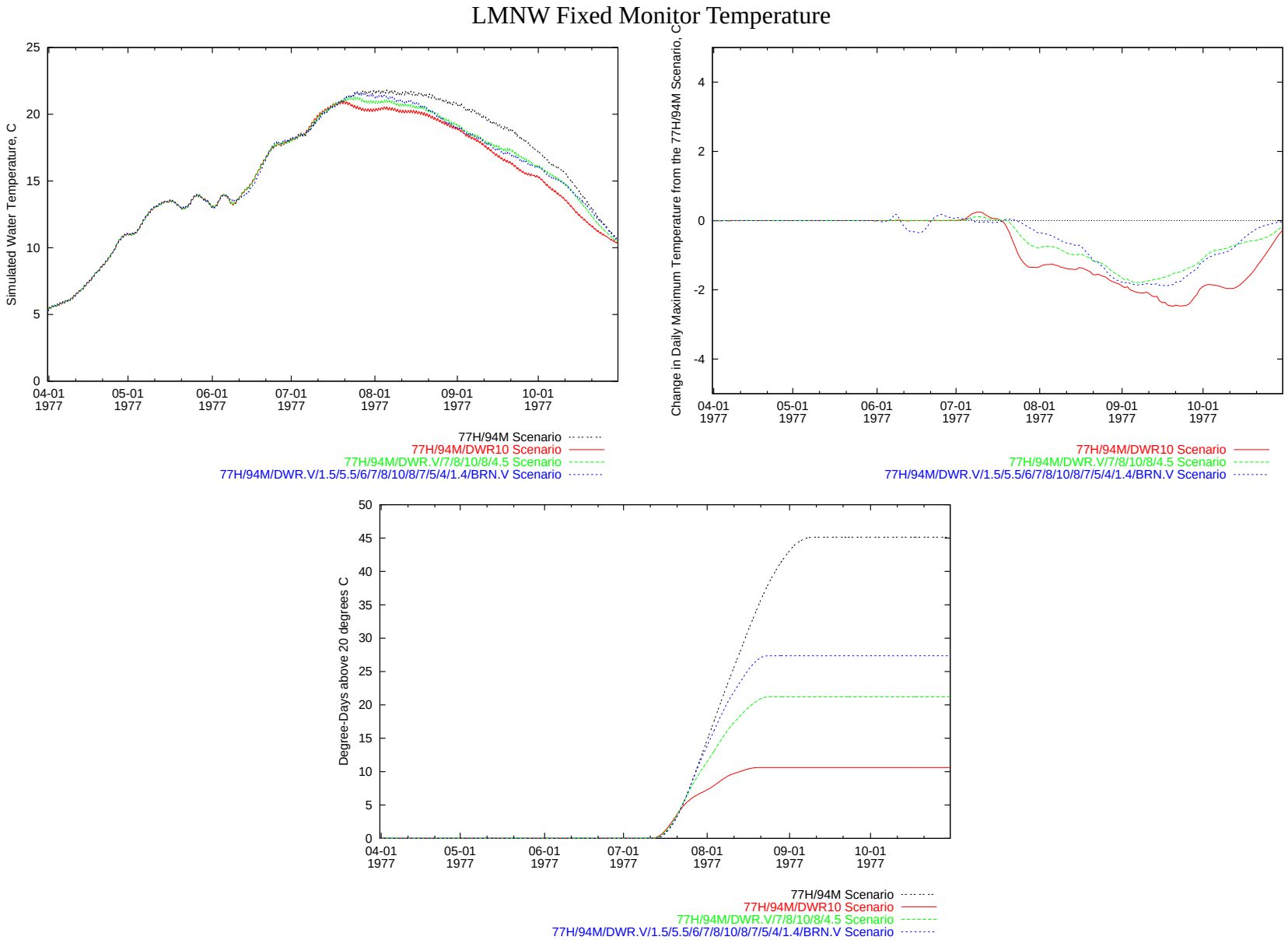

Figure 73: Time series comparison of simulated temperature at the LMNW Fixed Monitor.

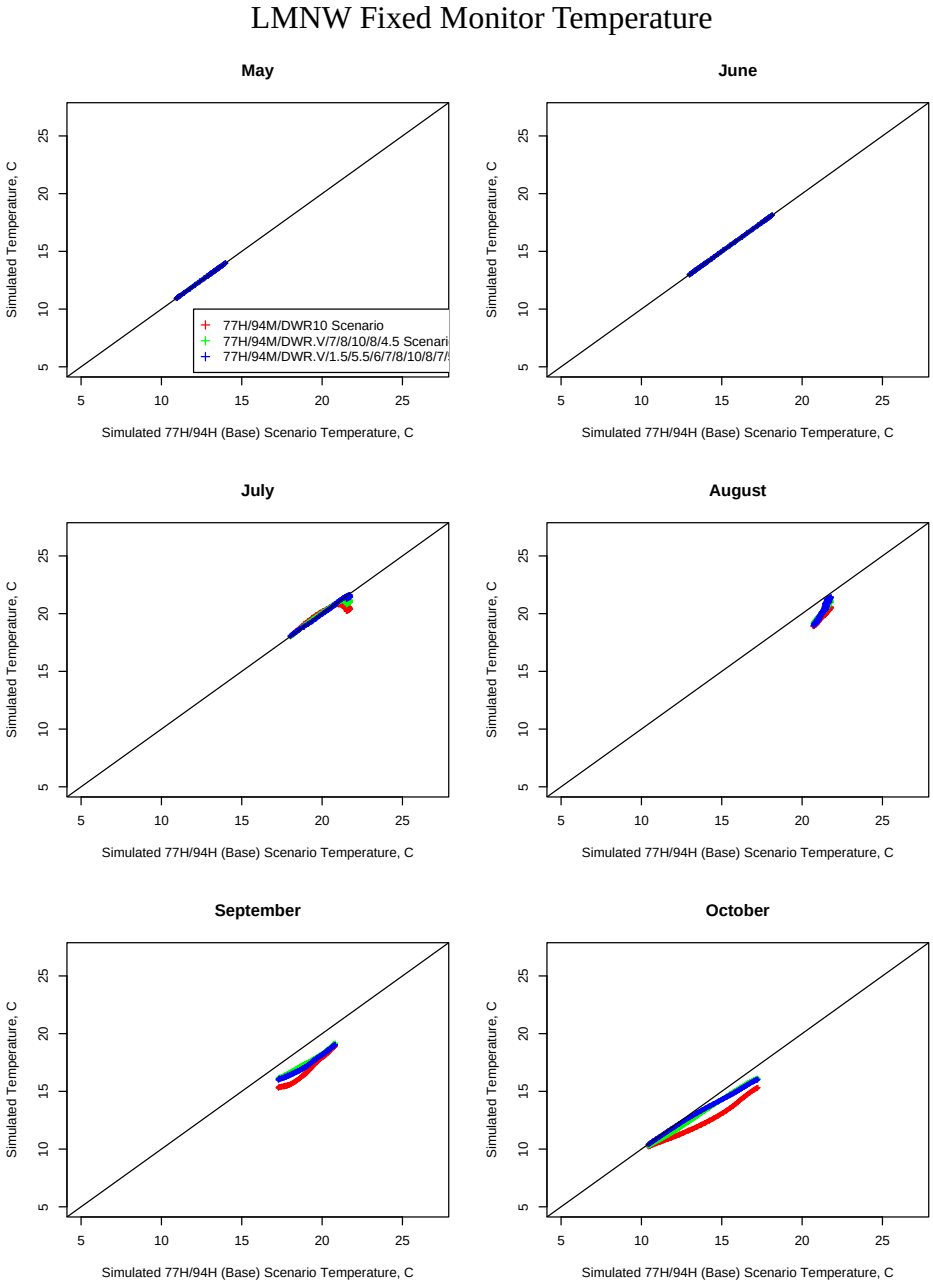

Figure 74: Scatter plot comparison, by month, of simulated temperature at the LMNW Fixed Monitor.

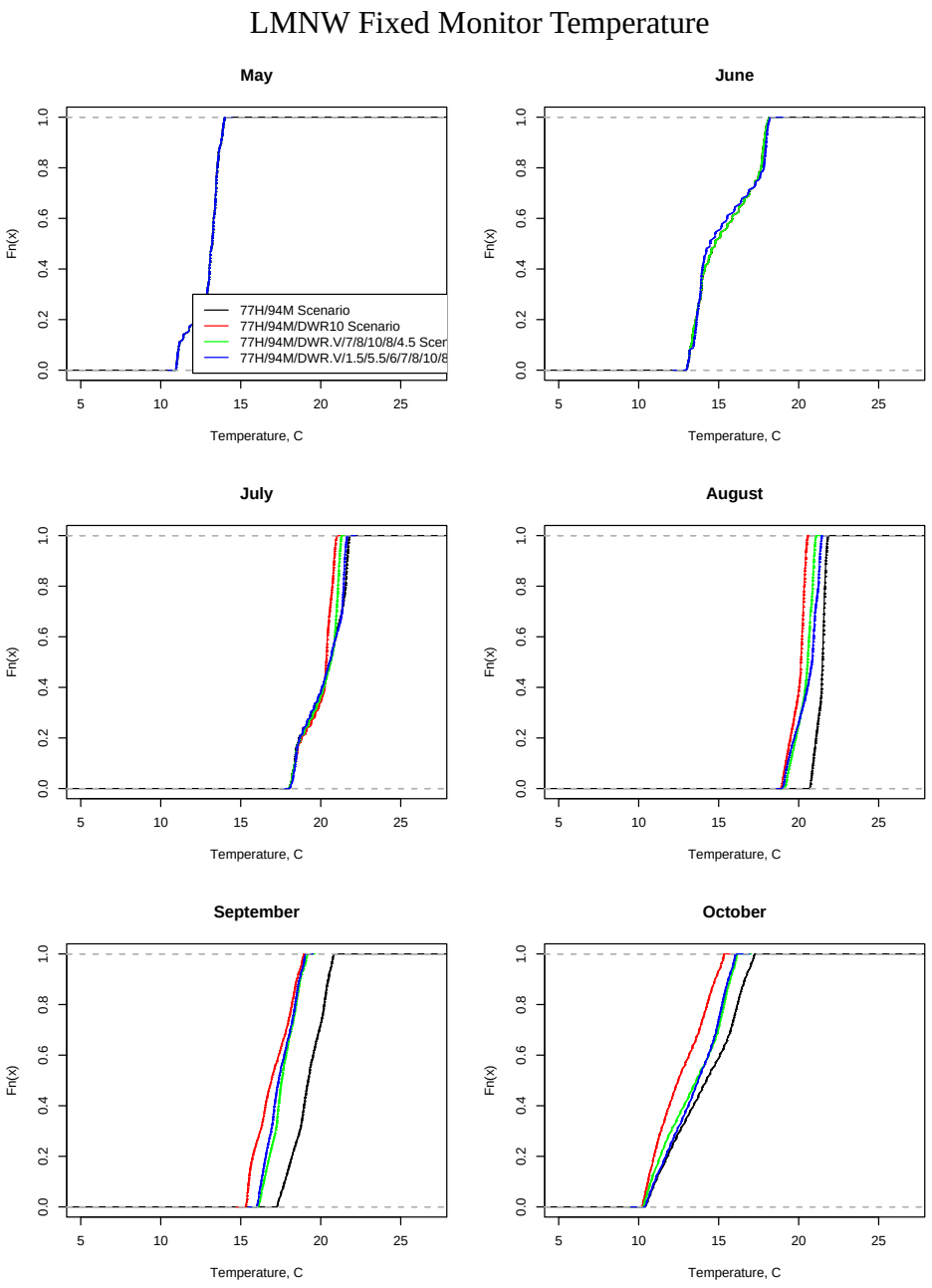

Figure 75: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the LMNW Fixed Monitor.

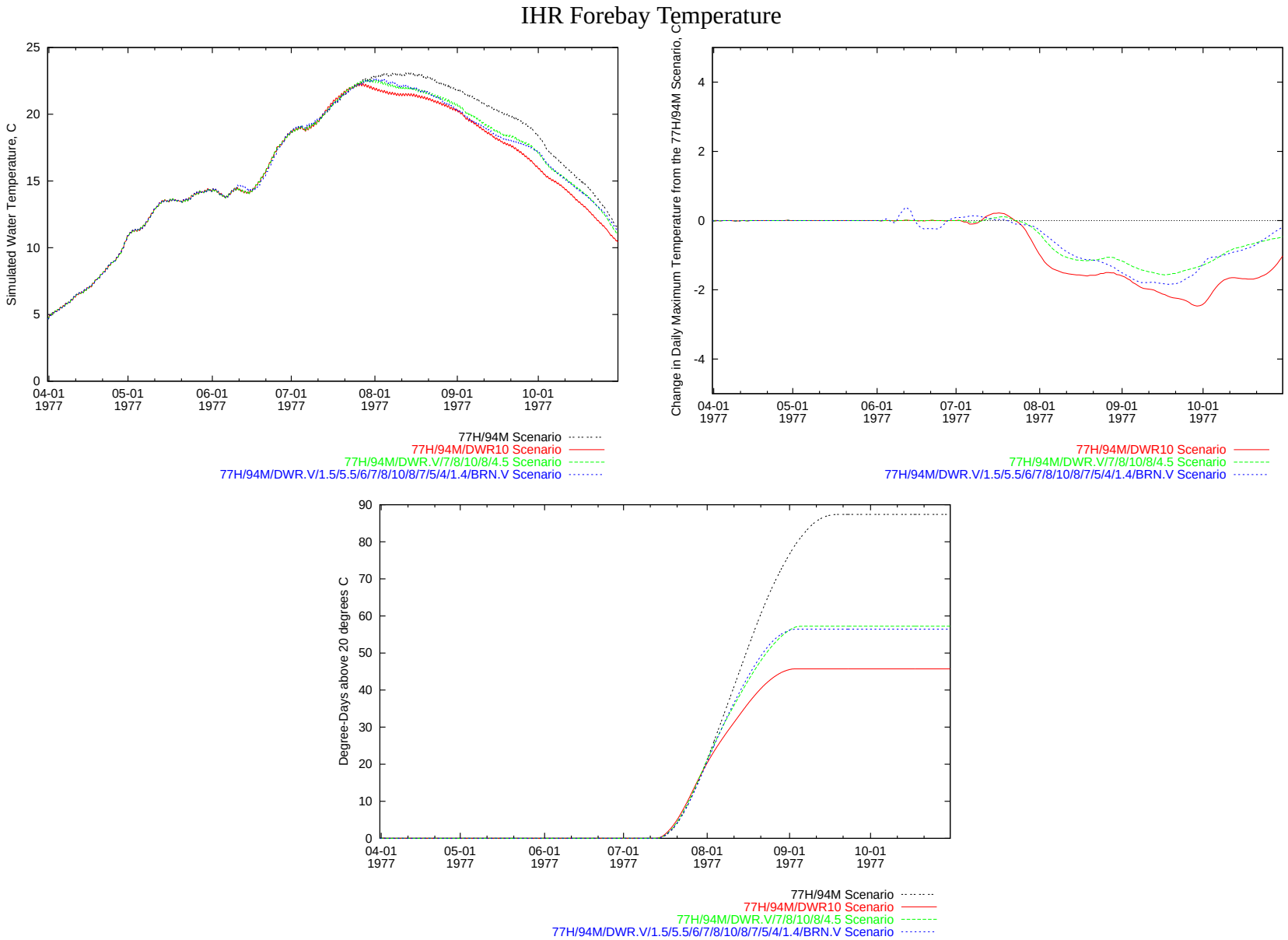

Figure 76: Time series comparison of simulated temperature at the IHR Forebay.

IHR Forebay Temperature

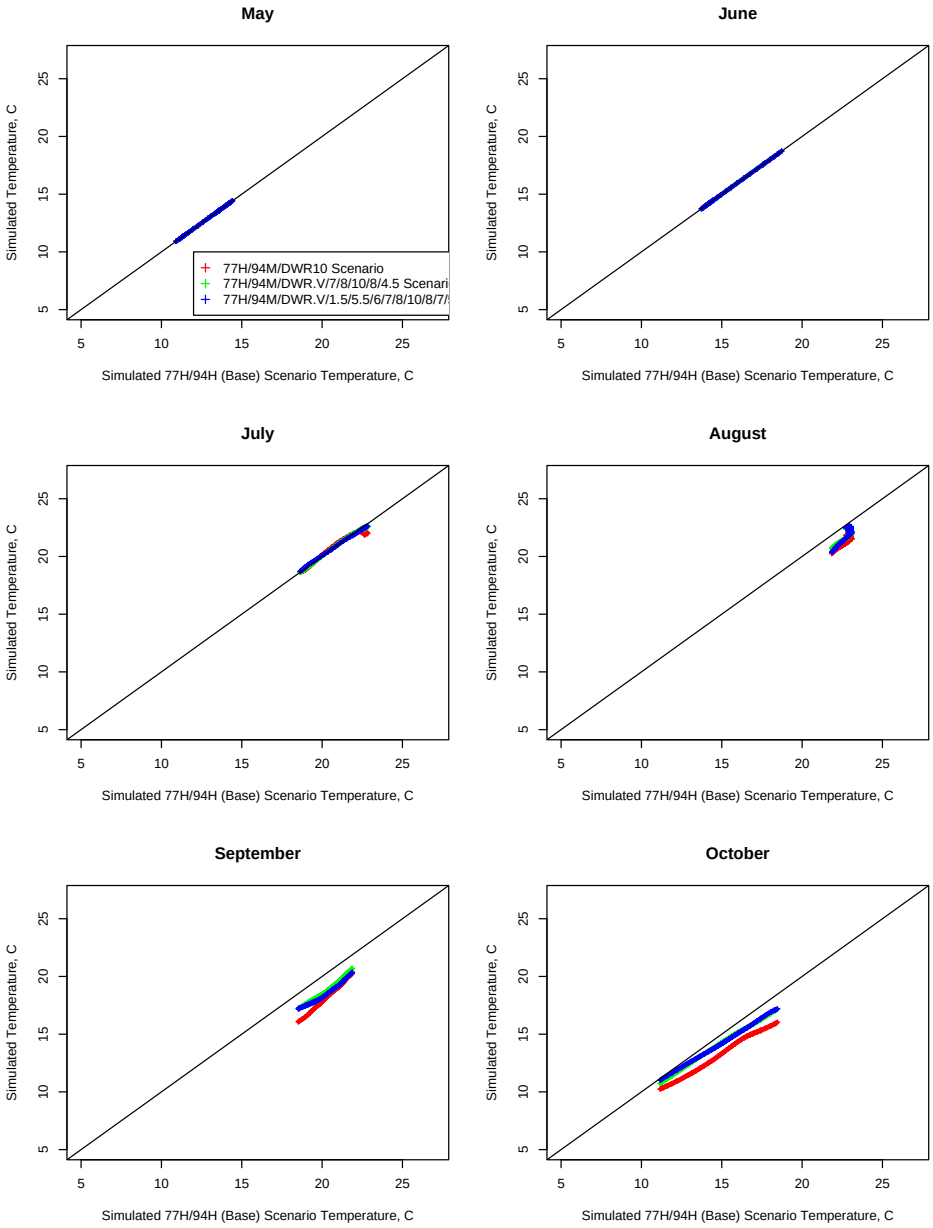

Figure 77: Scatter plot comparison, by month, of simulated temperature at the IHR Forebay.

IHR Forebay Temperature

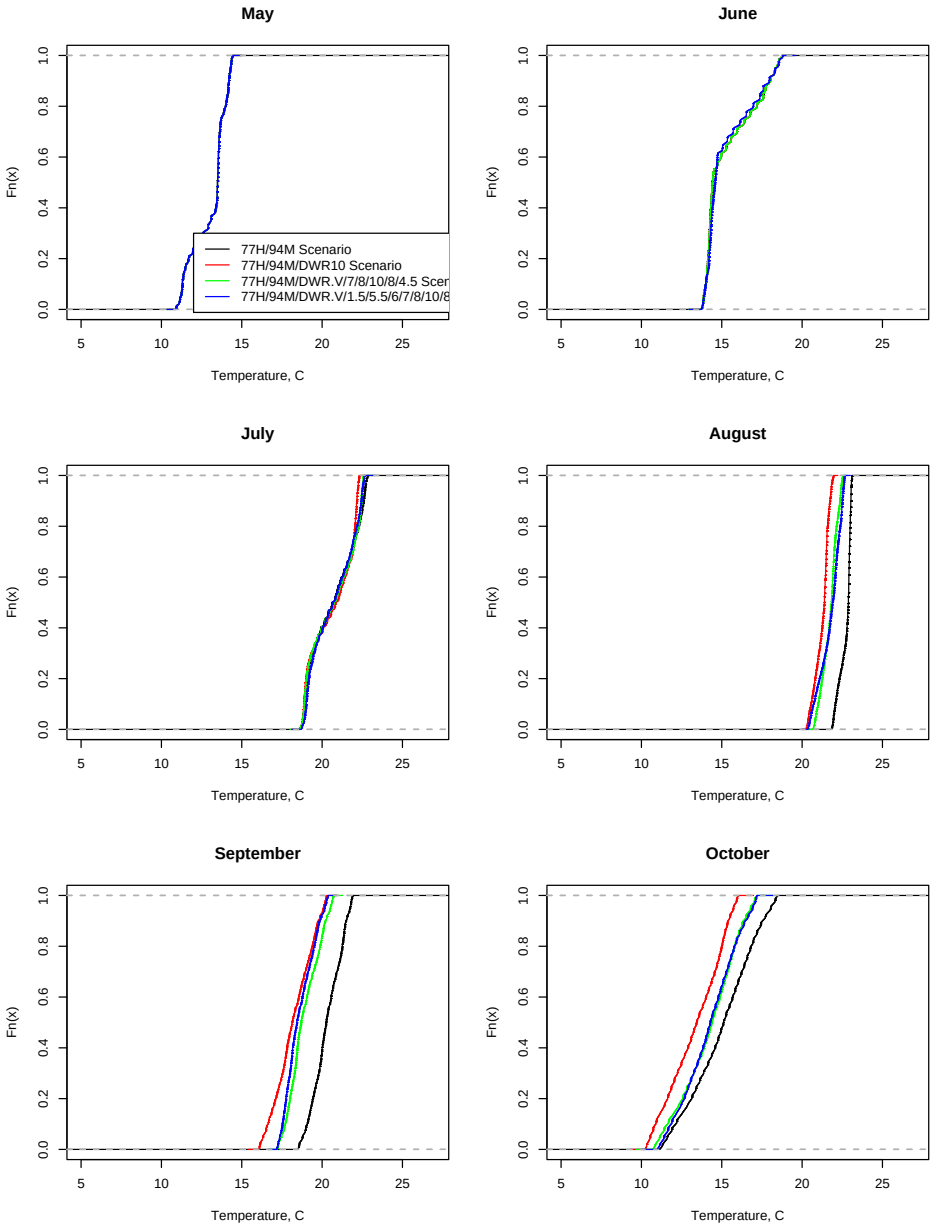

Figure 78: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the IHR Forebay.

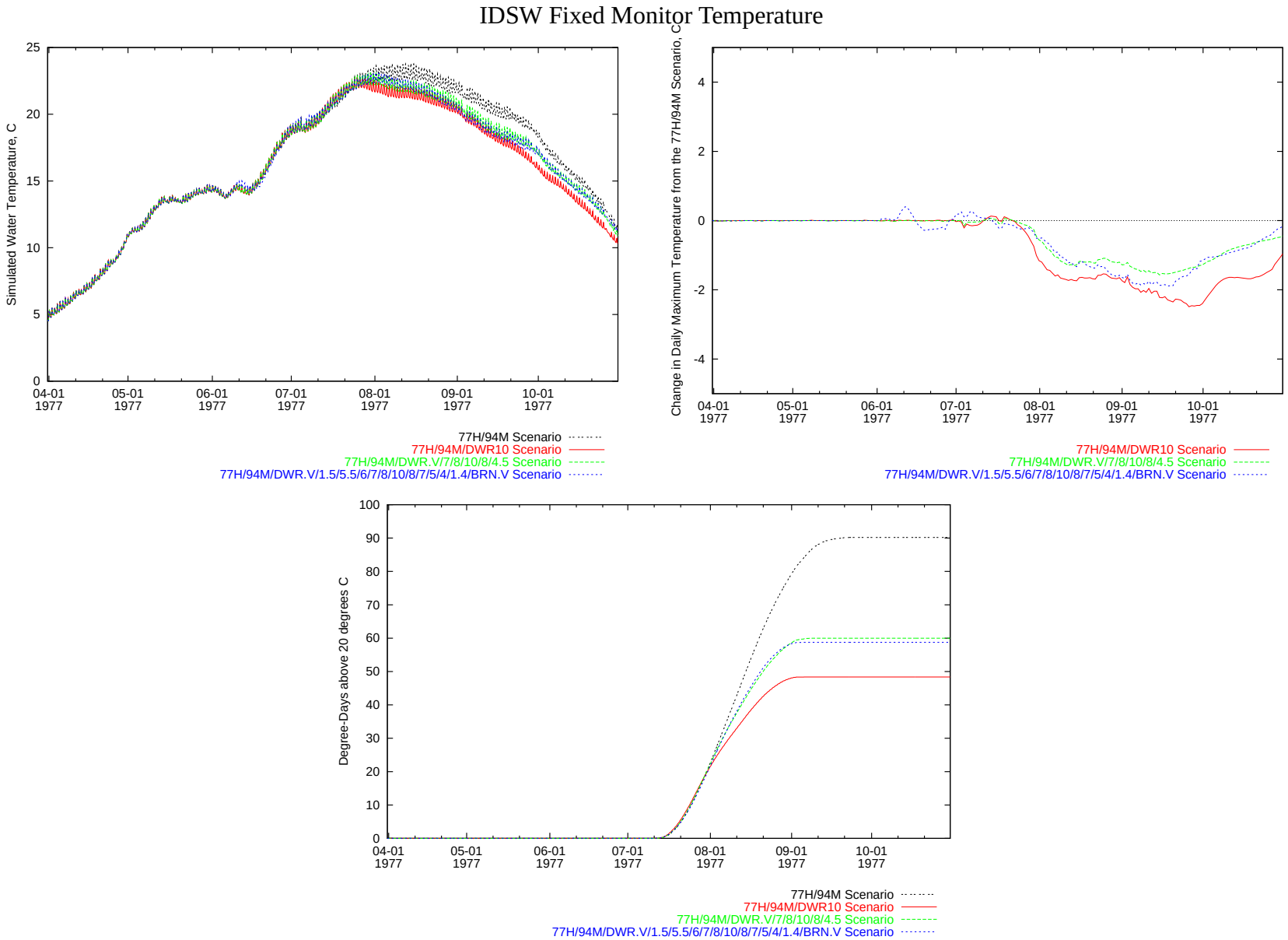

Figure 79: Time series comparison of simulated temperature at the IDSW Fixed Monitor.

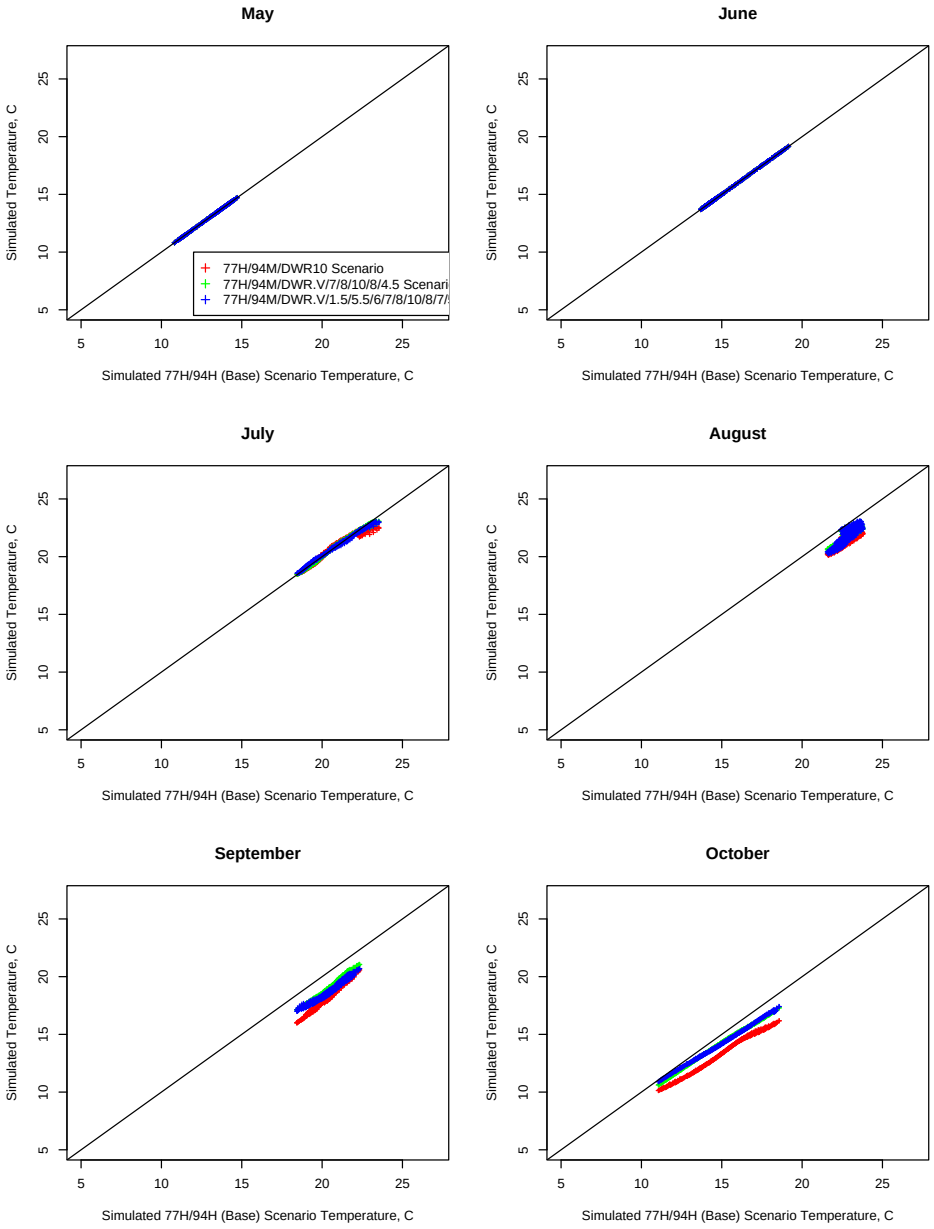

Figure 80: Scatter plot comparison, by month, of simulated temperature at the IDSW Fixed Monitor.

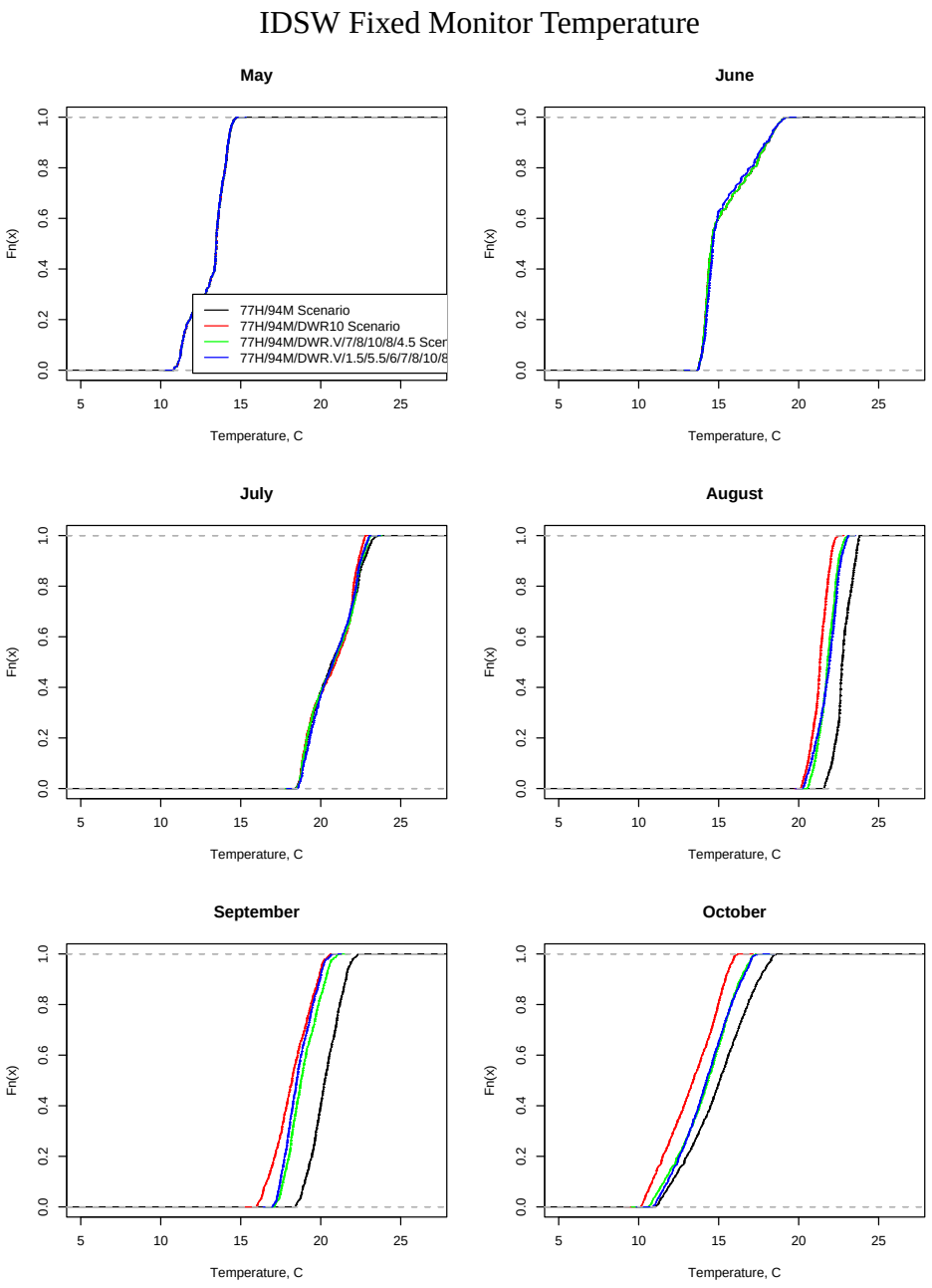

Figure 81: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the IDSW Fixed Monitor.

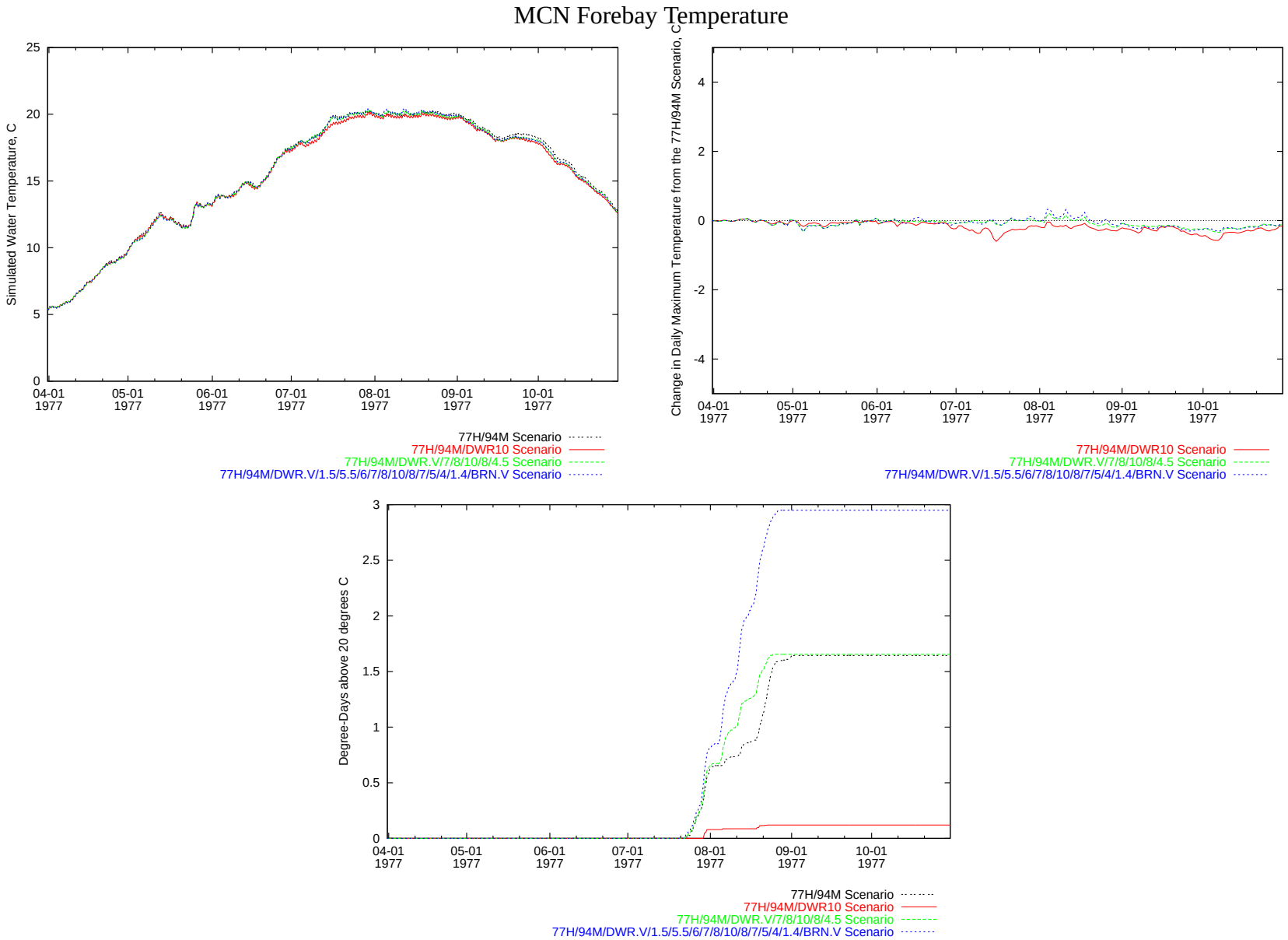

Figure 82: Time series comparison of simulated temperature at the MCN Forebay.

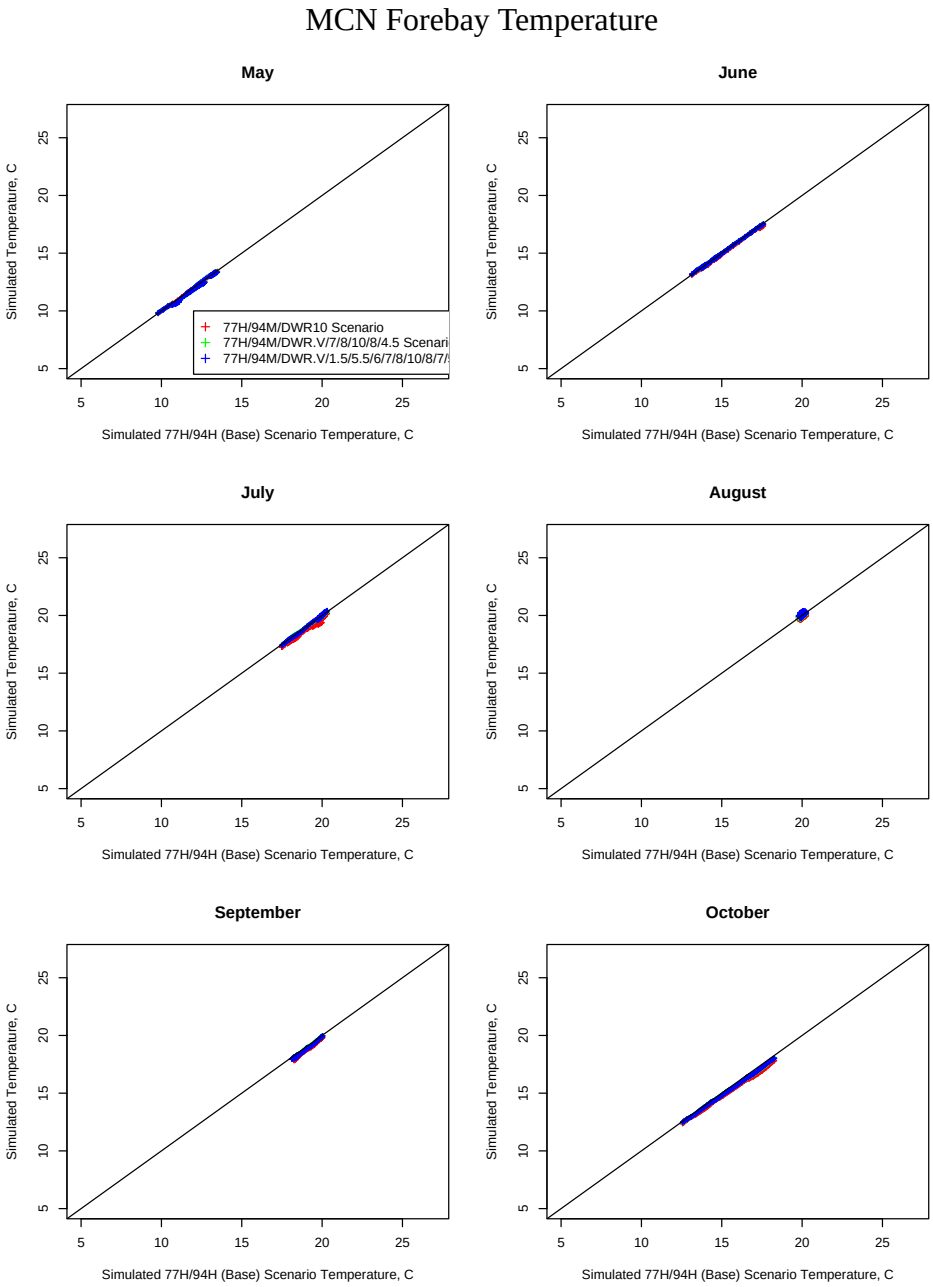

Figure 83: Scatter plot comparison, by month, of simulated temperature at the MCN Forebay.

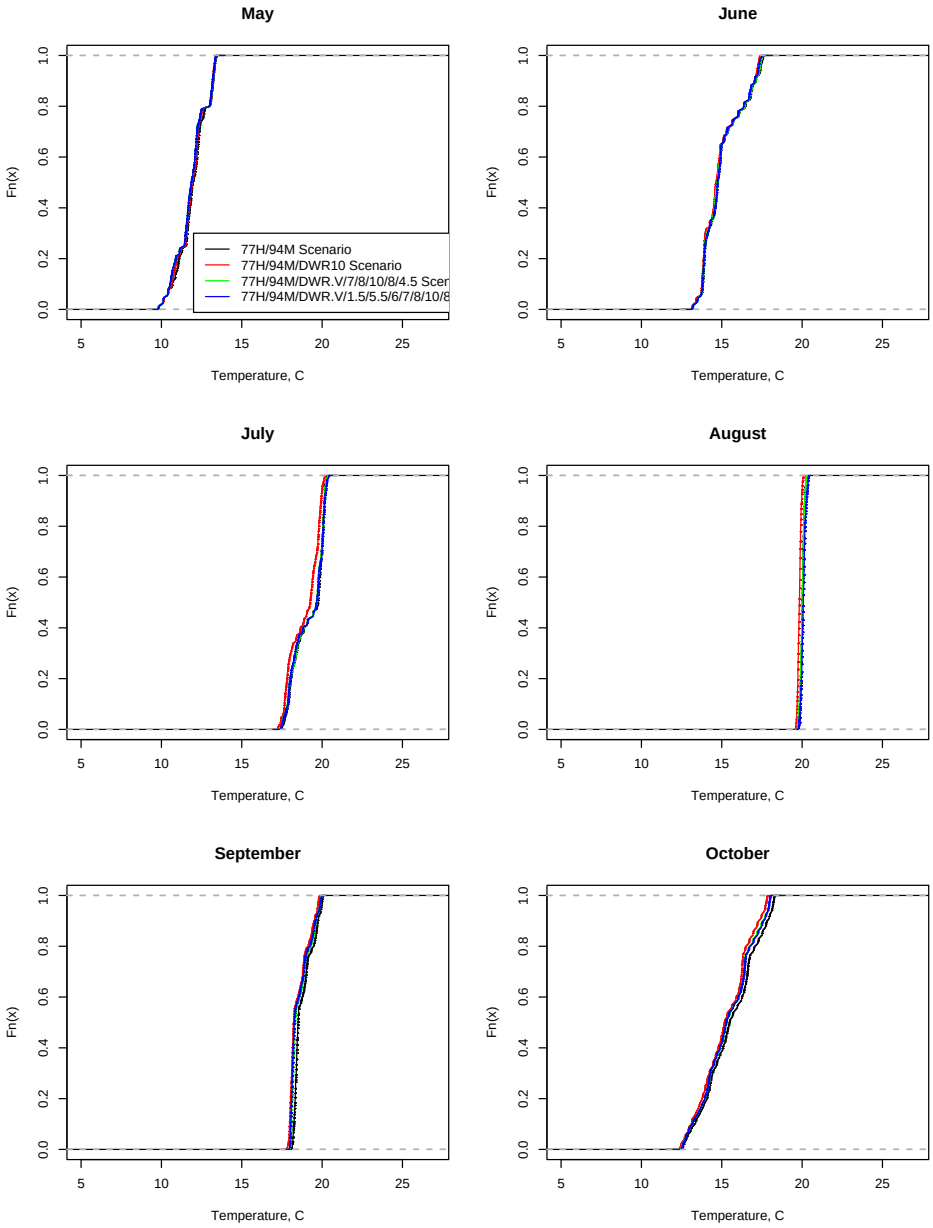

Figure 84: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the MCN Forebay.

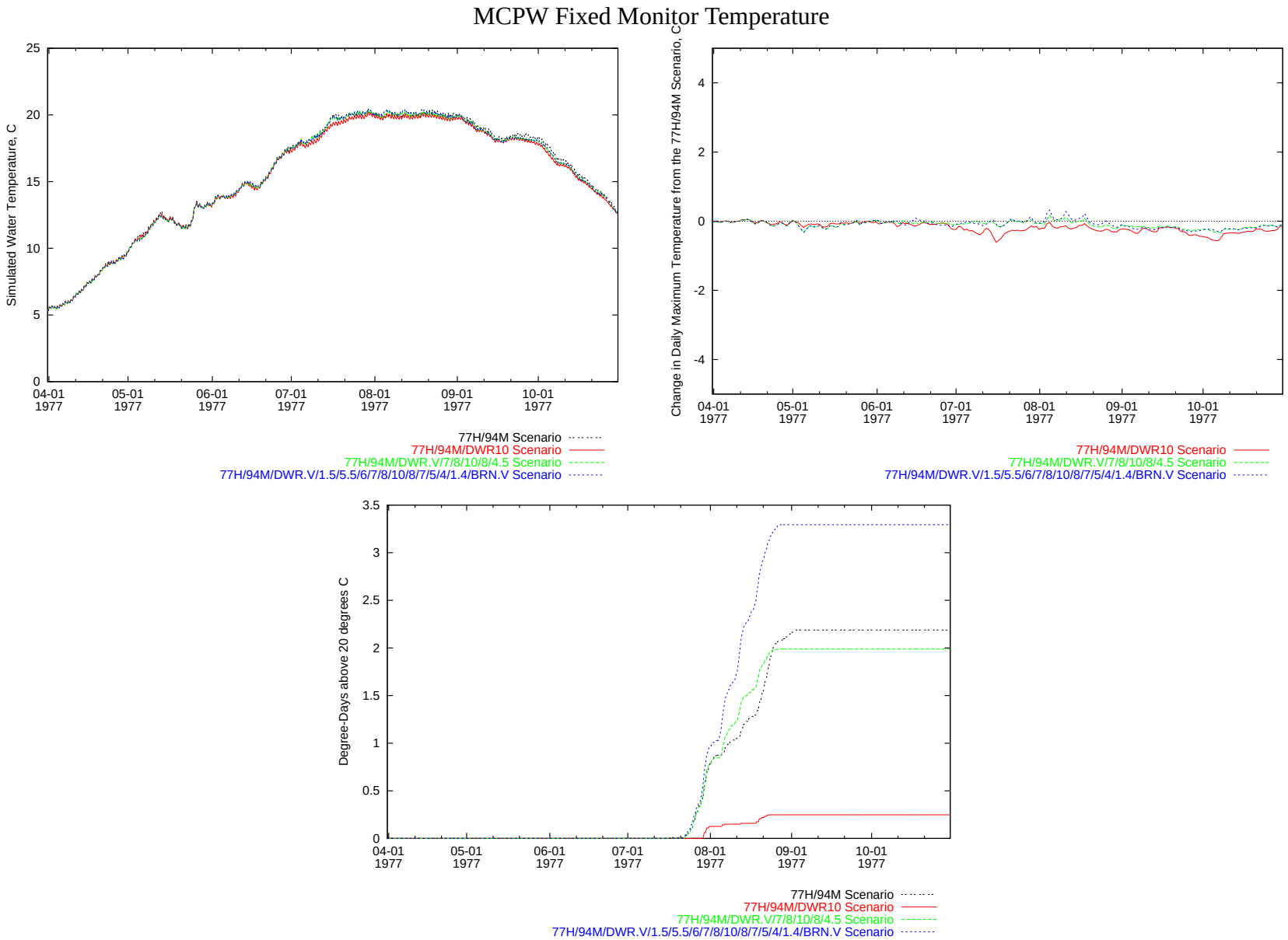

Figure 85: Time series comparison of simulated temperature at the MCPW Fixed Monitor.

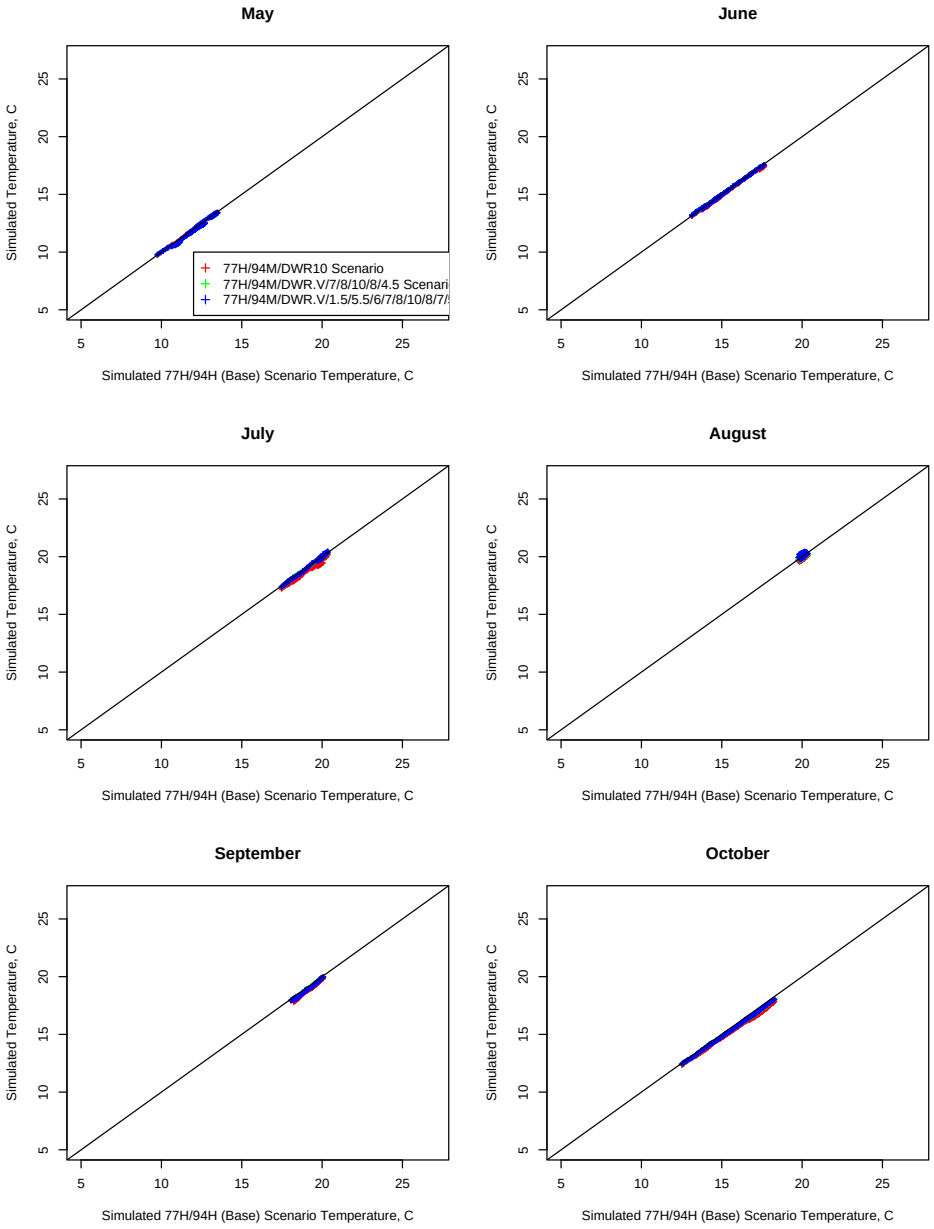

Figure 86: Scatter plot comparison, by month, of simulated temperature at the MCPW Fixed Monitor.

MCPW Fixed Monitor Temperature

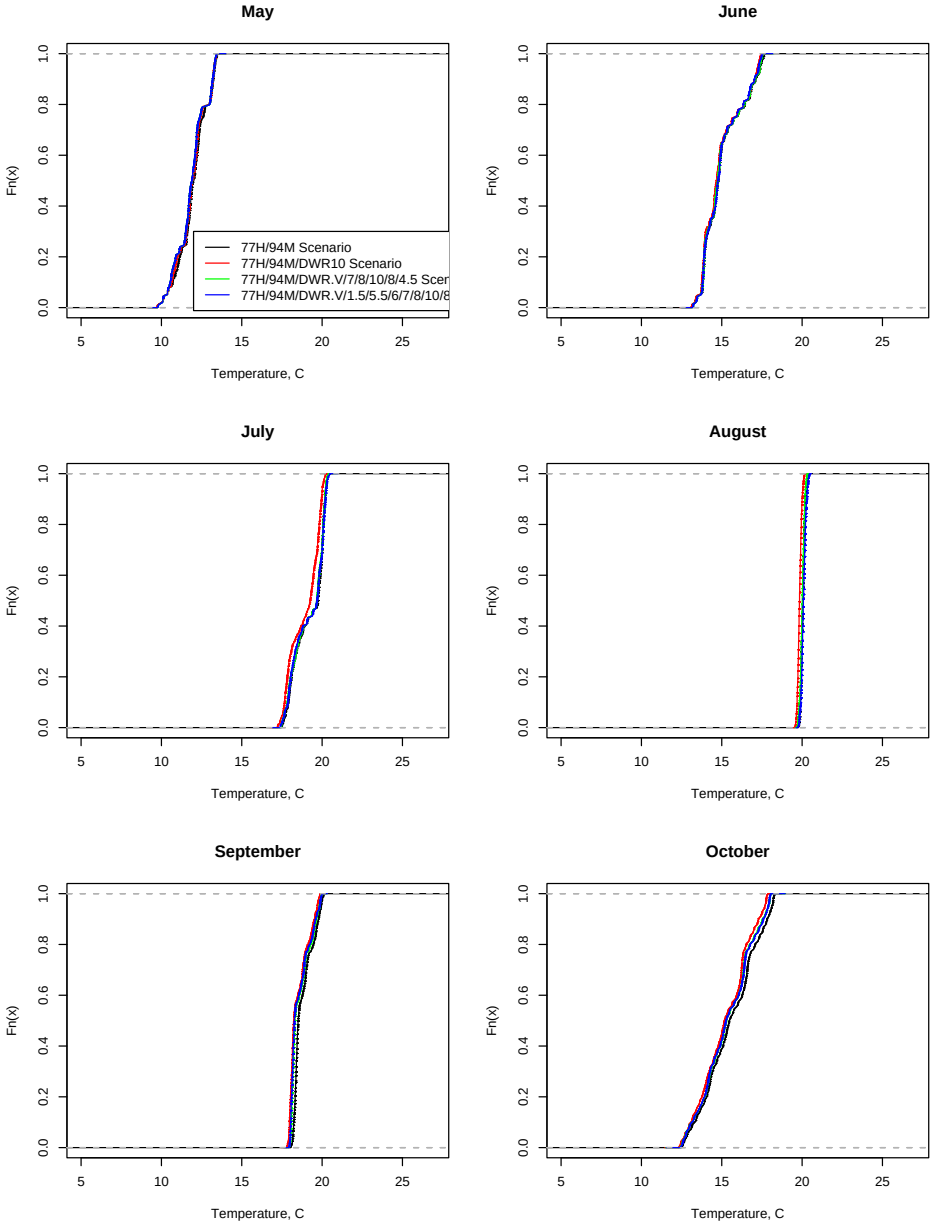

Figure 87: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the MCPW Fixed Monitor.

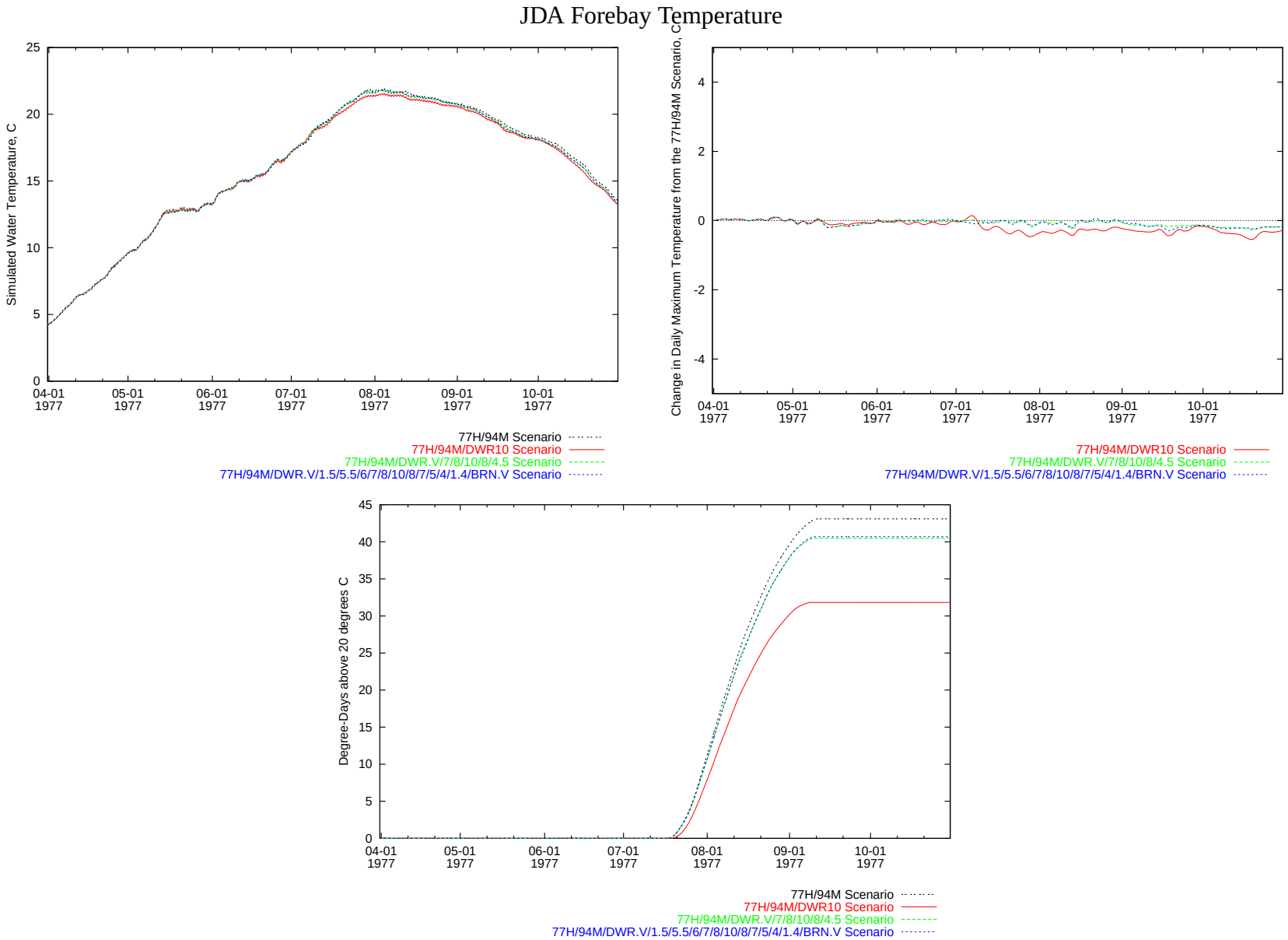

Figure 88: Time series comparison of simulated temperature at the JDA Forebay.

JDA Forebay Temperature

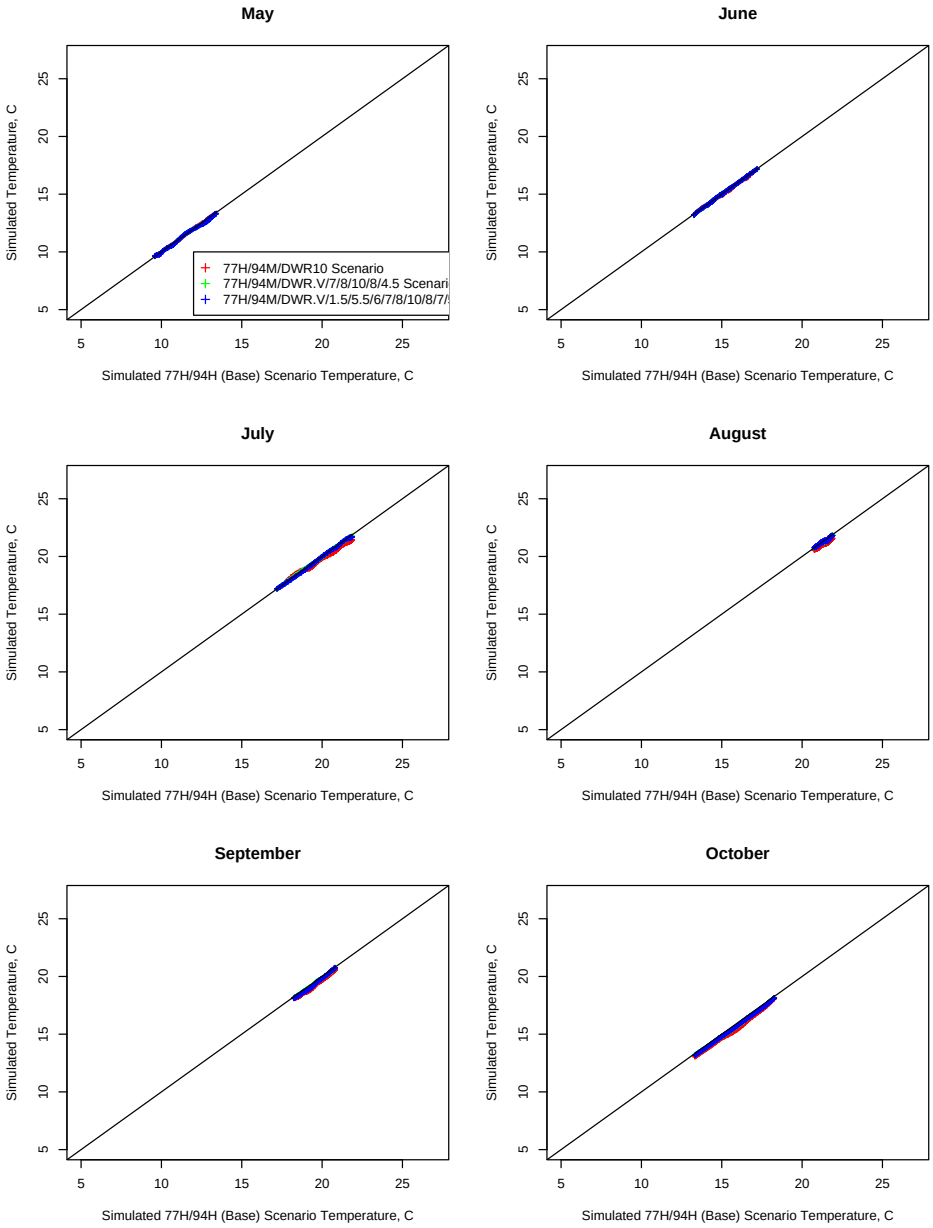

Figure 89: Scatter plot comparison, by month, of simulated temperature at the JDA Forebay.

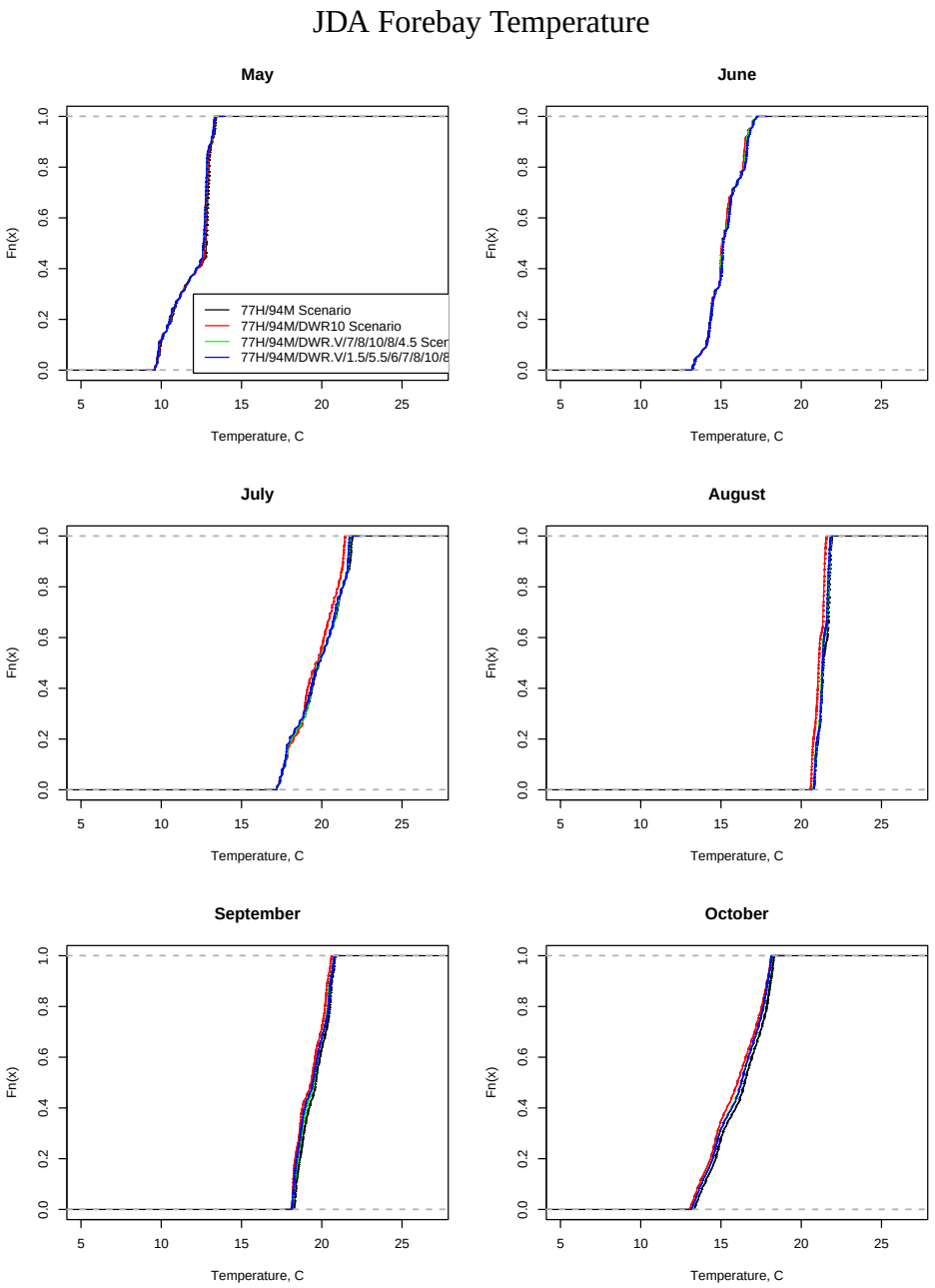

Figure 90: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the JDA Forebay.

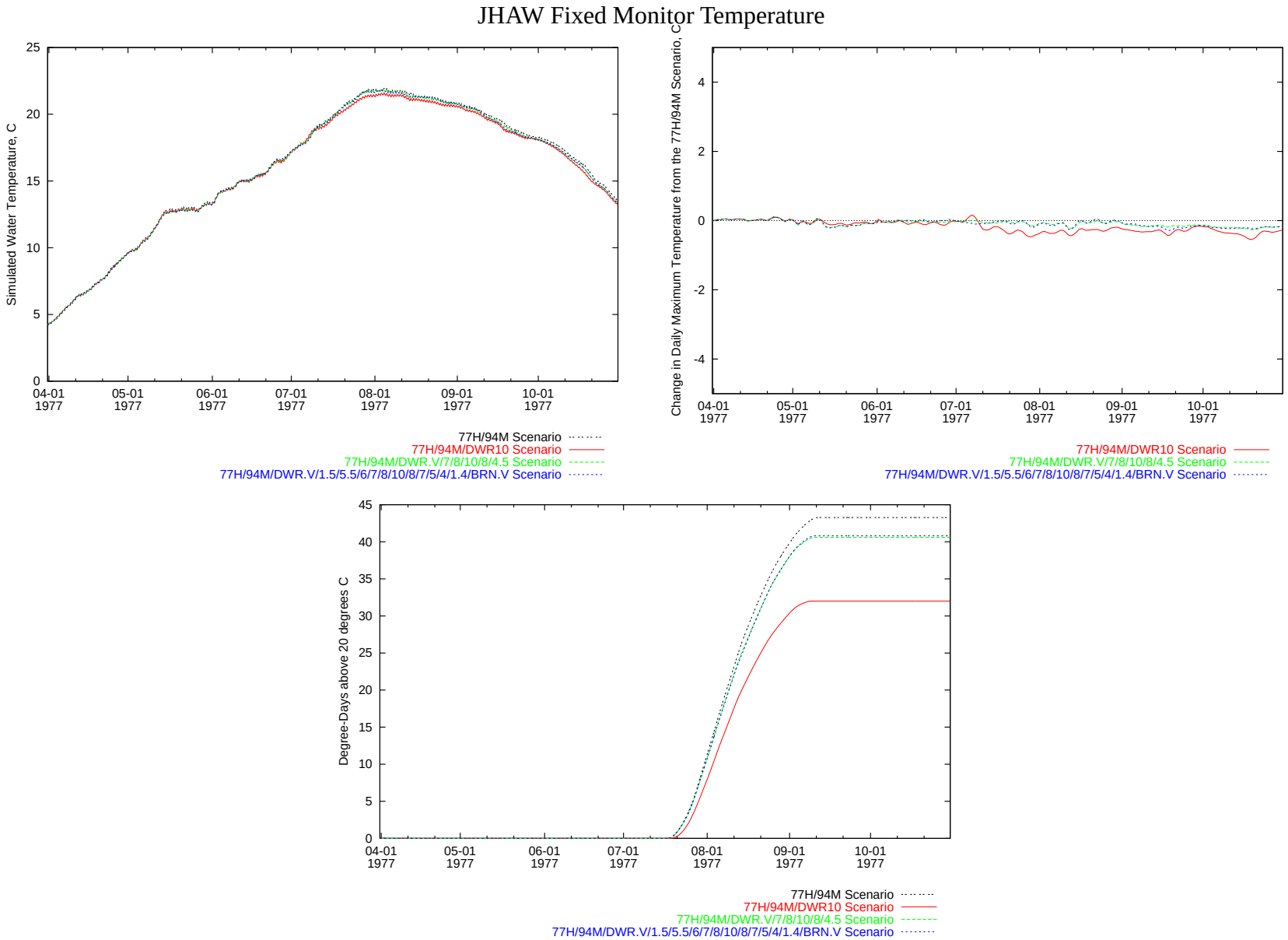

Figure 91: Time series comparison of simulated temperature at the JHAW Fixed Monitor.

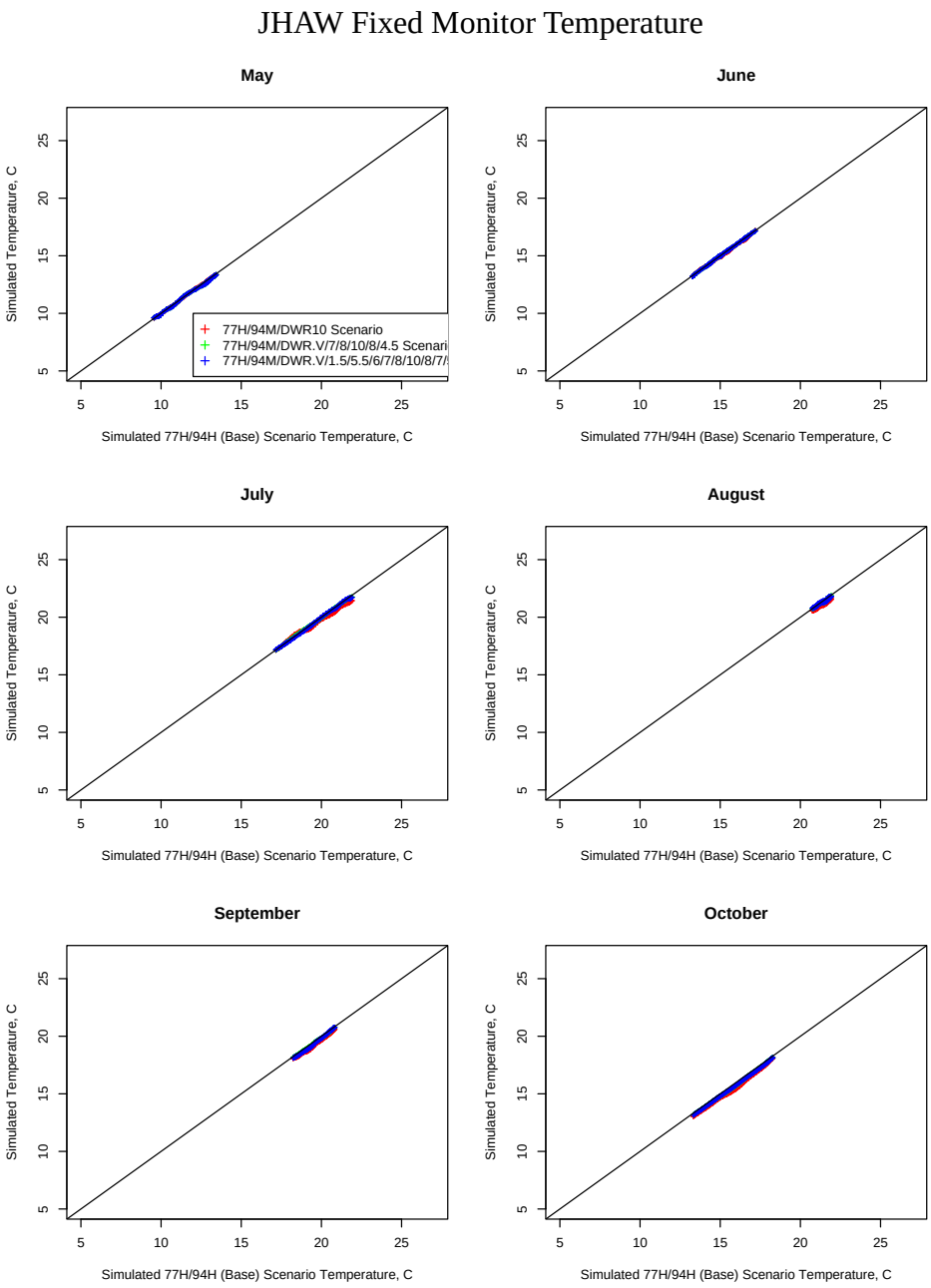

Figure 92: Scatter plot comparison, by month, of simulated temperature at the JHAW Fixed Monitor.

JHAW Fixed Monitor Temperature

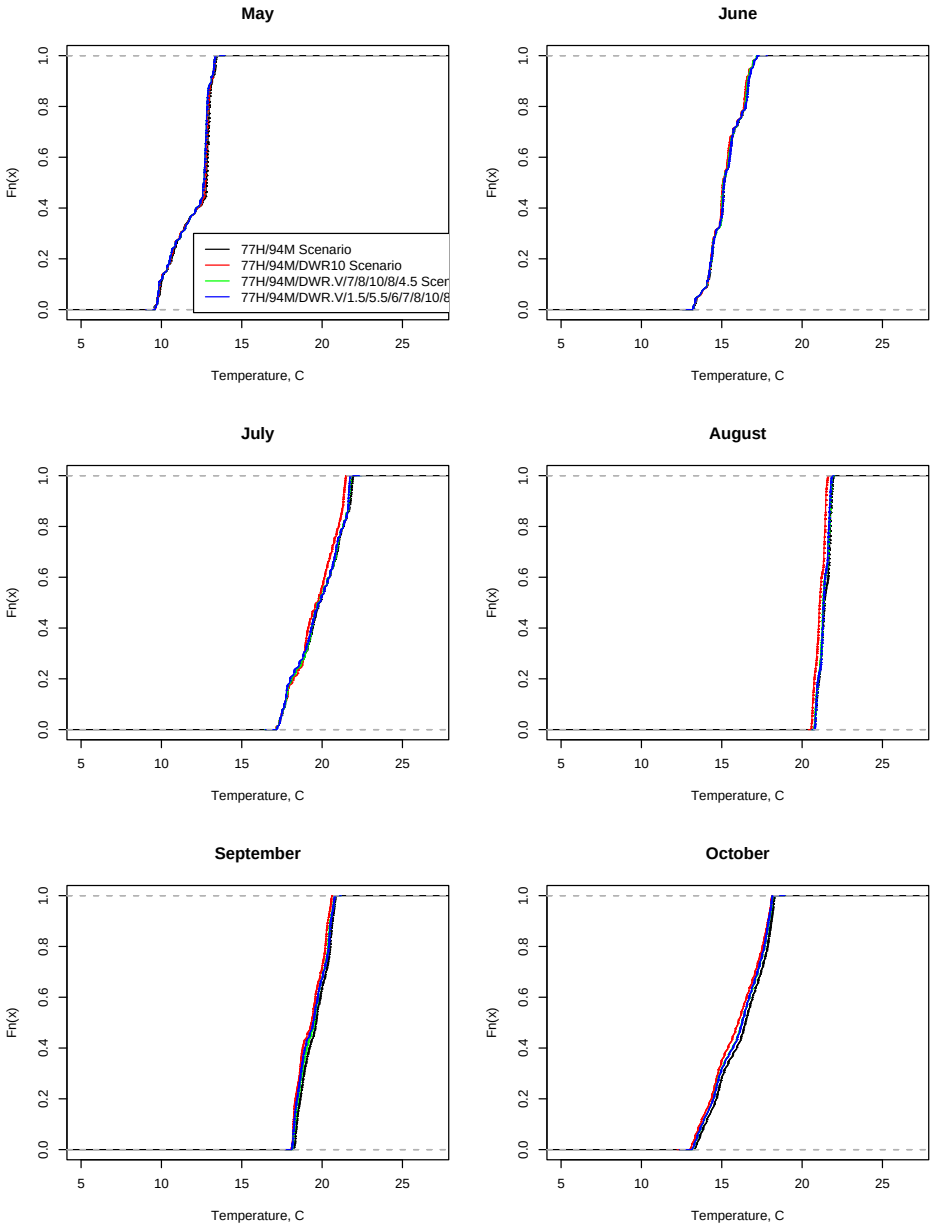

Figure 93: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the JHAW Fixed Monitor.

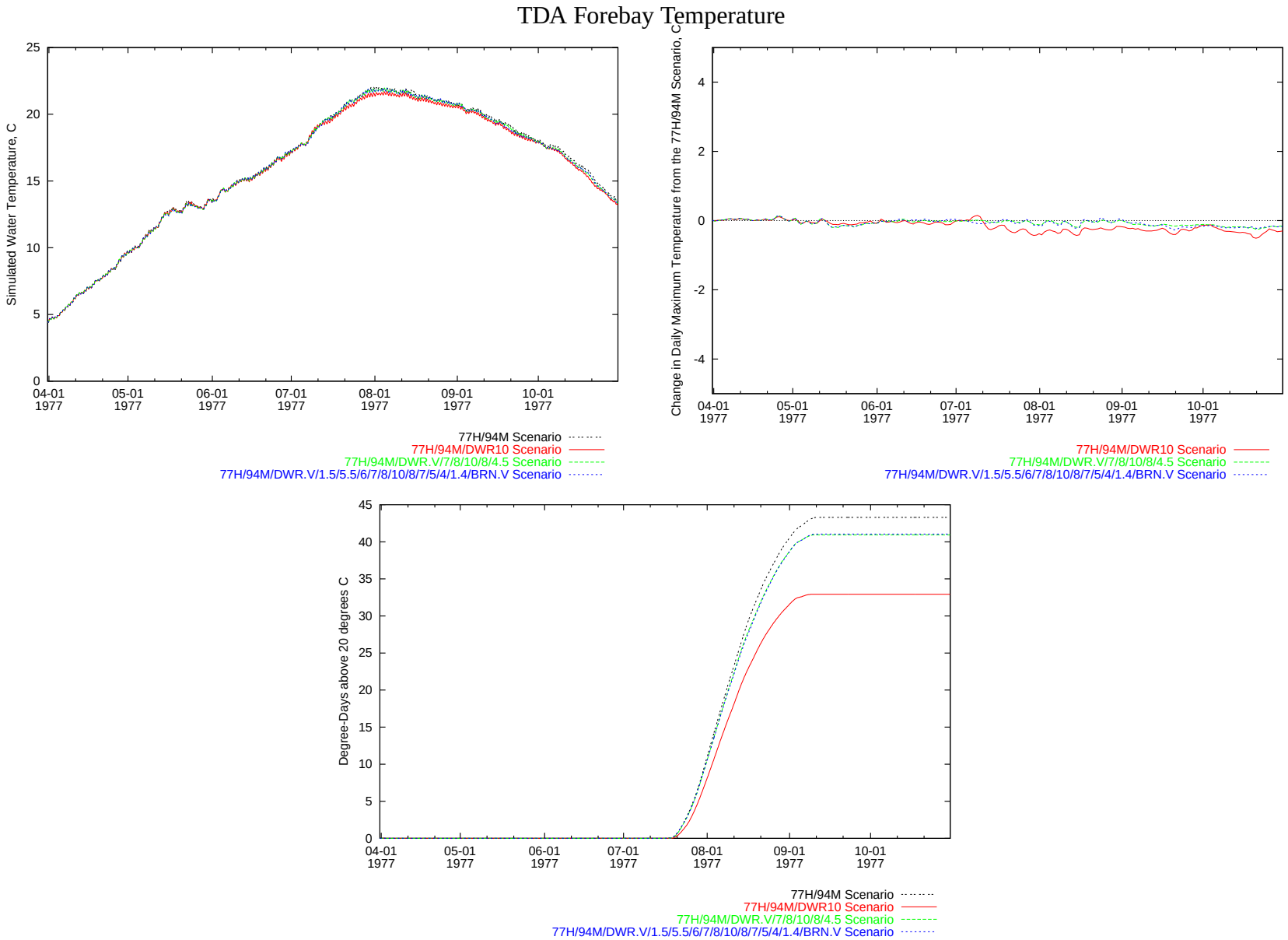

Figure 94: Time series comparison of simulated temperature at the TDA Forebay.

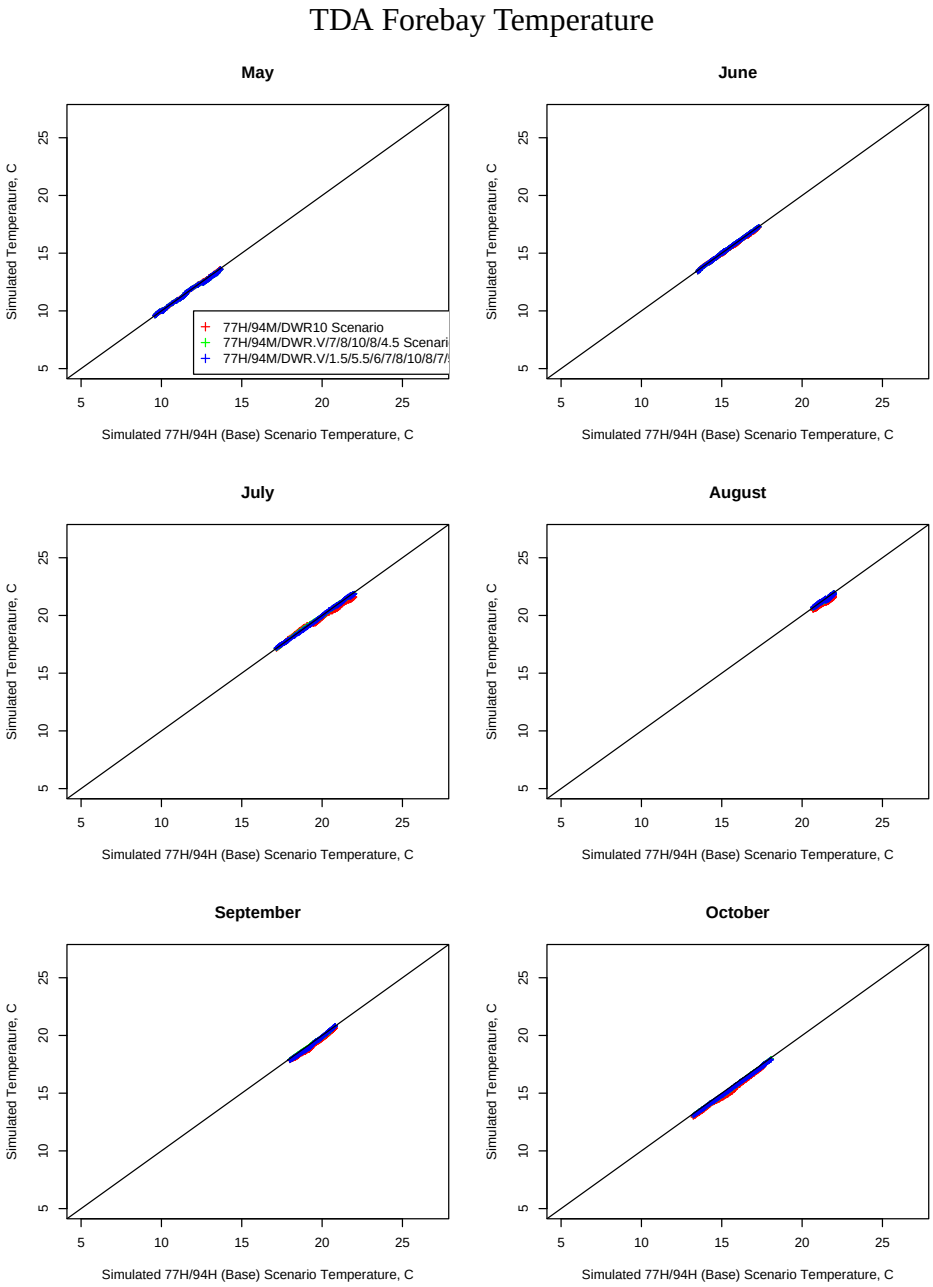

Figure 95: Scatter plot comparison, by month, of simulated temperature at the TDA Forebay.

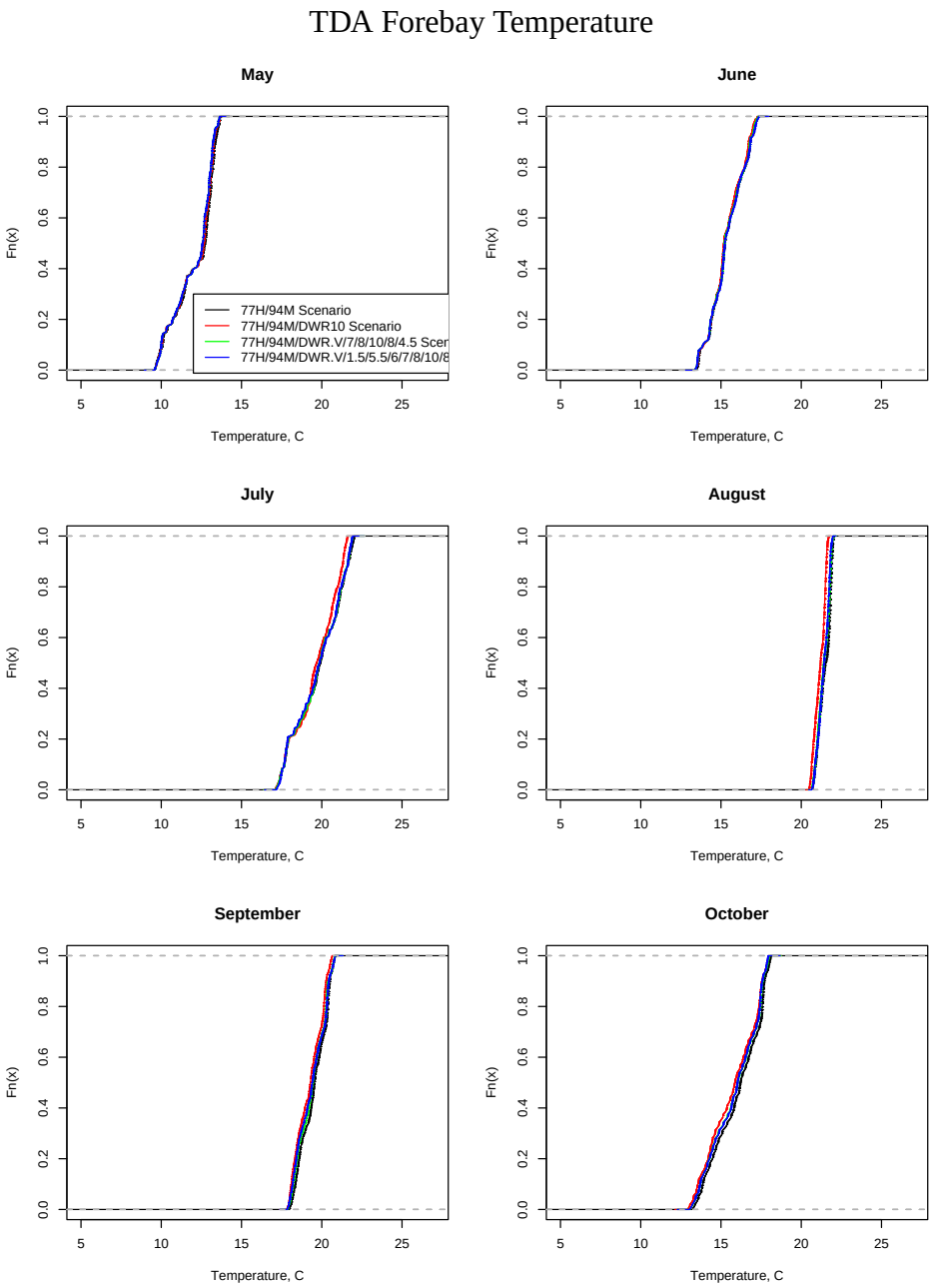

Figure 96: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the TDA Forebay.

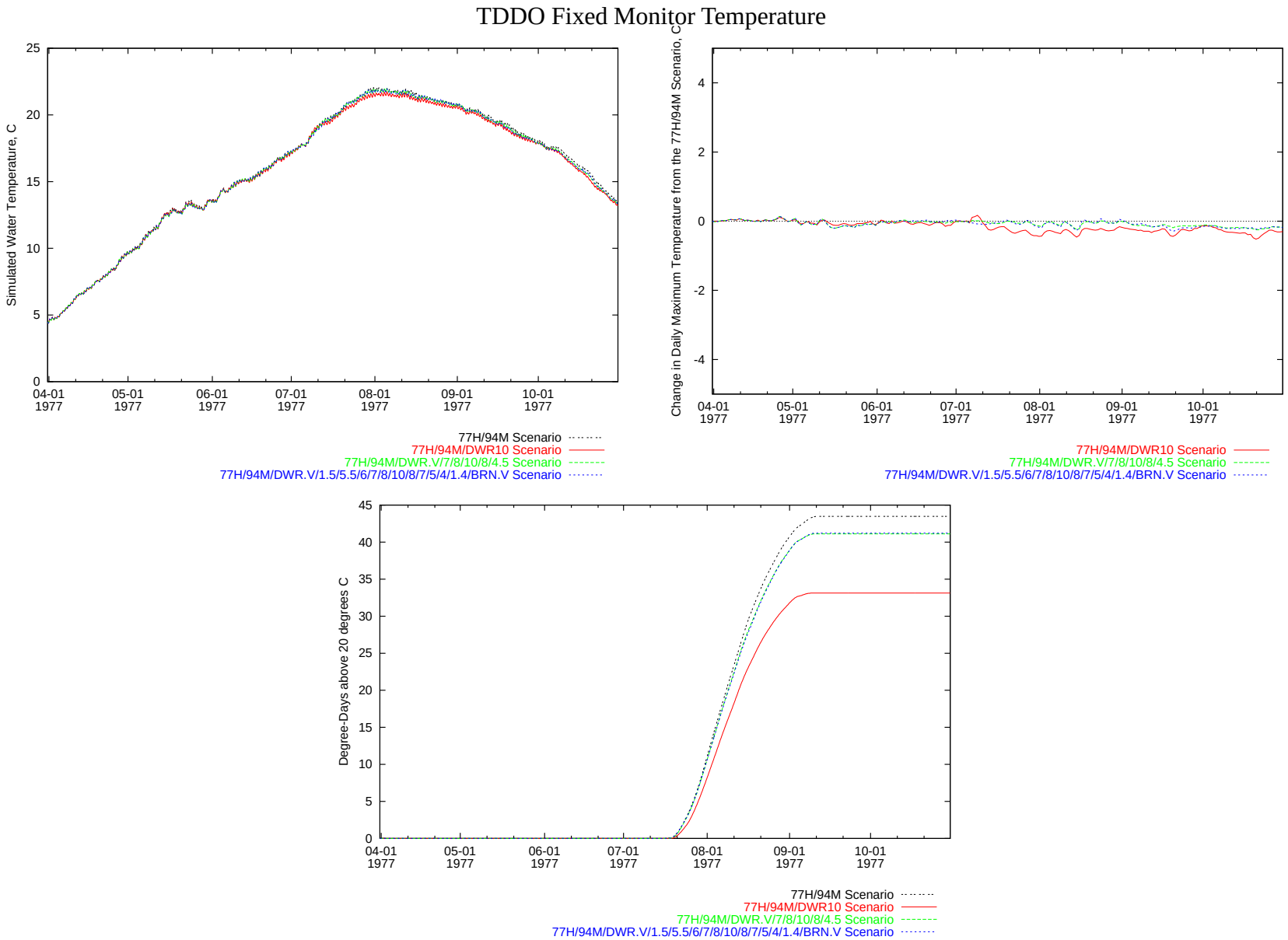

Figure 97: Time series comparison of simulated temperature at the TDDO Fixed Monitor.

TDDO Fixed Monitor Temperature

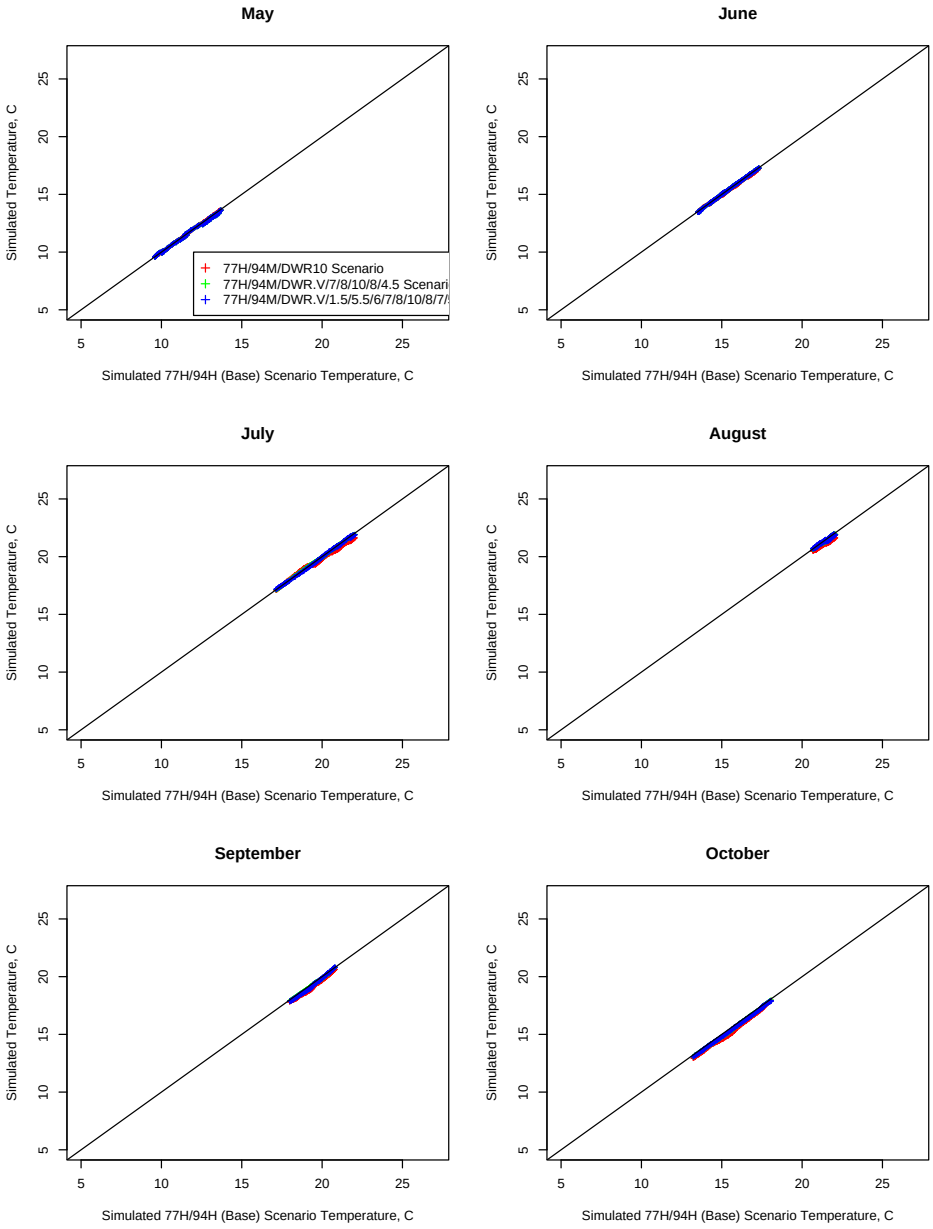

Figure 98: Scatter plot comparison, by month, of simulated temperature at the TDDO Fixed Monitor.

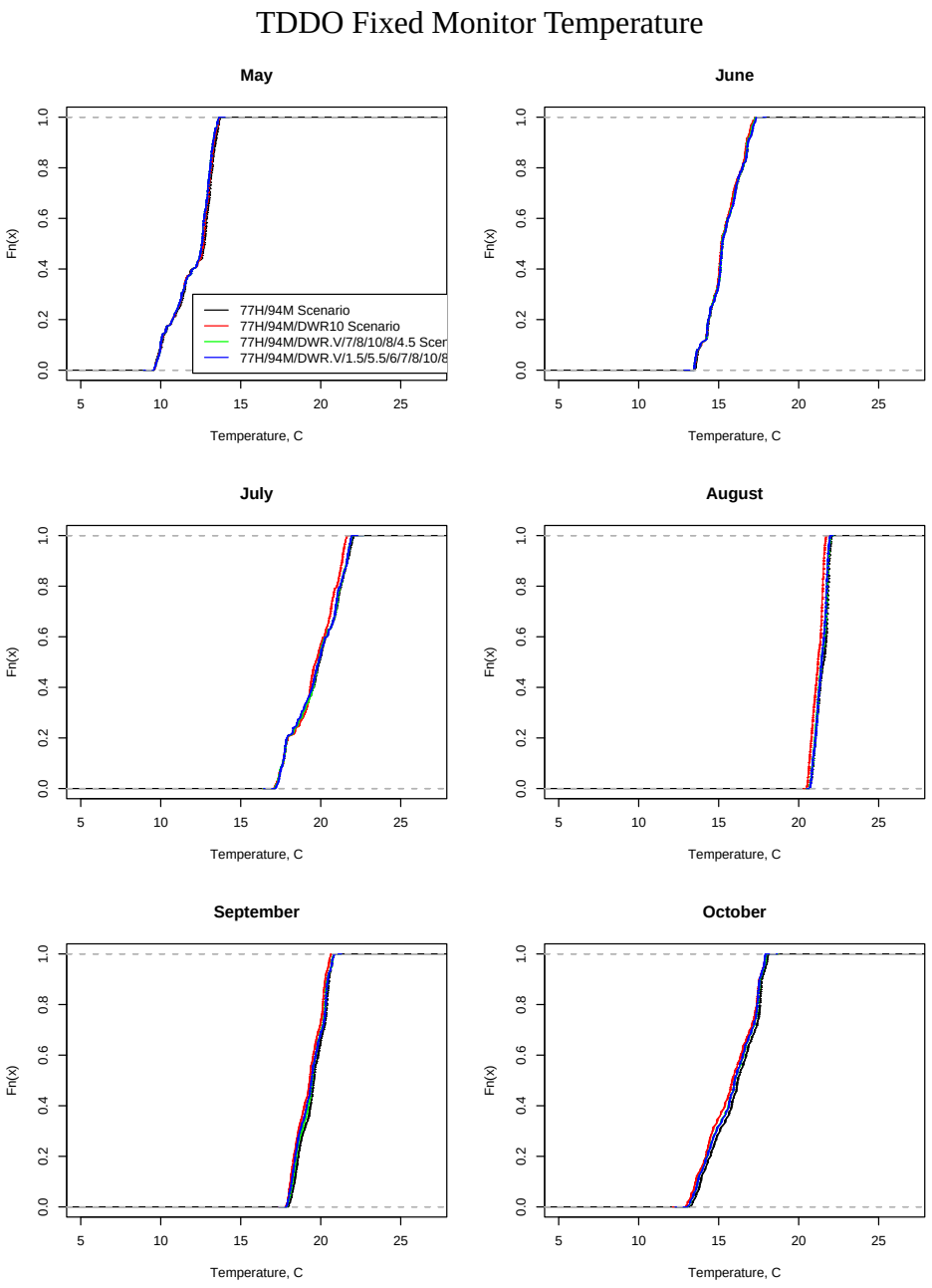

Figure 99: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the TDDO Fixed Monitor.

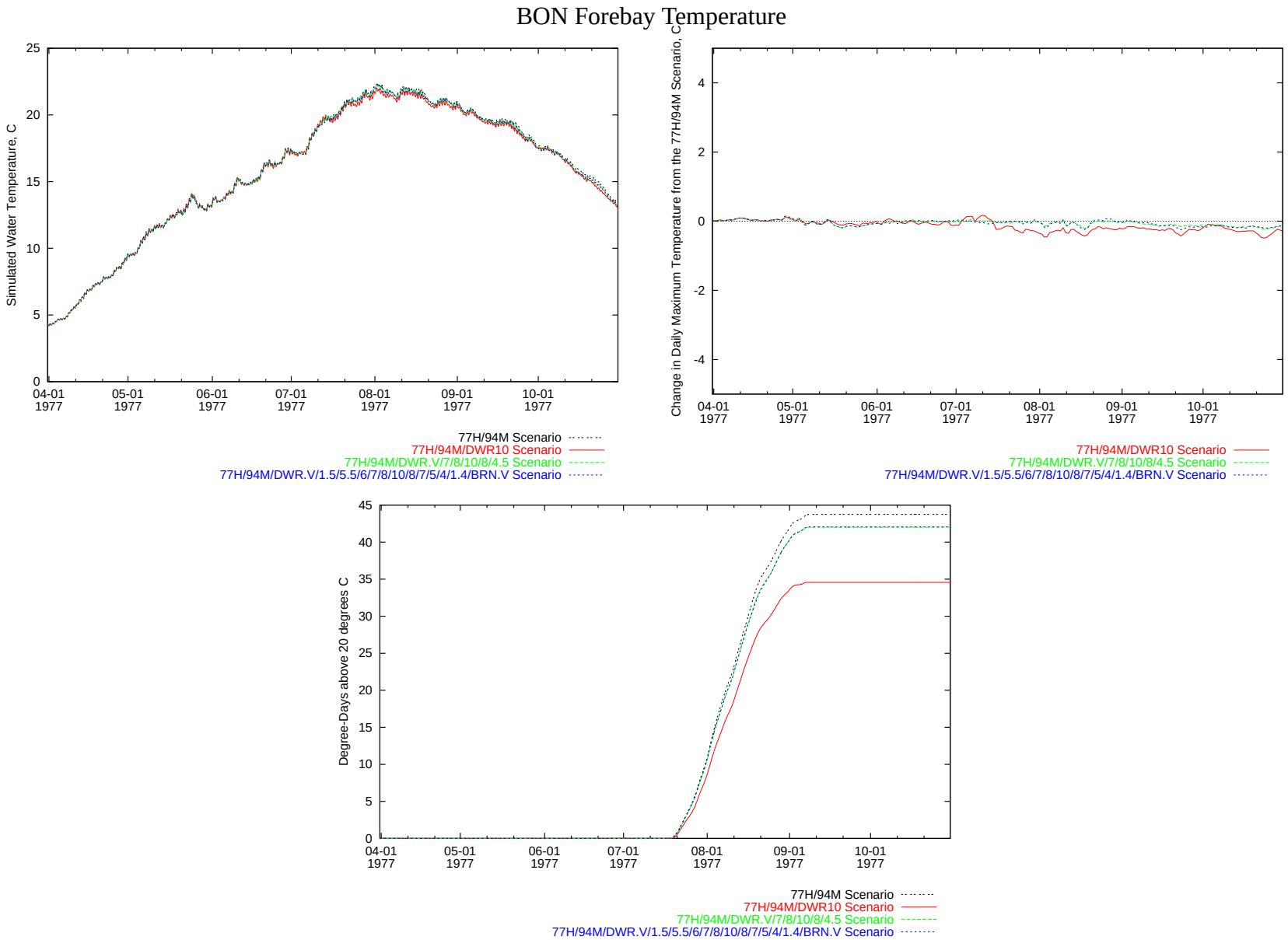

Figure 100: Time series comparison of simulated temperature at the BON Forebay.

BON Forebay Temperature

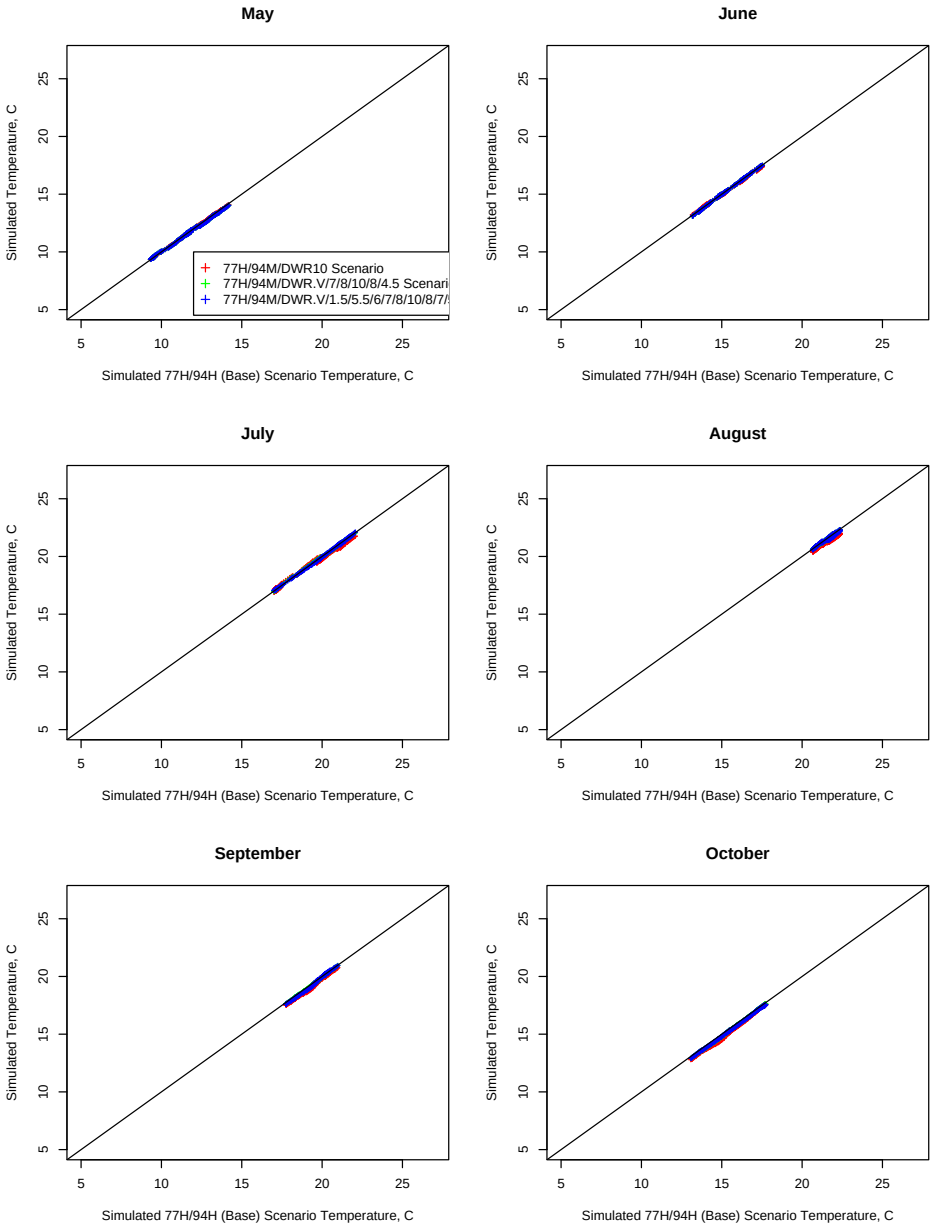

Figure 101: Scatter plot comparison, by month, of simulated temperature at the BON Forebay.

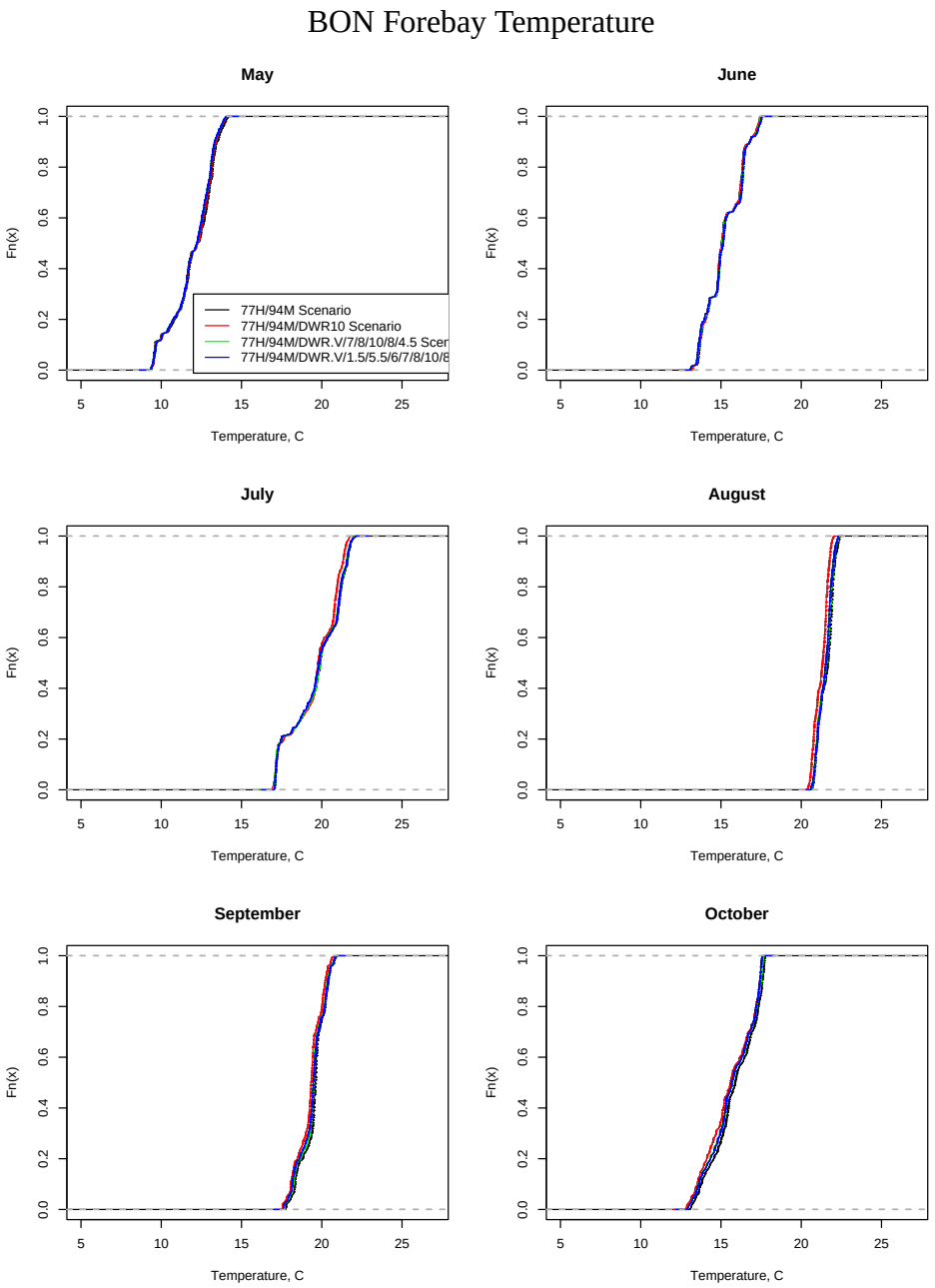

Figure 102: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the BON Forebay.

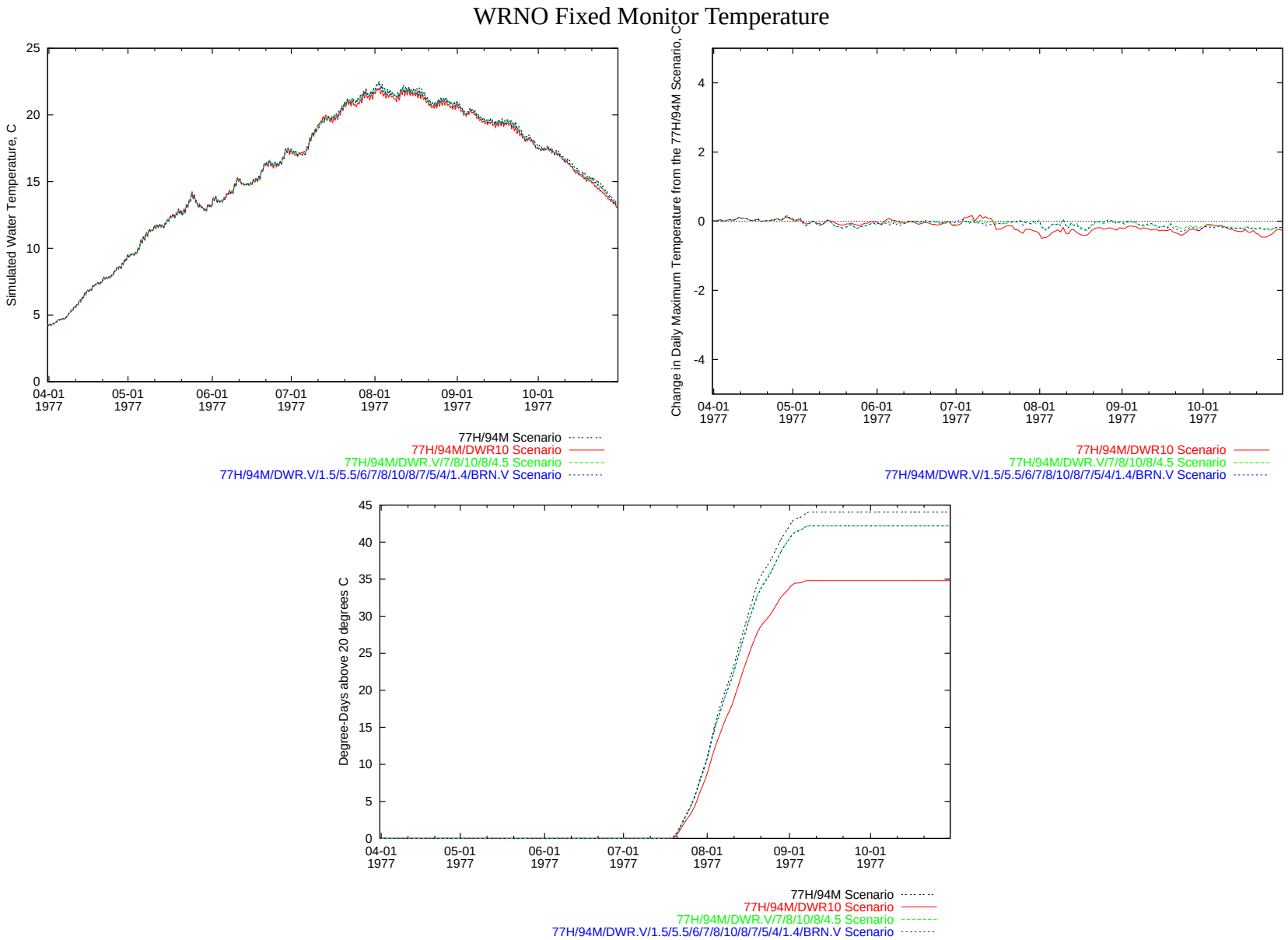

Figure 103: Time series comparison of simulated temperature at the WRNO Fixed Monitor.

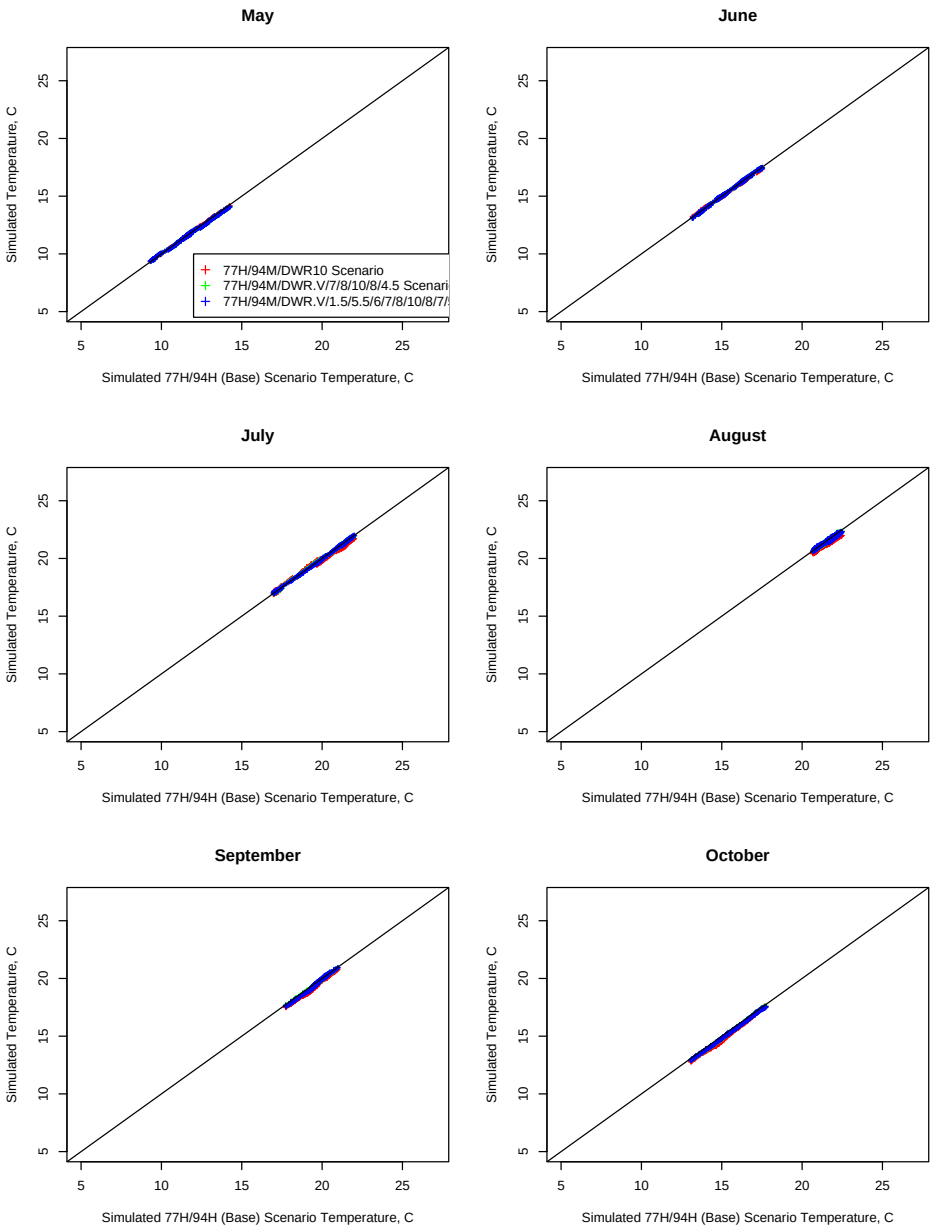

Figure 104: Scatter plot comparison, by month, of simulated temperature at the WRNO Fixed Monitor.

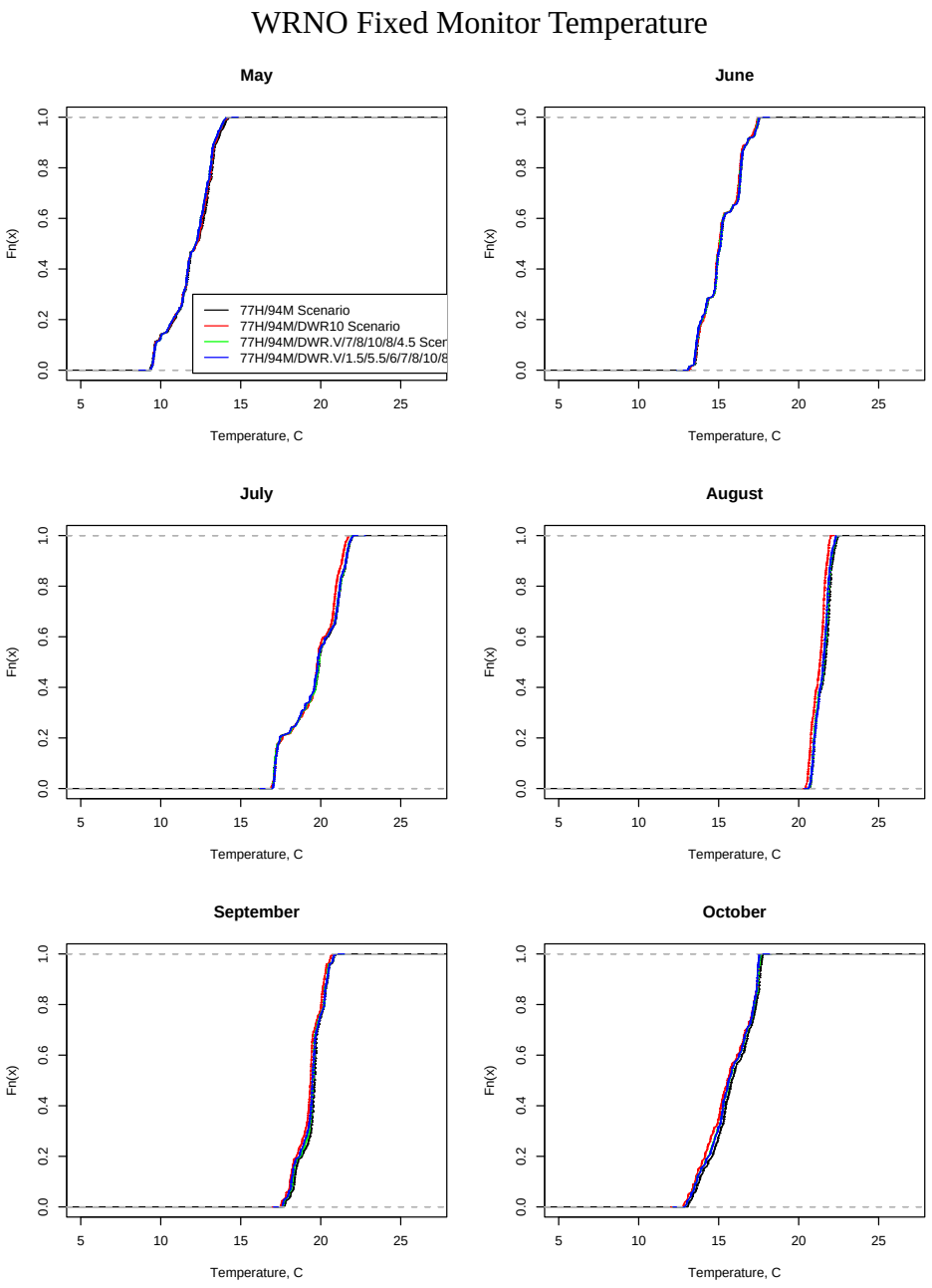

Figure 105: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the WRNO Fixed Monitor.

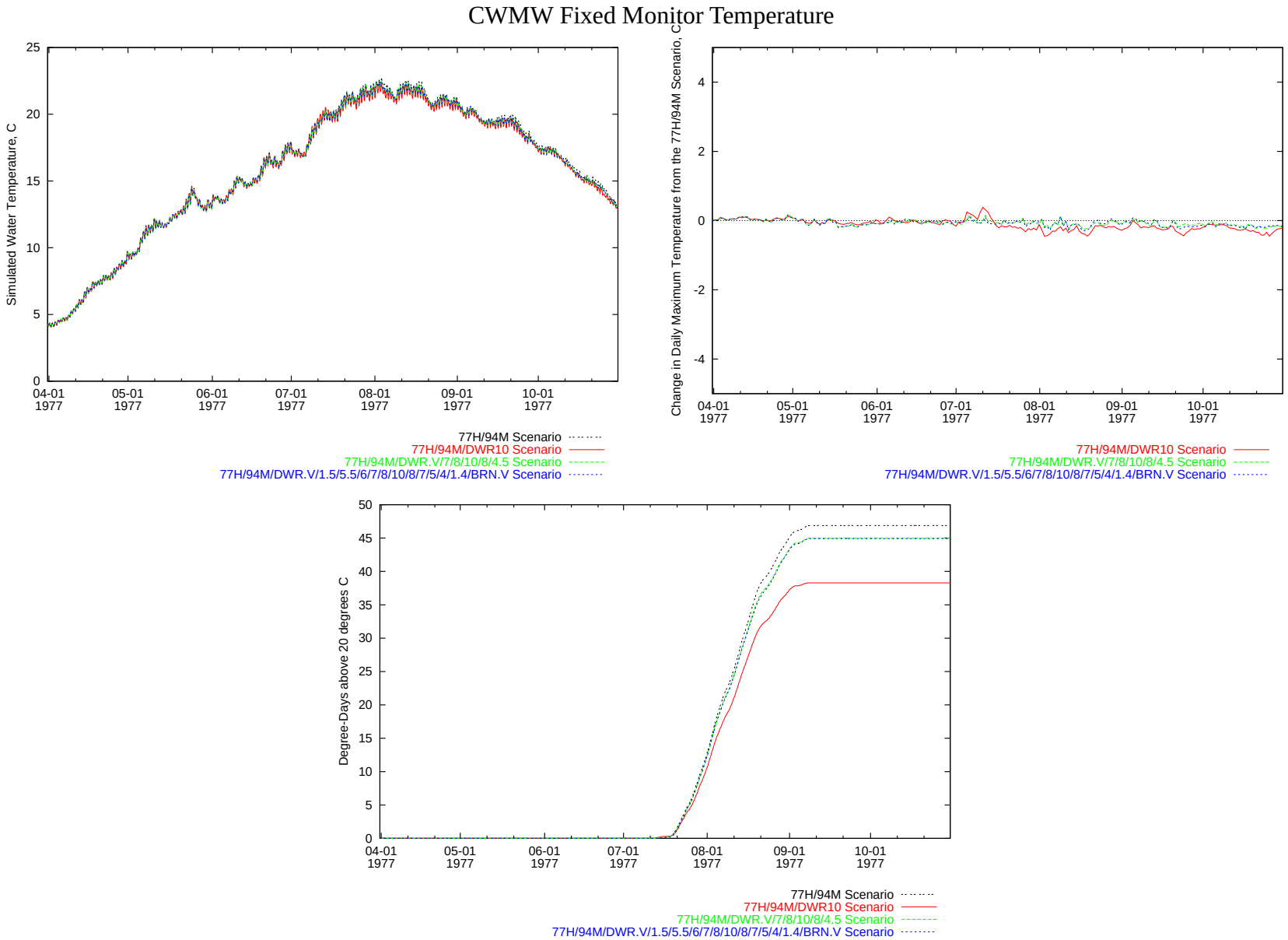

Figure 106: Time series comparison of simulated temperature at the CWMW Fixed Monitor.

CWMW Fixed Monitor Temperature

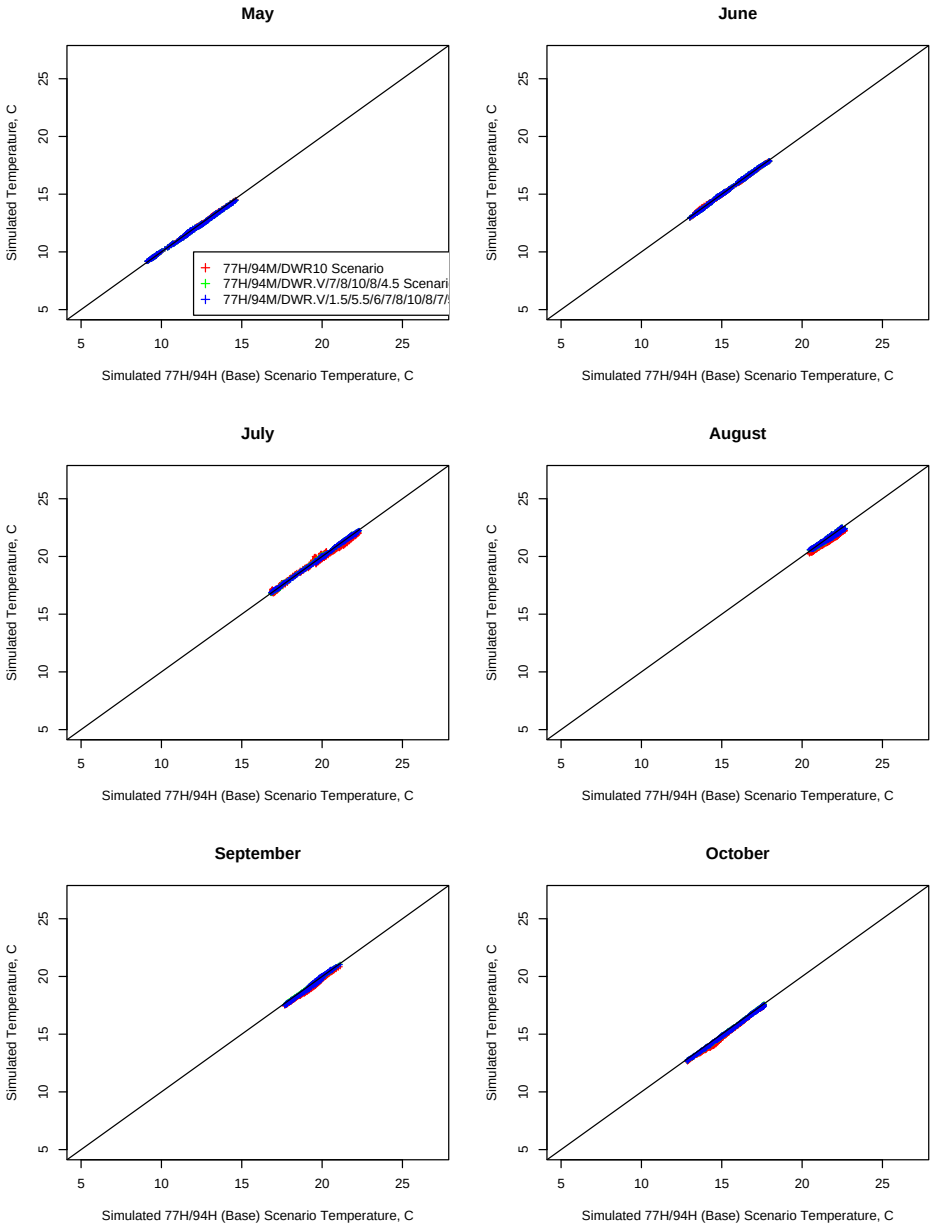

Figure 107: Scatter plot comparison, by month, of simulated temperature at the CWMW Fixed Monitor.

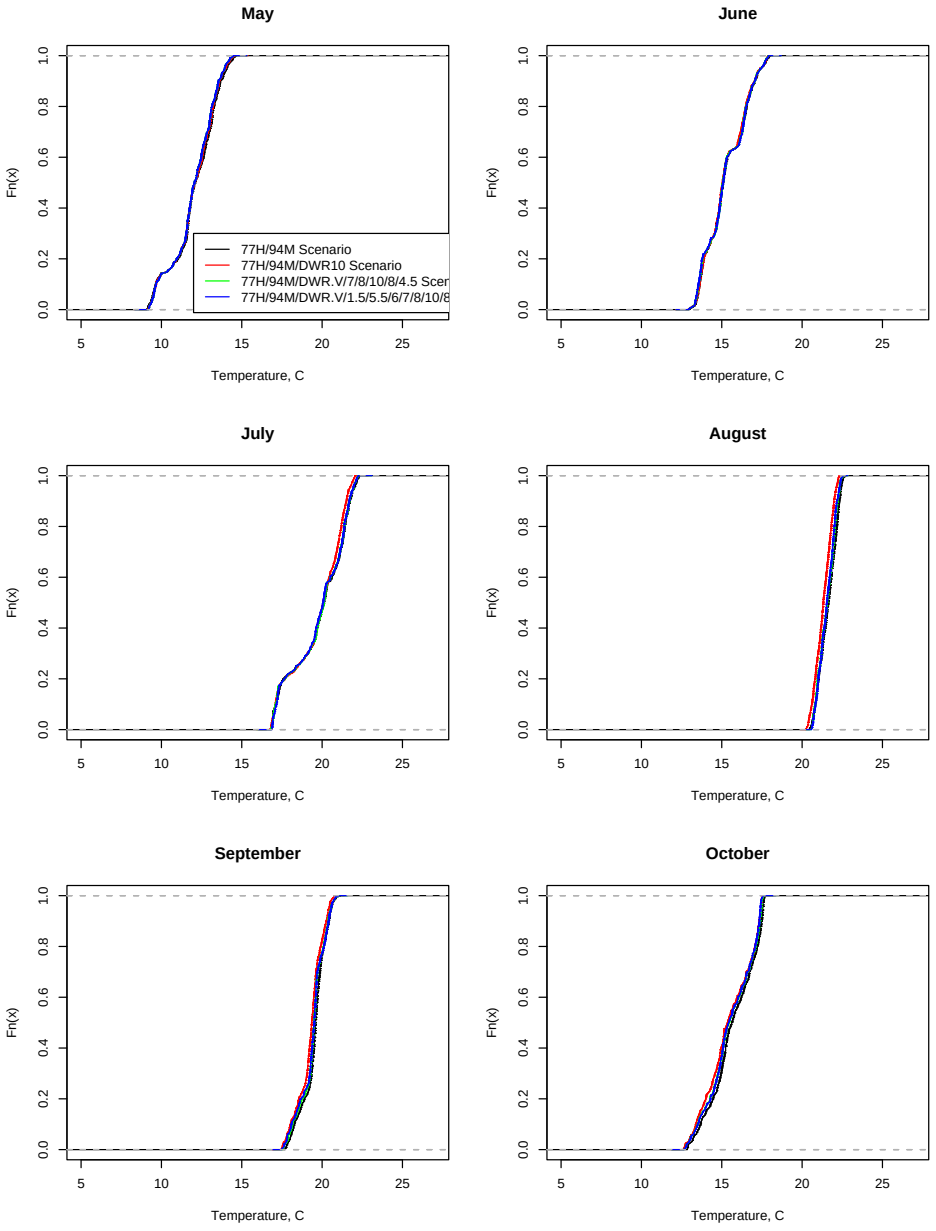

Figure 108: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the CWMW Fixed Monitor.

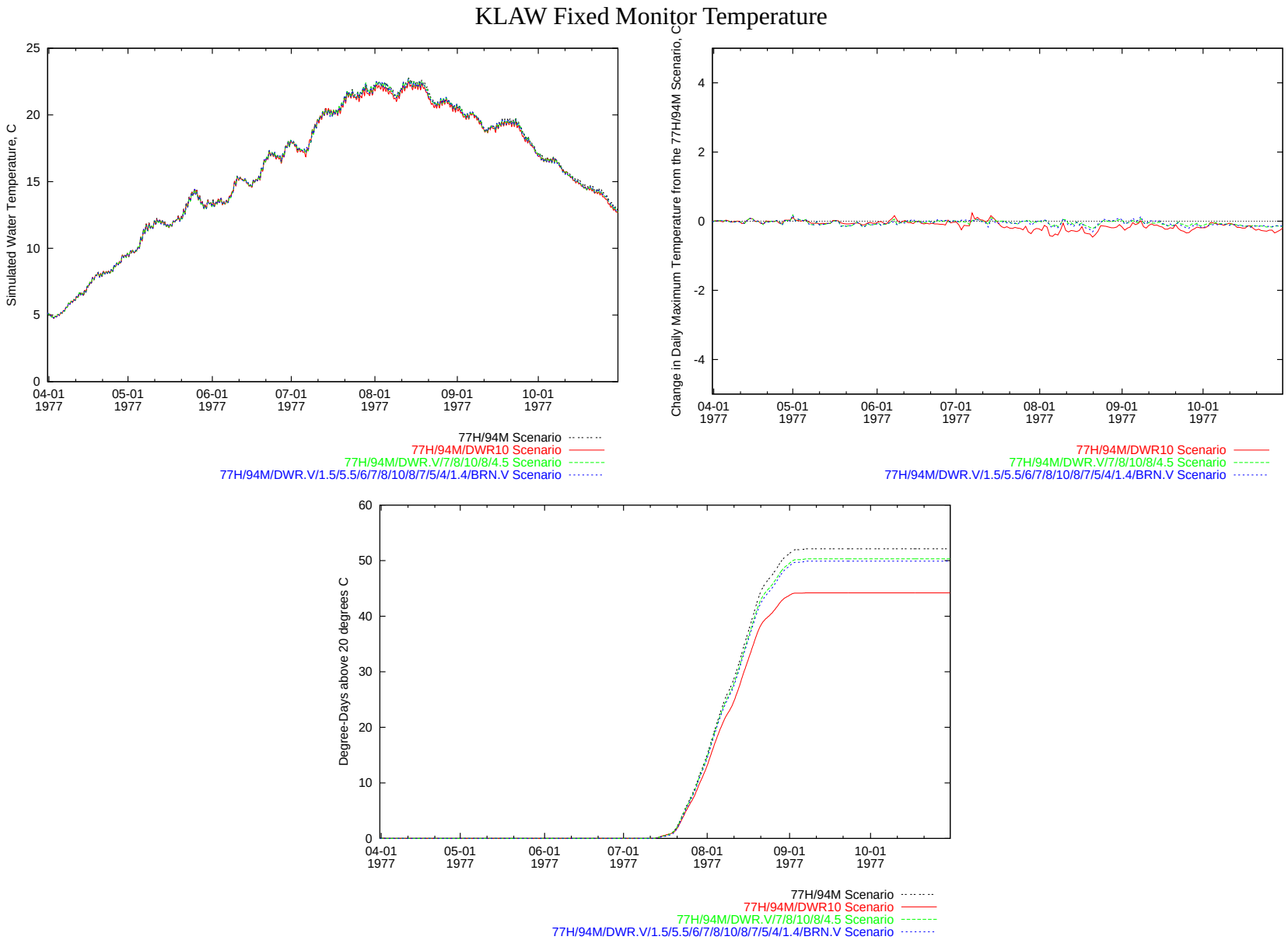

Figure 109: Time series comparison of simulated temperature at the KLAW Fixed Monitor.

KLAW Fixed Monitor Temperature

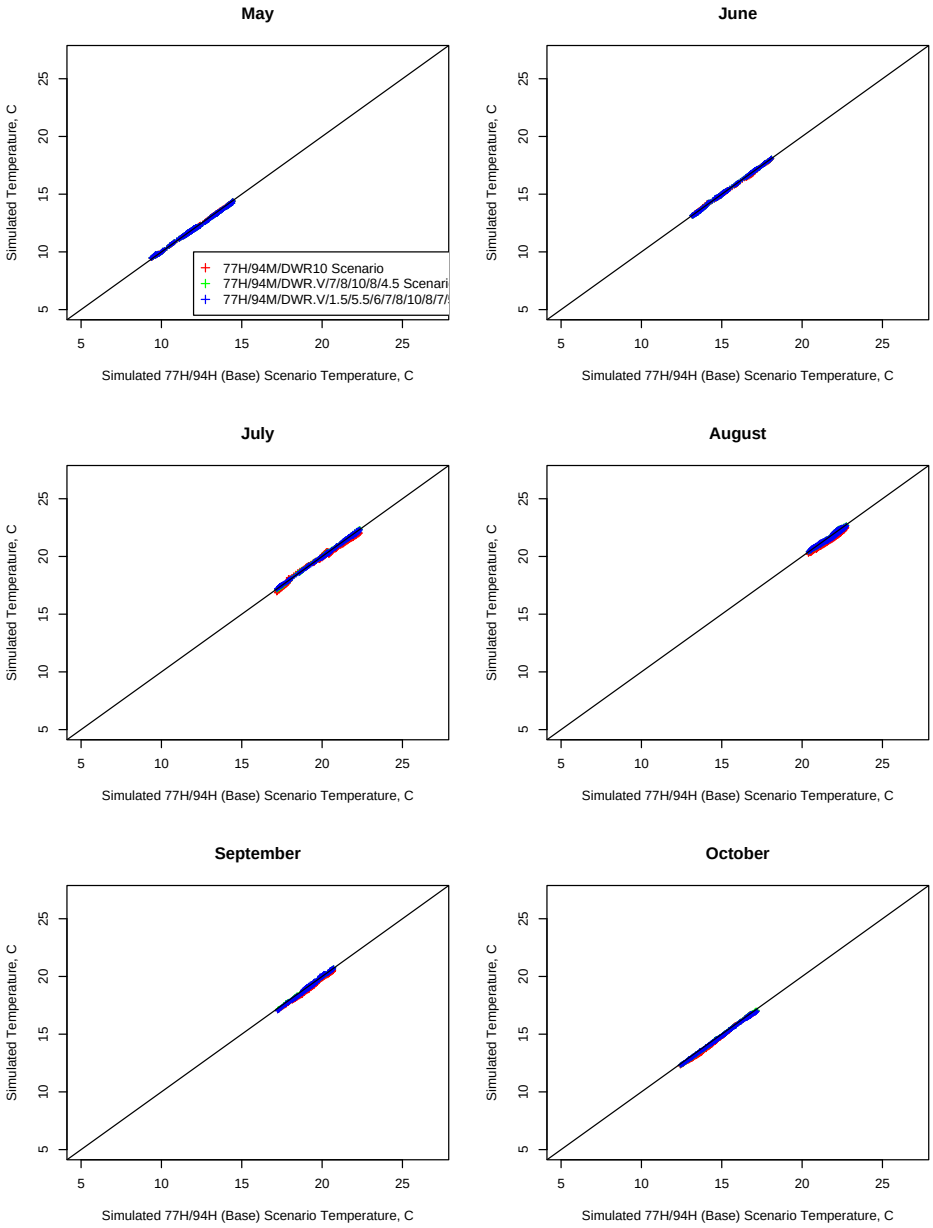

Figure 110: Scatter plot comparison, by month, of simulated temperature at the KLAW Fixed Monitor.

KLAW Fixed Monitor Temperature

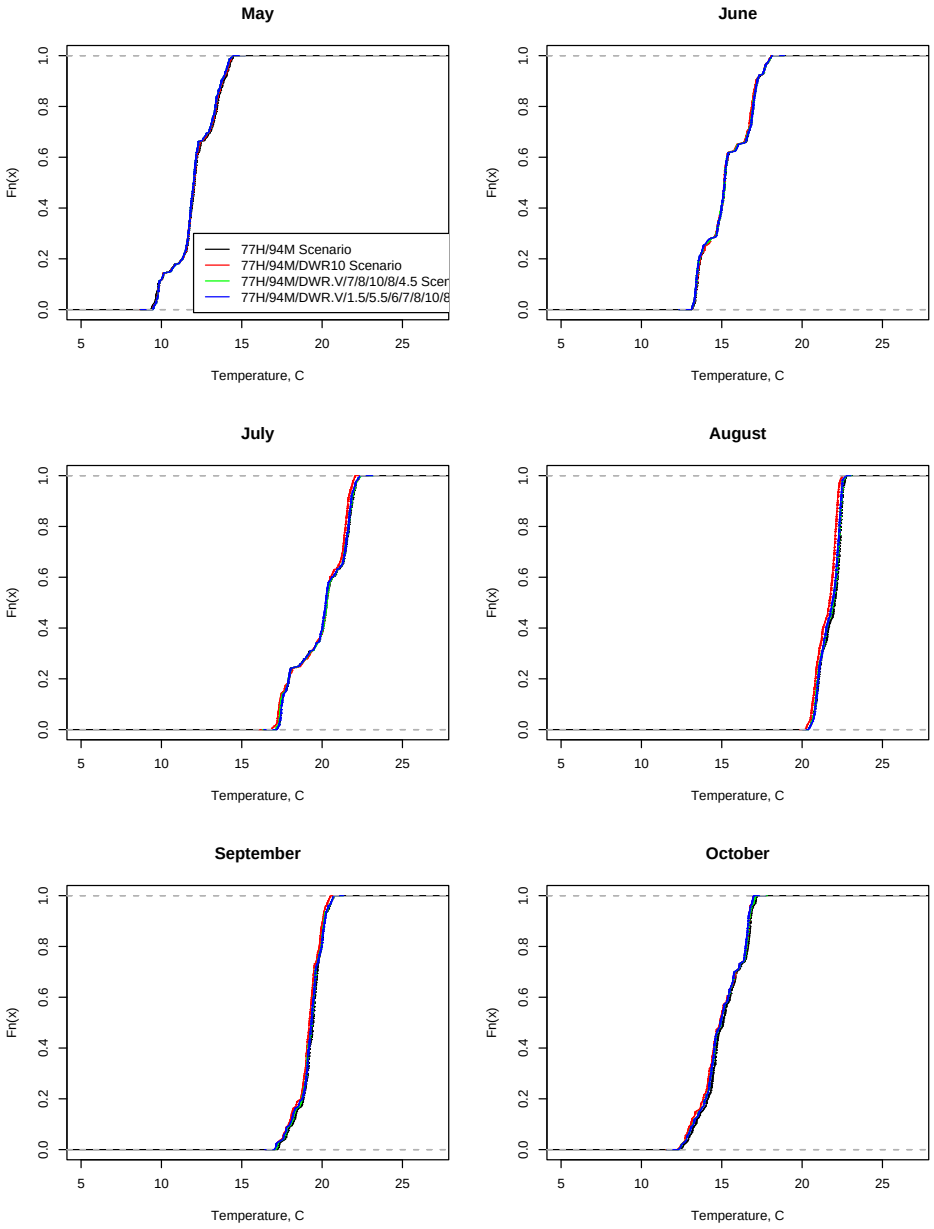

Figure 111: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the KLAW Fixed Monitor.

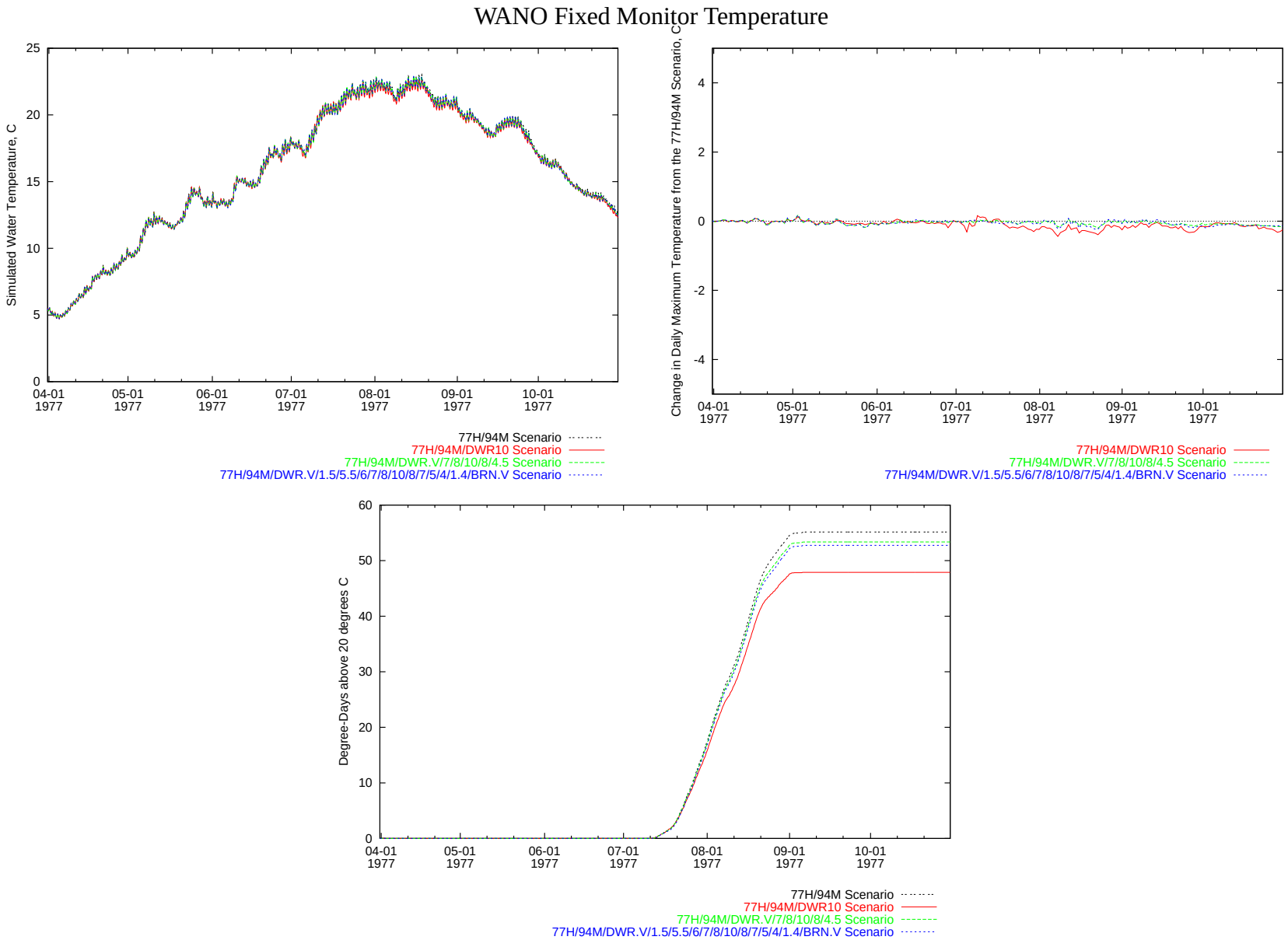

Figure 112: Time series comparison of simulated temperature at the WANO Fixed Monitor.

WANO Fixed Monitor Temperature

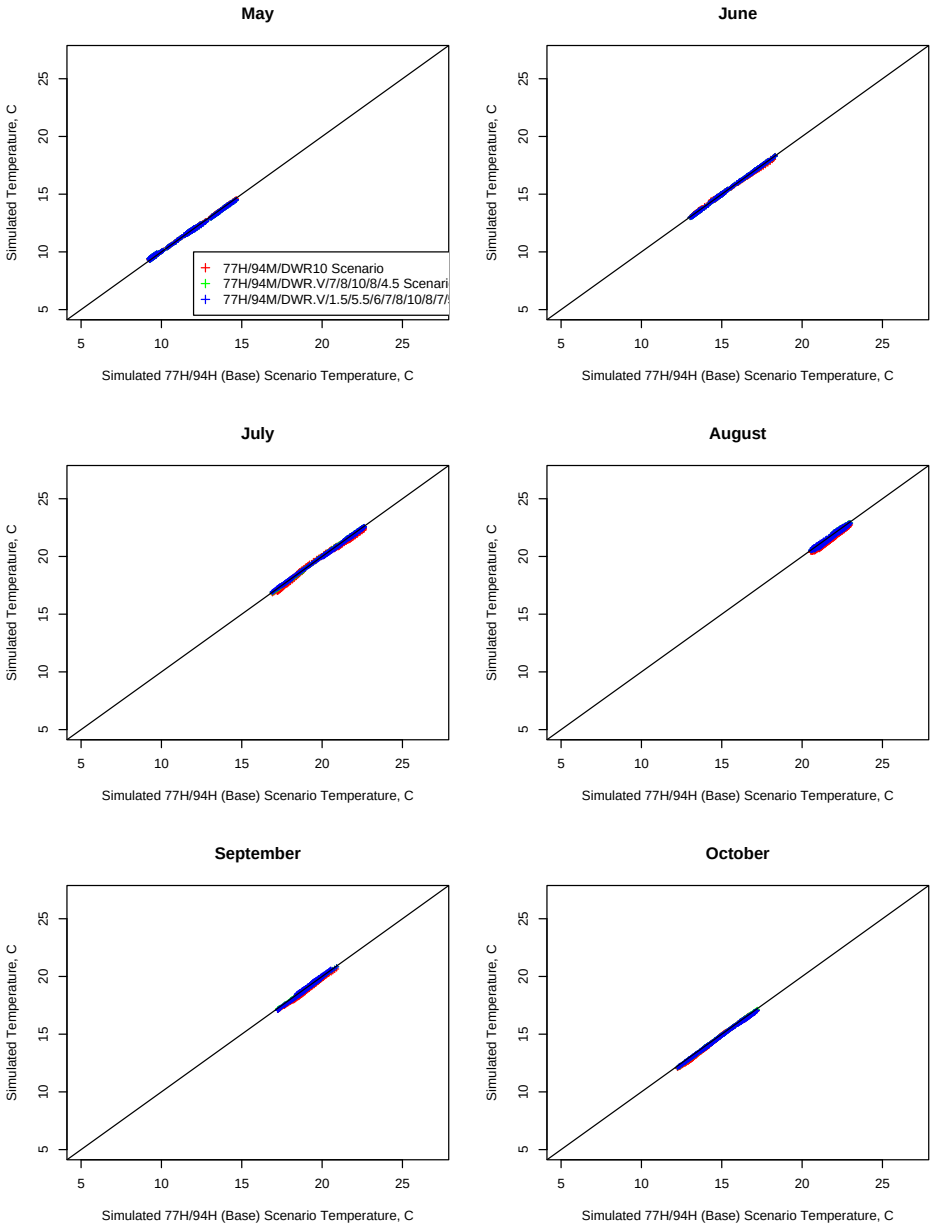

Figure 113: Scatter plot comparison, by month, of simulated temperature at the WANO Fixed Monitor.

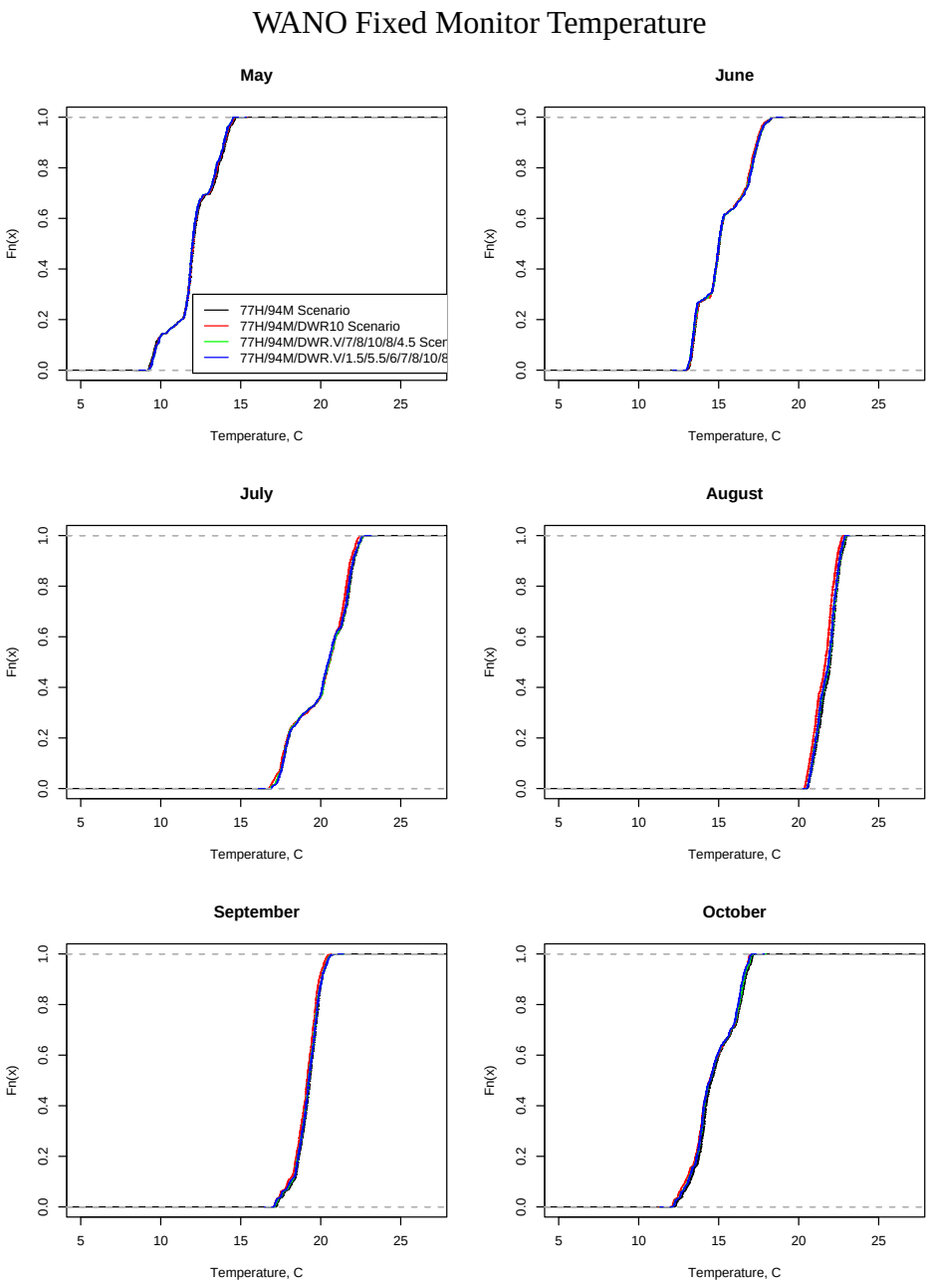

Figure 114: Cumulative frequency distribution (CFD) plot comparison, by month, of simulated temperature at the WANO Fixed Monitor.

7 Scenario Discharge Comparisons

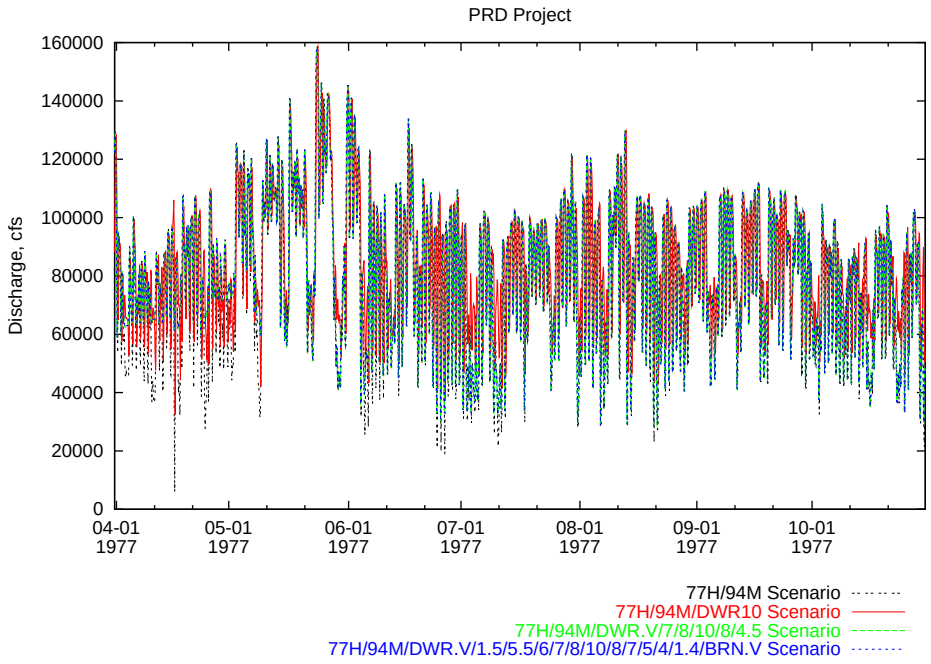

Figure 115: Comparison of simulated discharge at the PRD Project.

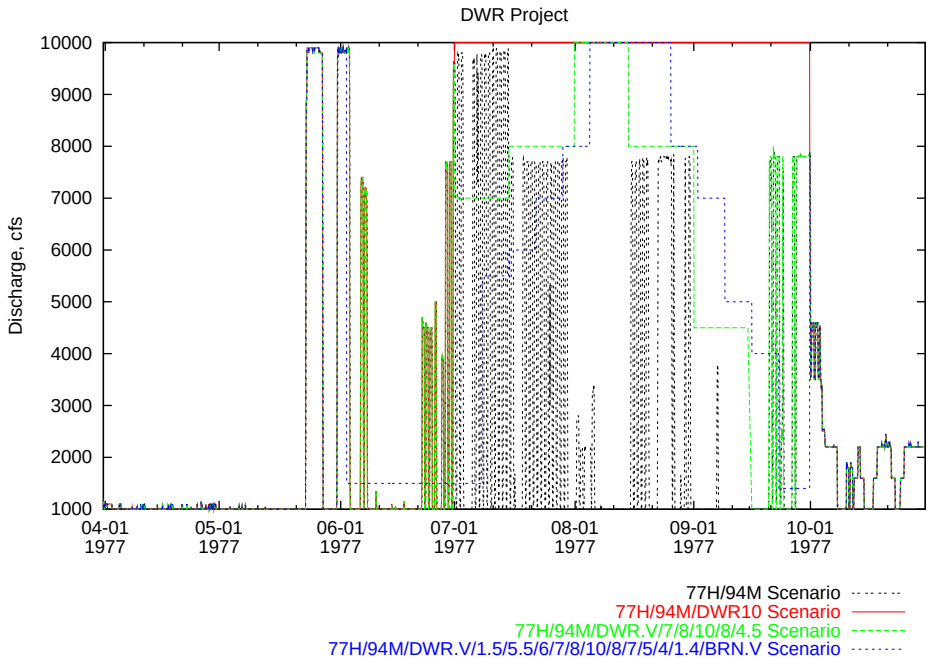

Figure 116: Comparison of simulated discharge at the DWR Project.

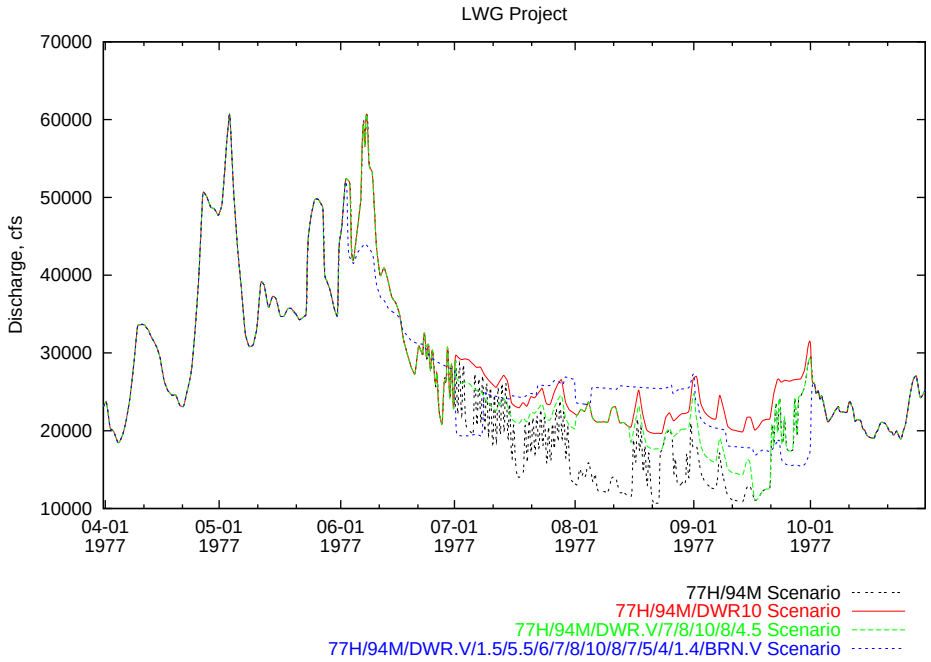

Figure 117: Comparison of simulated discharge at the LWG Project.

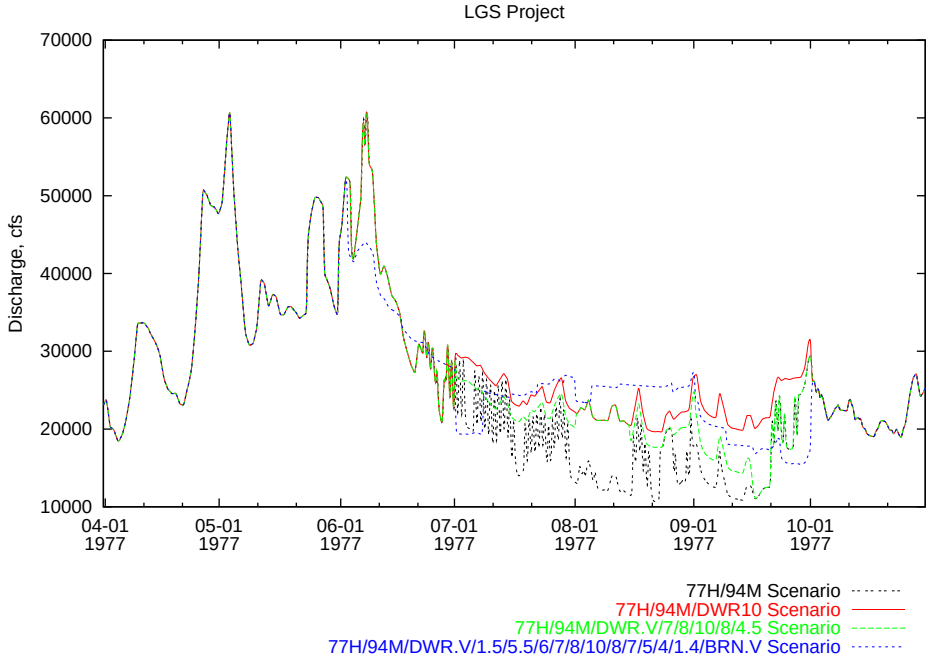

Figure 118: Comparison of simulated discharge at the LGS Project.

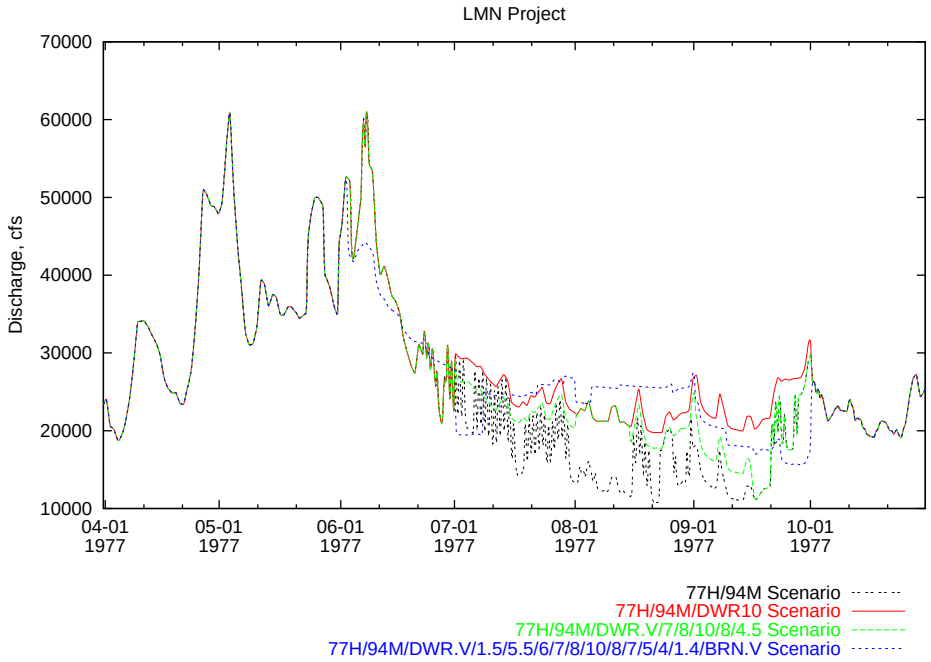

Figure 119: Comparison of simulated discharge at the LMN Project.

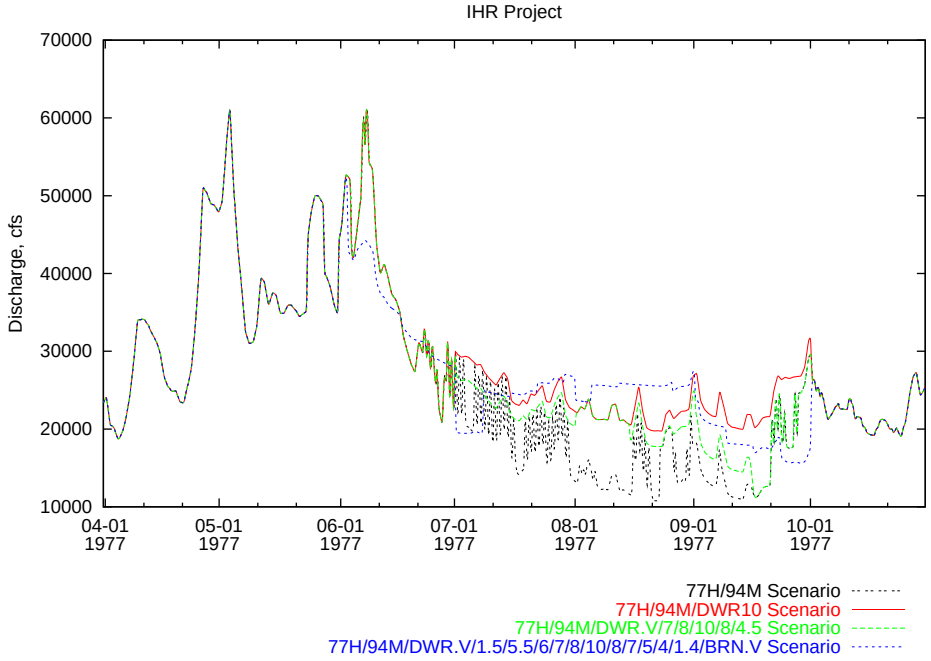

Figure 120: Comparison of simulated discharge at the IHR Project.

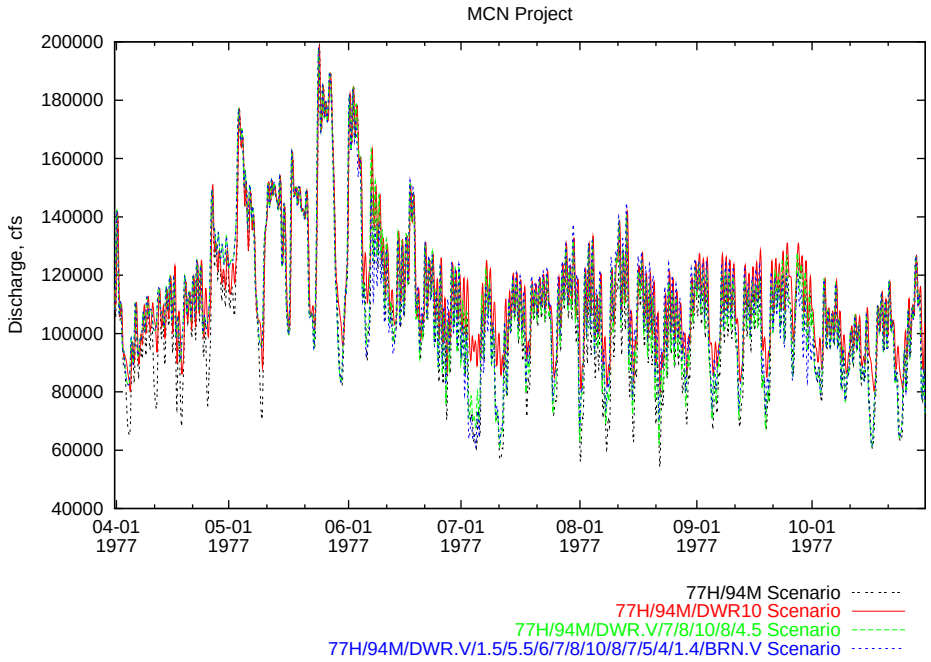

Figure 121: Comparison of simulated discharge at the MCN Project.

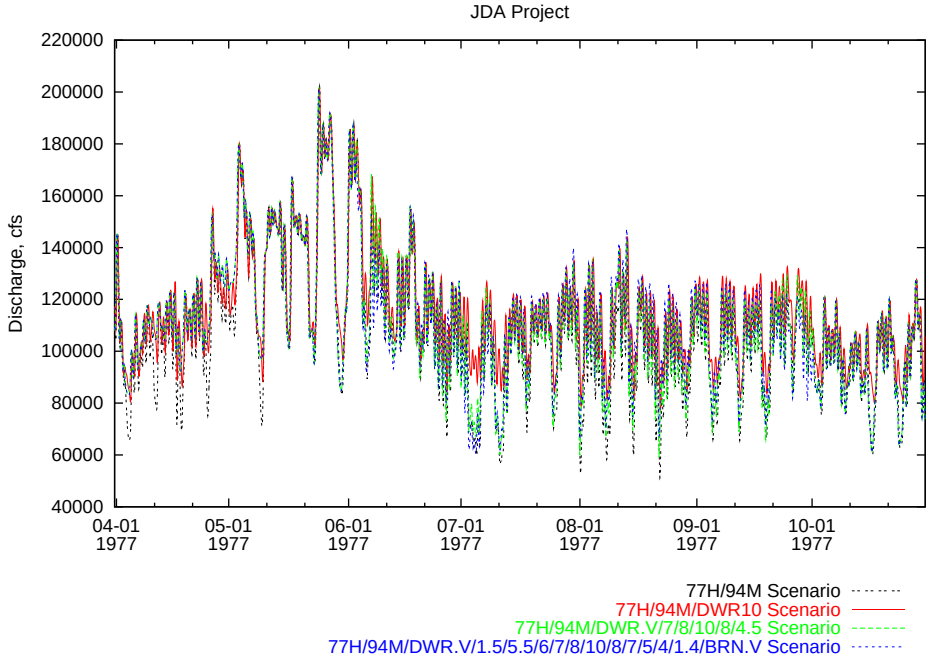

Figure 122: Comparison of simulated discharge at the JDA Project.

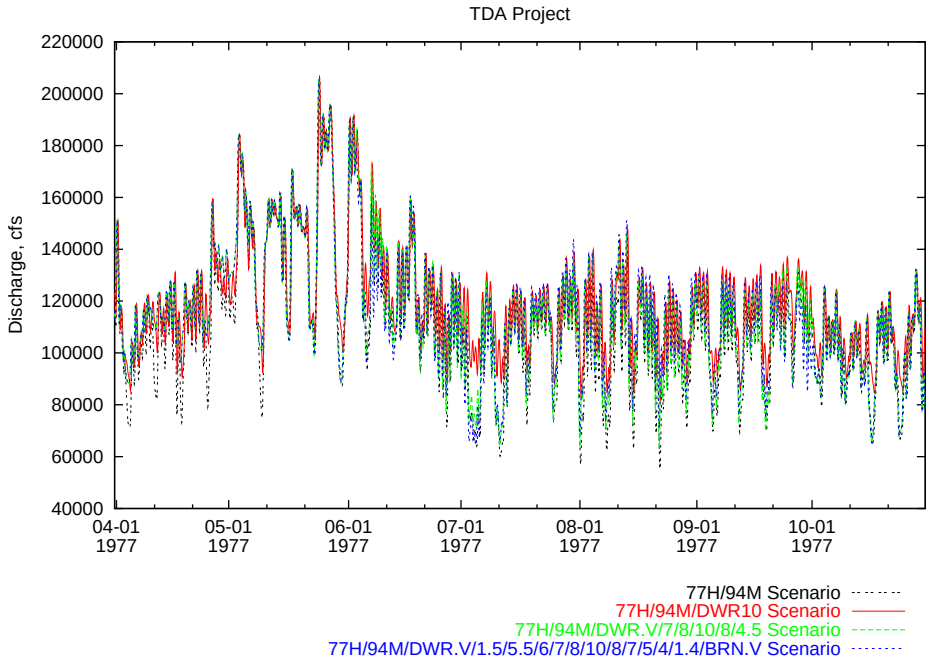

Figure 123: Comparison of simulated discharge at the TDA Project.

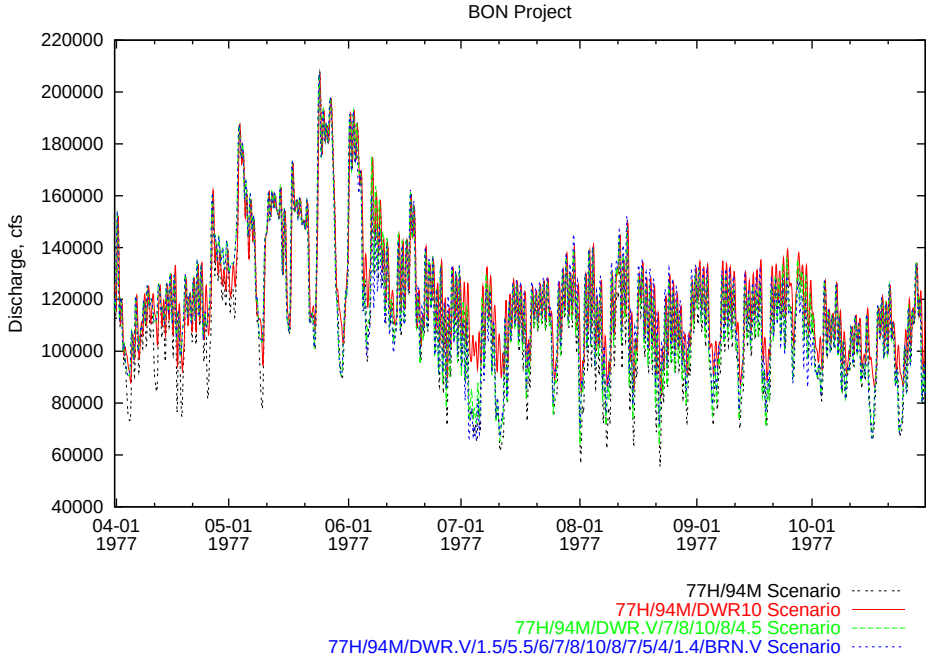

Figure 124: Comparison of simulated discharge at the BON Project.

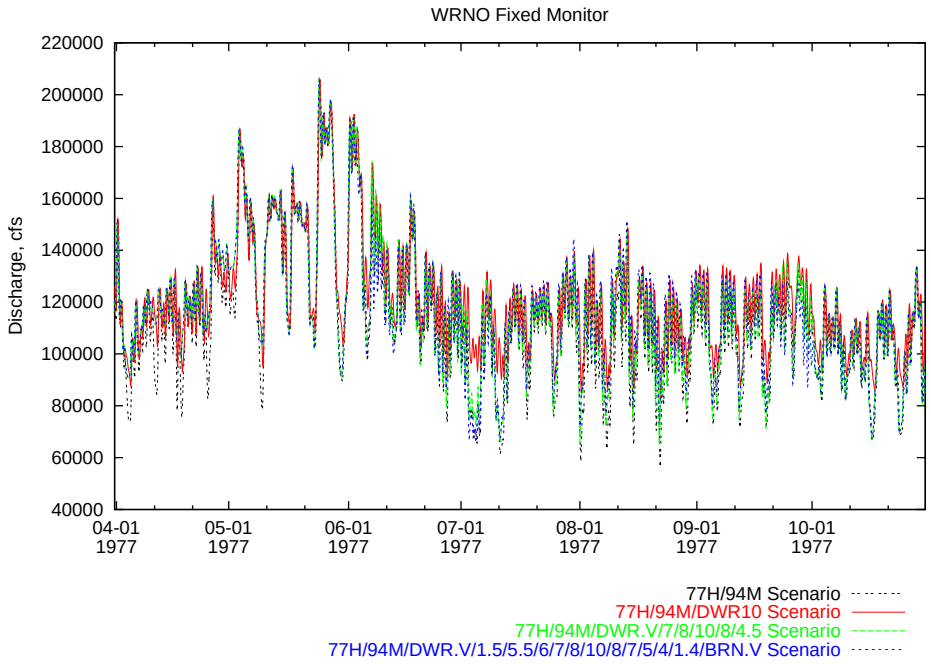

Figure 125: Comparison of simulated discharge at the WRNO Fixed Monitor.

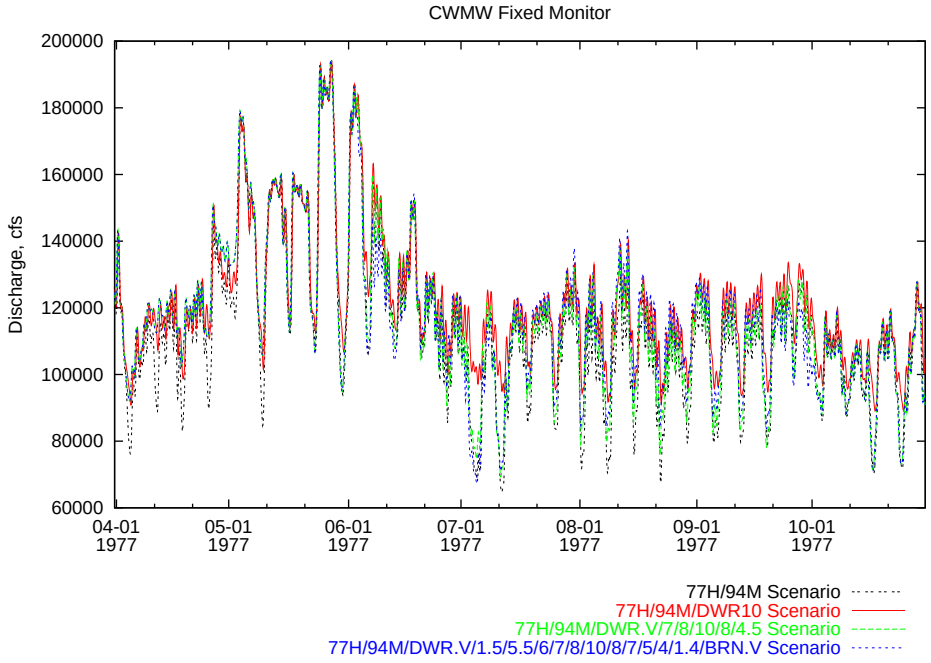

Figure 126: Comparison of simulated discharge at the CWMW Fixed Monitor.

A Estimation of Clearwater Main Stem Temperature

In the 1997 conditions and 77H/94M scenarios, water temperatures for the Clearwater main stem at Orofino and the North Fork Clearwater at Dworshak are assumed to be that observed at the USGS Spaulding gage downstream. This is acceptable since observed flows were used at both of those model boundaries.

In other scenarios, the flows used at the Dworshak model boundary differ from observed, and temperatures are synthetic, so that using the Spaulding temperatures at the Orofino boundary is not acceptable. In these scenarios, a temperature record is estimated for the Clearwater main stem at Orofino using the temperatures from the USGS gage on the North Fork of the Clearwater near Canyon Ranger station (13340600). The Canyon Ranger station was in operation during 1977 and overlaps the Orofino record from 1993 to 1996 (data in hand).

A simple linear regression of daily means at these two station was performed. The results are shown in Figure 127. The developed relation is

$$T_{\text{Orofino}} = 1.1049 T_{\text{Canyon}} + 0.6110$$

The adjusted coefficient of determination (r^2) of this relation is 0.9876 and the standard error is 0.79°C. Clearwater main stem temperatures estimated for 1977 using the above relation are shown in Figure 128.

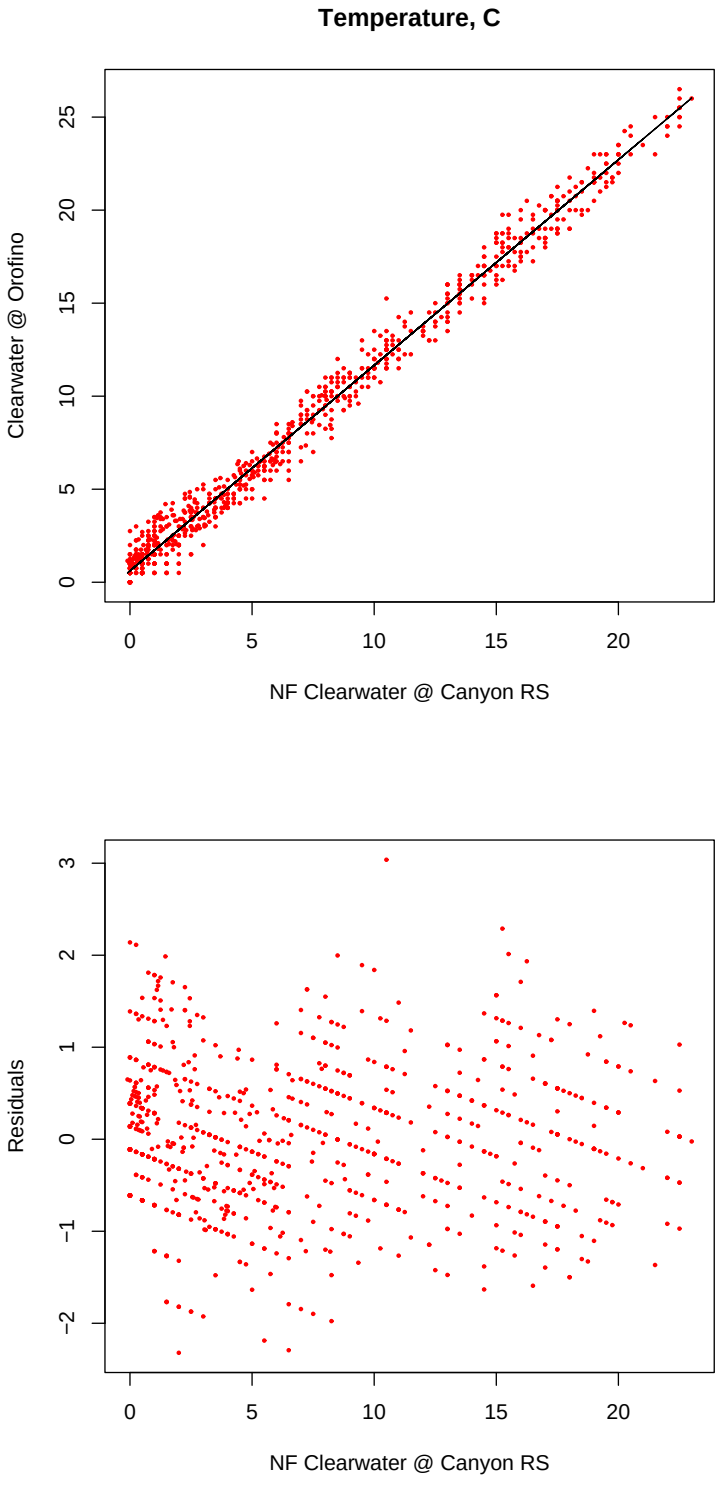

Figure 127: Linear regression estimating Clearwater main stem temperature from North Fork Clearwater temperatures.

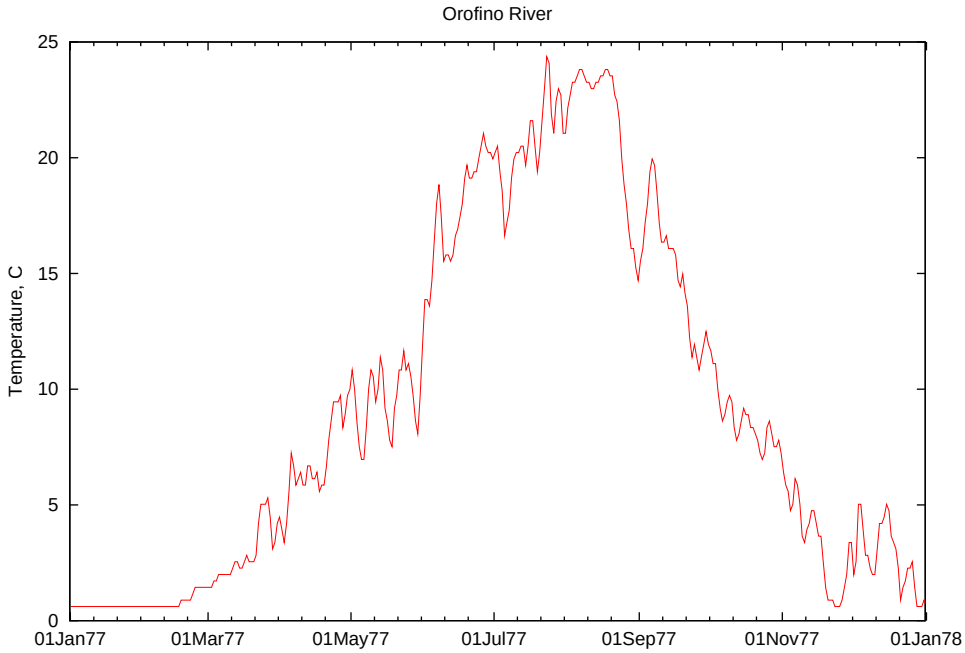

Figure 128: Estimated Clearwater main stem temperatures for 1977.

B Meterological Data

Hanford 1977 Meterology

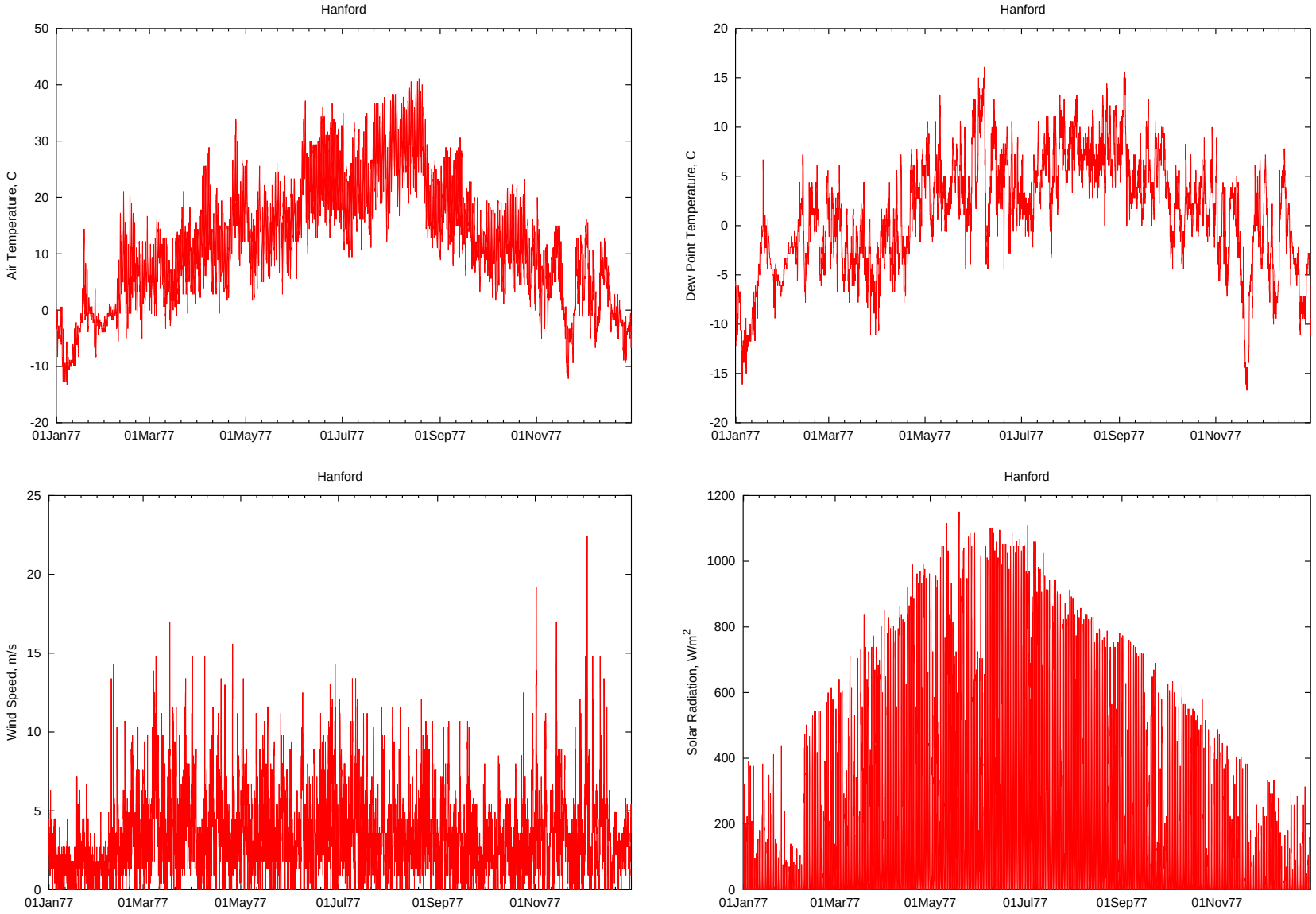

Figure 129: 1977 meterology data at Hanford.

Portland 1977 Meterology

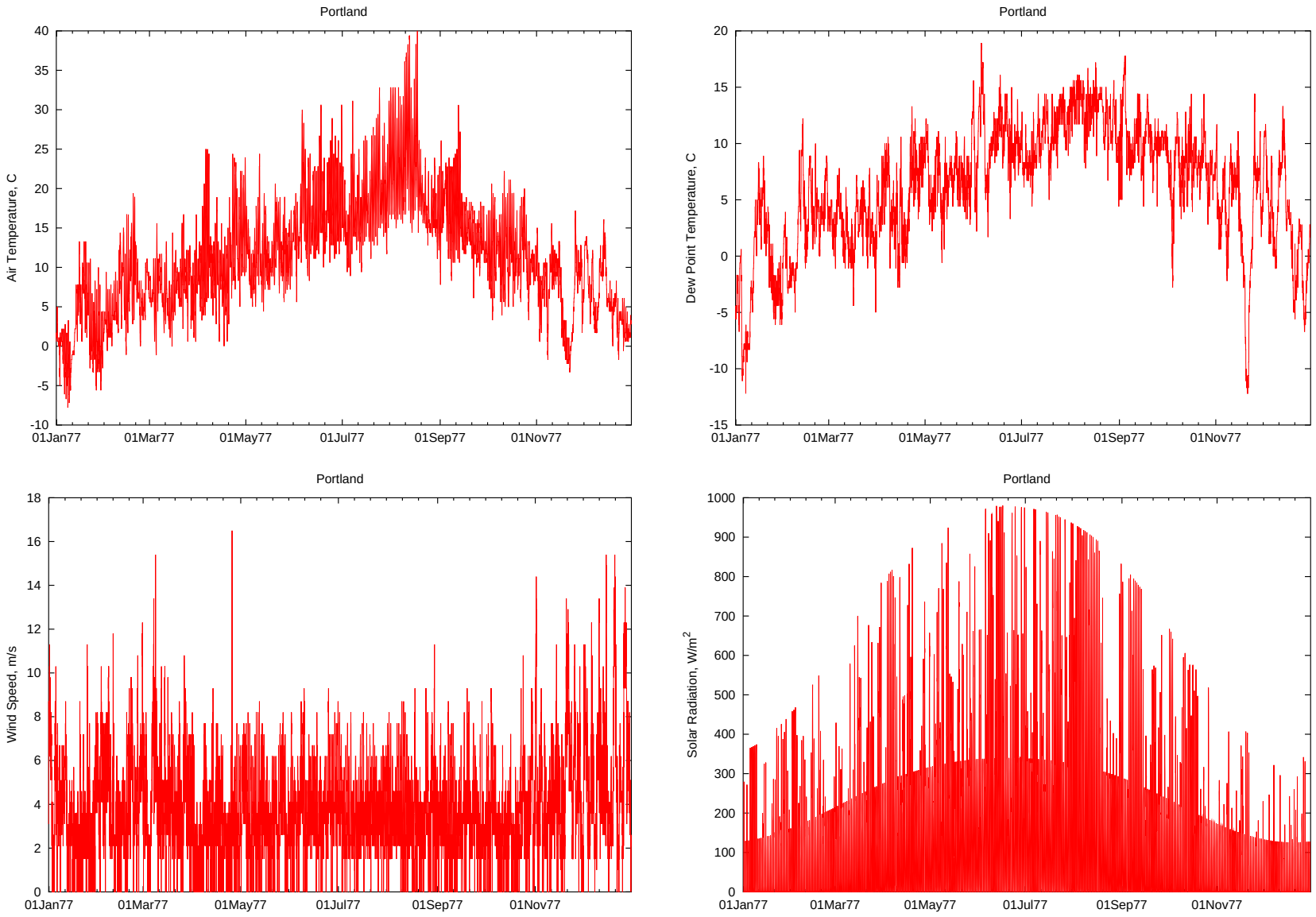

Figure 130: 1977 meterology data at Portland.

Wenatchee 1977 Meterology

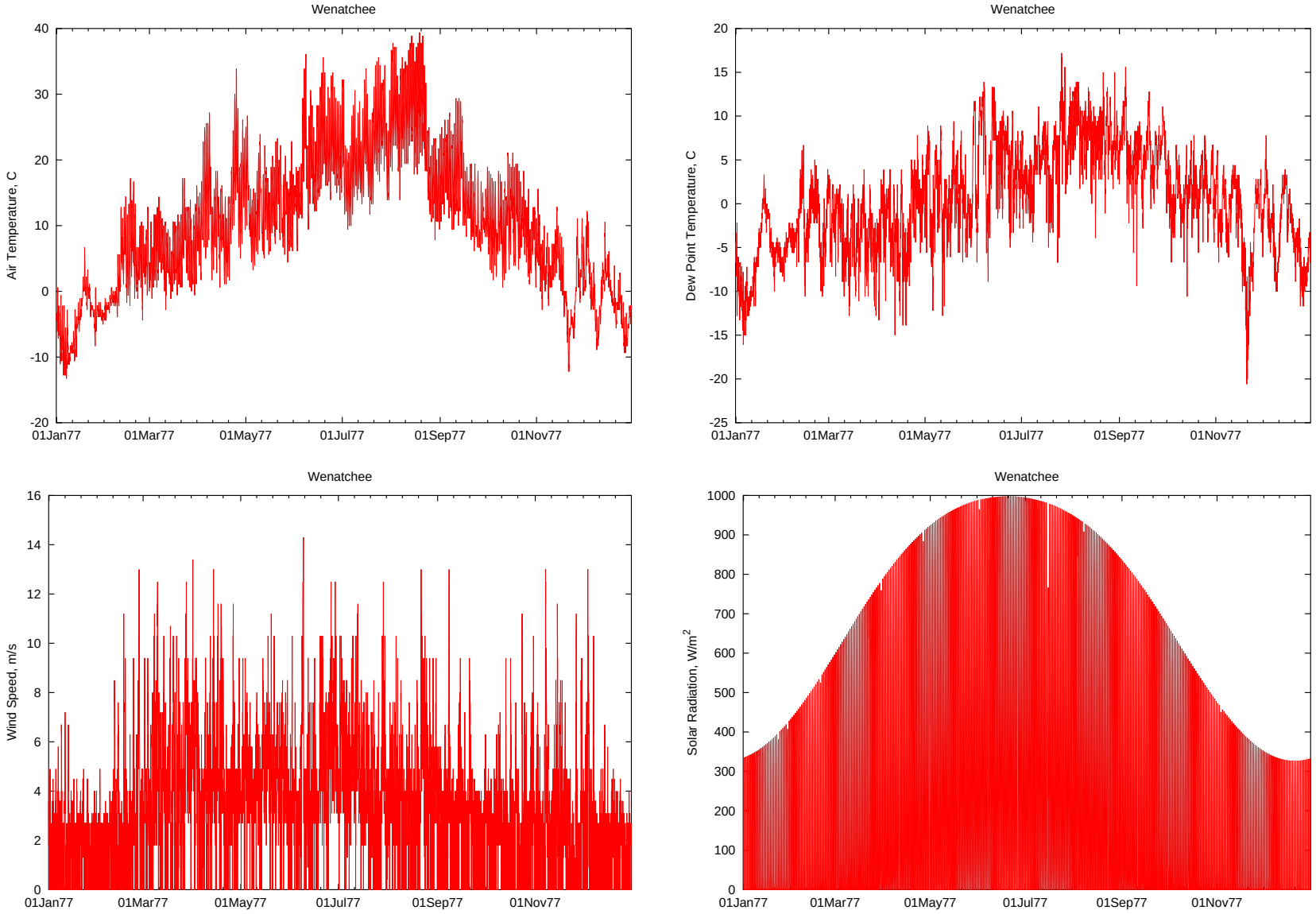

Figure 131: 1977 meterology data at Wenatchee.

Hanford 1994 Meterology

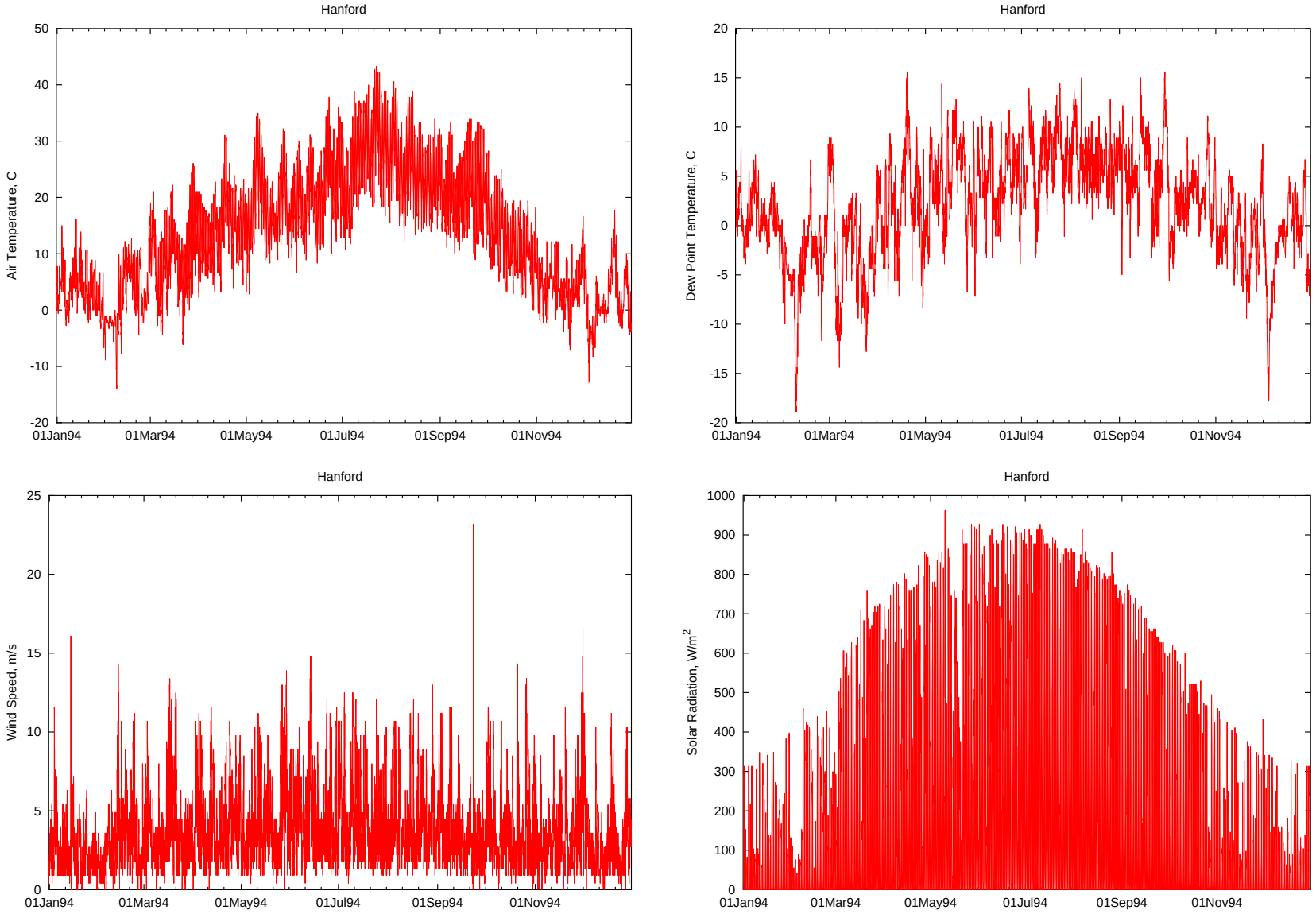

Figure 132: 1994 meterology data at Hanford.

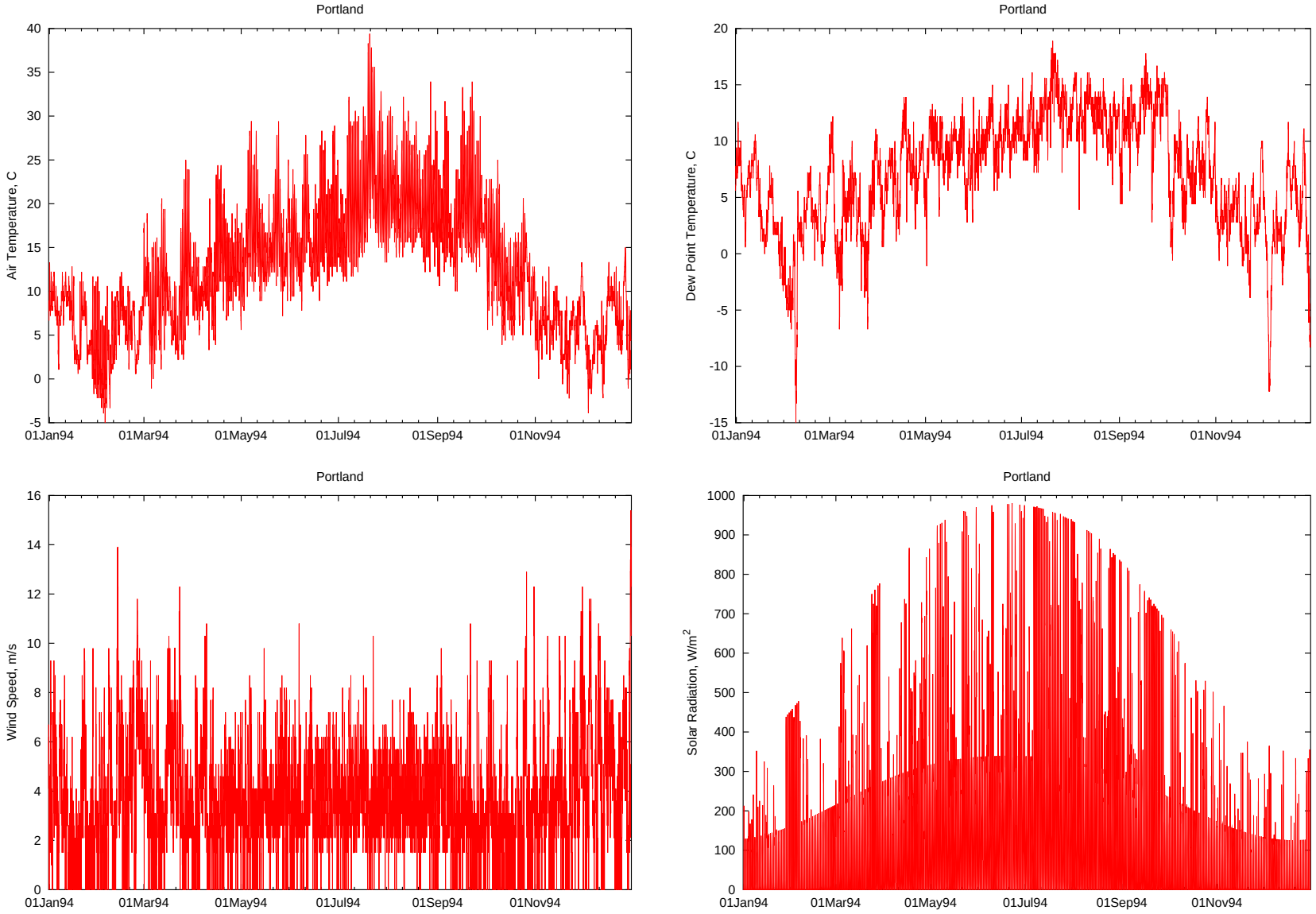

Figure 133: 1994 meterology data at Portland.

Wenatchee 1994 Meterology

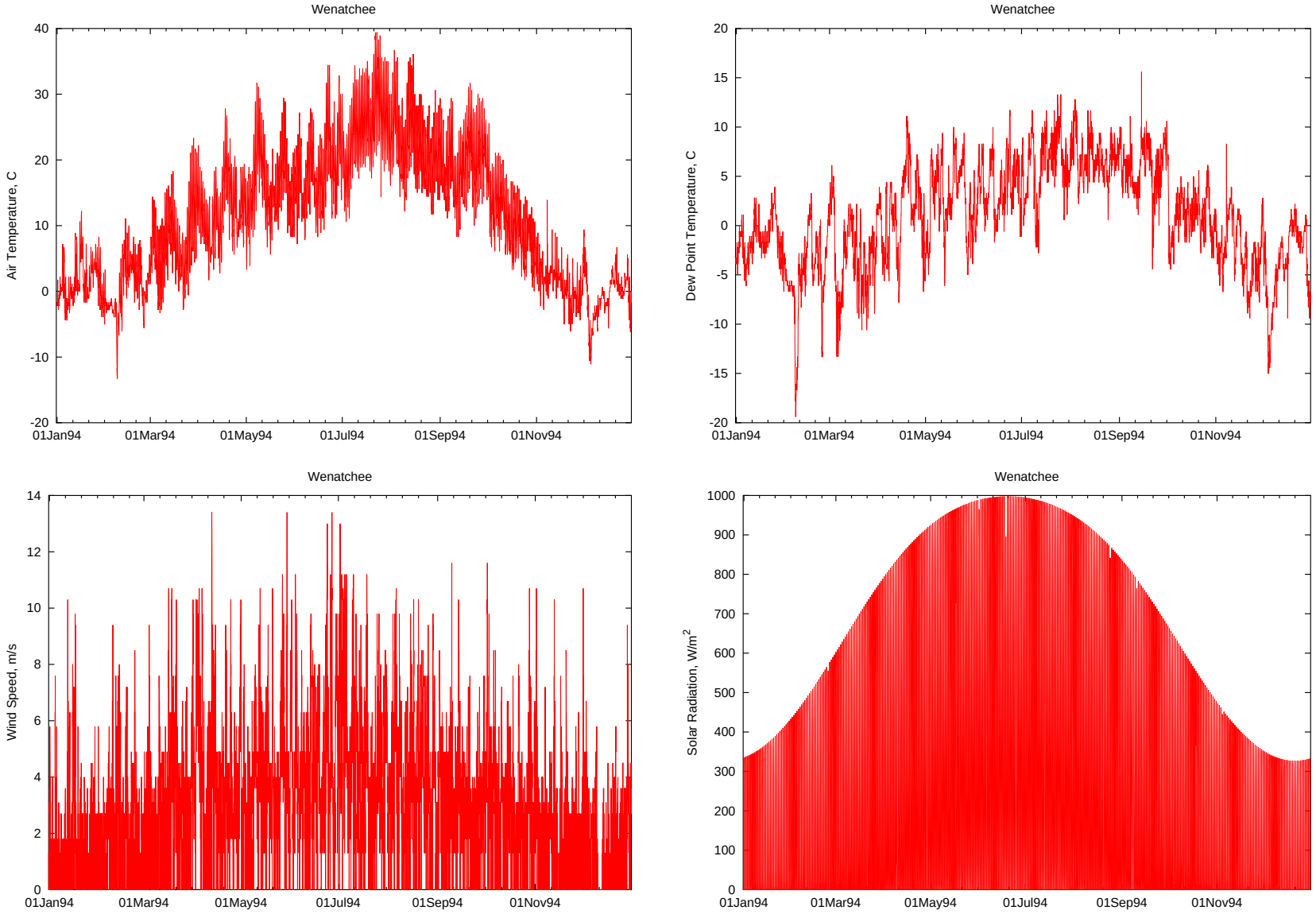

Figure 134: 1994 meterology data at Wenatchee.

C MASS1 Model Schematics

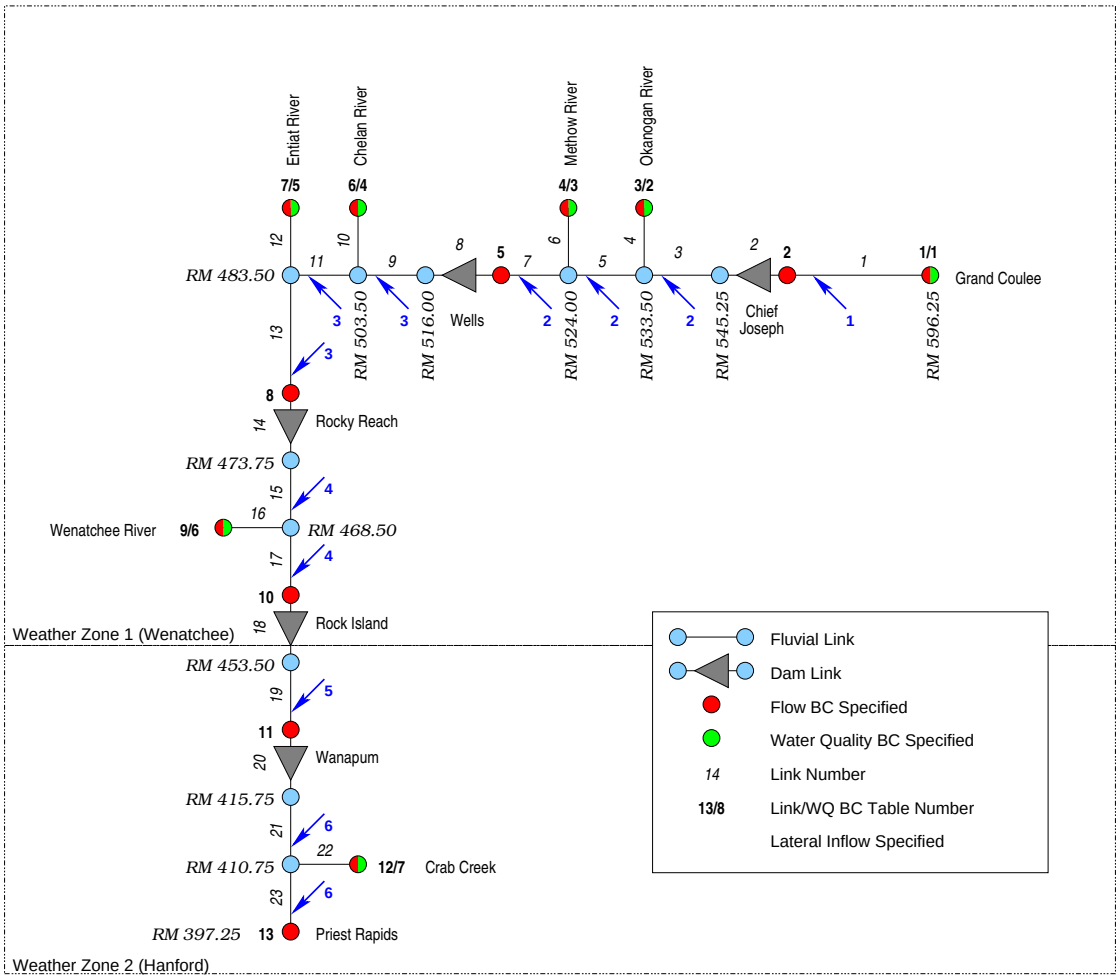

Figure 135: Schematic of MASS1 application to the mid-Columbia.

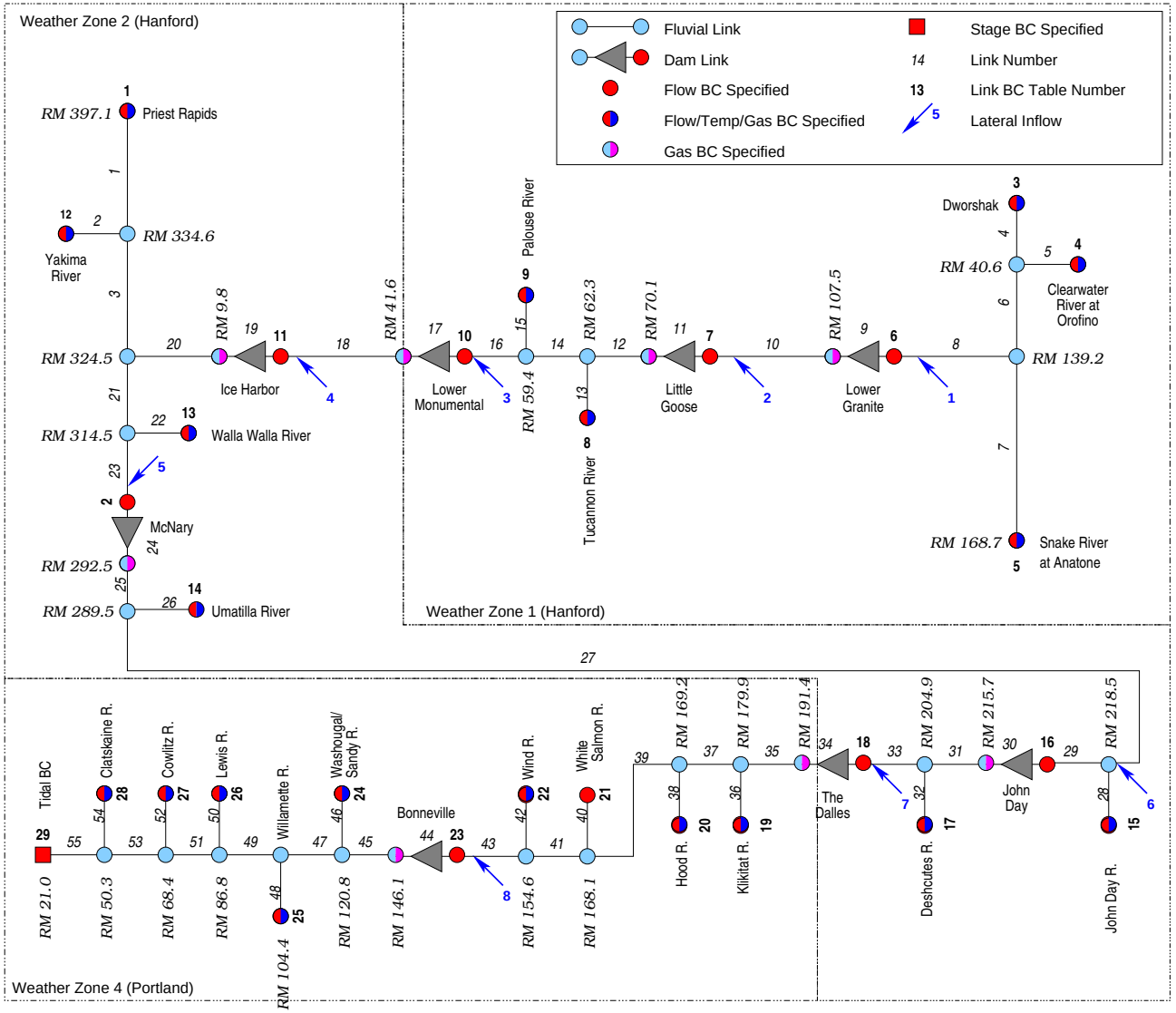

Figure 136: Schematic of MASS1 application to the lower Snake and Columbia Rivers.