



**U.S. Army Corps of Engineers
Walla Walla District**

Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers.

Part 10: Tidal Reach

FINAL REPORT

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Abstract

One of the major goals for the U.S. Army Corps of Engineers Dissolved Gas Abatement Study is to identify measures that could reduce levels of dissolved gas supersaturation in the Columbia and Snake Rivers caused by spillway discharges. Attaining this goal could contribute significantly to meeting water quality criteria and lowering gas bubble trauma in resident and migrating fish in these rivers. To achieve this goal, the Corps of Engineers is studying various operational and structural alternatives using field investigations and computational modeling tools to simulate the transport of dissolved gas in the river system.

Part 10 of the report series summarizes the development and application of a two-dimensional depth-averaged hydrodynamic and water quality model (MASS2) to the so-called Tidal Reach of the Lower Columbia River system. The Tidal Reach model domain extends from Bonneville Dam downstream to approximately Columbia River Mile 110.

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Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers.

Part 10: Tidal Reach

Under Biological Services Contract DACW68-96-D-0002, Delivery Order No. 8, Battelle, Pacific Northwest Division is developing and applying a two-dimensional hydrodynamic, transport model, and fish exposure model to the Lower Columbia and Snake River systems. This work is an element of the U.S. Army Corps of Engineers Dissolved Gas Abatement Program (DGAS).

Part 8 of the report series describes the application of the model to the so-called Tidal Reach of the Columbia River. The modeled domain encompasses the following region:

- Bonneville Dam, at Columbia rivermile (RM) 145
- Downstream Tidal Reach boundary at Columbia RM 110

1 Application of the Hydrodynamics and Water Quality Models to the Columbia River Tidal Reach

A two-dimensional-depth averaged hydrodynamics and transport model has been developed and applied to the part of the Columbia River that forms Tidal Reach. The model simulates time-varying distributions of the depth-averaged velocities, water temperature, and total dissolved gas. Further details concerning the model including the governing equations and solutions procedures are provided in Part 1 of the report series (Richmond, Perkins, and Scheibe, 1998).

The section discusses the general aspects of the application of the models to the Columbia River Tidal reach. The data used to assign the bathymetry and boundary conditions are described in Appendix A. Summaries of the field data in the calibration and verification simulations are provided in Appendix B through Appendix D.

Hydrodynamics were verified using Spring 1996 and Summer 1997 Acoustic Doppler Current Profiler (ADCP) data. Dissolved gas and temperature verification used the Spring 1996, Summer 1996, and Summer 1997 pool study data.

1.1 Model Grid

The computational grid was generated using the Gridgen 9.1 code. Gridgen 9.1 is software for the generation of 3D, multiple block, structured grids. The code was developed for NASA Ames Research Center (Steinbrenner and Chawner, 1995).

To create the grid, a data file containing discrete geographical locations that outline the river shoreline was imported to Gridgen. In Gridgen, curves containing the data points were created and joined to enclose 2-dimensional flow regions. Grid spacing was set in

each flow region and the grids were smoothed using the Gridgen elliptic solver. The elliptic solver was used to minimize grid twist and skew. The flow regions were then joined end to end in the downstream direction to make up the entire flow domain and the entire 2-dimensional grid was written to file. Once the grid was created bottom elevations in each cell were assigned using the bathymetric data and procedure described in Appendix A.

The model grid for the reach is shown in Figure 1. Larger scale maps of the model grid near the Bonneville dam and downstream model boundaries are shown in Figure 2 and Figure 3. Note that several small islands were not included in the model and these were replaced with bottom elevation approximately 2 ft below the low water surface elevation (the water is about 2 ft deep where the islands are).

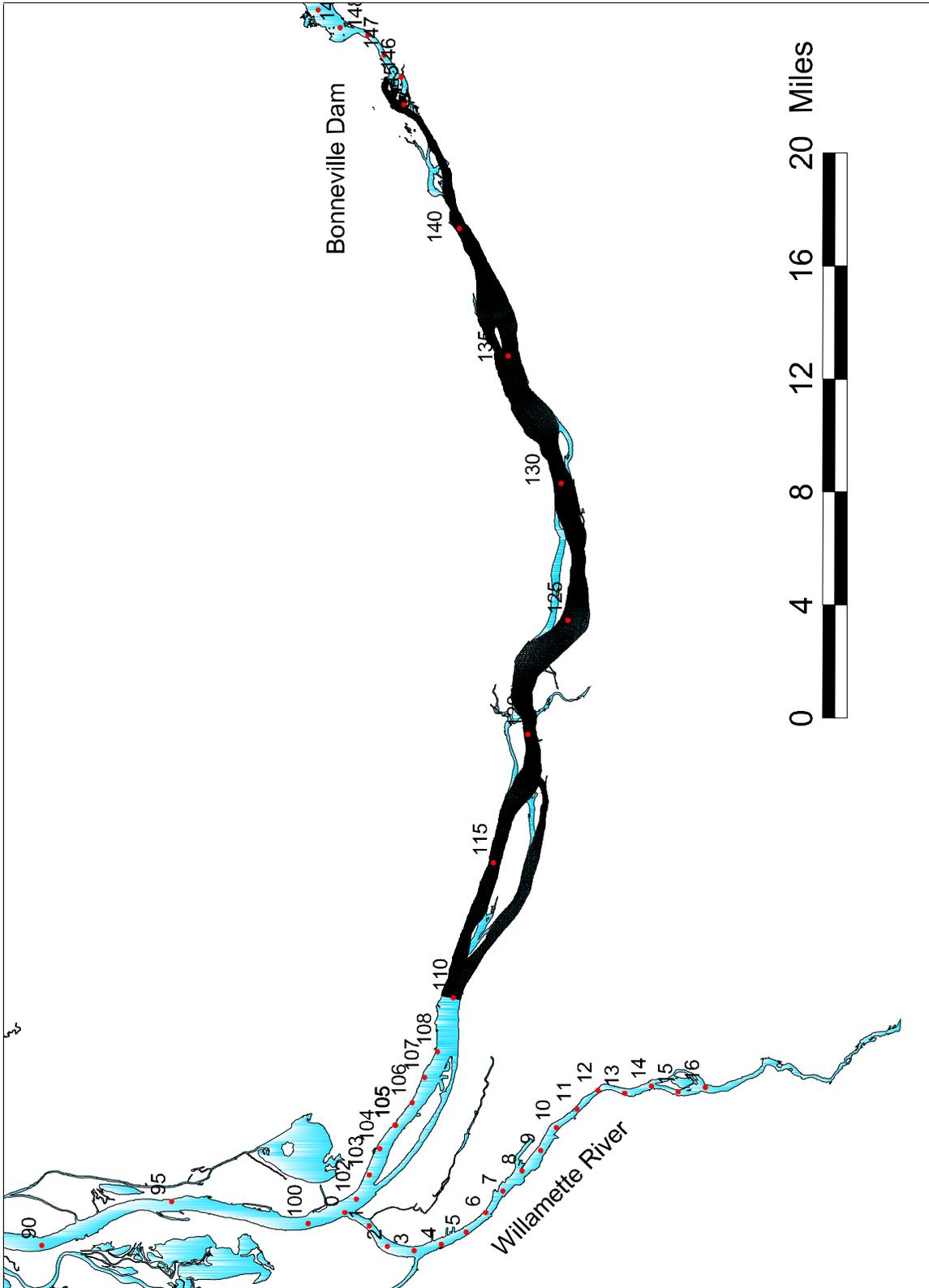


Figure 1. Model grid for the Tidal reach.

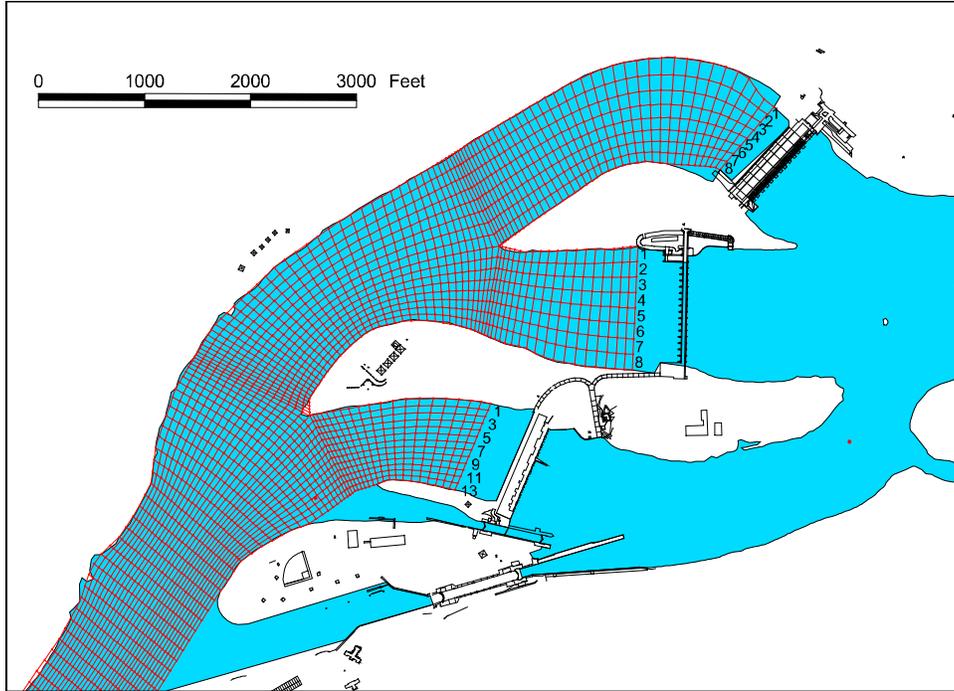


Figure 2. Model grid near Bonneville Dam.

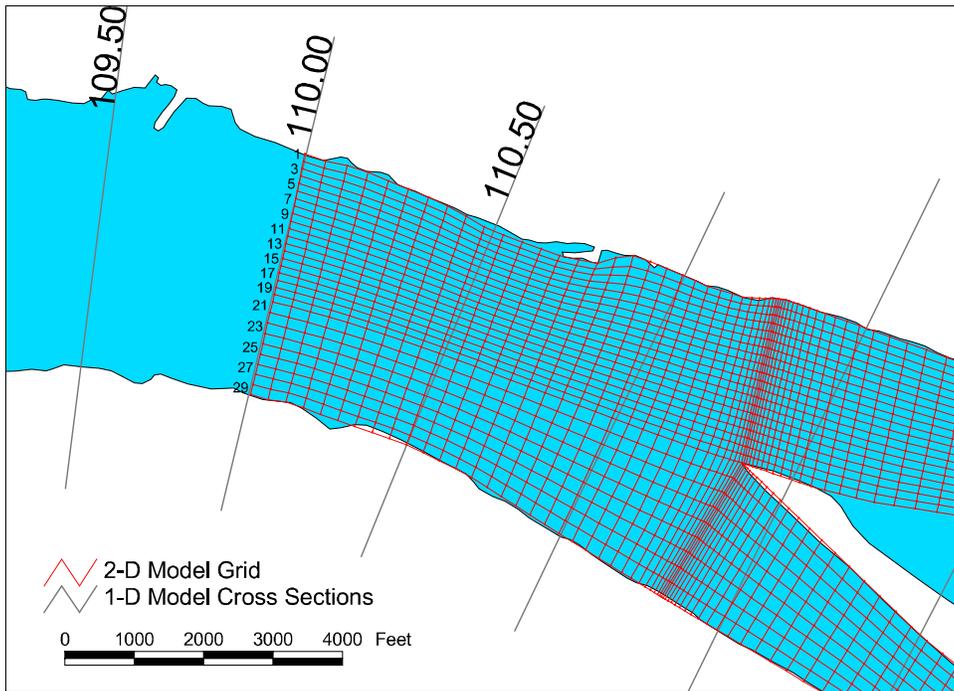


Figure 3. Model grid near Columbia river mile 110.

1.2 Boundary Conditions

1.2.1 Bonneville Dam Sourcing Function

Spillway TDG concentrations were estimated using the Bonneville dam TDG sourcing function presented by USACE (1996):

$$S_s = 105.61 + 0.21Q_s \quad (1)$$

where

S_s = TDG saturation of spillway flow, percent; and

Q_s = spillway flow, cfs.

Forebay temperatures and barometric pressures were used to compute concentration from the saturation estimated using equation (1).

1.3 Hydrodynamics Calibration and Verification

The model hydrodynamics were calibrated primarily using the Bonneville dam tailwater elevation gage. ADCP velocity measurements were available for two Tidal reach study periods. Due to instrumentation problems the coordinates of the ADCP data were subject to uncertain errors. Therefore, at this time, use of the ADCP data was restricted to qualitative comparisons with the model simulations.

In the spring 1996 and summer 1997 simulations, a time step of 50 seconds was used; 30 seconds was used for the summer 1996 simulation. The simulations also used constant longitudinal and lateral turbulent eddy viscosities of $0.2 \text{ ft}^2/\text{s}$.

1.3.1 Bonneville Tailwater

The first step in the calibration procedure was to select a spatially uniform value of the Manning roughness coefficient that would yield computed water surface elevations in satisfactory agreement with the Bonneville dam tailwater gage. The Spring 1996 study period was selected for calibration. Simulations were performed using Manning n values in the range of 0.026 to 0.027. Figure 4 compares the model simulation and measured tailwater elevation for a n-value of 0.026 which was chosen as the final parameter value to be used in the remainder of the Tidal reach simulations.

The selected n-value was verified for the Summer 1996 and Summer 1997 study periods; results are shown in Figure 5 and Figure 6, respectively.

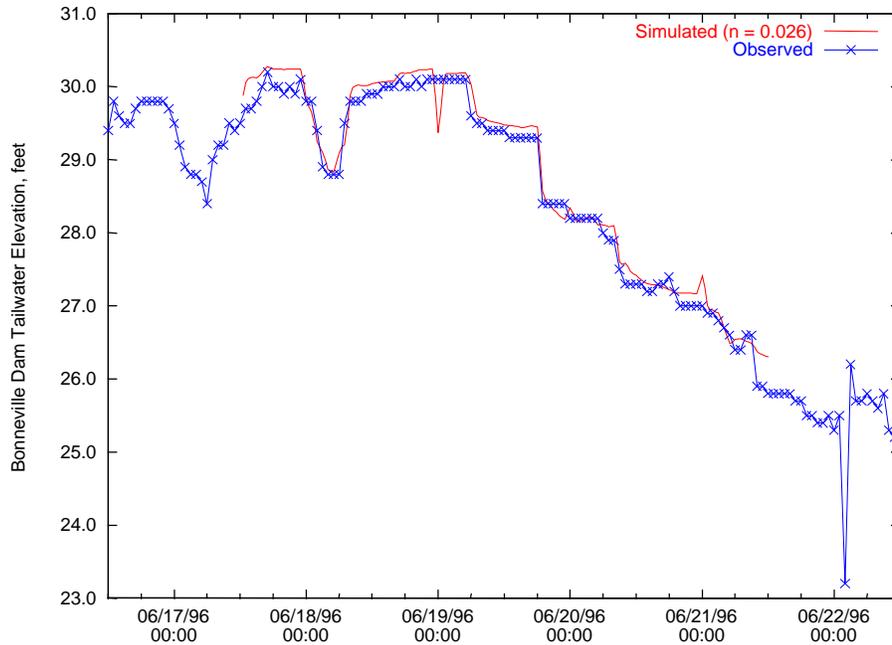


Figure 4. Comparison of simulated (Manning’s $n = 0.026$) and measured water surface elevation at the Bonneville dam tailwater gage during the Spring 1996 study period

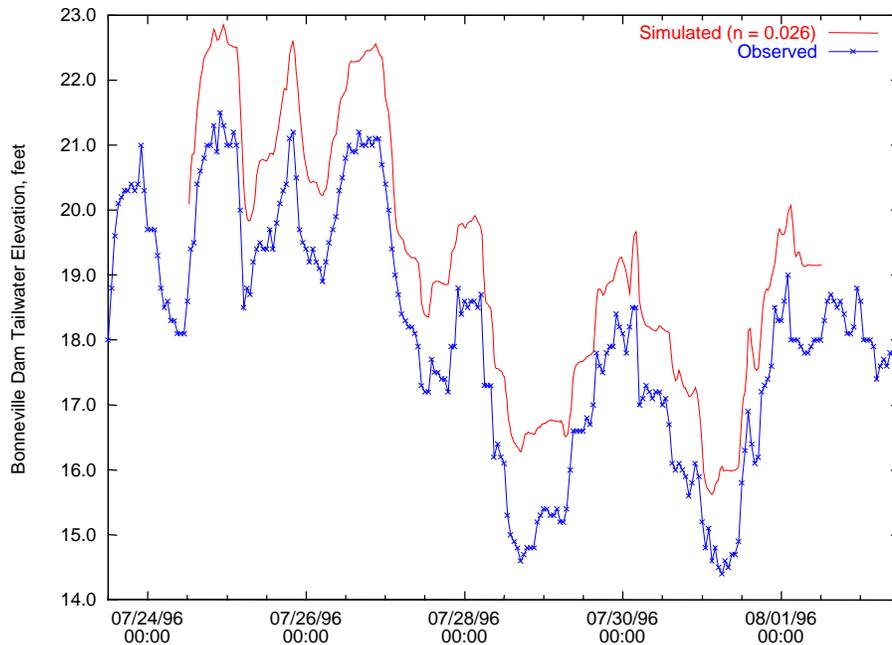


Figure 5. Comparison of simulated (Manning’s $n = 0.026$) and measured water surface elevation at the Bonneville dam tailwater gage during the Summer 1996 study period

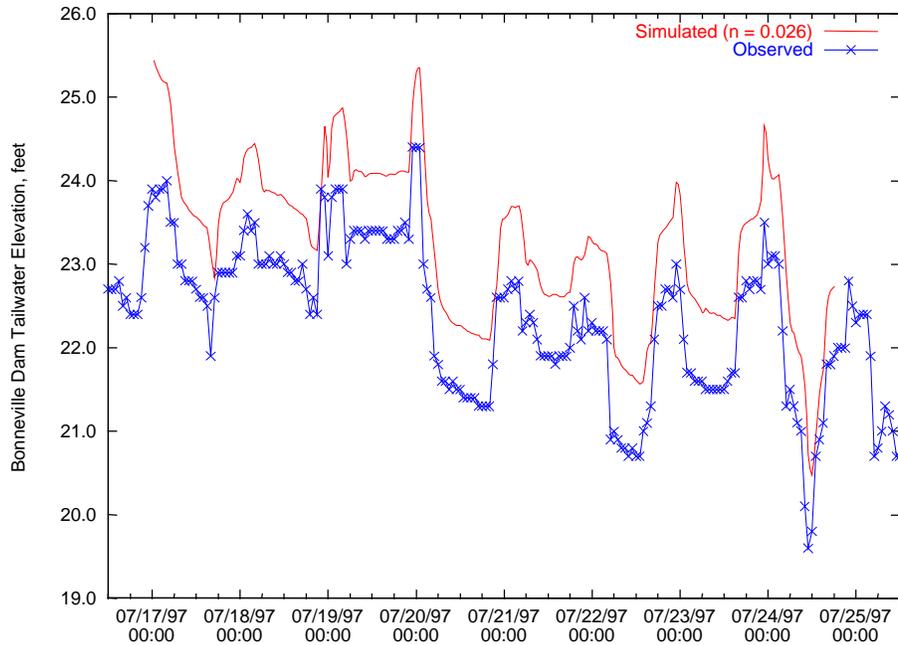


Figure 6. Comparison of simulated (Manning’s $n = 0.026$) and measured water surface elevation at the McNary dam tailwater gage during the Summer 1997 study period

1.3.2 Spring 1996 ADCP Data

Once the manning n value was selected, the model was run for the operational conditions that existed when the Spring ADCP measurements were performed. The manning n value was not altered from the value of 0.026 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged ADCP data in Figure 7 through Figure 14.

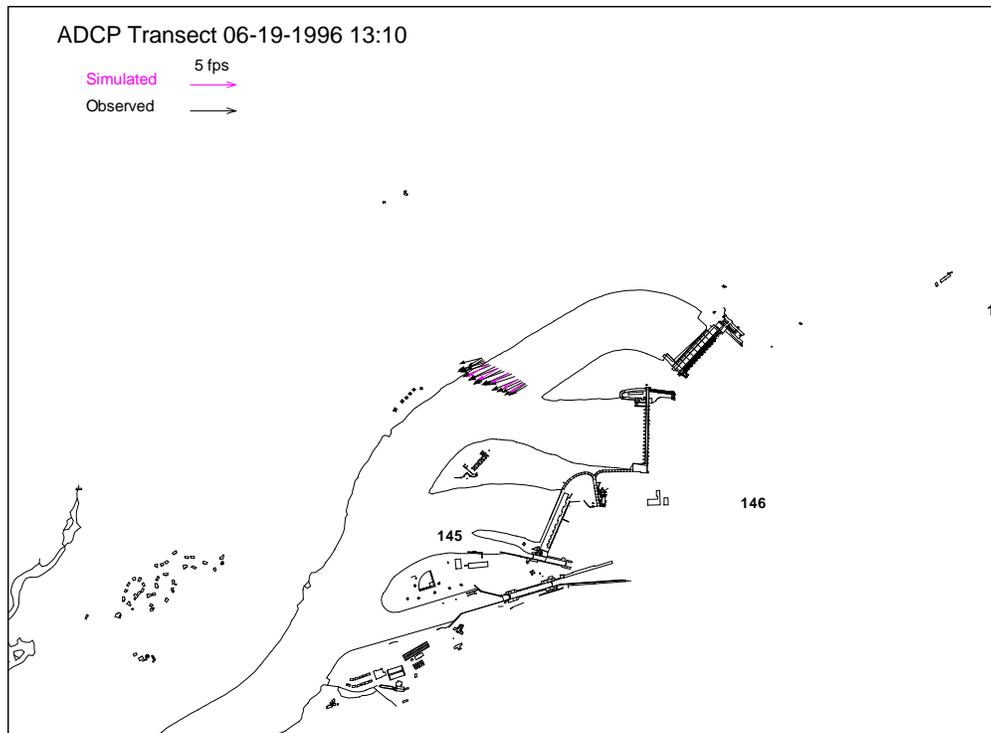


Figure 7. Simulated and observed depth-averaged velocities near Tidal Reach on 6-19-1996.

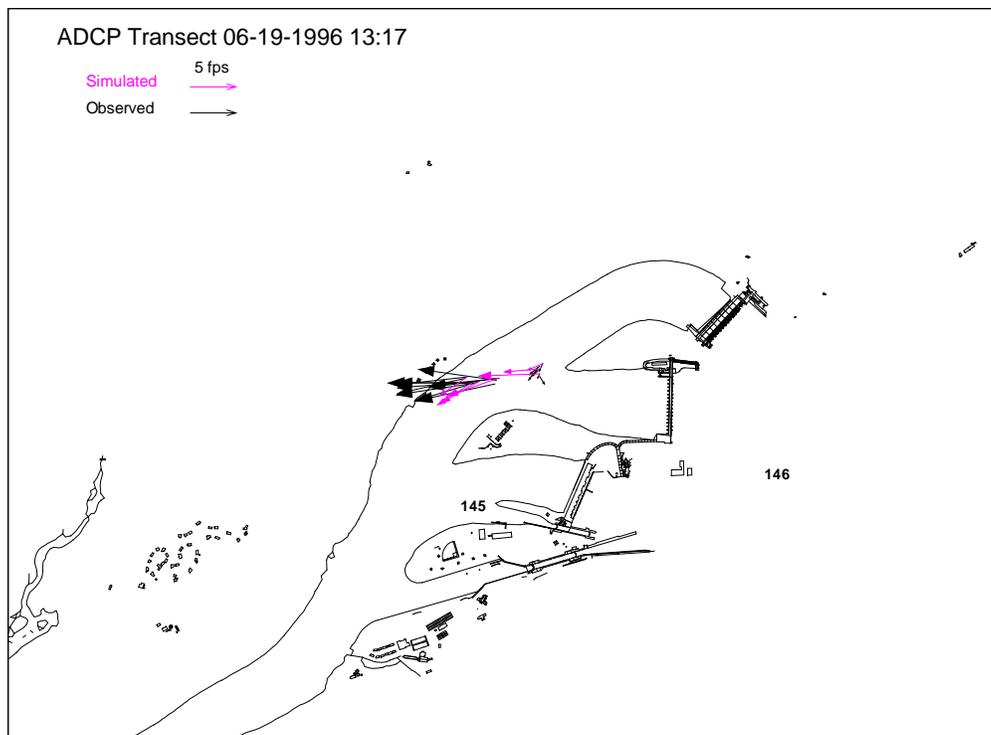


Figure 8. Simulated and observed depth-averaged velocities near Tidal Reach on 6-19-1996.

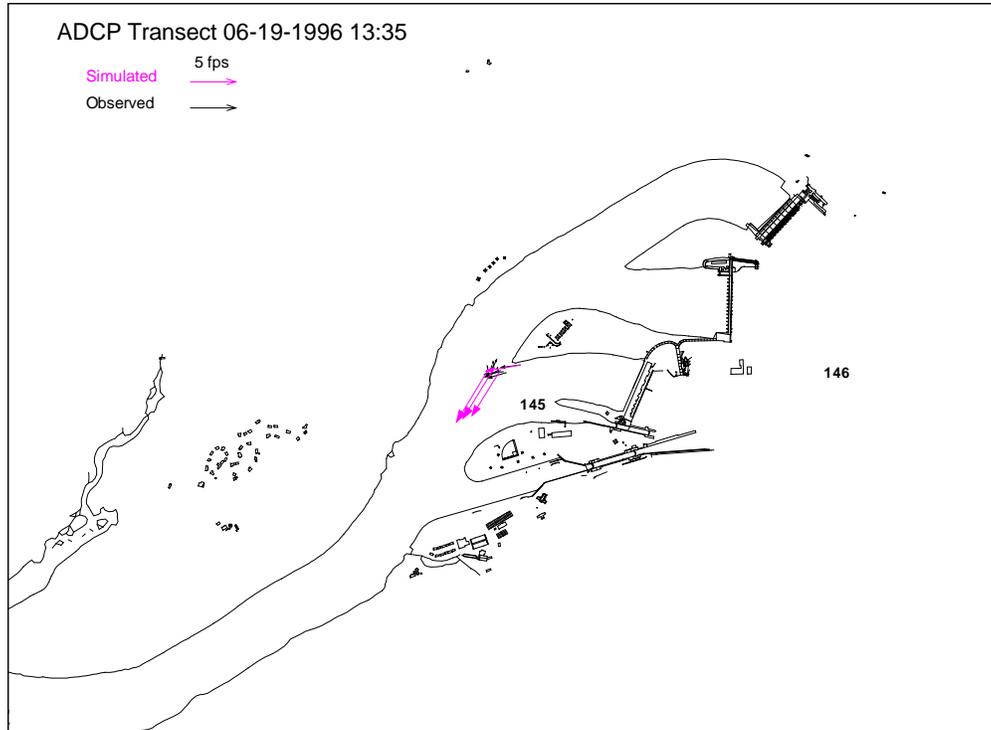


Figure 9. Simulated and observed depth-averaged velocities near Tidal Reach on 6-20-1996.

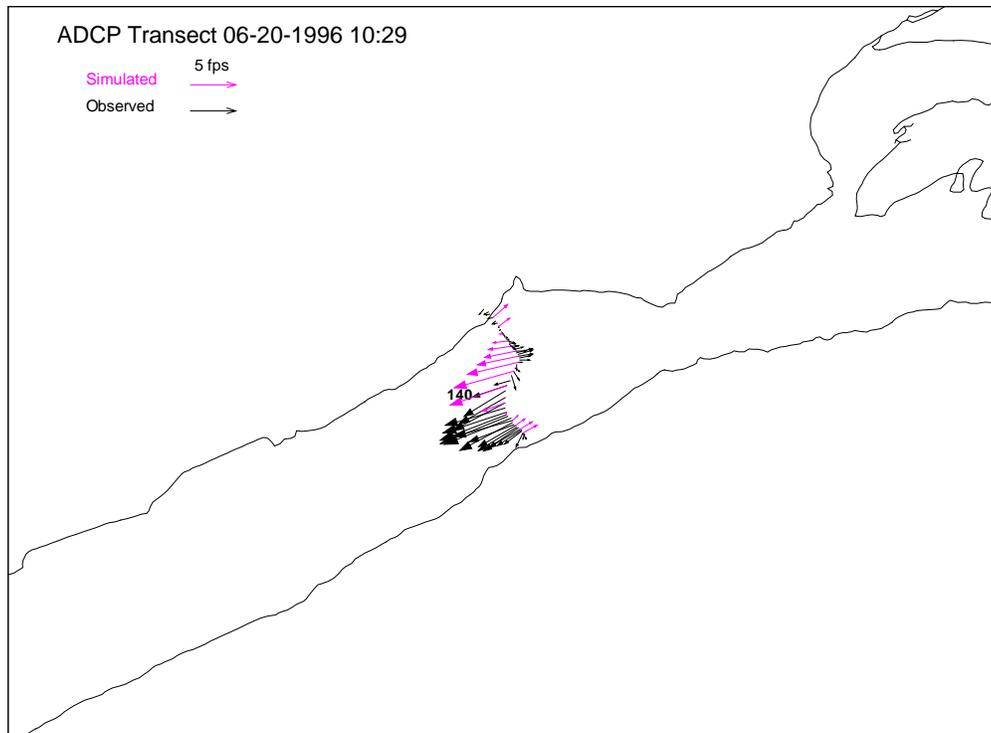


Figure 10. Simulated and observed depth-averaged velocities near Columbia River Mile 140 on 6-20-1996.

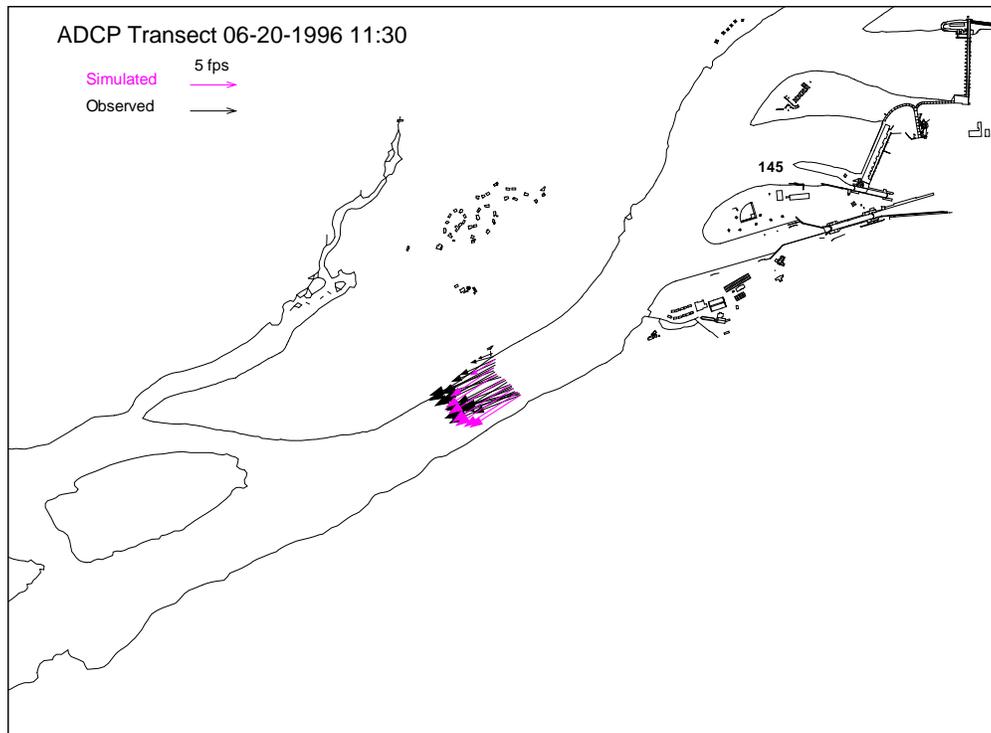


Figure 11. Simulated and observed depth-averaged velocities near Columbia River Mile 140 on 6-20-1996.

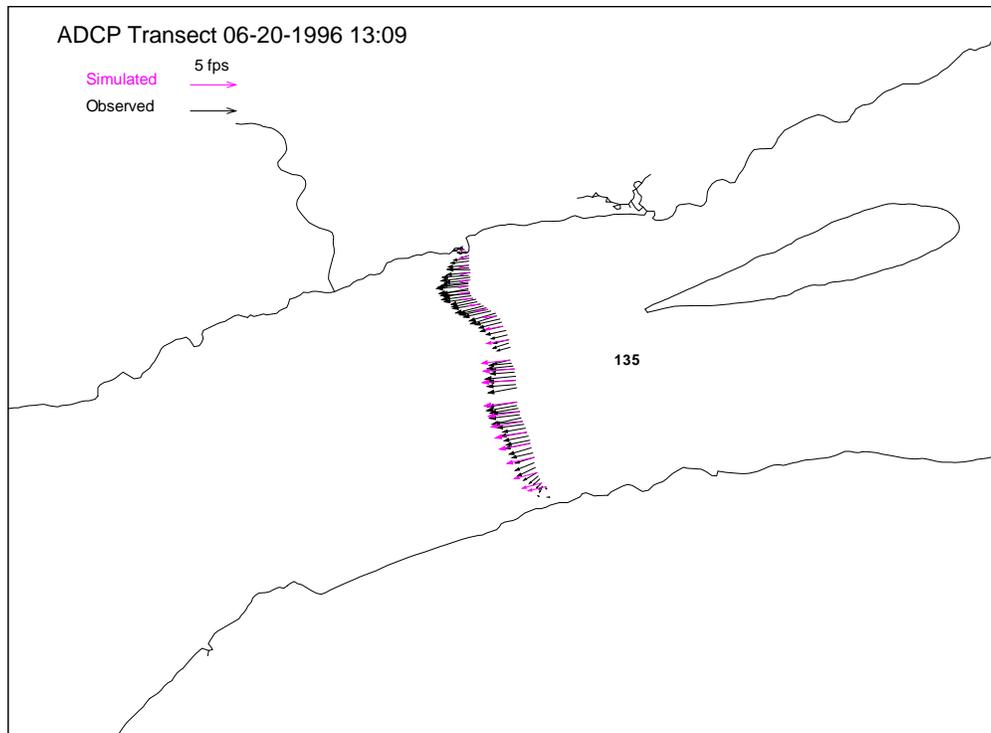


Figure 12. Simulated and observed depth-averaged velocities near Columbia River Mile 135 on 6-20-1996.

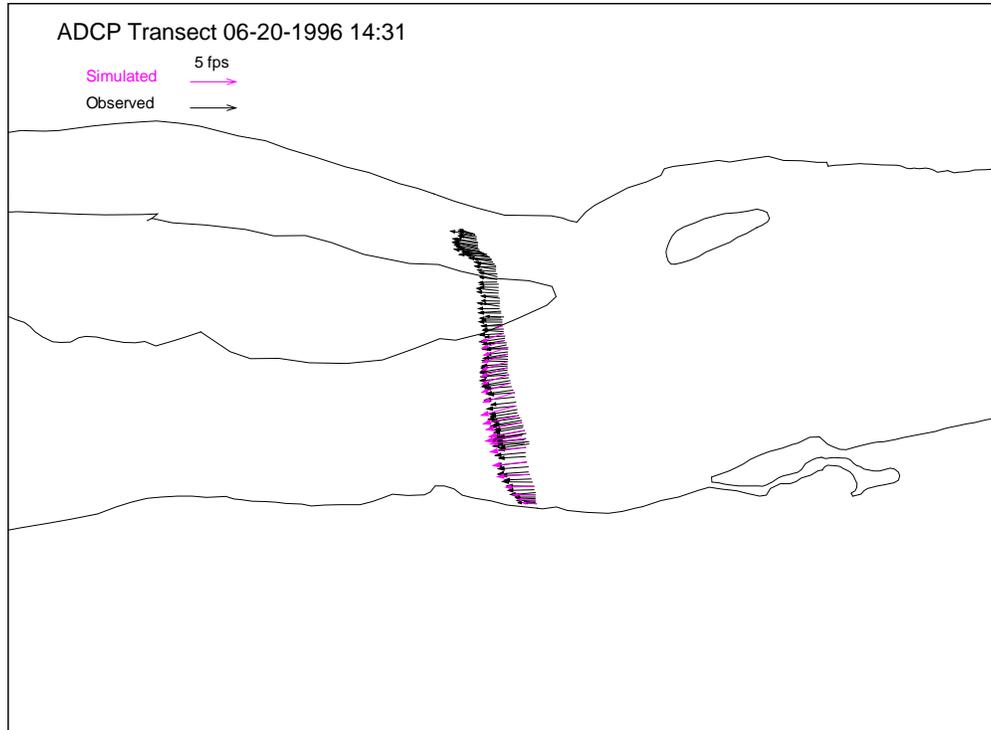


Figure 13. Simulated and observed depth-averaged velocities near Tidal Reach on 6-20-1996.

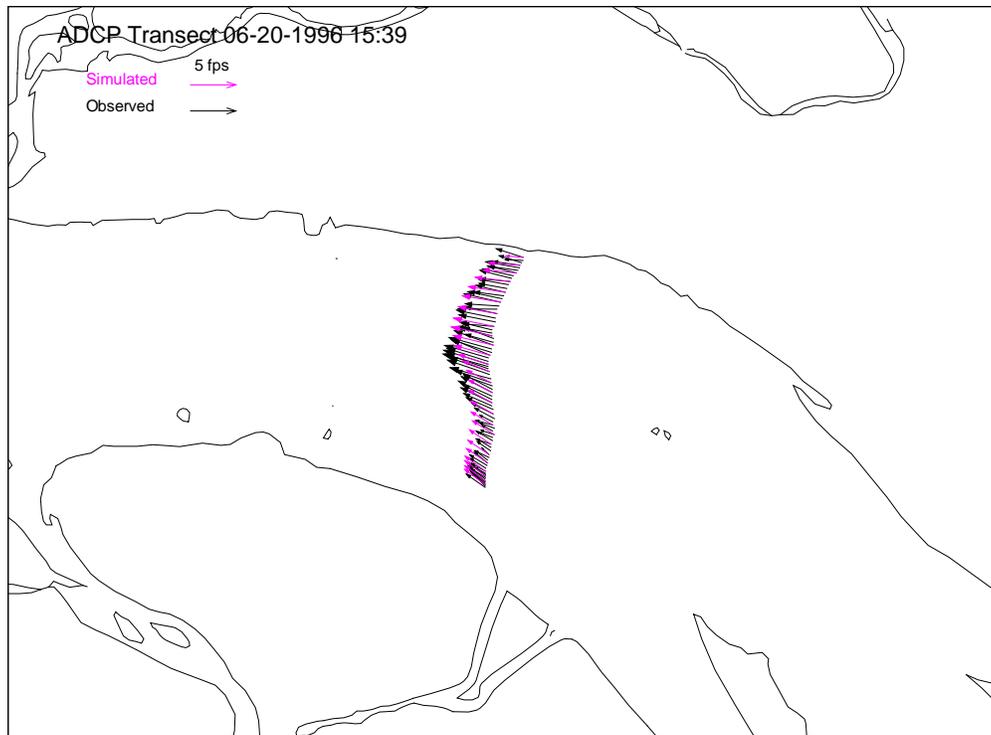


Figure 14. Simulated and observed depth-averaged velocities near Tidal Reach on 6-20-1996.

1.3.3 Summer 1997 ADCP Data

Once the Manning n value was selected, the model was run for the operational conditions that existed when the Summer 1997 ADCP measurements were performed. The Manning n value was not altered from the value of 0.026 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged ADCP data in Figure 15 through Figure 46.

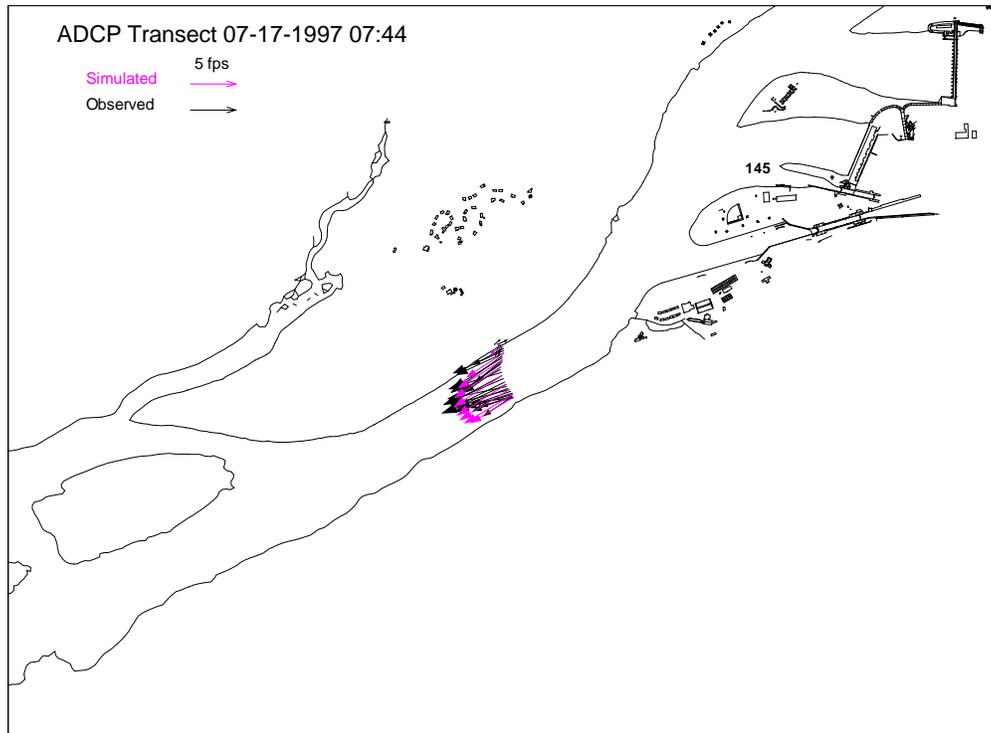


Figure 15. Simulated and observed depth-averaged velocities near Columbia River Mile 145 on 7-17-1997.

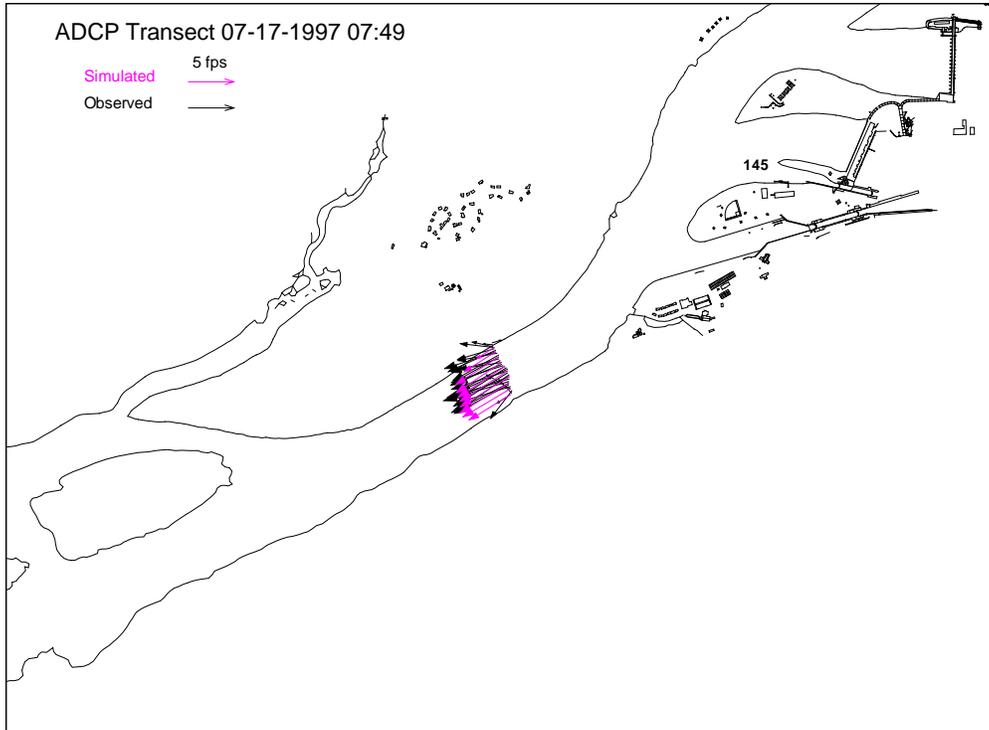


Figure 16. Simulated and observed depth-averaged velocities near Columbia River Mile 145 on 7-17-1997.

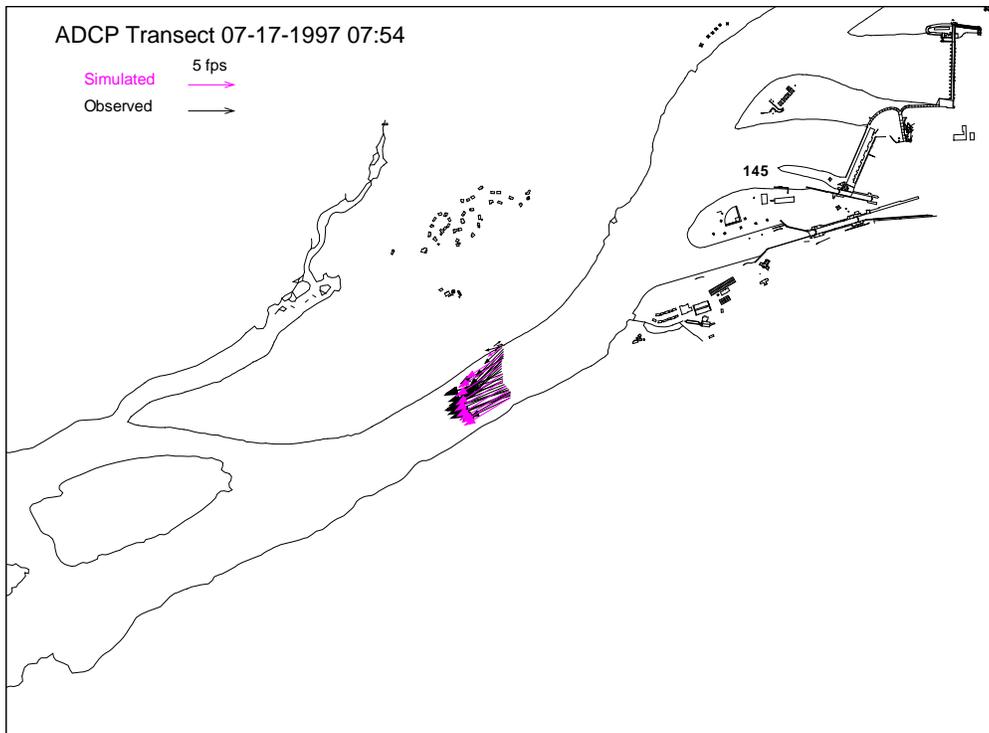


Figure 17. Simulated and observed depth-averaged velocities near Columbia River Mile 145 on 7-17-1997.

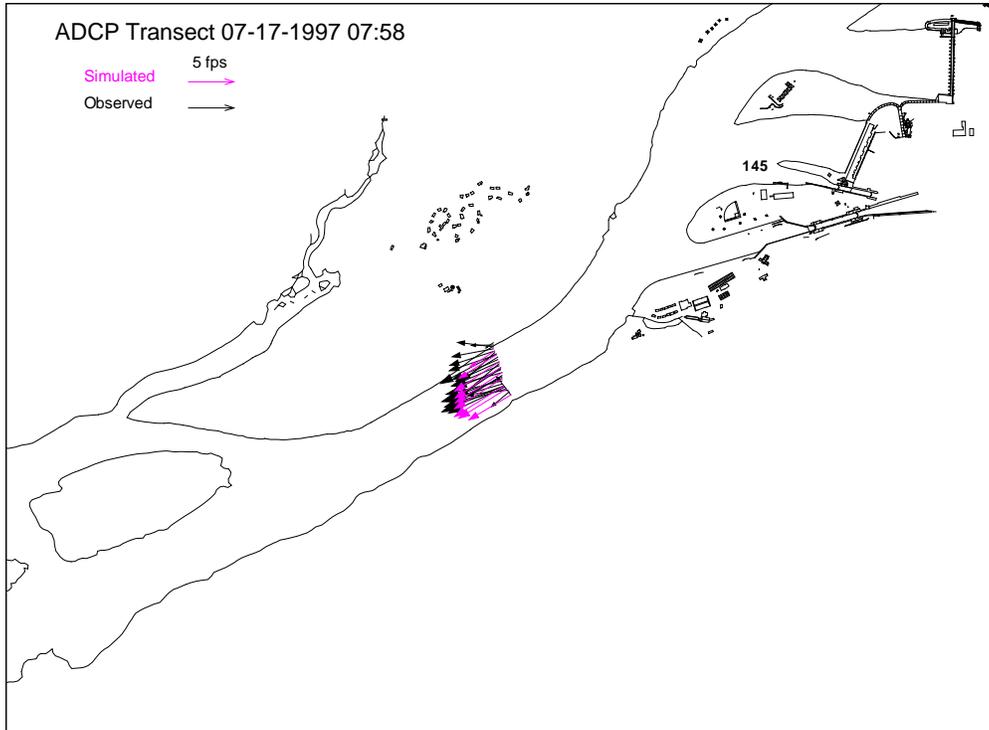


Figure 18. Simulated and observed depth-averaged velocities near Columbia River Mile 145 on 7-17-1997.

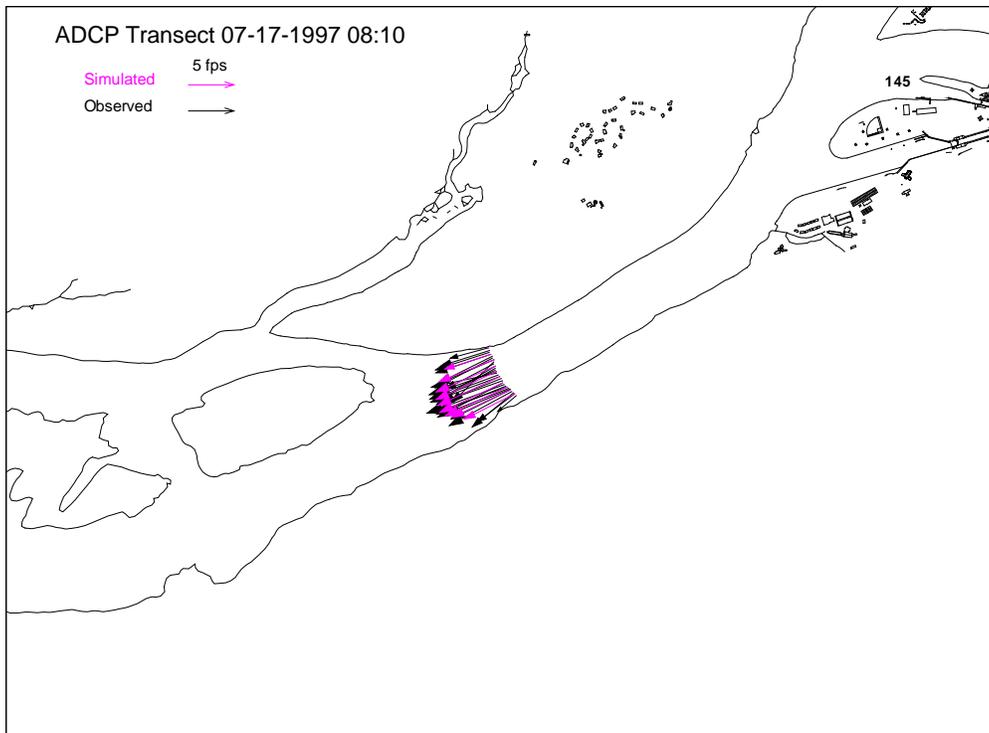


Figure 19. Simulated and observed depth-averaged velocities near Columbia River Mile 145 on 7-17-1997.

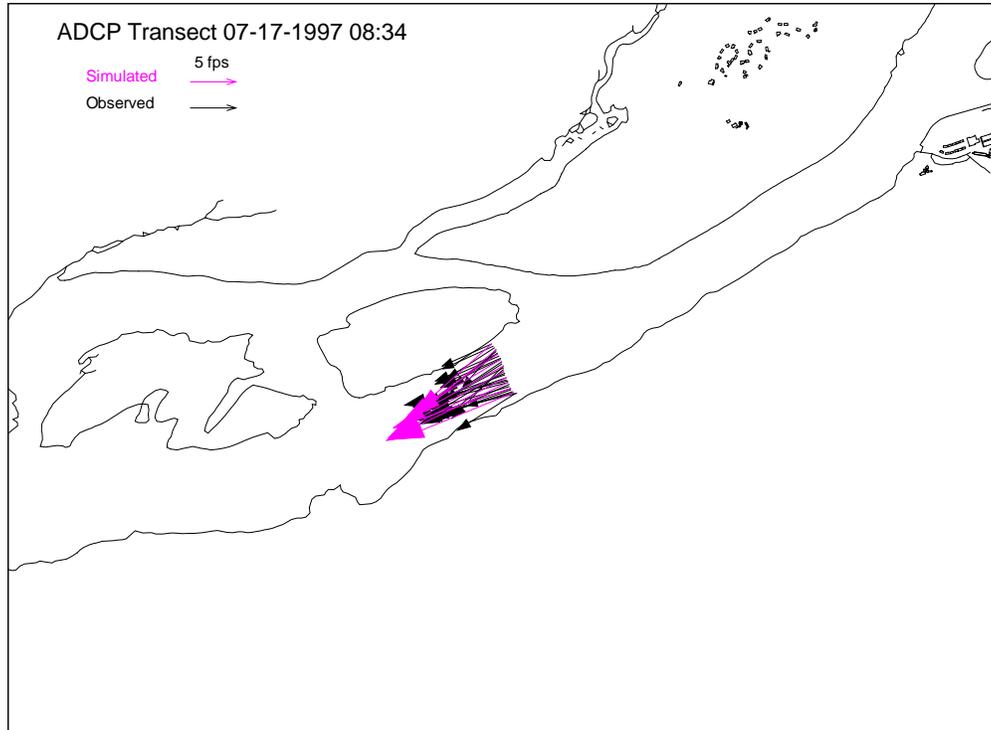


Figure 20. Simulated and observed depth-averaged velocities near Columbia River Mile 143 on 7-17-1997.

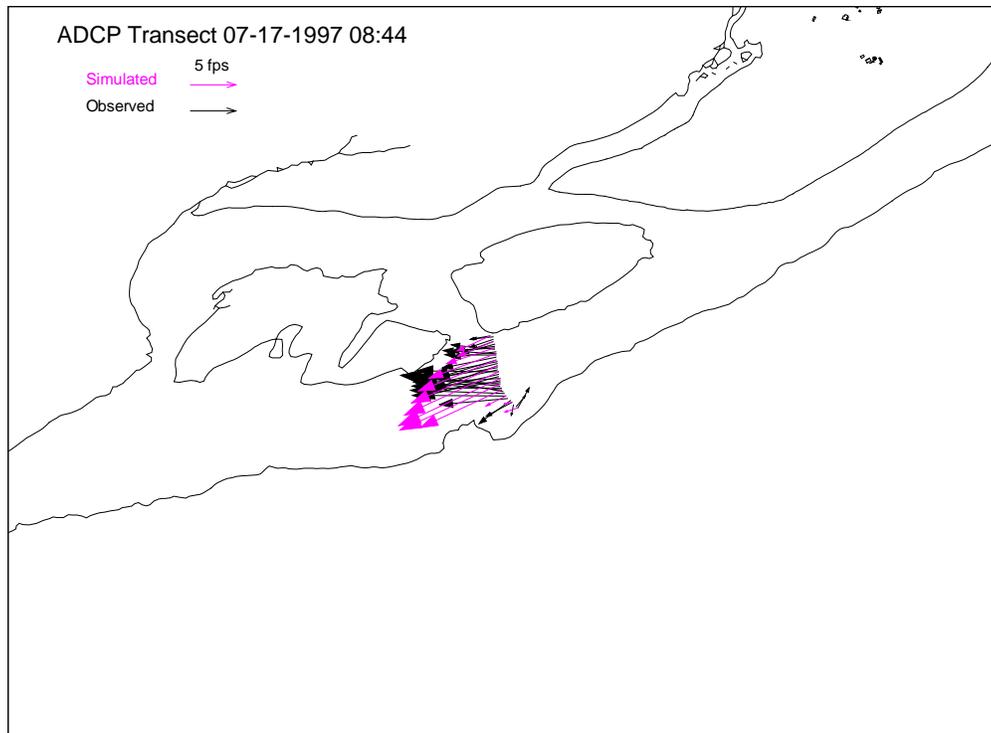


Figure 21. Simulated and observed depth-averaged velocities near Columbia River Mile 142 on 7-17-1997.

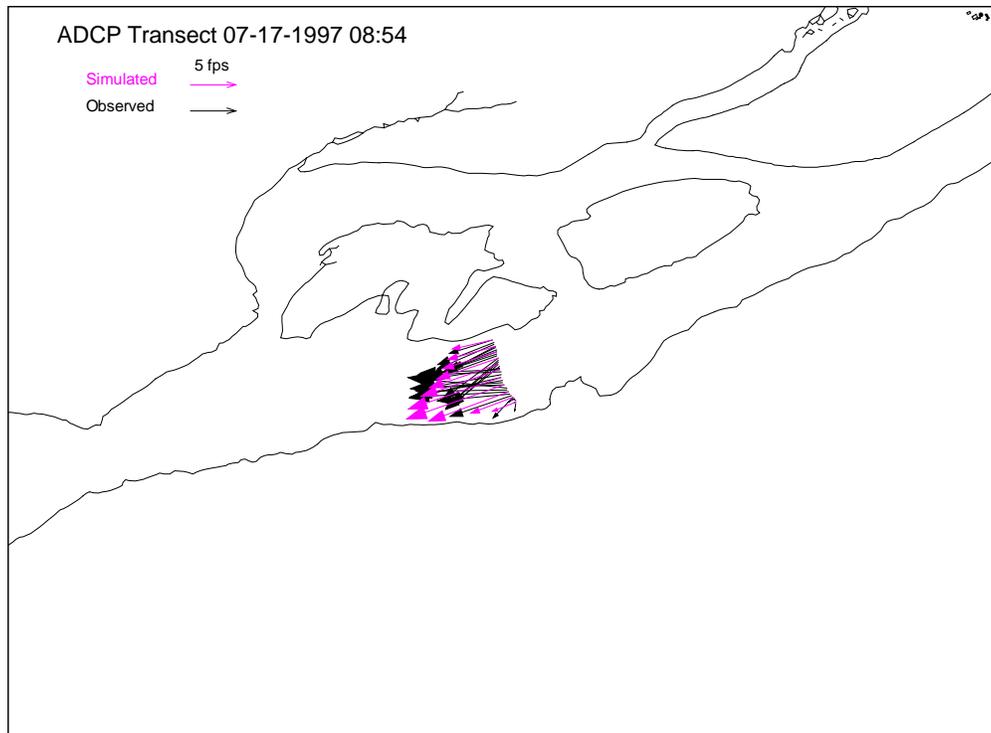


Figure 22. Simulated and observed depth-averaged velocities near Columbia River Mile 142 on 7-17-1997.

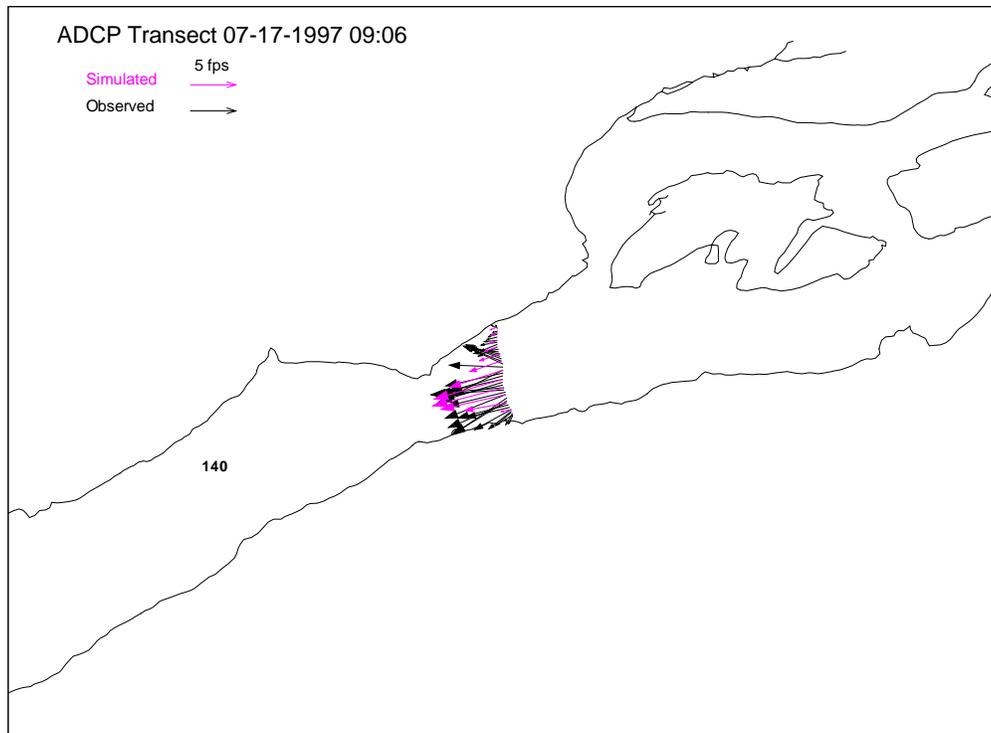


Figure 23. Simulated and observed depth-averaged velocities near Columbia River Mile 141 on 7-17-1997.

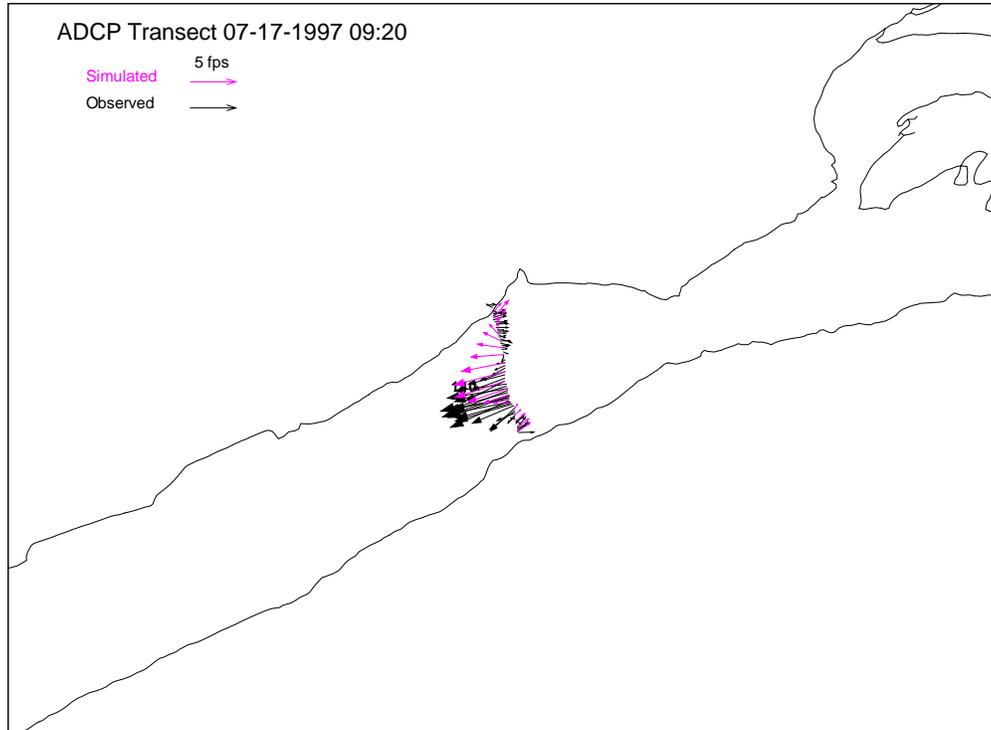


Figure 24. Simulated and observed depth-averaged velocities near Columbia River Mile 140 on 7-17-1997.

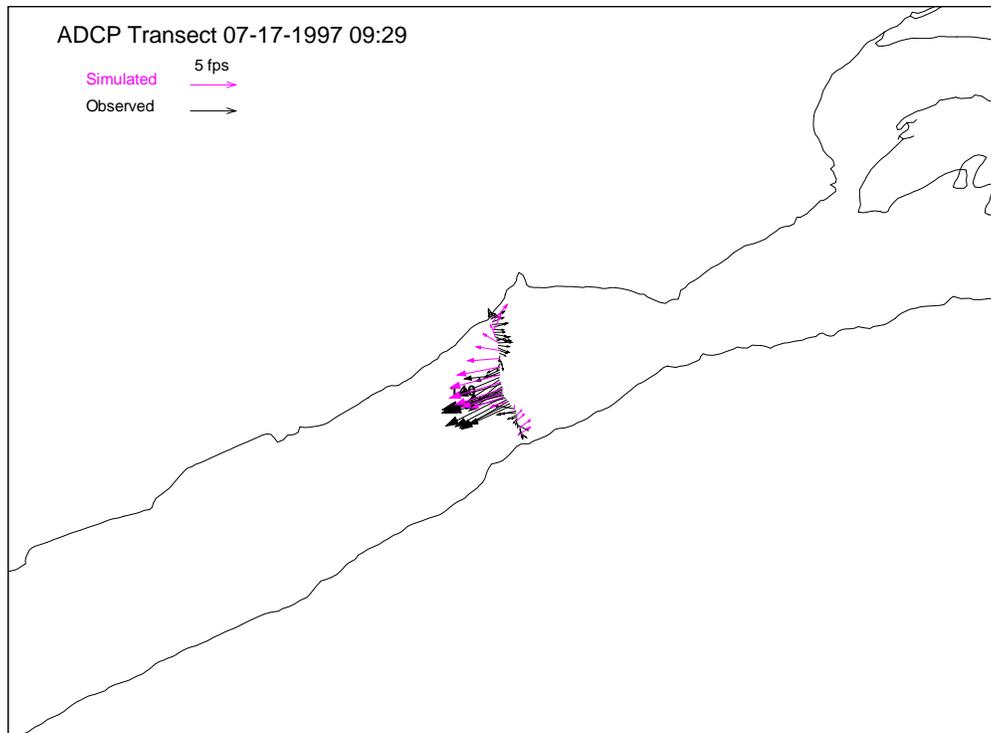


Figure 25. Simulated and observed depth-averaged velocities near Columbia River Mile 140 on 7-17-1997.

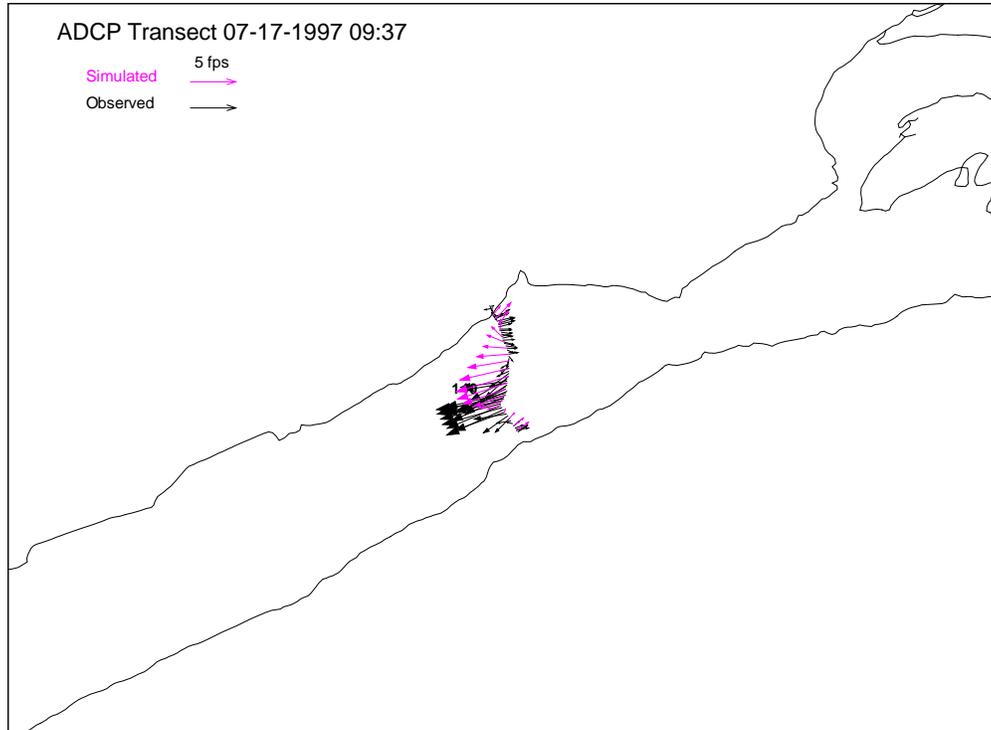


Figure 26. Simulated and observed depth-averaged velocities near Columbia River Mile 140 on 7-17-1997.

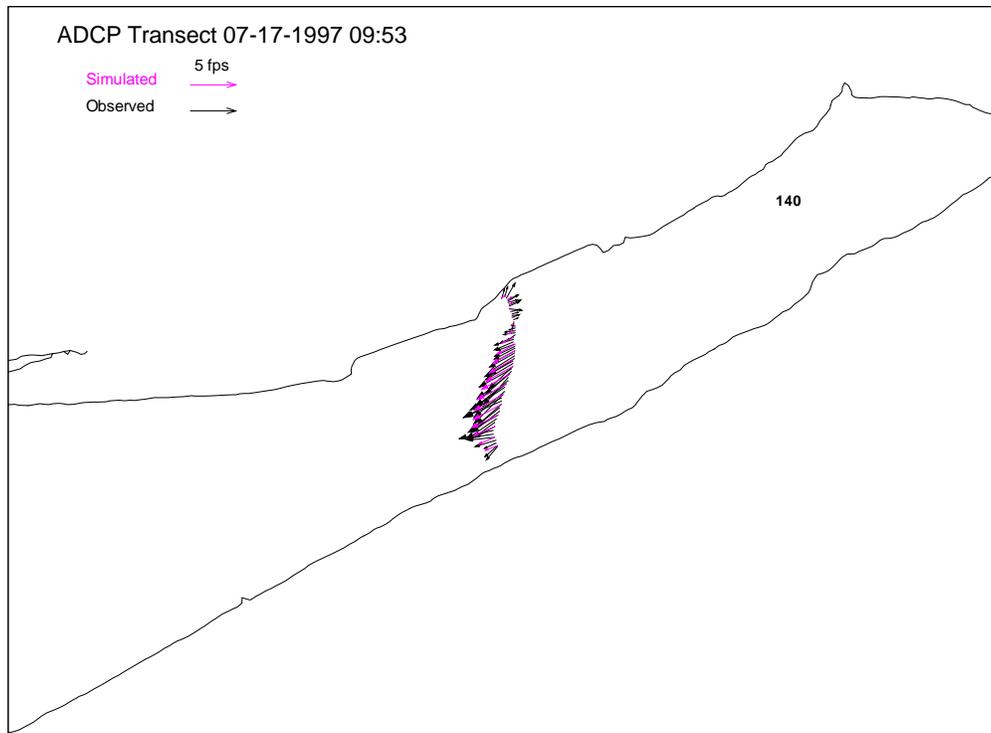


Figure 27. Simulated and observed depth-averaged velocities near Columbia River Mile 139 on 7-17-1997.

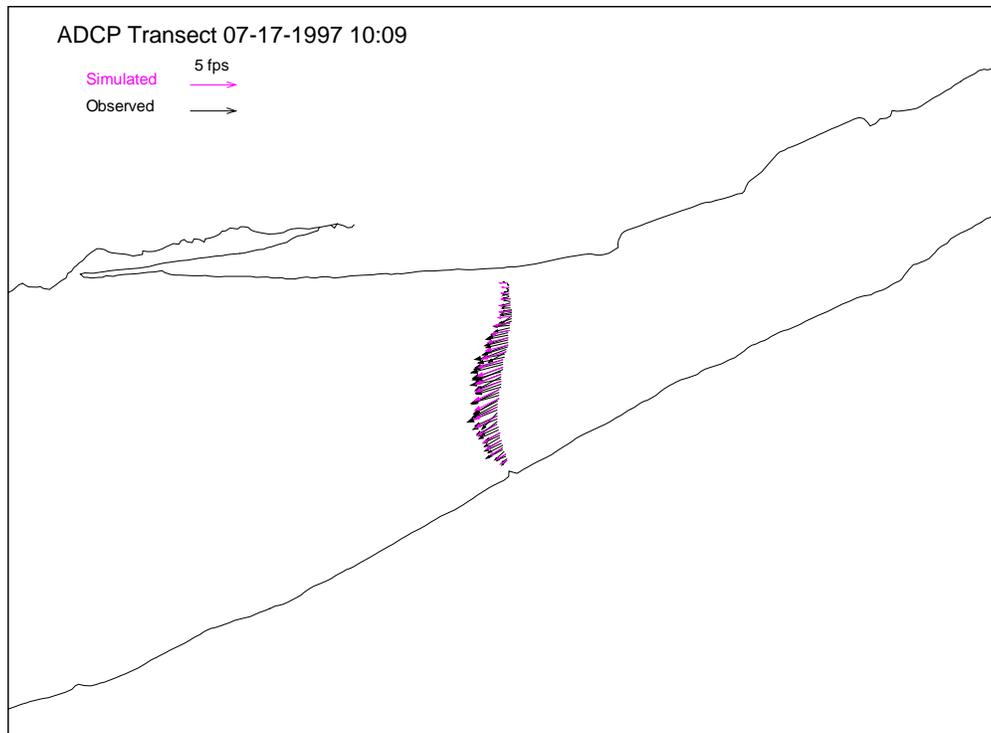


Figure 28. Simulated and observed depth-averaged velocities near Columbia River Mile 138 on 7-17-1997.

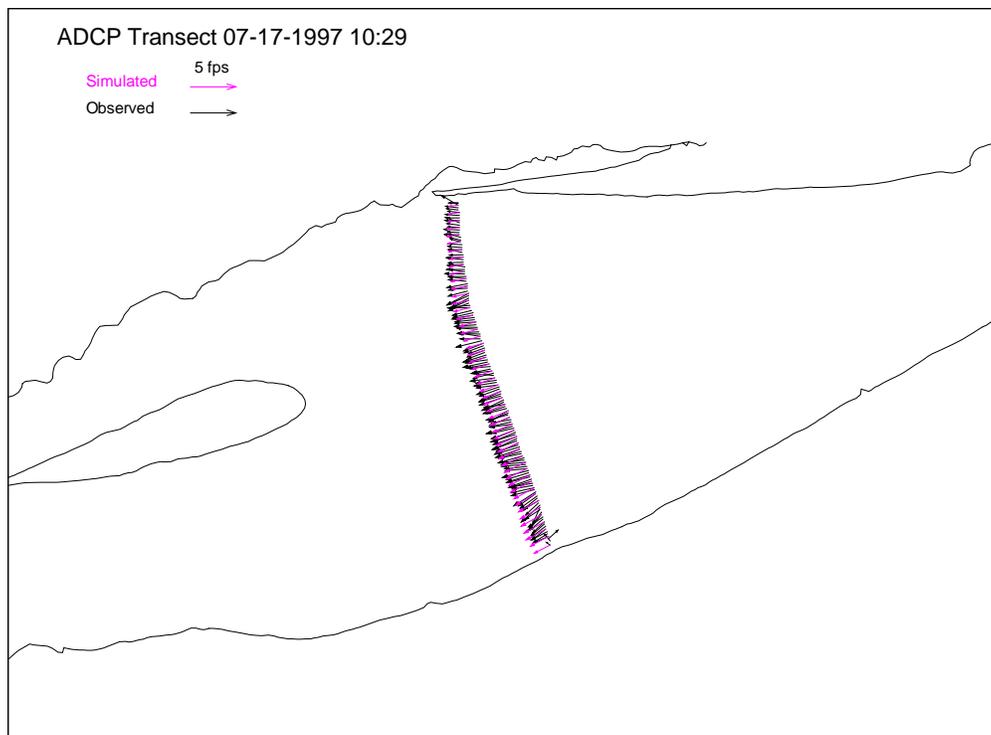


Figure 29. Simulated and observed depth-averaged velocities near Columbia River Mile 137 on 7-17-1997.

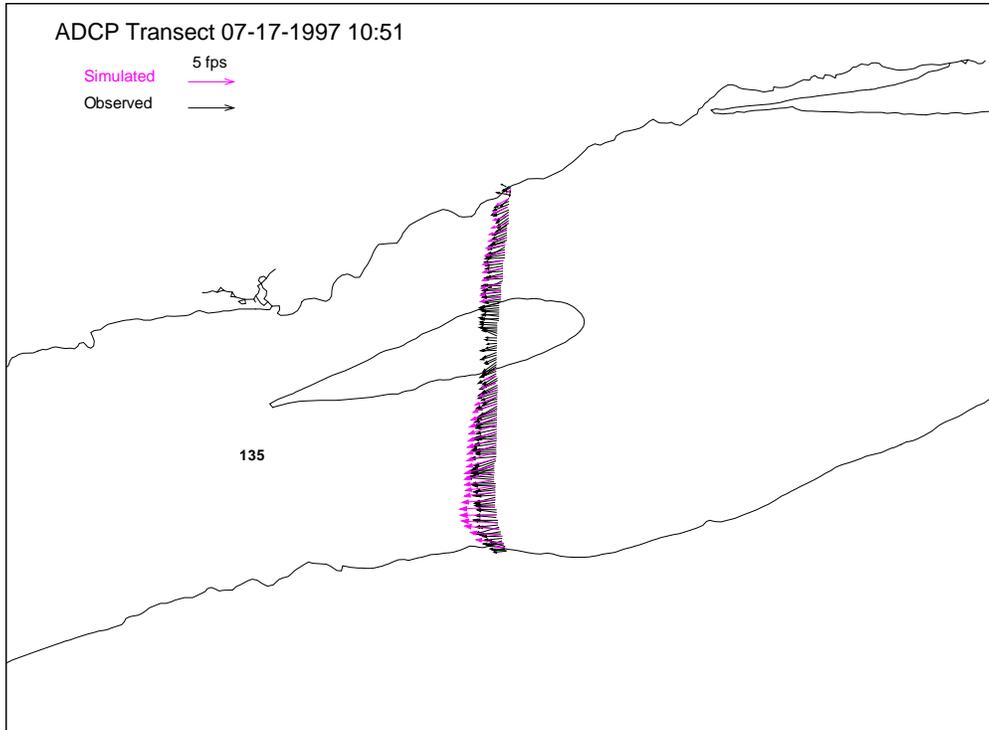


Figure 30. Simulated and observed depth-averaged velocities near Columbia River Mile 136 on 7-17-1997.

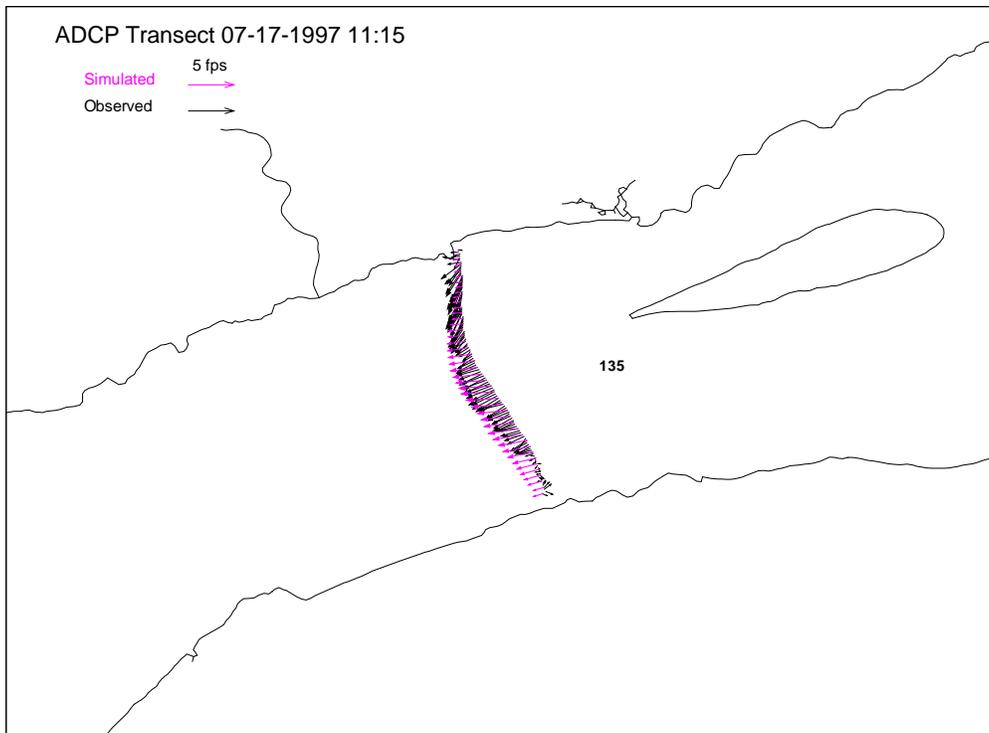


Figure 31. Simulated and observed depth-averaged velocities near Columbia River Mile 136 on 7-17-1997.

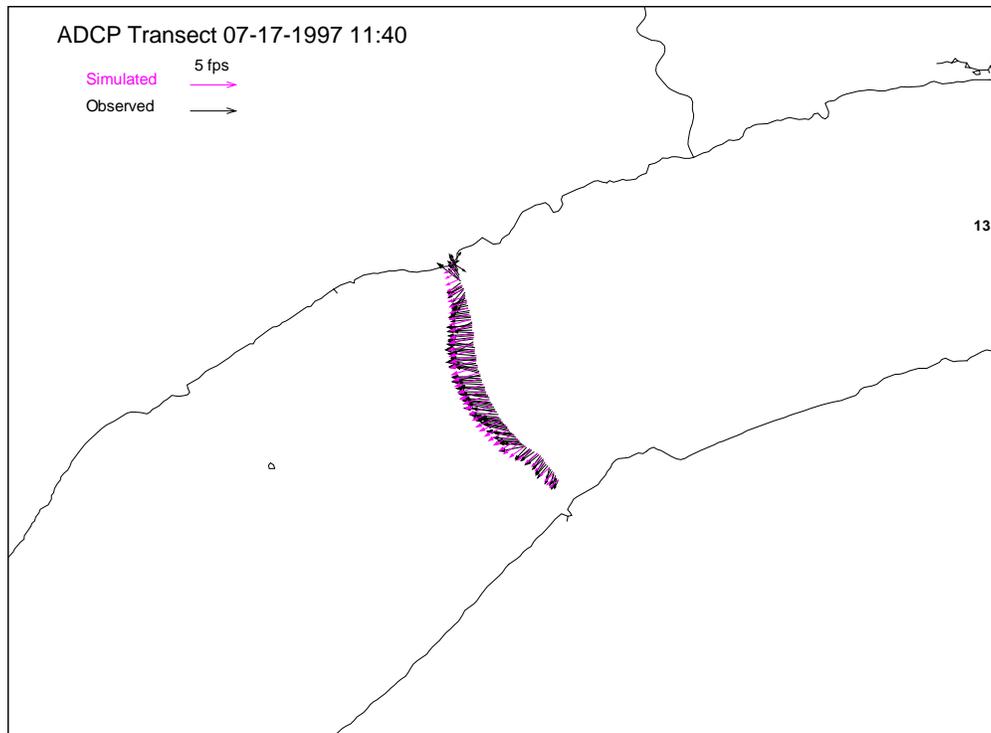


Figure 32. Simulated and observed depth-averaged velocities near Columbia River Mile 135 on 7-17-1997.

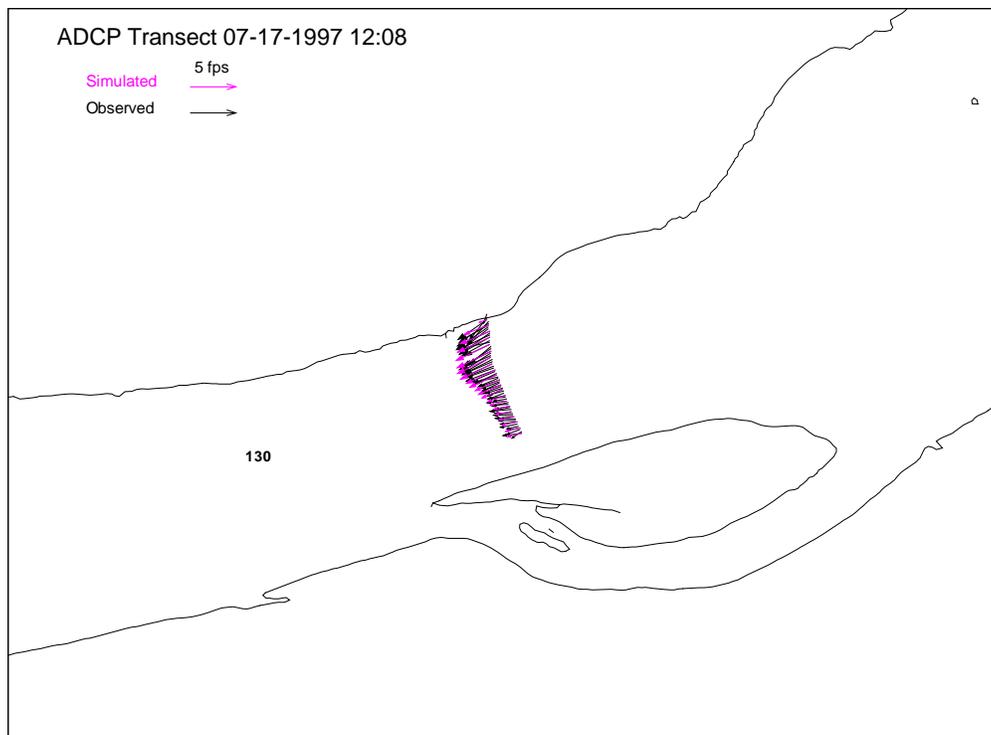


Figure 33. Simulated and observed depth-averaged velocities near Columbia River Mile 130 on 7-17-1997.

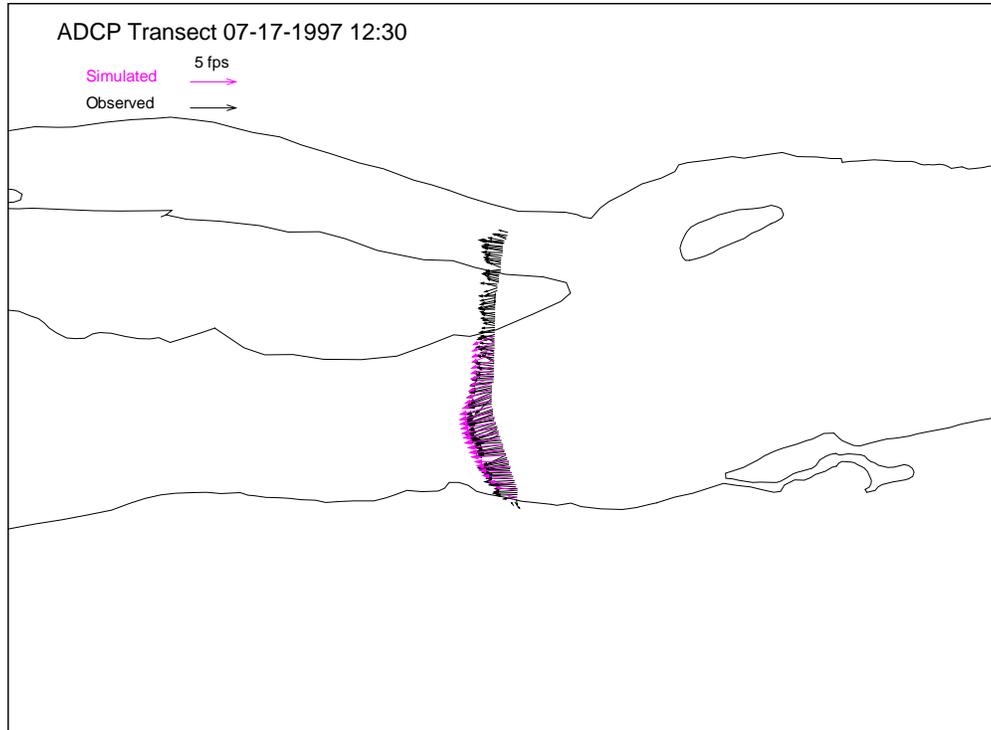


Figure 34. Simulated and observed depth-averaged velocities near Columbia River Mile 129 on 7-17-1997.

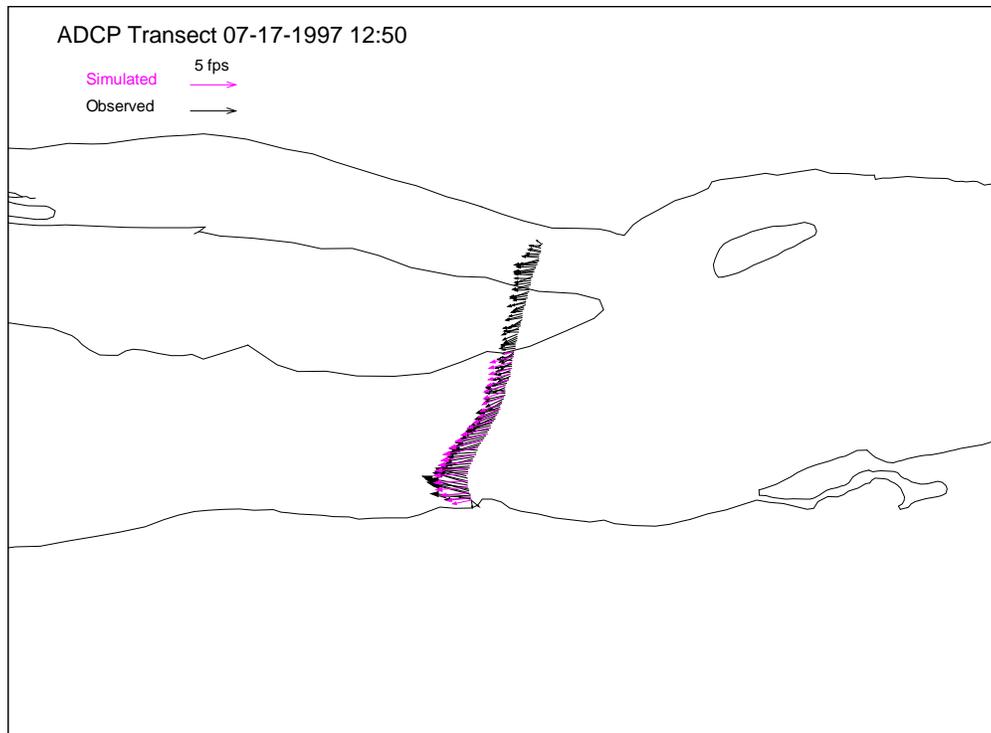


Figure 35. Simulated and observed depth-averaged velocities near Columbia River Mile 129 on 7-17-1997.

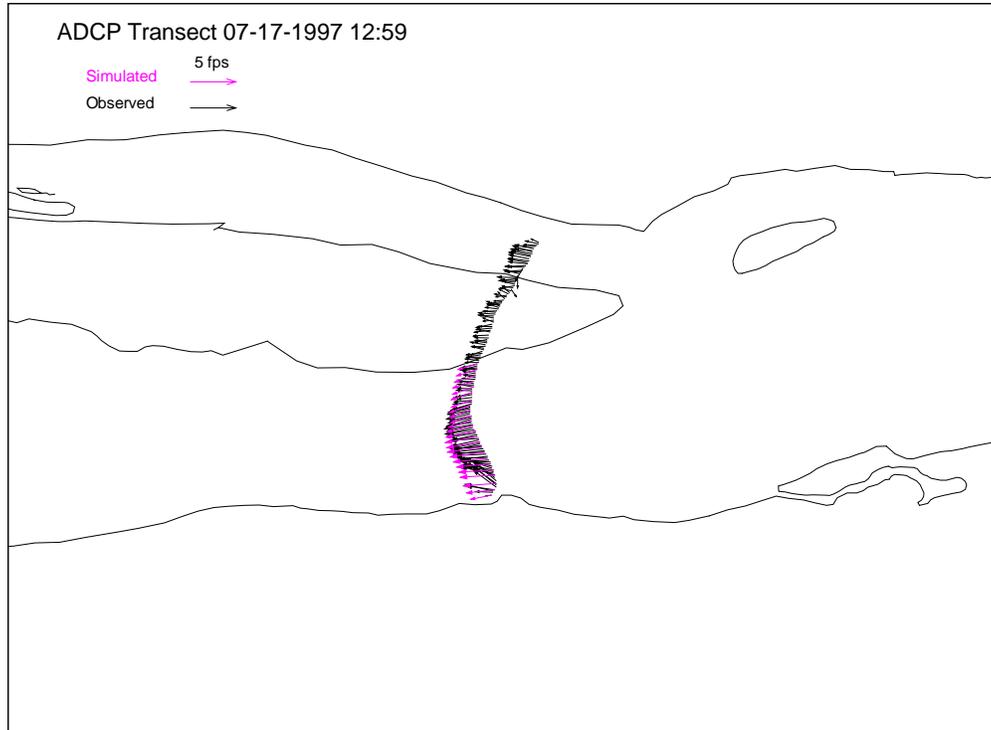


Figure 36. Simulated and observed depth-averaged velocities near Columbia River Mile 129 on 7-17-1997.

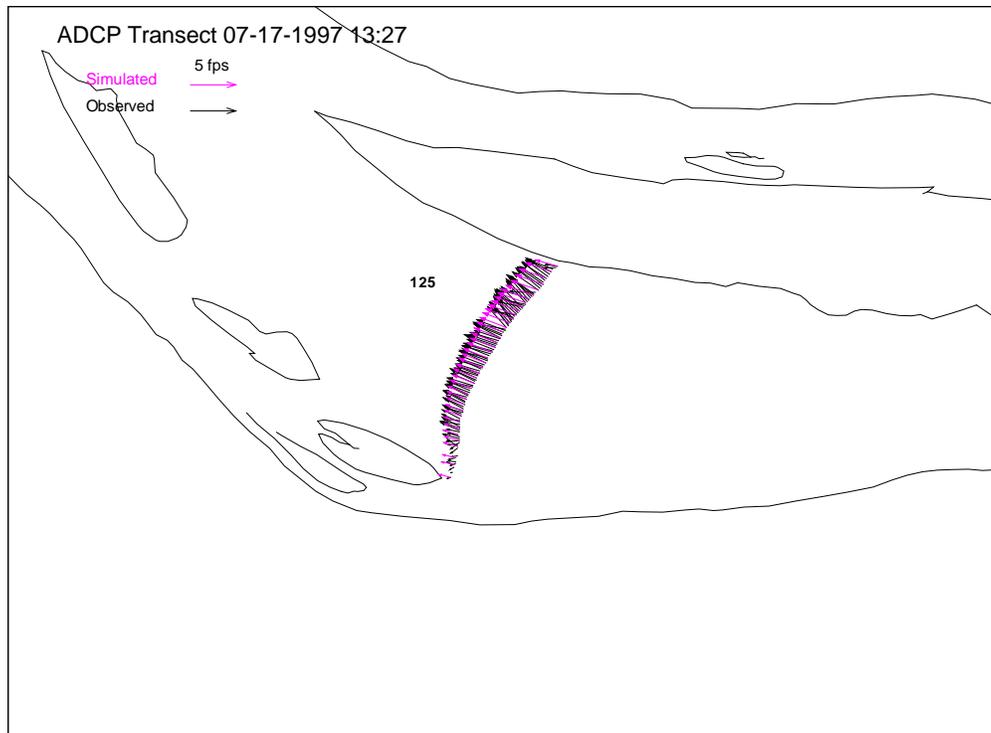


Figure 37. Simulated and observed depth-averaged velocities near Columbia River Mile 126 on 7-17-1997.

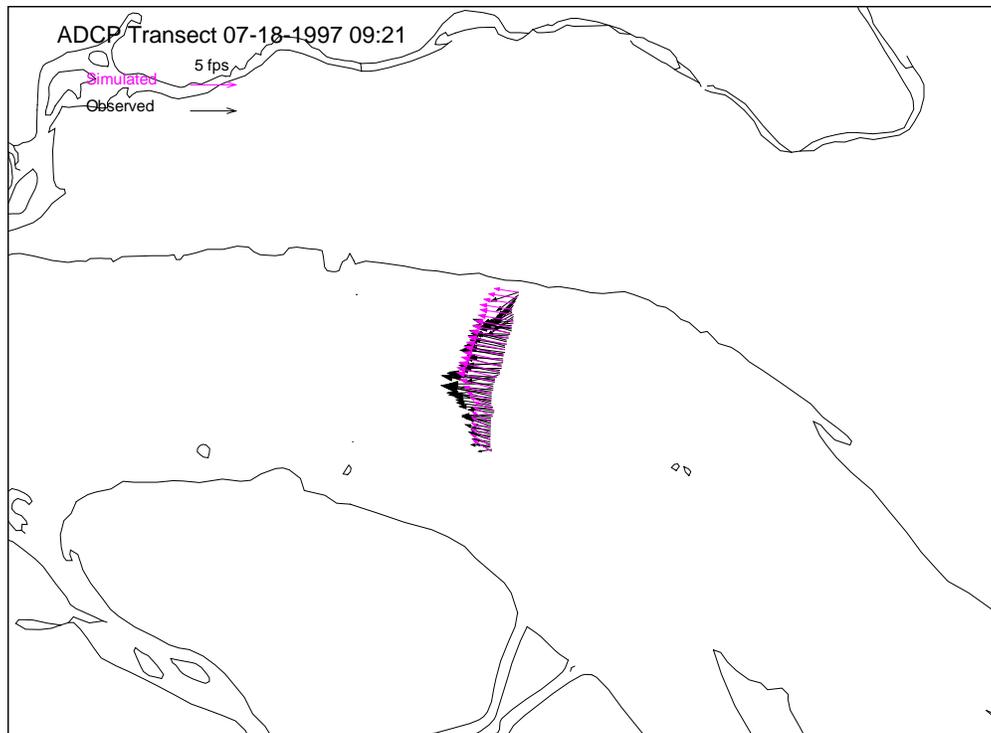


Figure 38. Simulated and observed depth-averaged velocities near Columbia River Mile 124 on 7-18-1997.

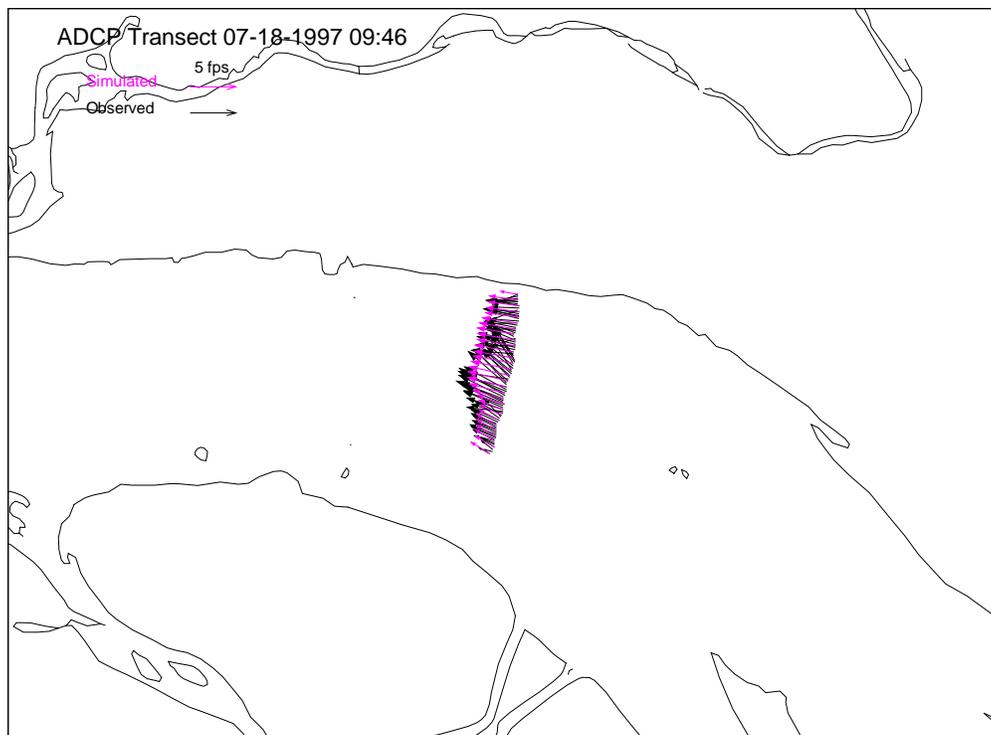


Figure 39. Simulated and observed depth-averaged velocities near Columbia River Mile 124 on 7-18-1997.

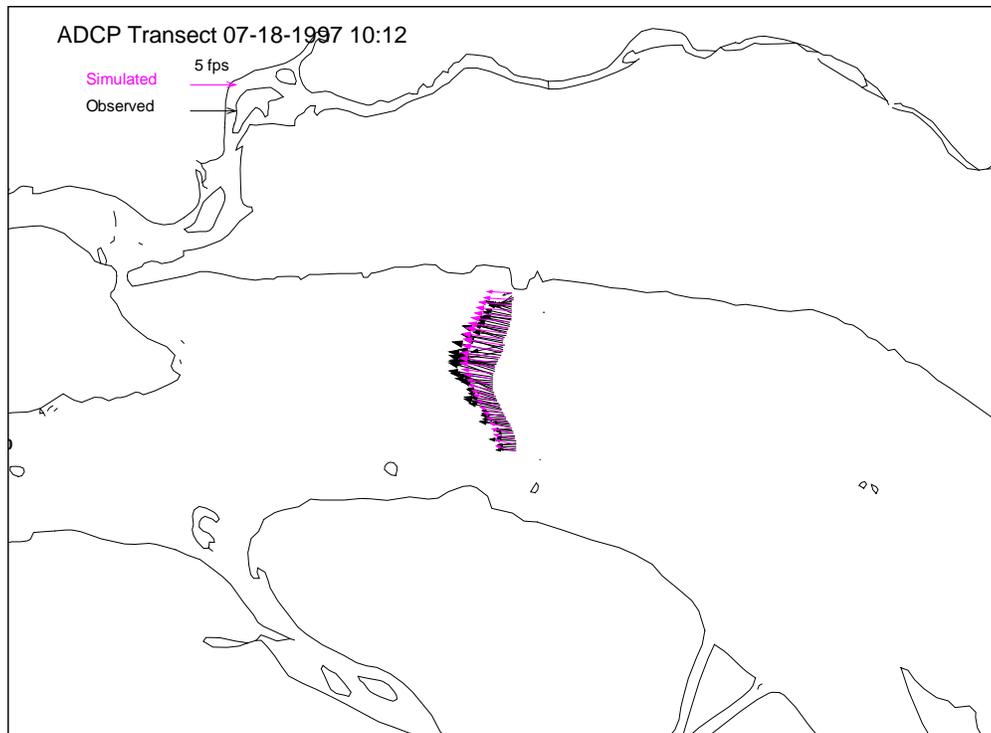


Figure 40. Simulated and observed depth-averaged velocities near Columbia River Mile 123 on 7-18-1997.

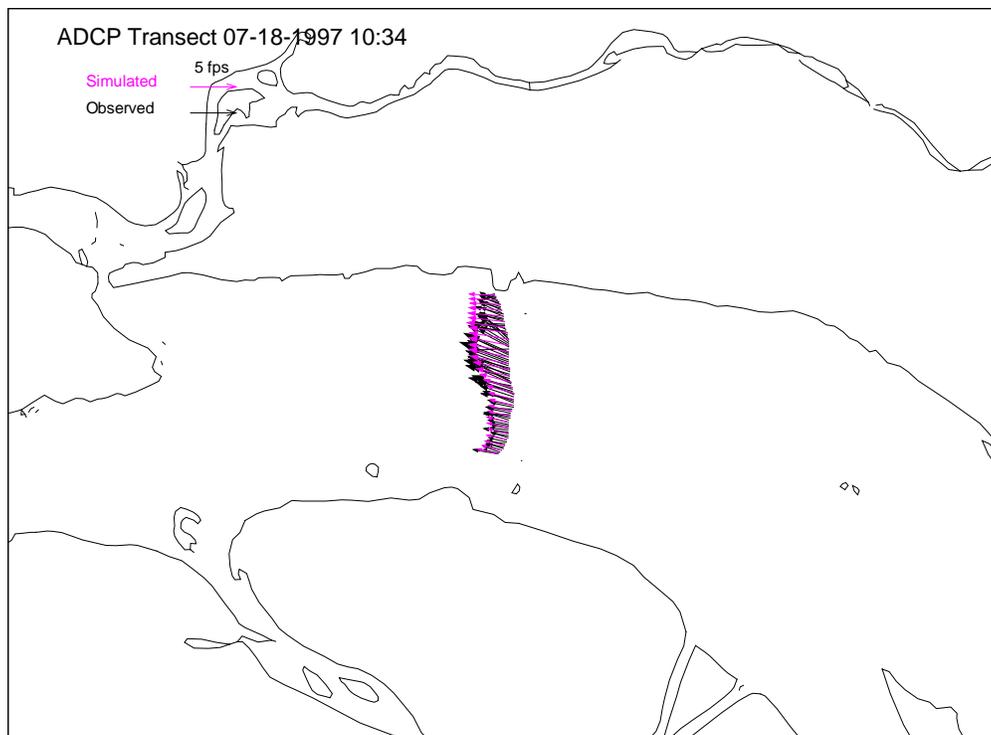


Figure 41. Simulated and observed depth-averaged velocities near Columbia River Mile 123 on 7-18-1997.

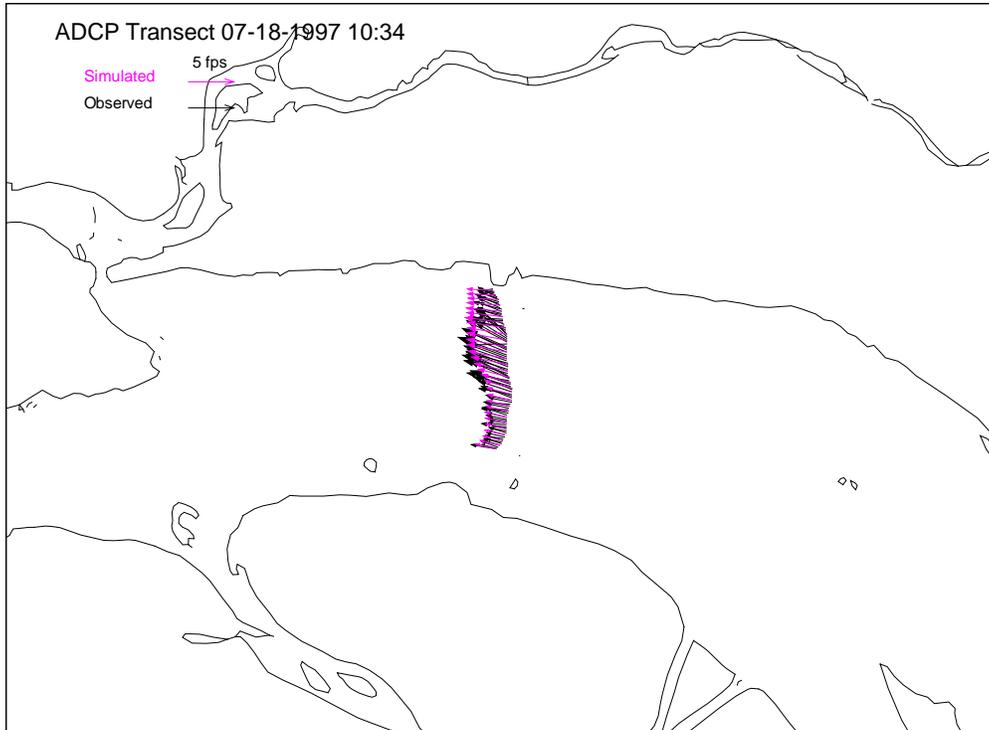


Figure 42. Simulated and observed depth-averaged velocities near Columbia River Mile 123 on 7-18-1997.

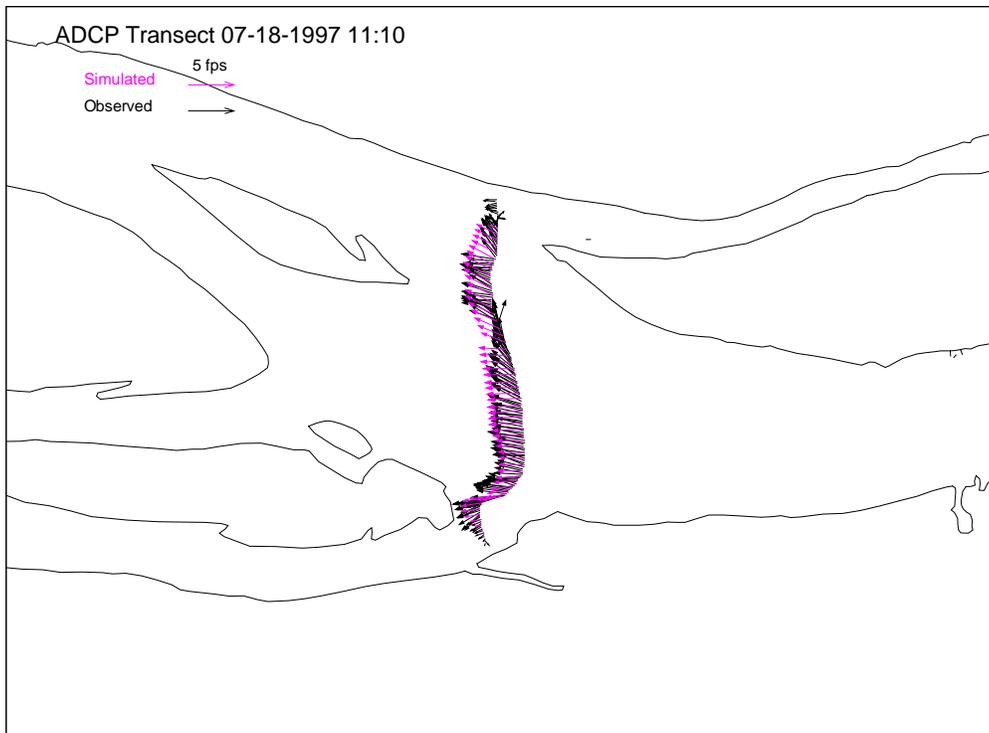


Figure 43. Simulated and observed depth-averaged velocities near Columbia River Mile 118 on 7-18-1997.

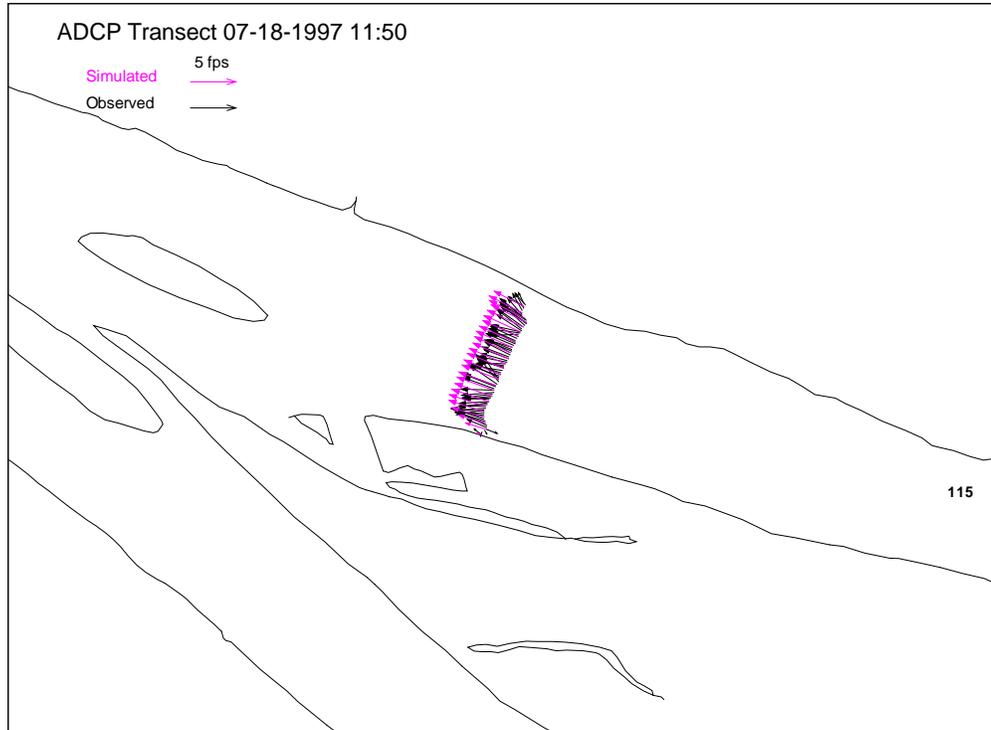


Figure 44. Simulated and observed depth-averaged velocities near Columbia River Mile 115 on 7-18-1997.

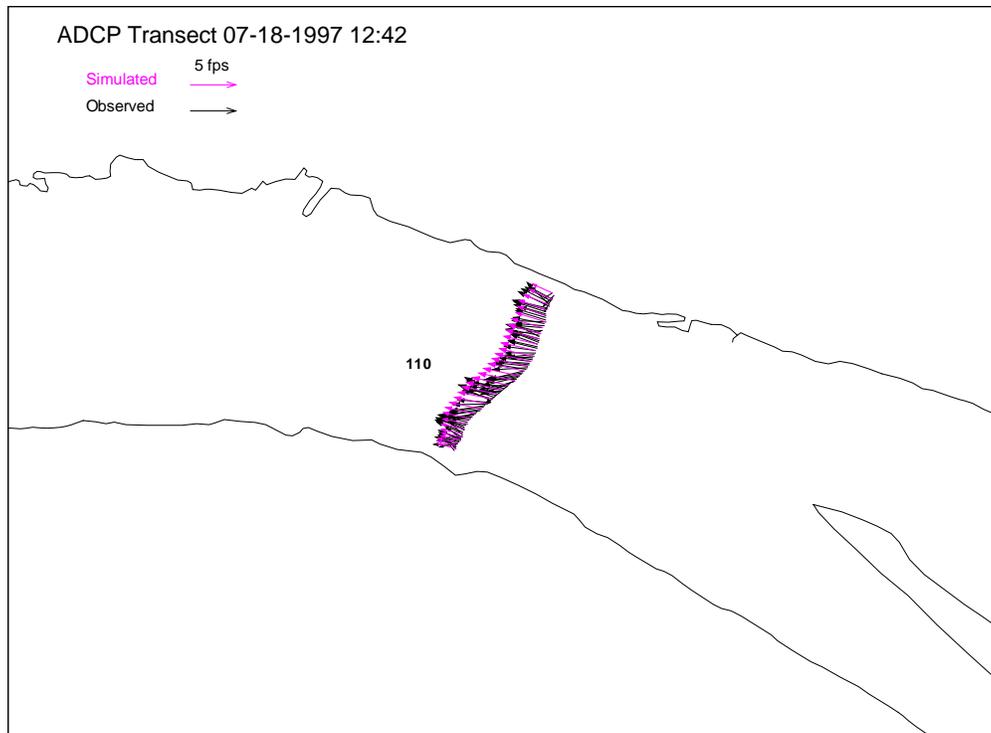


Figure 45. Simulated and observed depth-averaged velocities near Columbia River Mile 110 on 7-18-1997.

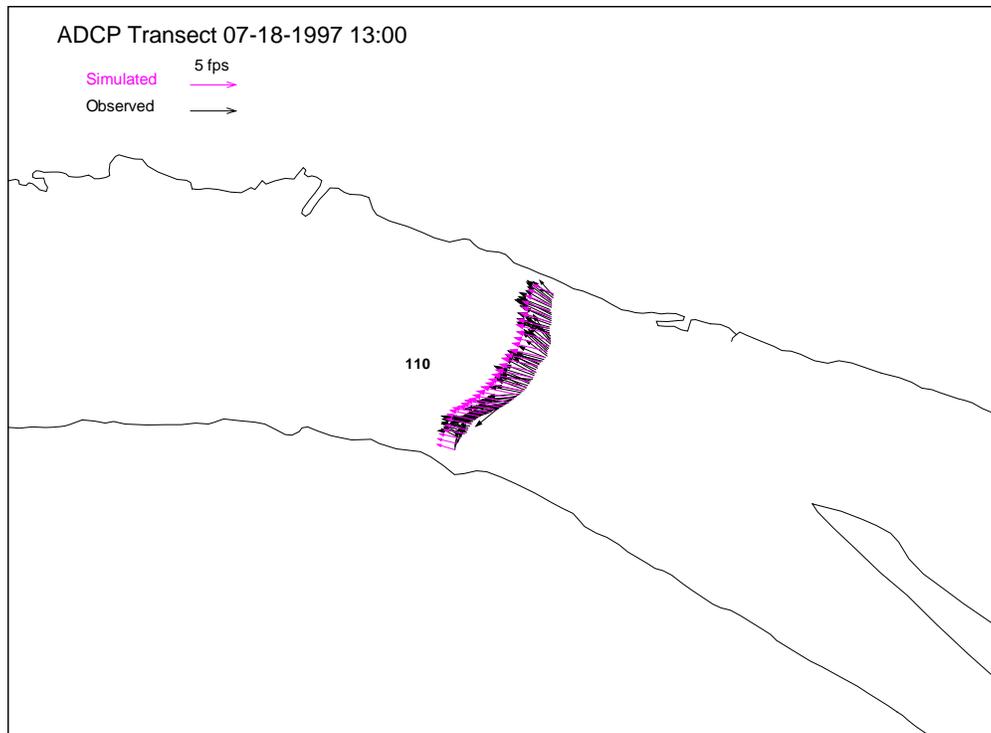


Figure 46. Simulated and observed depth-averaged velocities near Columbia River Mile 110 on 7-18-1997.

1.3.4 Simulated spatial velocity distribution during the Spring 1996 study.

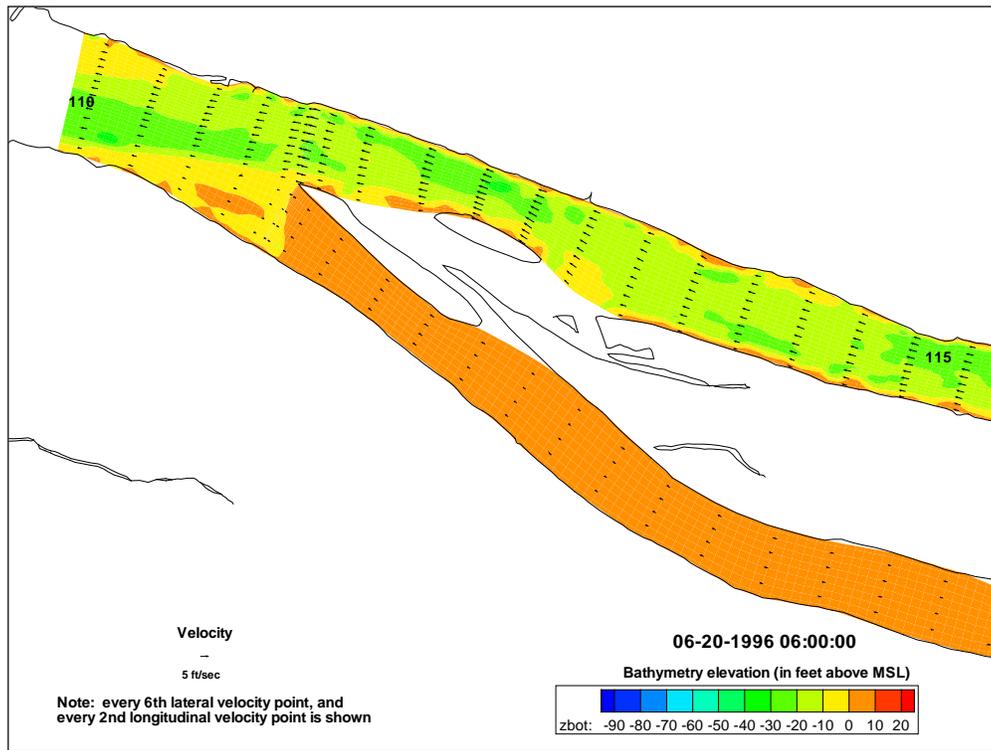


Figure 47. Spatial velocity distribution during the Spring 1996 study period.

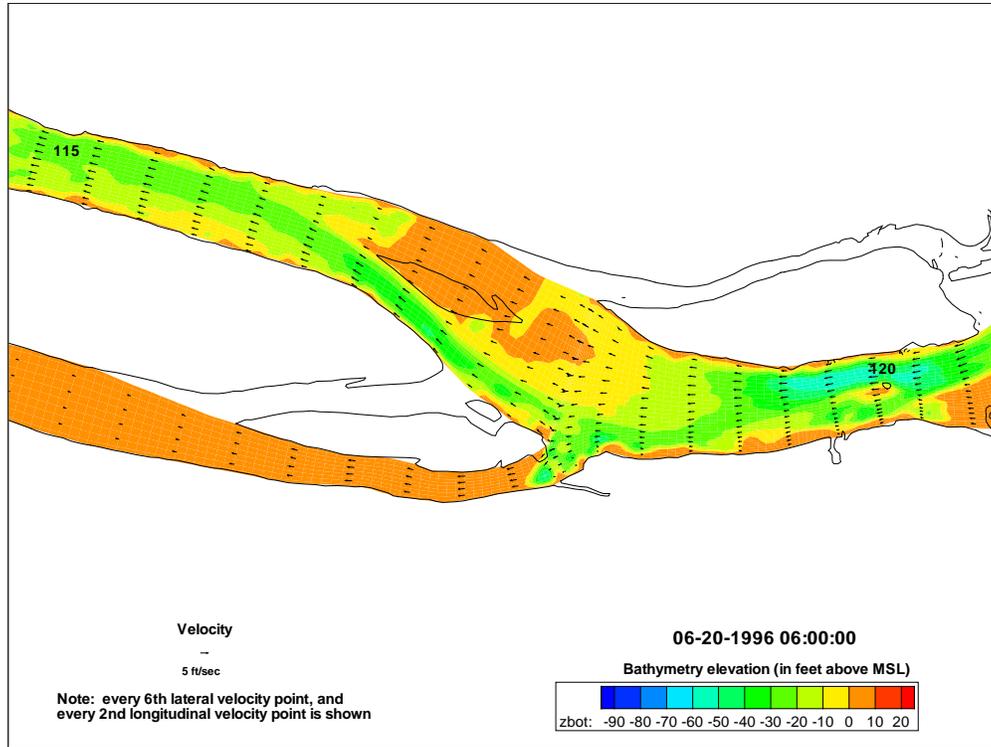


Figure 48. Spatial velocity distribution during the Spring 1996 study period.

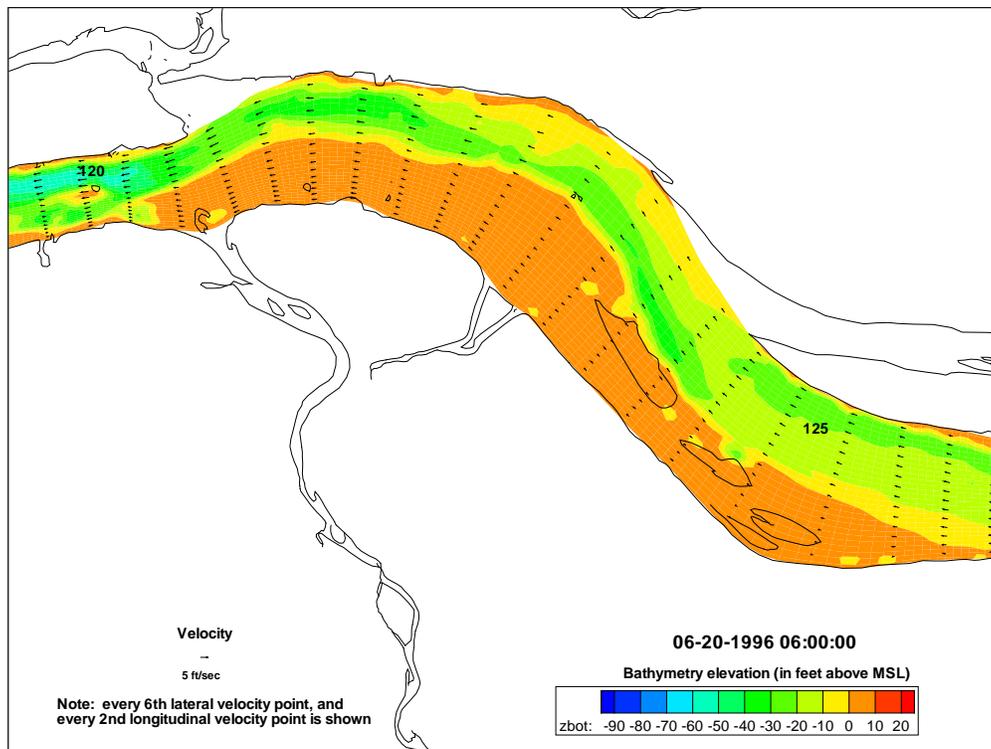


Figure 49. Spatial velocity distribution during the Spring 1996 study period.

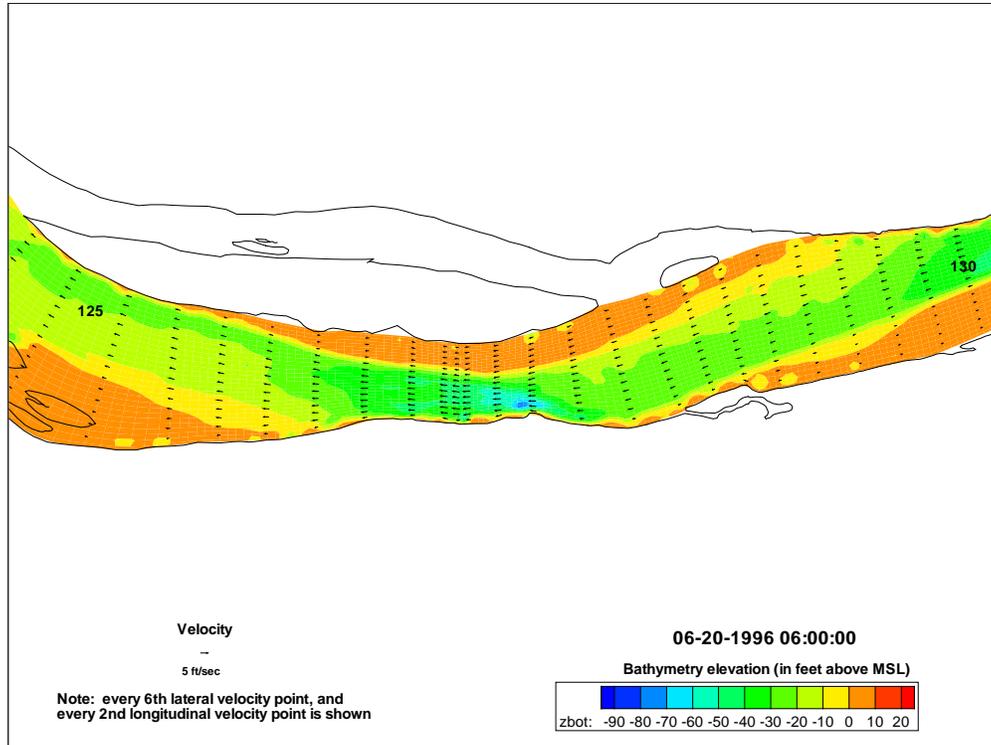


Figure 50. Spatial velocity distribution during the Spring 1996 study period.

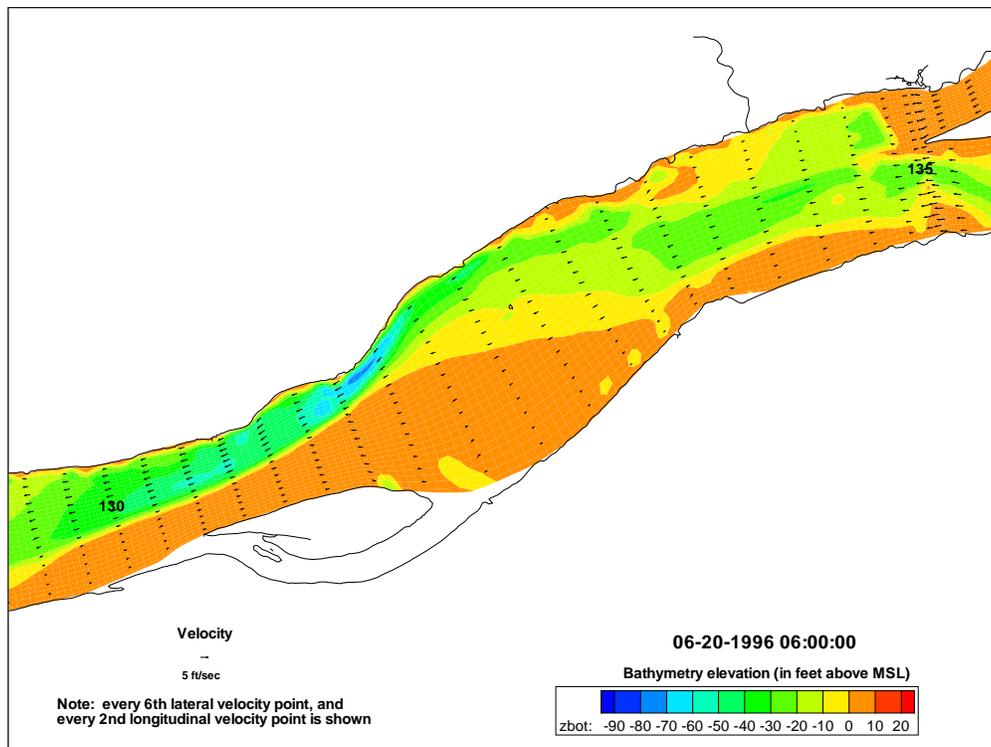


Figure 51. Spatial velocity distribution during the Spring 1996 study period.

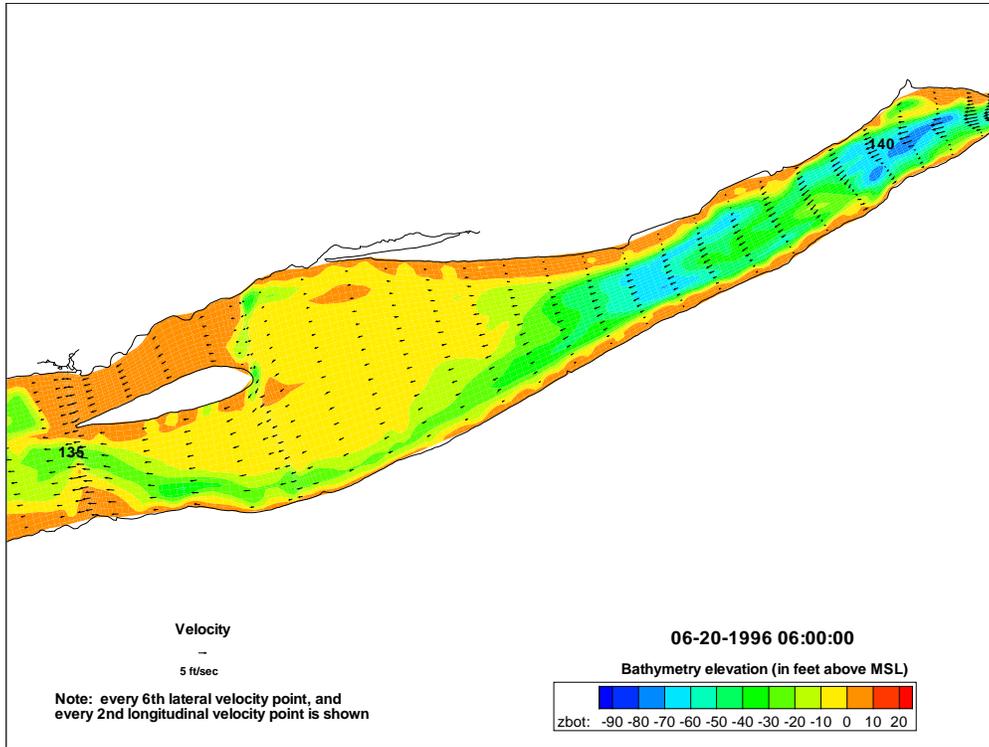


Figure 52. Spatial velocity distribution during the Spring 1996 study period.

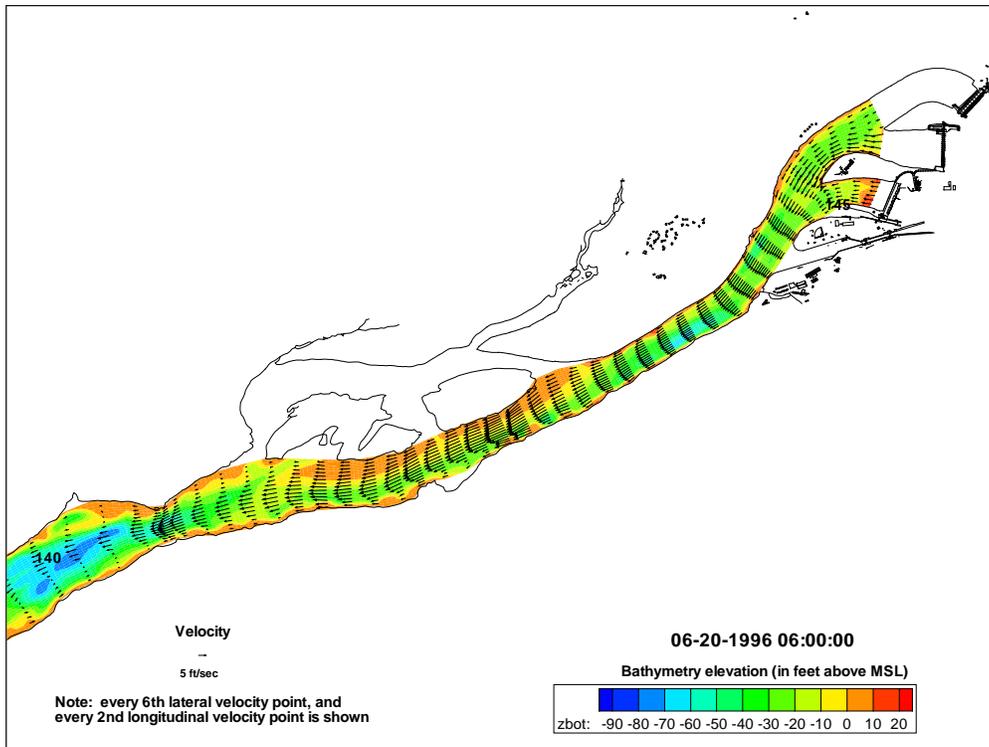


Figure 53. Spatial velocity distribution during the Spring 1996 study period.

1.4 Water Quality Calibration and Verification

1.4.1 Spring 1996 Simulation

Boundary Conditions using Bonneville Sourcing Function and Forebay FMS Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as FMS-BC in the figure and table captions.

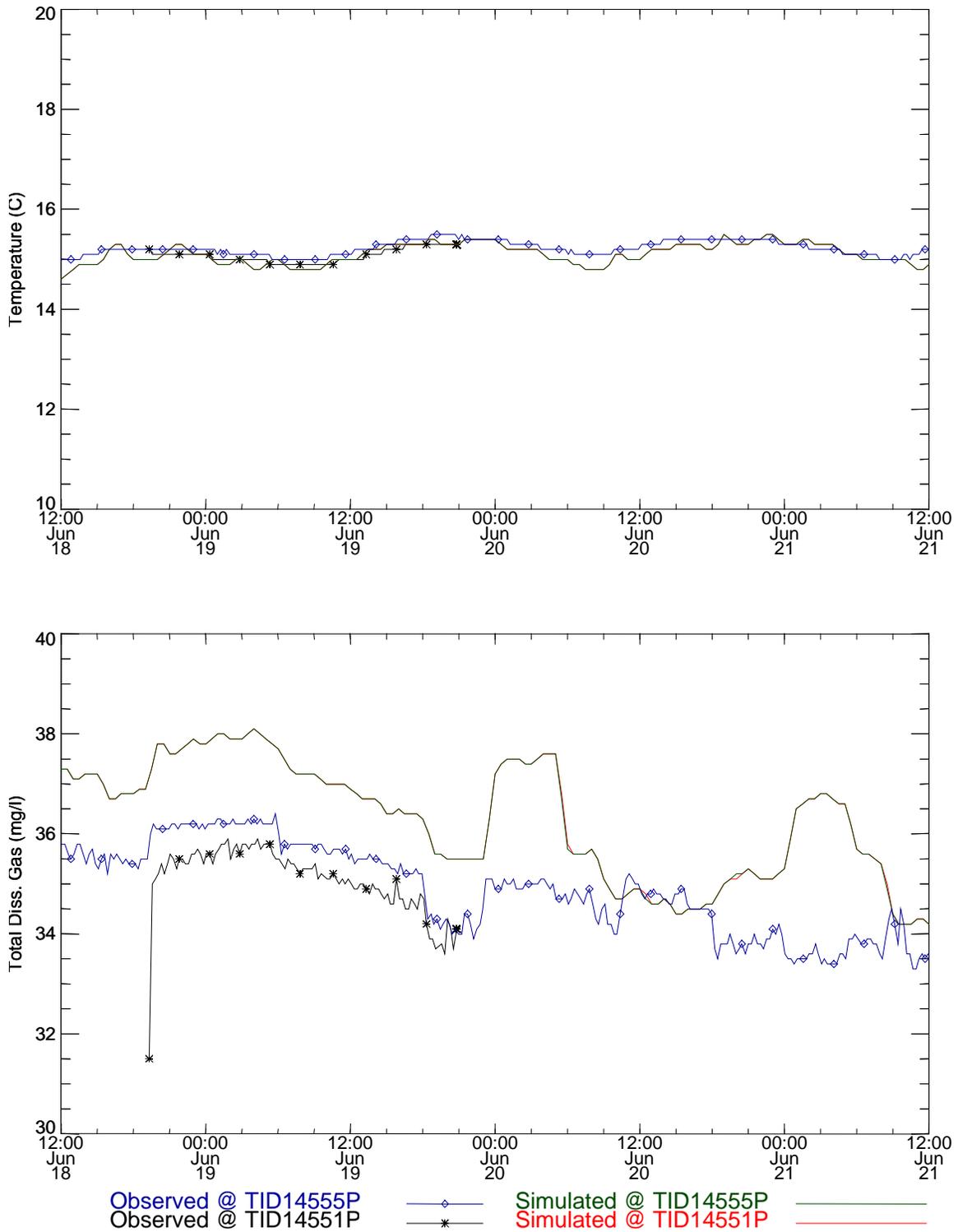


Figure 54. Temperature and total dissolved gas time series near Columbia River mile 145.5 for the Spring 1996 study period (FMS-BC).

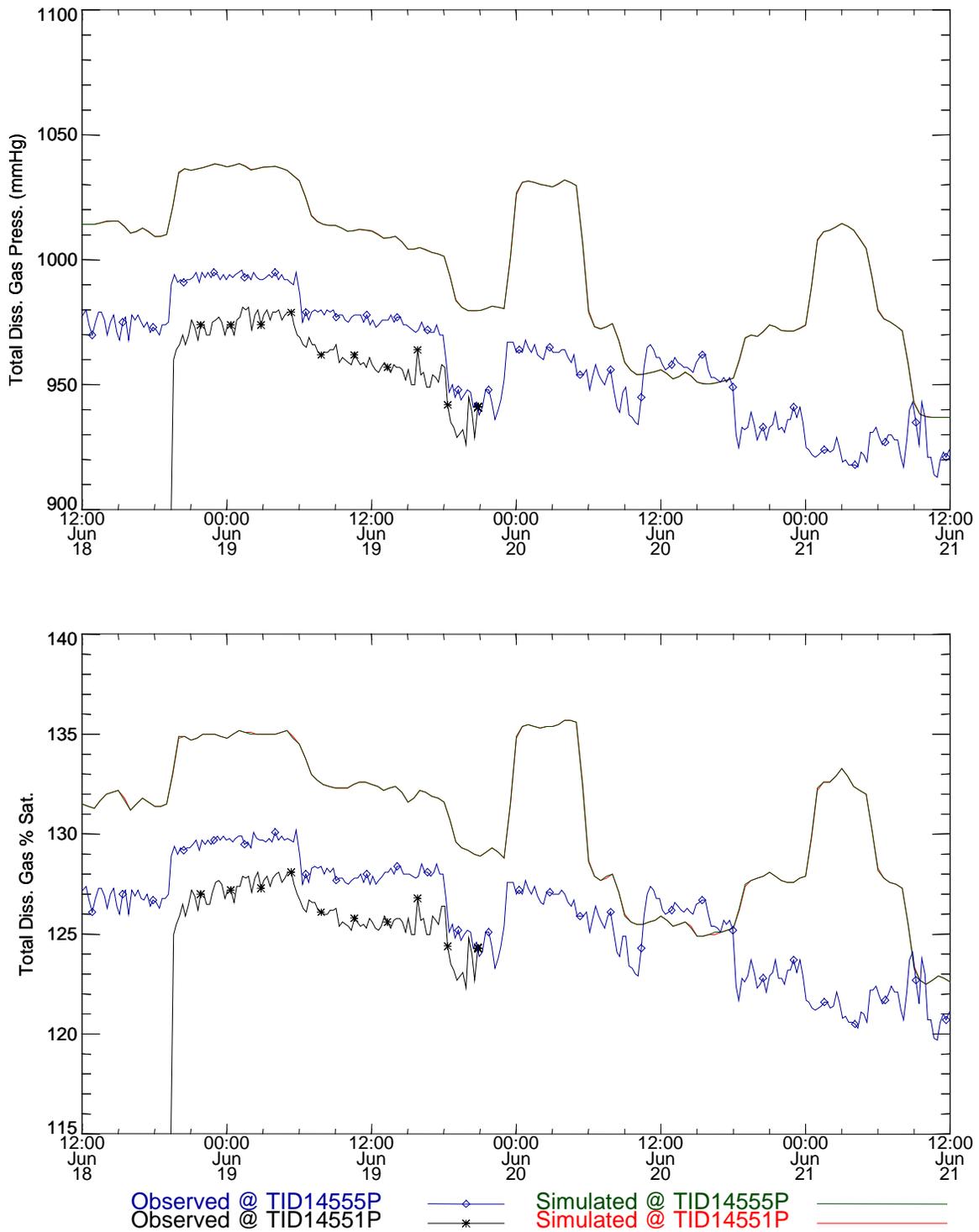


Figure 55. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 145.5 for the Spring 1996 study period (FMS-BC).

Table 1. Statistical summary of measurements and simulations near Columbia River mile 145.5 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14551P	15.07	15.07	0.13	0.18	0.09
TID14555P	15.19	15.07	0.15	0.18	0.15
Concentration					
TID14551P	35.1	37.15	0.66	0.74	2.09
TID14555P	35.69	37.15	0.6	0.74	1.48
Gas Pressure					
TID14551P	961.92	1018.78	16.15	17.52	58.07
TID14555P	980.08	1018.75	14.24	17.55	39.03
% Saturation					
TID14551P	126.01	133.16	1.86	1.76	7.32
TID14555P	128.39	133.16	1.4	1.75	4.82

Table 2. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 145.5 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID14551P	100	0	1	2
TID14555P	100	1	50	55

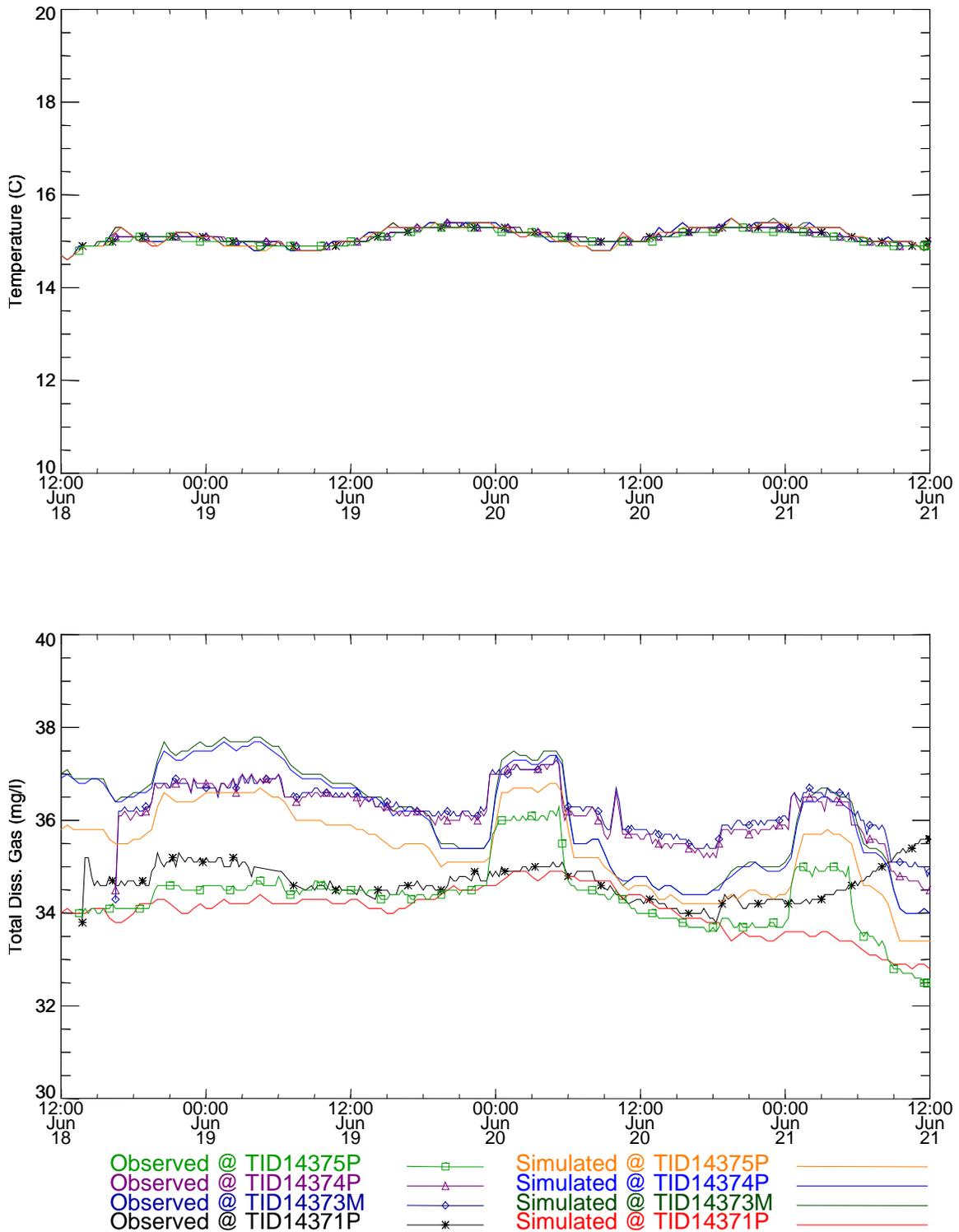


Figure 56. Temperature and total dissolved gas time series near Columbia River mile 143.7 for the Spring 1996 study period (FMS-BC).

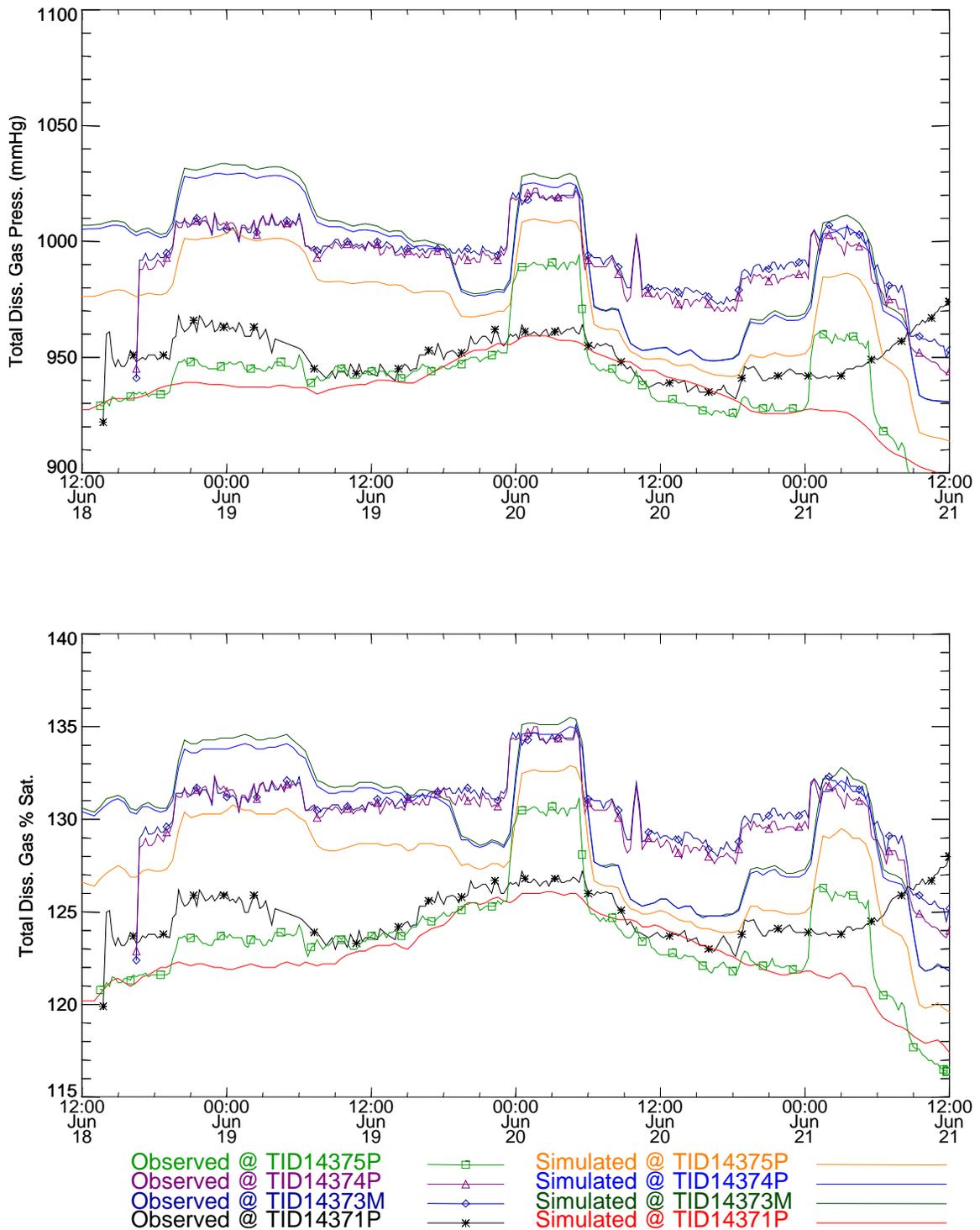


Figure 57. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 143.7 for the Spring 1996 study period (FMS-BC).

Table 3. Statistical summary of measurements and simulations at river mile 143.7 during the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14371P	15.12	15.13	0.14	0.18	0.1
TID14373M	15.12	15.14	0.14	0.19	0.11
TID14374P	15.13	15.14	0.13	0.18	0.1
TID14375P	15.08	15.13	0.13	0.18	0.11
Concentration					
TID14371P	34.68	34.03	0.38	0.53	0.91
TID14373M	36.19	36.11	0.68	1.12	0.89
TID14374P	36.1	36.04	0.71	1.08	0.78
TID14375P	34.36	35.39	0.76	0.91	1.16
Gas Pressure					
TID14371P	951.4	936.1	9.6	14.43	22.92
TID14373M	992.27	992.43	18.85	29.73	23.29
TID14374P	989.87	990.26	19.67	28.51	20.53
TID14375P	941.91	972.56	21.5	24.19	33.69
% Saturation					
TID14371P	124.91	122.66	1.29	2.1	3.19
TID14373M	130.28	130.02	2.66	3.64	3.08
TID14374P	129.96	129.74	2.73	3.48	2.72
TID14375P	123.67	127.43	3.01	3.02	4.18

Table 4. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 143.7 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID14371P	100	82.59	90.69	90.28
TID14373M	100	83.4	94.33	93.93
TID14374P	100	88.66	94.74	94.33
TID14375P	100	56.28	66.4	69.64

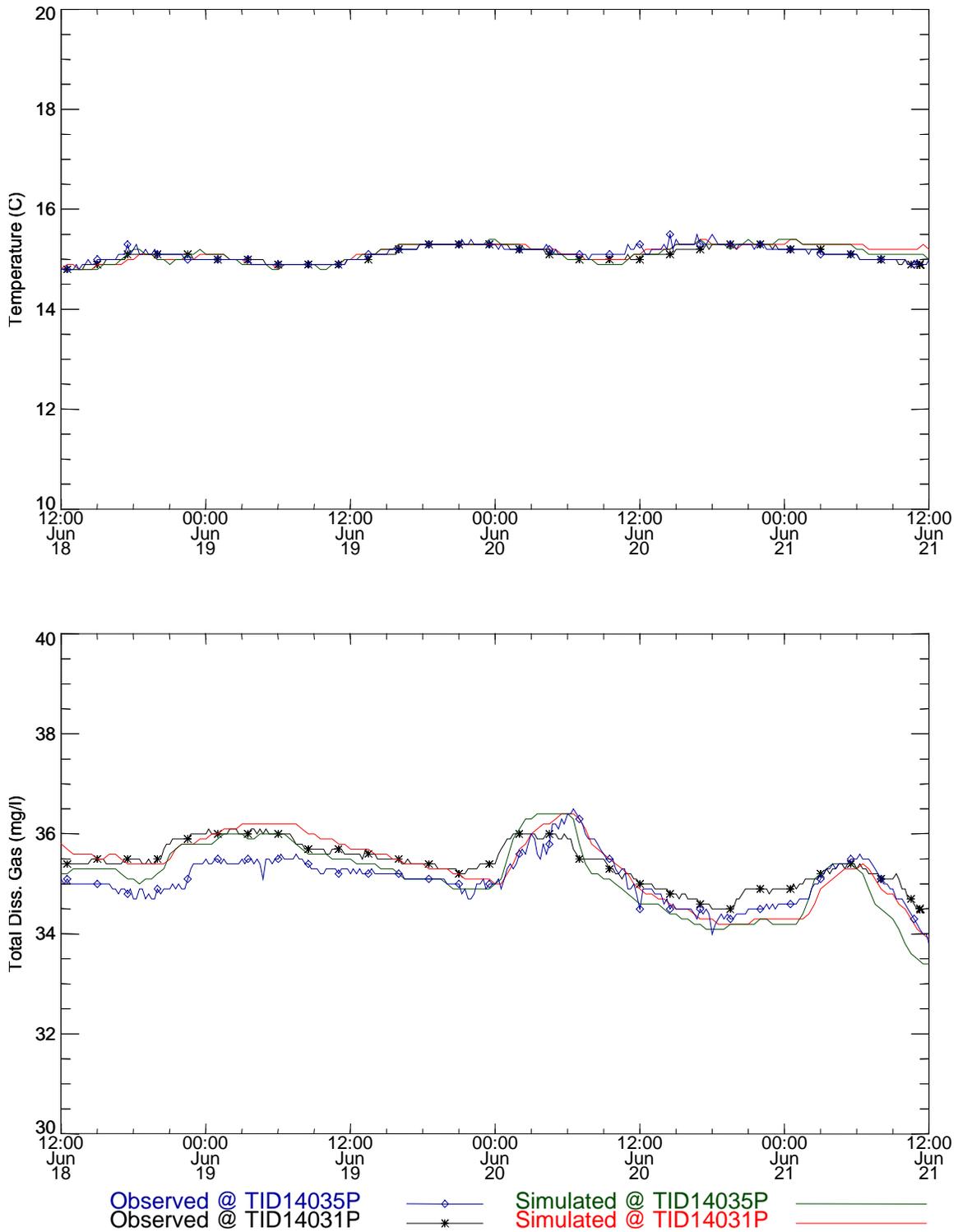


Figure 58. Temperature and total dissolved gas time series near Columbia River mile 140.3 for the Spring 1996 study period (FMS-BC).

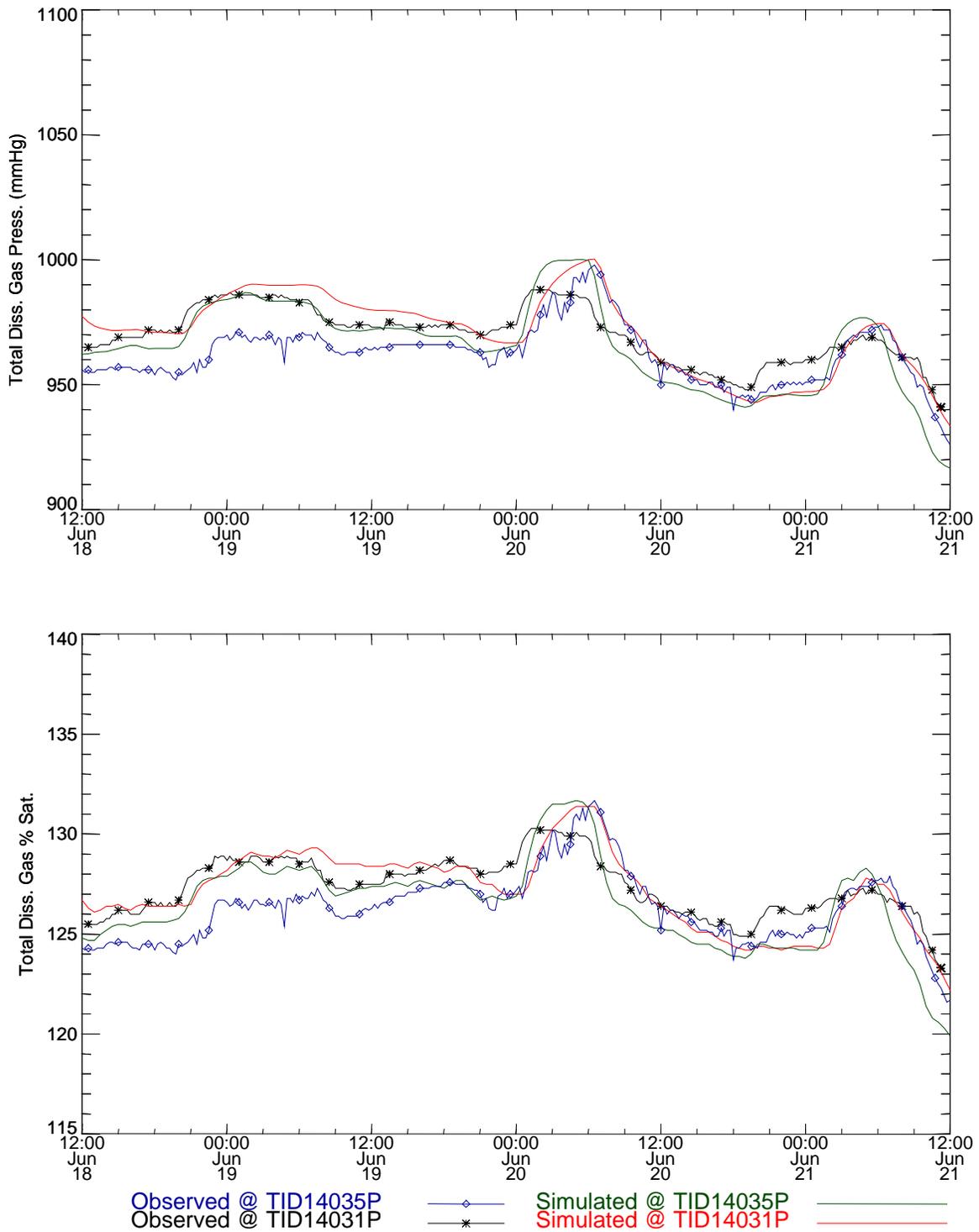


Figure 59. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 140.3 for the Spring 1996 study period (FMS-BC).

Table 5. Statistical summary of measurements and simulations near Columbia River mile 140.3 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14031P	15.09	15.14	0.14	0.16	0.11
TID14035P	15.11	15.12	0.15	0.18	0.11
Concentration					
TID14031P	35.41	35.33	0.43	0.64	0.31
TID14035P	35.1	35.15	0.46	0.67	0.38
Gas Pressure					
TID14031P	970.27	971.29	10.92	15.24	7.56
TID14035P	962.69	966.34	11.38	16.75	10.52
% Saturation					
TID14031P	127.37	127.23	1.42	1.88	1
TID14035P	126.37	126.59	1.72	2.13	1.33

Table 6. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 140.3 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID14031P	100	100	100	100
TID14035P	100	100	100	100

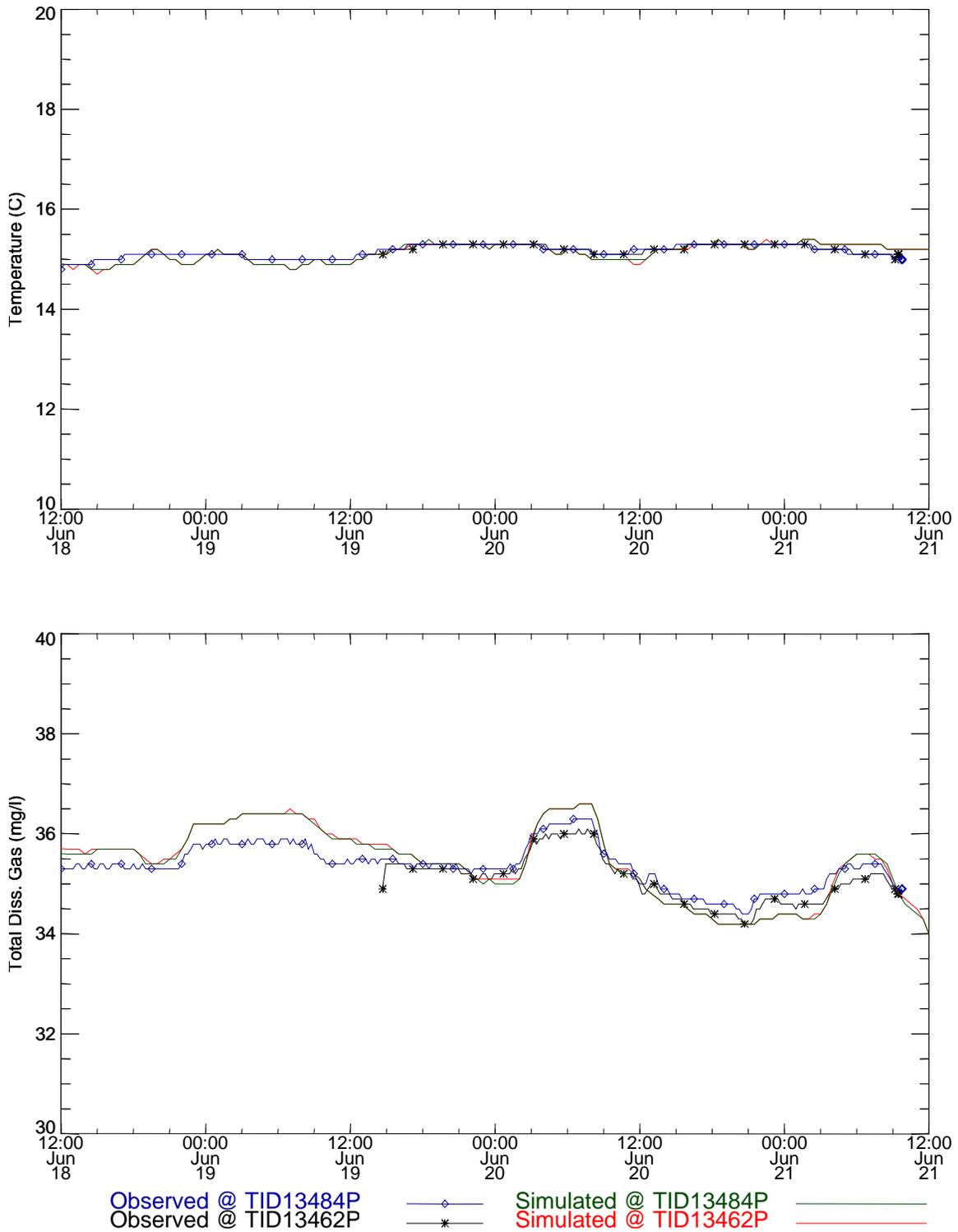


Figure 60. Temperature and total dissolved gas time series near Columbia River mile 134.6 for the Spring 1996 study period (FMS-BC).

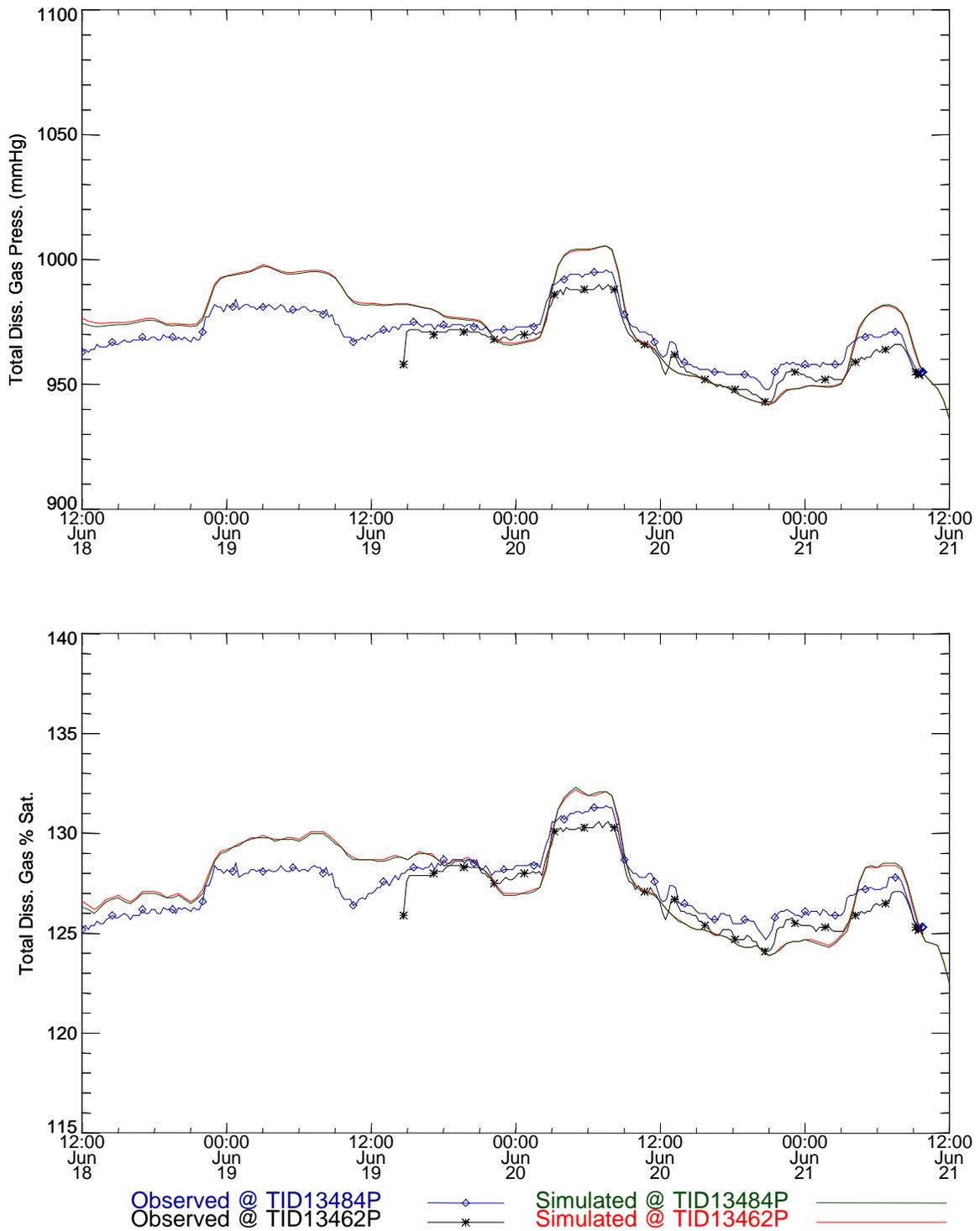


Figure 61. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 134.6 for the Spring 1996 study period (FMS-BC).

Table 7. Statistical summary of measurements and simulations near Columbia River mile 134.6 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID13462P	15.23	15.23	0.08	0.11	0.09
TID13484P	15.23	15.24	0.08	0.11	0.09
Concentration					
TID13462P	35.08	35.16	0.48	0.7	0.28
TID13484P	35.25	35.15	0.48	0.7	0.28
Gas Pressure					
TID13462P	964.48	968.66	12.48	17.99	8.45
TID13484P	969.14	968.52	12.29	18.11	7.4
% Saturation					
TID13462P	127.04	127.29	1.76	2.36	0.96
TID13484P	127.66	127.27	1.72	2.38	1

Table 8. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 134.6 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID13462P	100	100	100	100
TID13484P	100	100	100	100

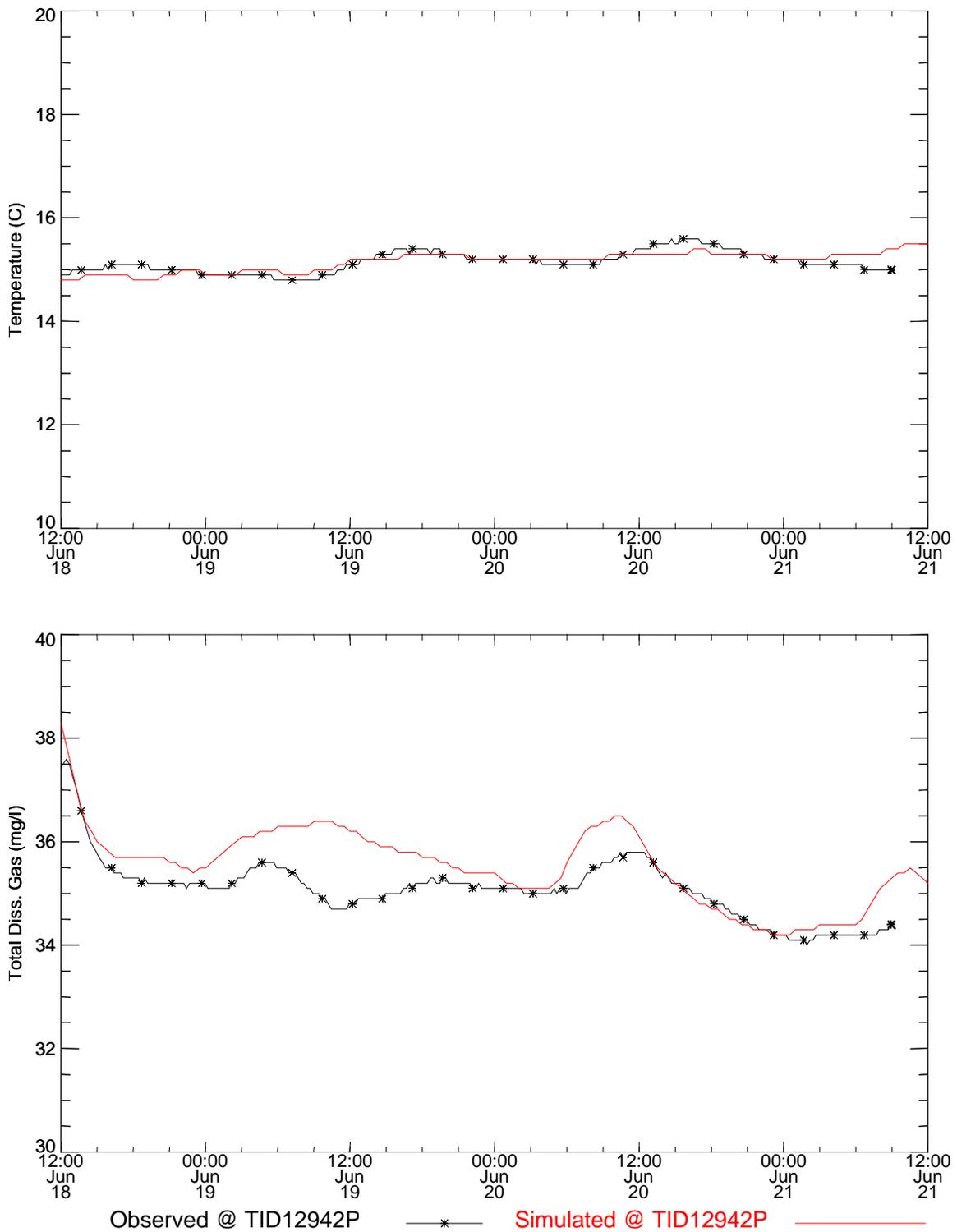


Figure 62. Temperature and total dissolved gas time series near Columbia River mile 129.4 for the Spring 1996 study period (FMS-BC).

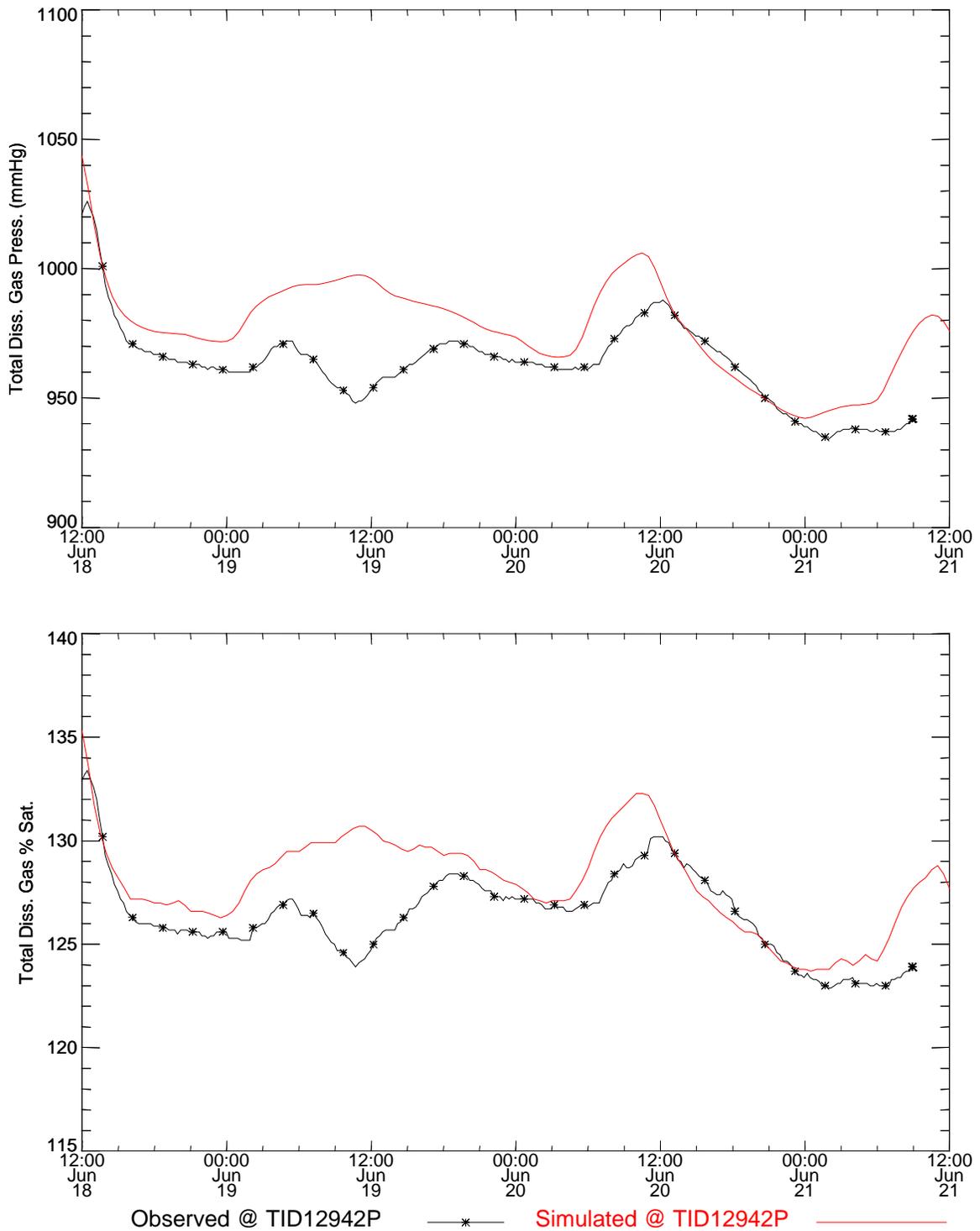


Figure 63. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 129.4 for the Spring 1996 study period (FMS-BC).

Table 9. Statistical summary of measurements and simulations near Columbia River mile 129.4 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID12942P	15.14	15.16	0.2	0.18	0.17
Concentration TID12942P	35.06	35.53	0.6	0.74	0.64
Gas Pressure TID12942P	962.14	977.1	16.28	18.45	20
% Saturation TID12942P	126.31	127.99	2.09	2.3	2.41

Table 10. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 129.4 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12942P	100	90.34	91.72	95.86

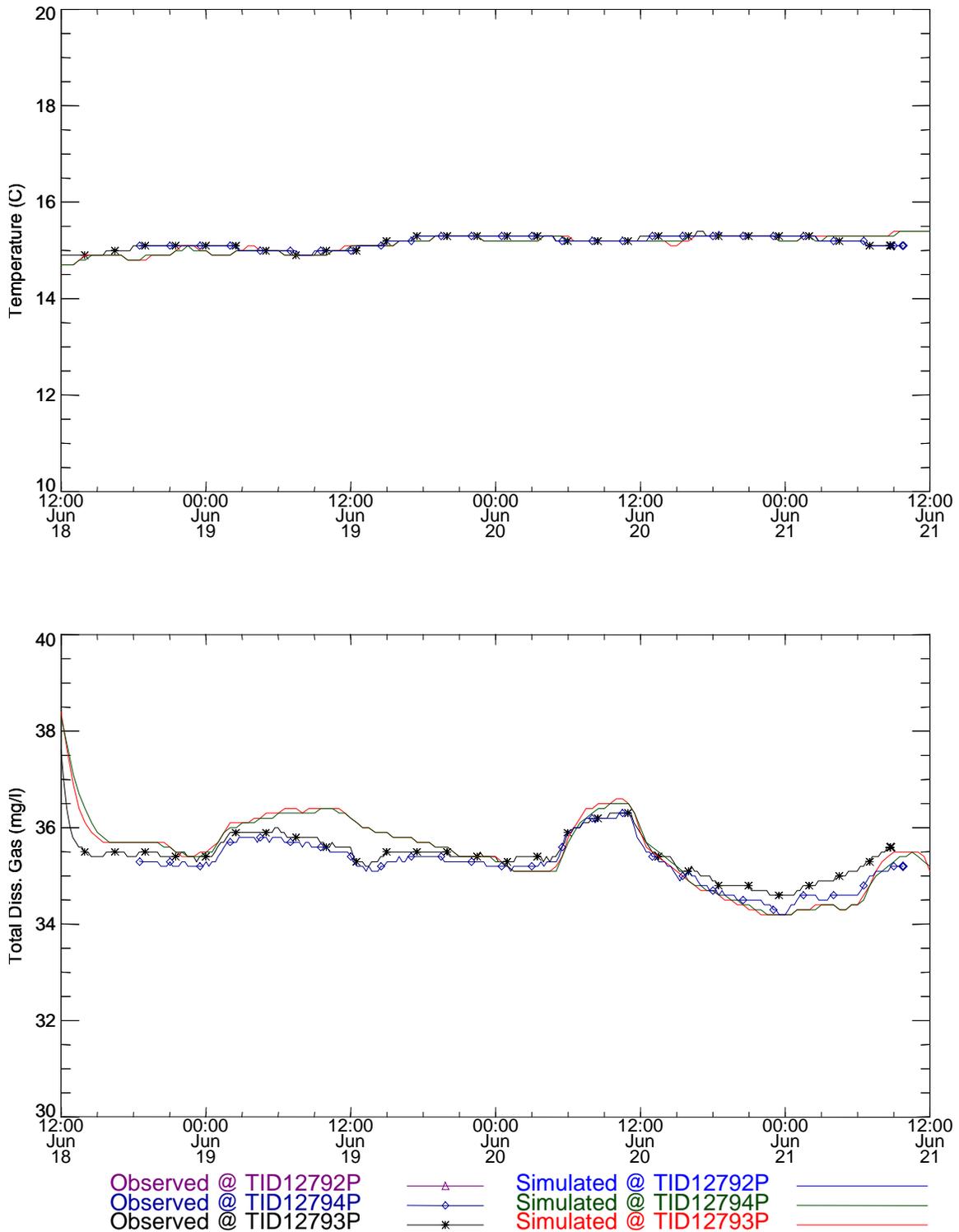


Figure 64. Temperature and total dissolved gas time series near Columbia River mile 127.9 for the Spring 1996 study period (FMS-BC).

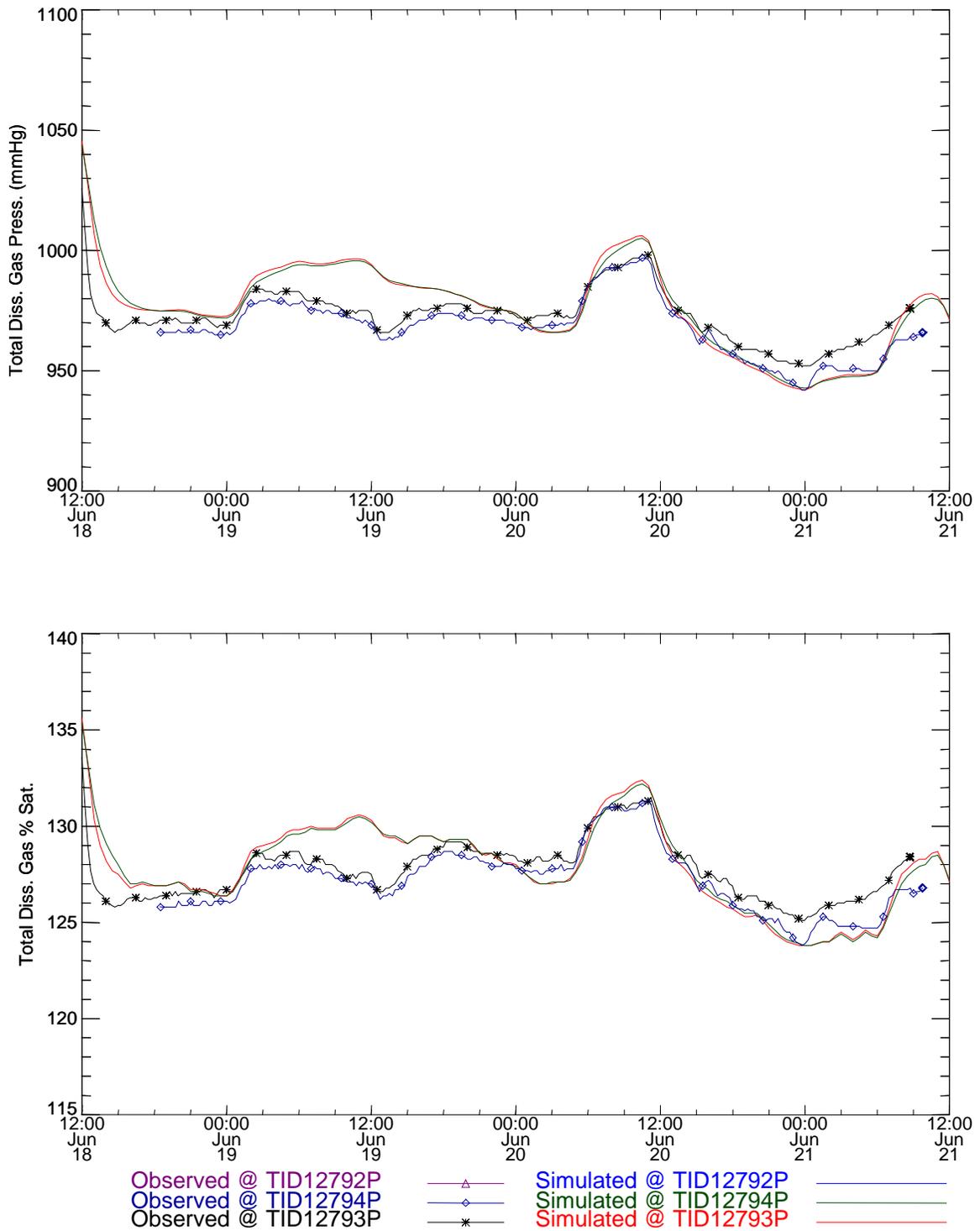


Figure 65. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 127.9 for the Spring 1996 study period (FMS-BC).

Table 11. Statistical summary of measurements and simulations near Columbia River mile 127.9 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID12793P	15.16	15.14	0.13	0.17	0.12
TID12794P	15.18	15.14	0.11	0.17	0.14
Concentration					
TID12793P	35.46	35.52	0.43	0.75	0.4
TID12794P	35.26	35.51	0.45	0.74	0.52
Gas Pressure					
TID12793P	973.23	976.47	10.72	18.23	10.63
TID12794P	967.8	976.43	11.34	17.9	14.38
% Saturation					
TID12793P	127.77	127.91	1.52	2.27	1.36
TID12794P	127.05	127.9	1.63	2.22	1.72

Table 12. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 127.9 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12793P	100	98.62	100	100
TID12794P	100	96.55	97.93	97.93

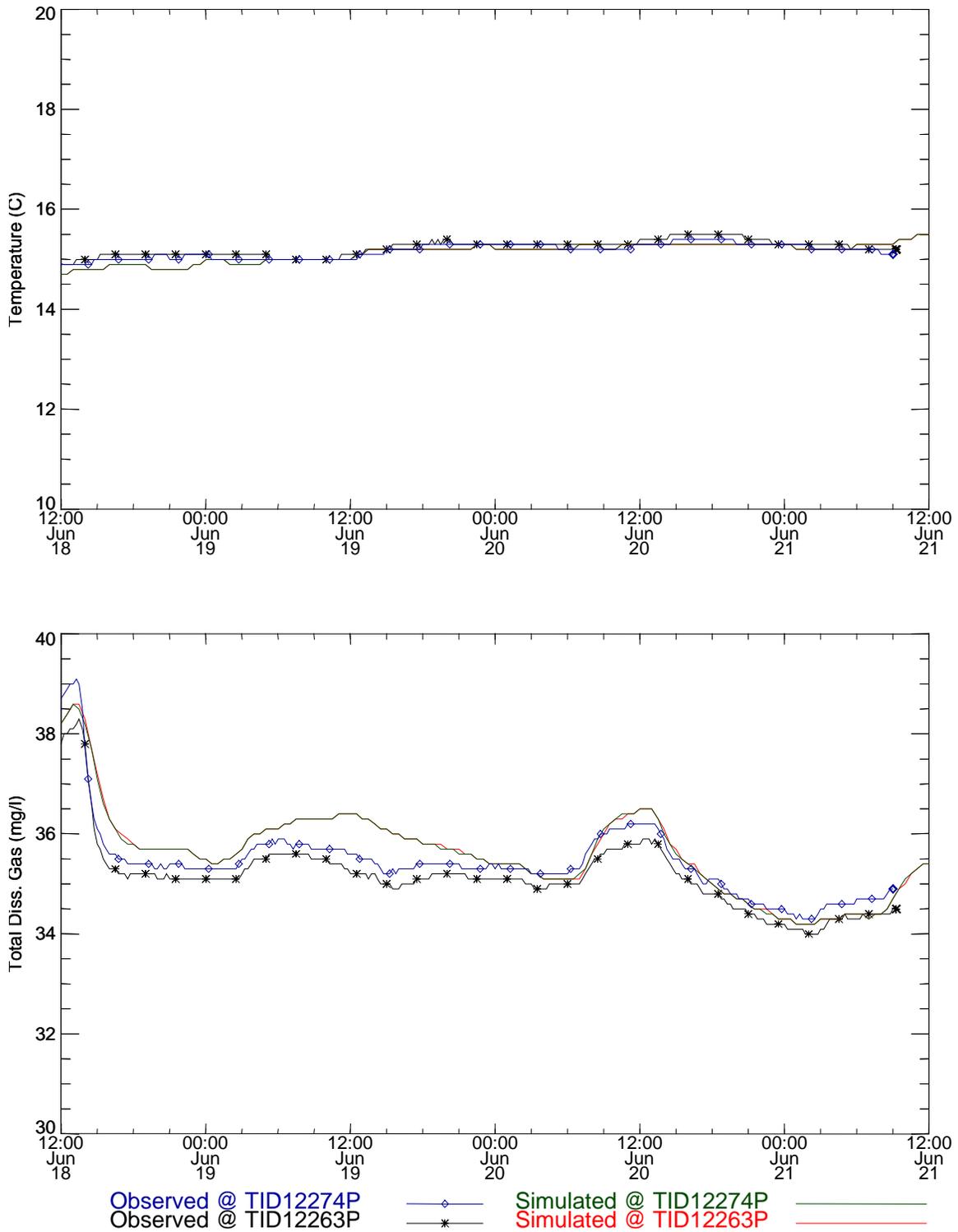


Figure 66. Temperature and total dissolved gas time series near Columbia River mile 122.6 for the Spring 1996 study period (FMS-BC).

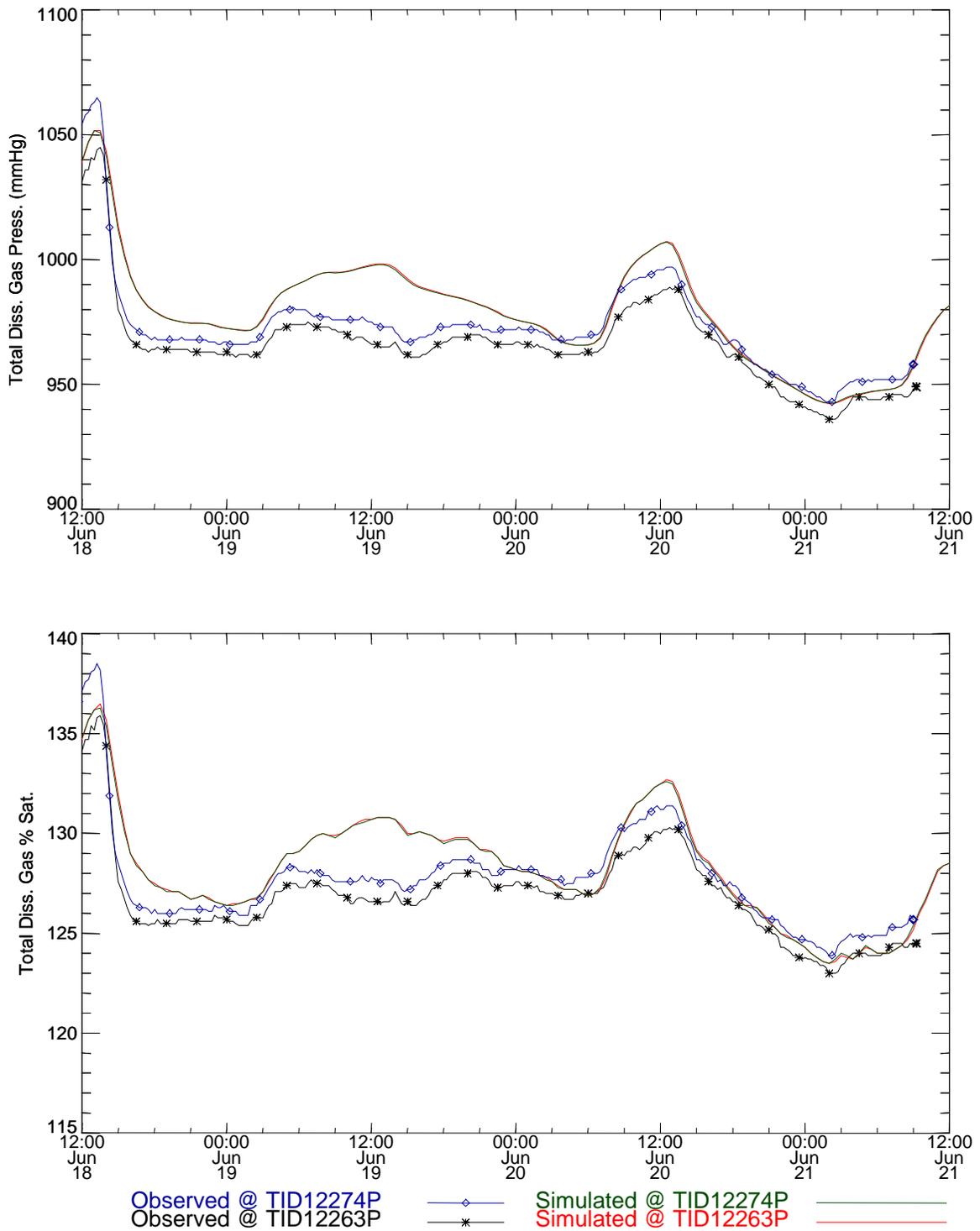


Figure 67. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 122.6 for the Spring 1996 study period (FMS-BC).

Table 13. Statistical summary of measurements and simulations near Columbia River mile 122.6 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID12263P	15.23	15.14	0.15	0.19	0.15
TID12274P	15.17	15.14	0.14	0.19	0.12
Concentration					
TID12263P	35.13	35.61	0.72	0.88	0.58
TID12274P	35.42	35.61	0.78	0.87	0.38
Gas Pressure					
TID12263P	965.56	979.02	18.14	21.83	16.02
TID12274P	972.08	978.87	19.63	21.67	11.31
% Saturation					
TID12263P	126.74	128.24	2.27	2.72	1.92
TID12274P	127.6	128.22	2.46	2.69	1.39

Table 14. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 122.6 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12263P	100	91.72	100	100
TID12274P	100	99.31	100	100

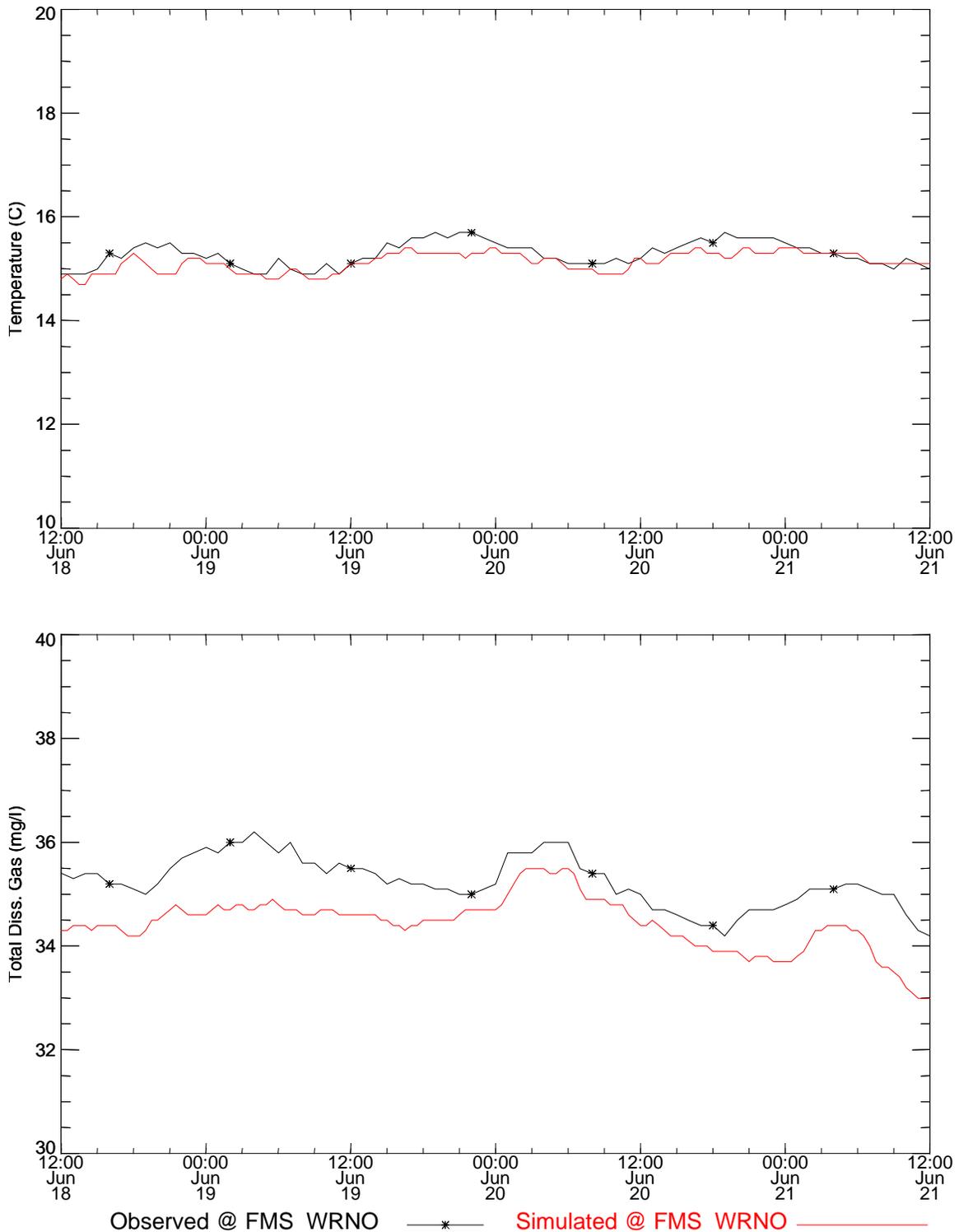


Figure 68. Temperature and total dissolved gas time series near fixed monitor WRNO for the Spring 1996 study period (FMS-BC).

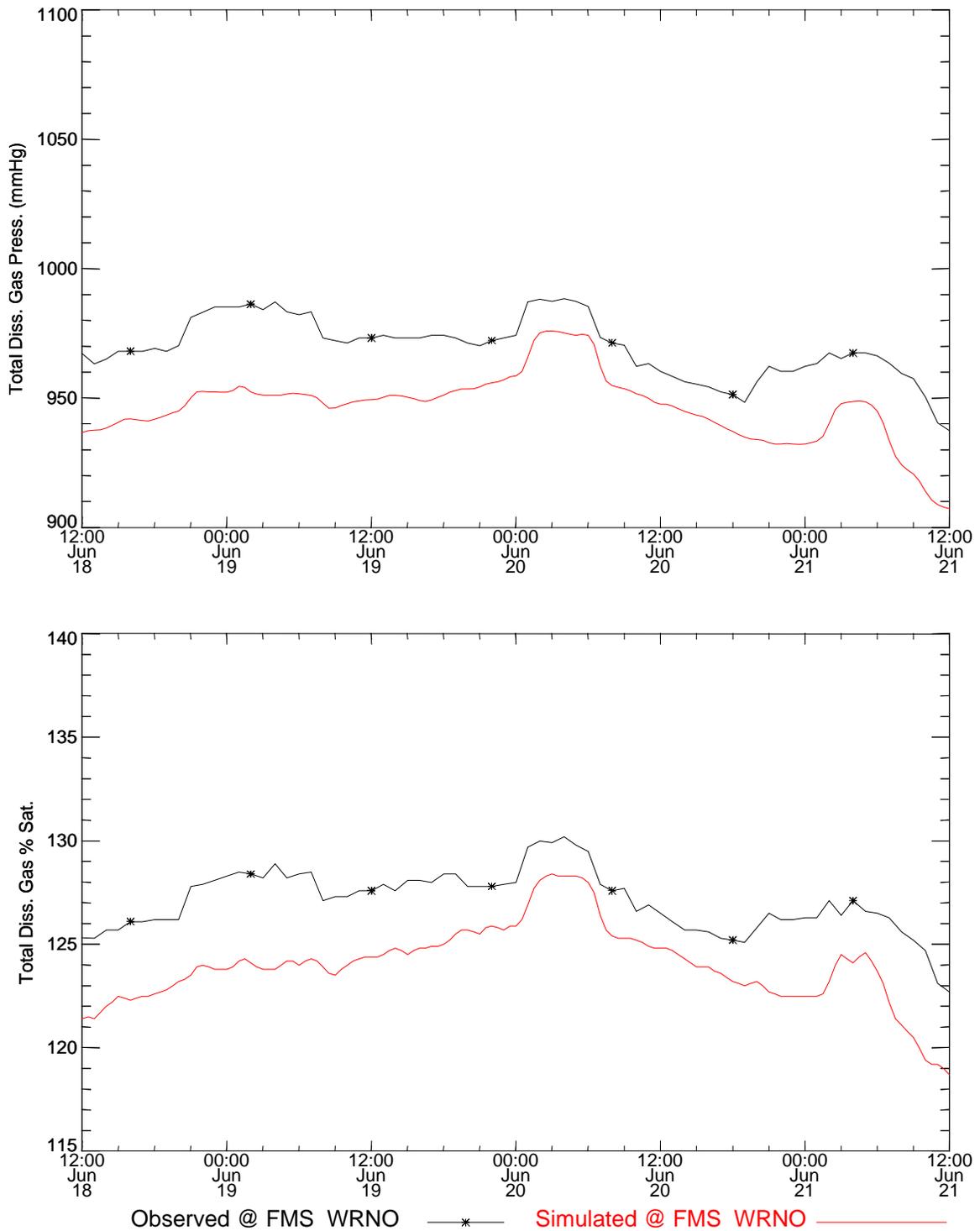


Figure 69. Total dissolved gas pressure and saturation time series comparisons near fixed monitor WRNO for the Spring 1996 study period (FMS-BC).

Table 15. Statistical summary of measurements and simulations near fixed monitor WRNO during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_WRNO	15.28	15.13	0.23	0.19	0.22
Concentration FMS_WRNO	35.24	34.43	0.48	0.51	0.87
Gas Pressure FMS_WRNO	969.8	946.75	11.3	13.18	24.28
% Saturation FMS_WRNO	127.09	124.01	1.45	1.91	3.24

Table 16. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor SRNO for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_WRNO	100	75.86	100	98.62

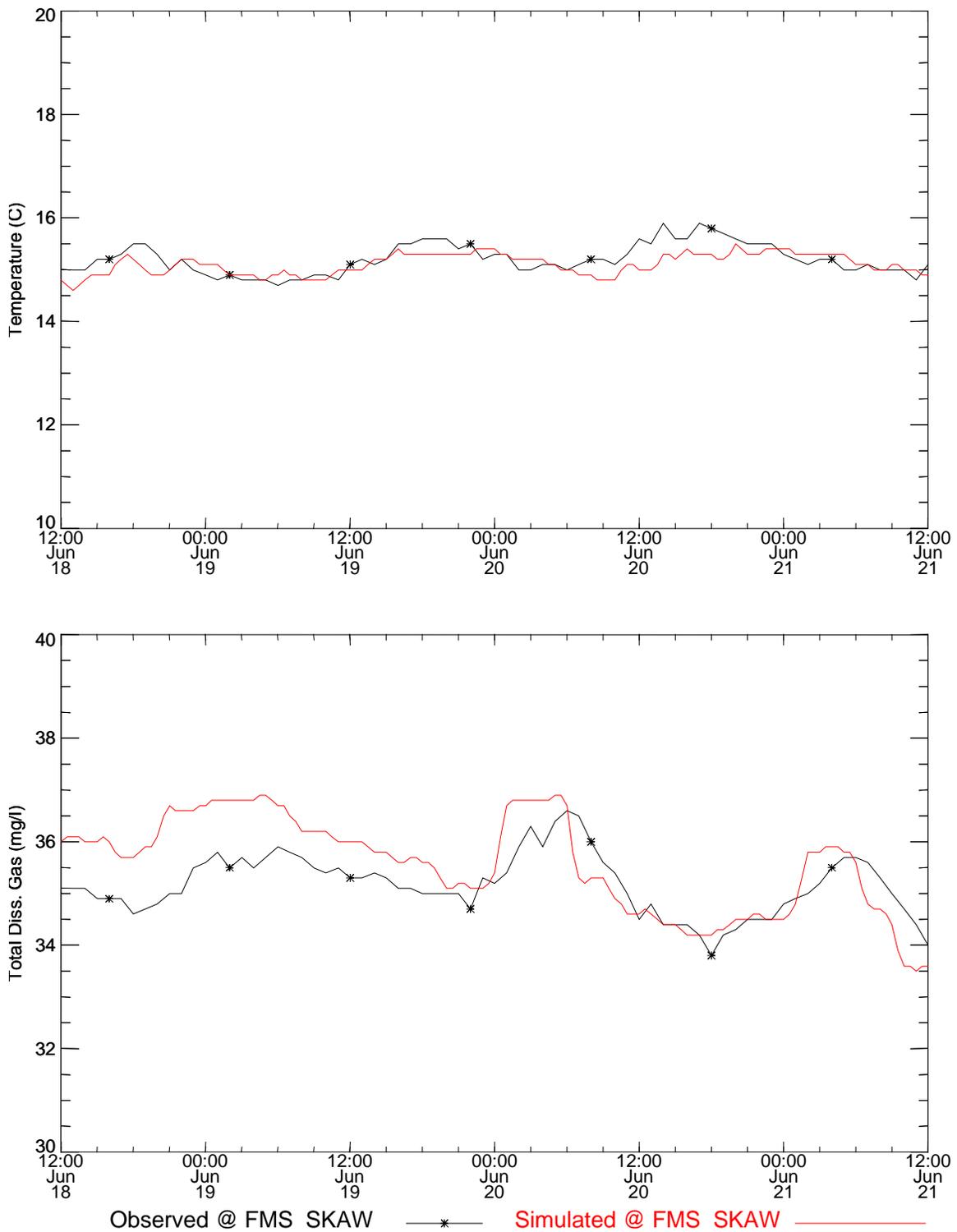


Figure 70. Temperature and total dissolved gas time series near fixed monitor SKAW for the Spring 1996 study period (FMS-BC).

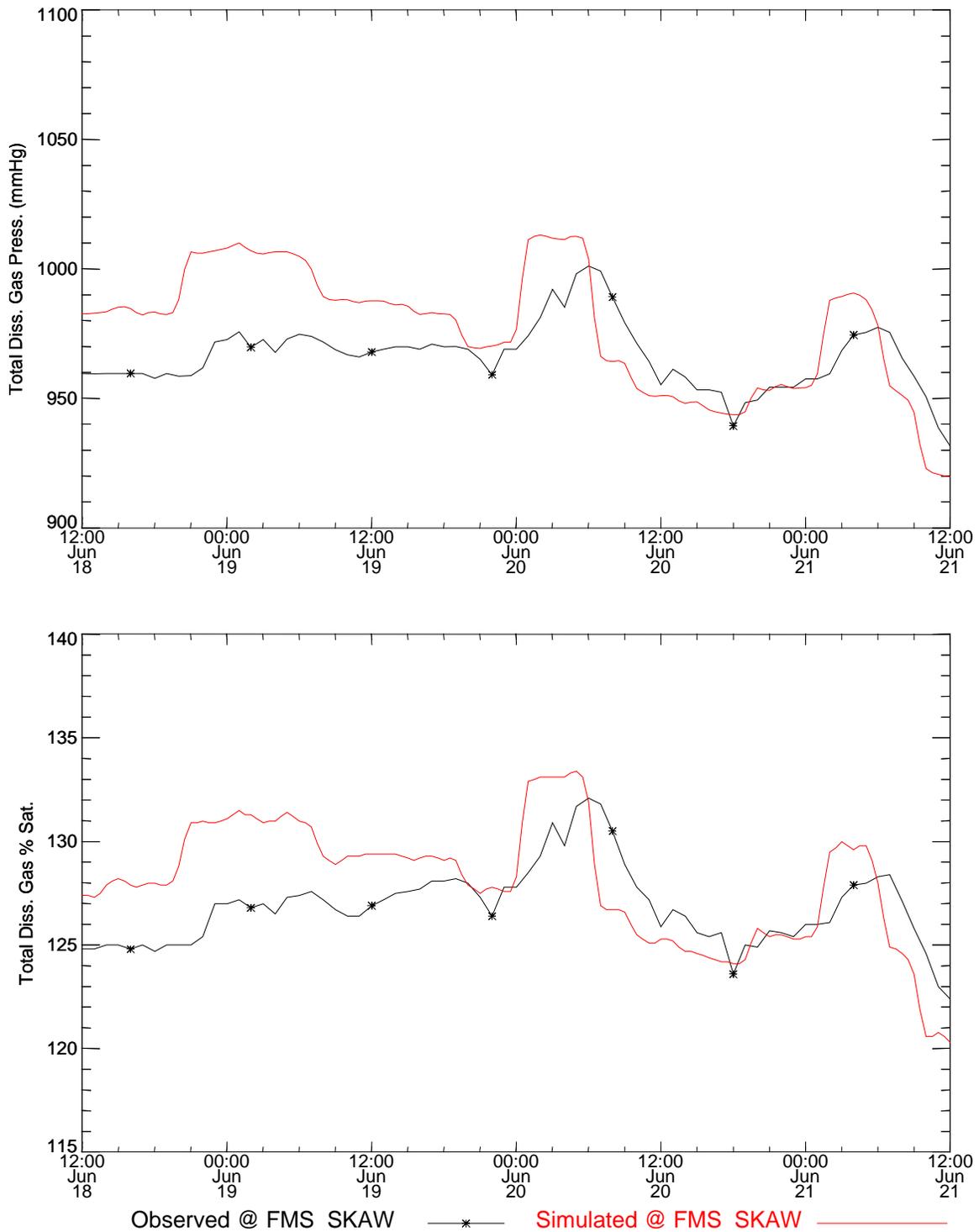


Figure 71. Total dissolved gas pressure and saturation time series comparisons near fixed monitor SKAW for the Spring 1996 study period (FMS-BC).

Table 17. Statistical summary of measurements and simulations near fixed monitor SKAW during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_SKAW	15.21	15.11	0.29	0.2	0.25
Concentration FMS_SKAW	35.17	35.57	0.57	0.92	0.76
Gas Pressure FMS_SKAW	966.31	977.29	12.45	23.71	21.46
% Saturation FMS_SKAW	126.86	128.01	1.85	2.92	2.69

Table 18. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor SKAW for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_SKAW	100	79.31	95.86	97.24

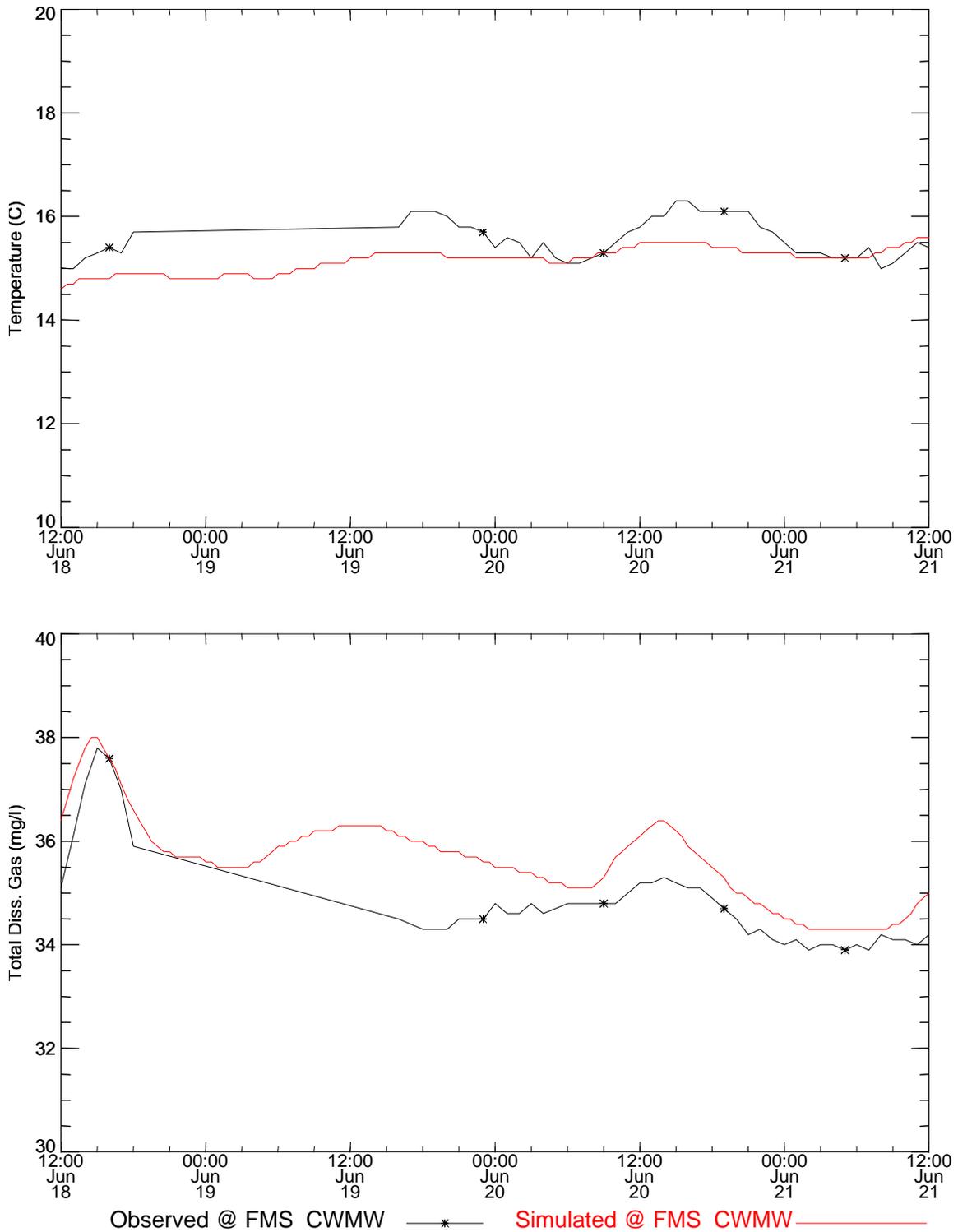


Figure 72. Temperature and total dissolved gas time series near fixed monitor CWMW for the Spring 1996 study period (FMS-BC).

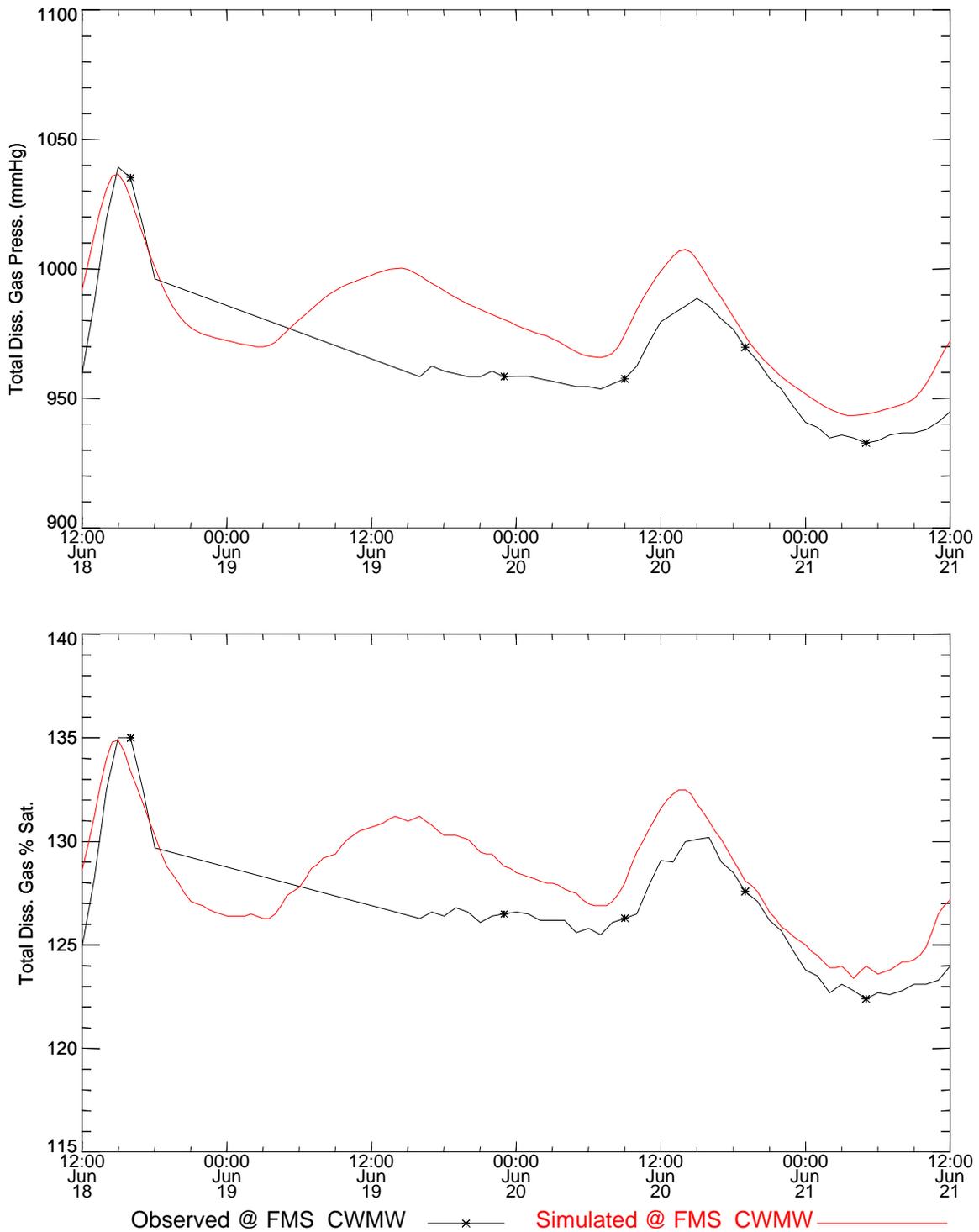


Figure 73. Total dissolved gas pressure and saturation time series comparisons near fixed monitor CWMW for the Spring 1996 study period (FMS-BC).

Table 19. Statistical summary of measurements and simulations near fixed monitor CWMW during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_CWMW	15.63	15.16	0.32	0.23	0.58
Concentration FMS_CWMW	34.91	35.63	0.8	0.82	0.87
Gas Pressure FMS_CWMW	967.38	979.9	22.36	20.93	18.67
% Saturation FMS_CWMW	127.01	128.36	2.62	2.67	2.28

Table 20. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor CWMW for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_CWMW	100	73.79	96.55	100

Boundary Conditions using Temporary Monitored Field Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.

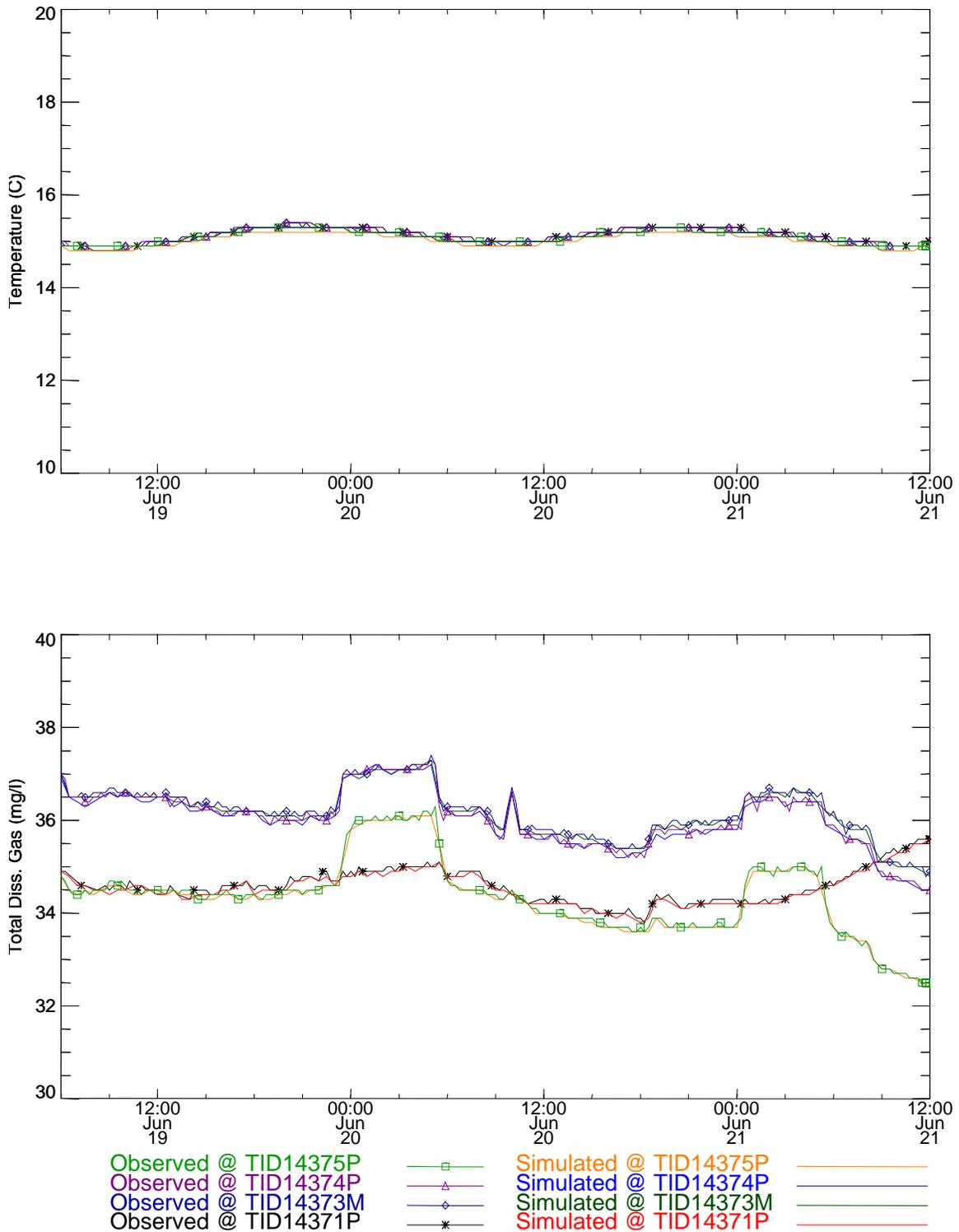


Figure 74. Temperature and total dissolved gas time series near Columbia River mile 143.7 for the Spring 1996 study (TM-BC).

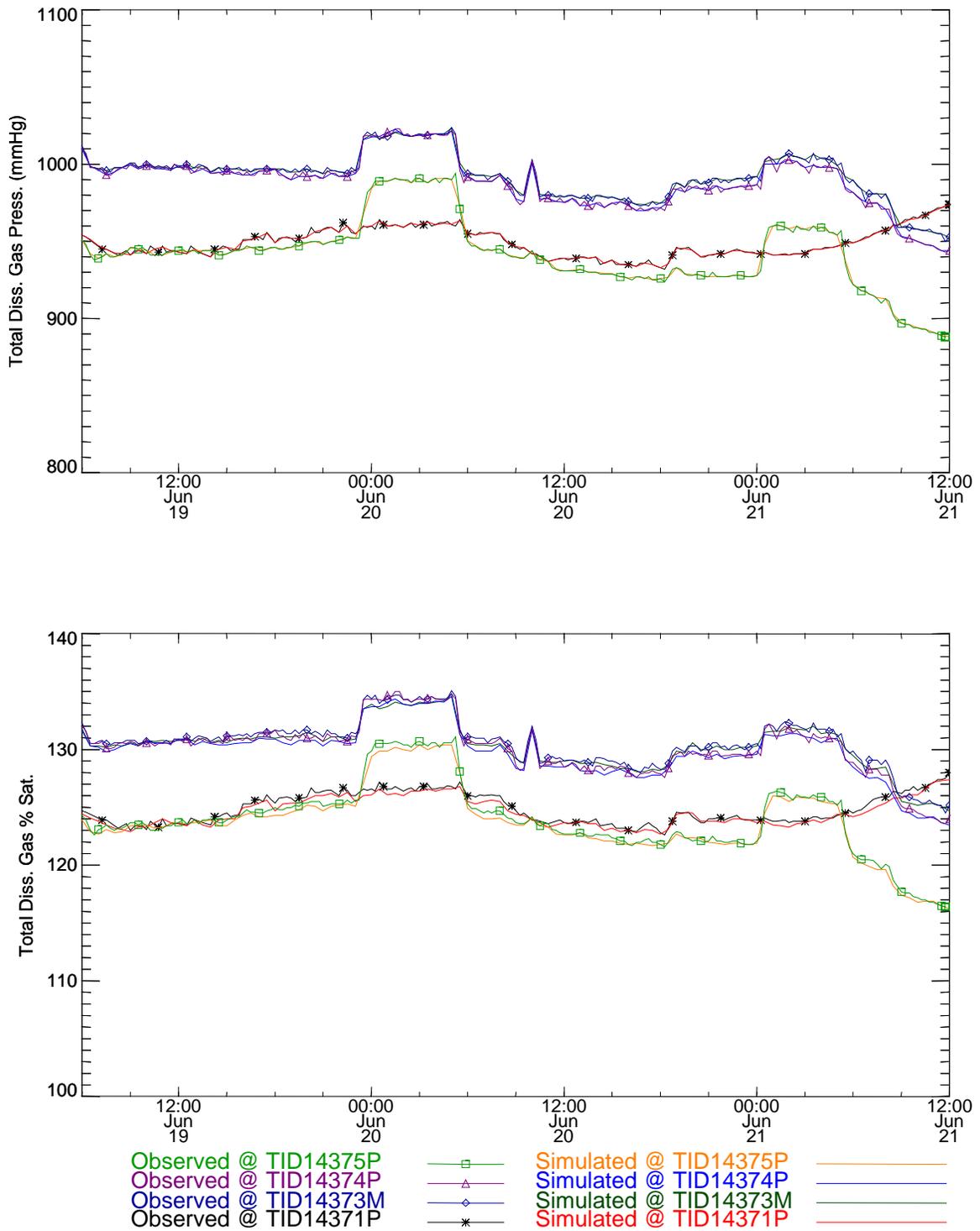


Figure 75. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 143.7 for the Spring 1996 study period (TM-BC).

Table 21. Statistical summary of measurements and simulations near Columbia River mile 143.7 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14371P	15.15	15.1	0.15	0.15	0.06
TID14373M	15.14	15.09	0.15	0.15	0.07
TID14374P	15.14	15.1	0.15	0.14	0.06
TID14375P	15.1	15.04	0.14	0.14	0.08
Concentration					
TID14371P	34.6	34.55	0.38	0.37	0.07
TID14373M	36.2	36.15	0.56	0.56	0.09
TID14374P	36.07	36.03	0.63	0.63	0.09
TID14375P	34.36	34.32	0.86	0.85	0.08
Gas Pressure					
TID14371P	949.72	949.68	9.42	9.36	1.04
TID14373M	992.78	992.72	16.02	15.73	1.67
TID14374P	989.49	989.39	17.89	17.72	1.83
TID14375P	942.2	942.25	24.29	23.96	1.78
% Saturation					
TID14371P	124.96	124.69	1.32	1.23	0.36
TID14373M	130.63	130.35	2.21	2.13	0.41
TID14374P	130.2	129.9	2.45	2.4	0.43
TID14375P	123.98	123.71	3.34	3.25	0.4

Table 22. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 143.7 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID14371P	100	100	100	100
TID14373M	100	100	100	100
TID14374P	100	100	100	100
TID14375P	100	100	100	100

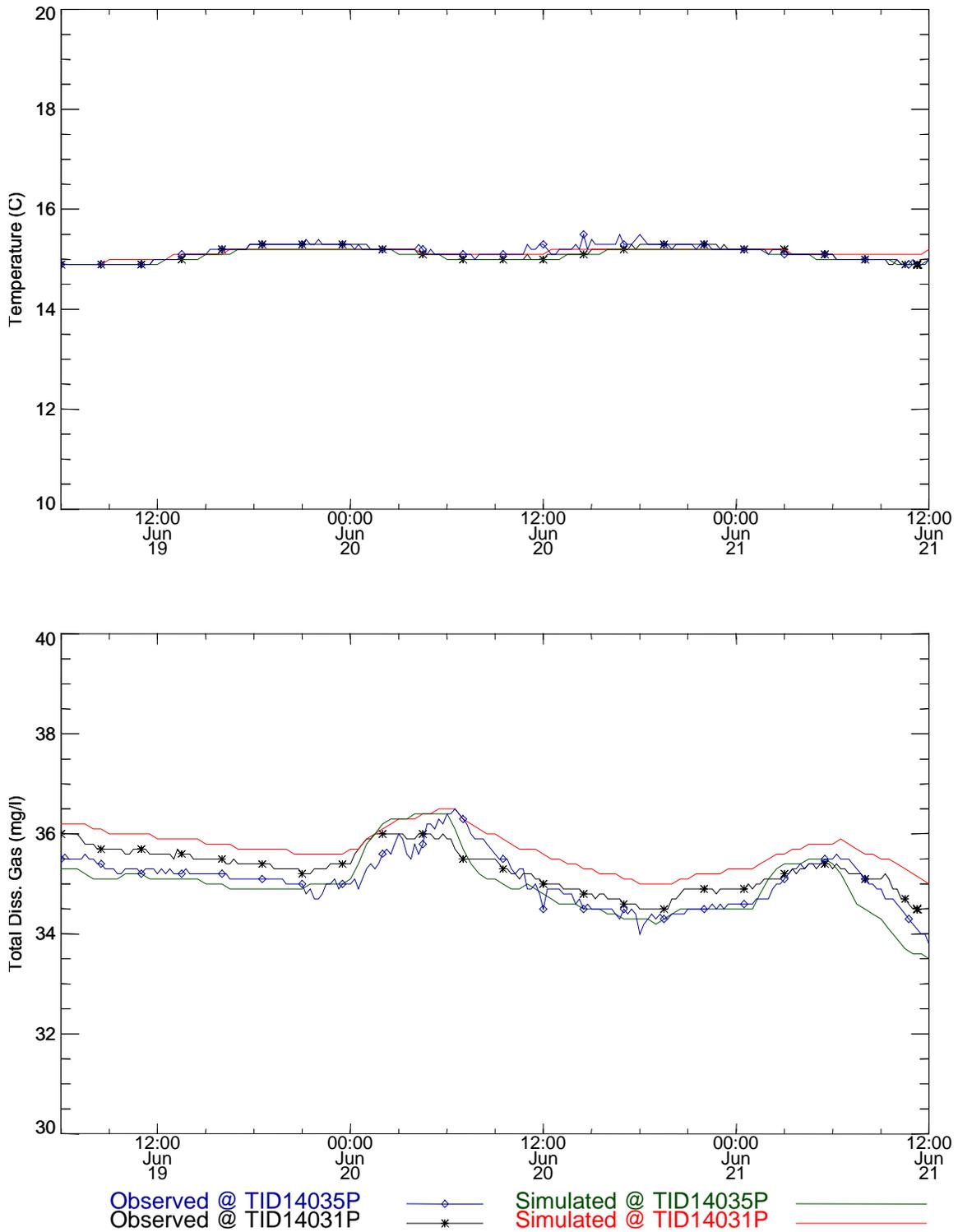


Figure 76. Temperature and total dissolved gas time series near Columbia River mile 140.3 for the Spring 1996 study (TM-BC).

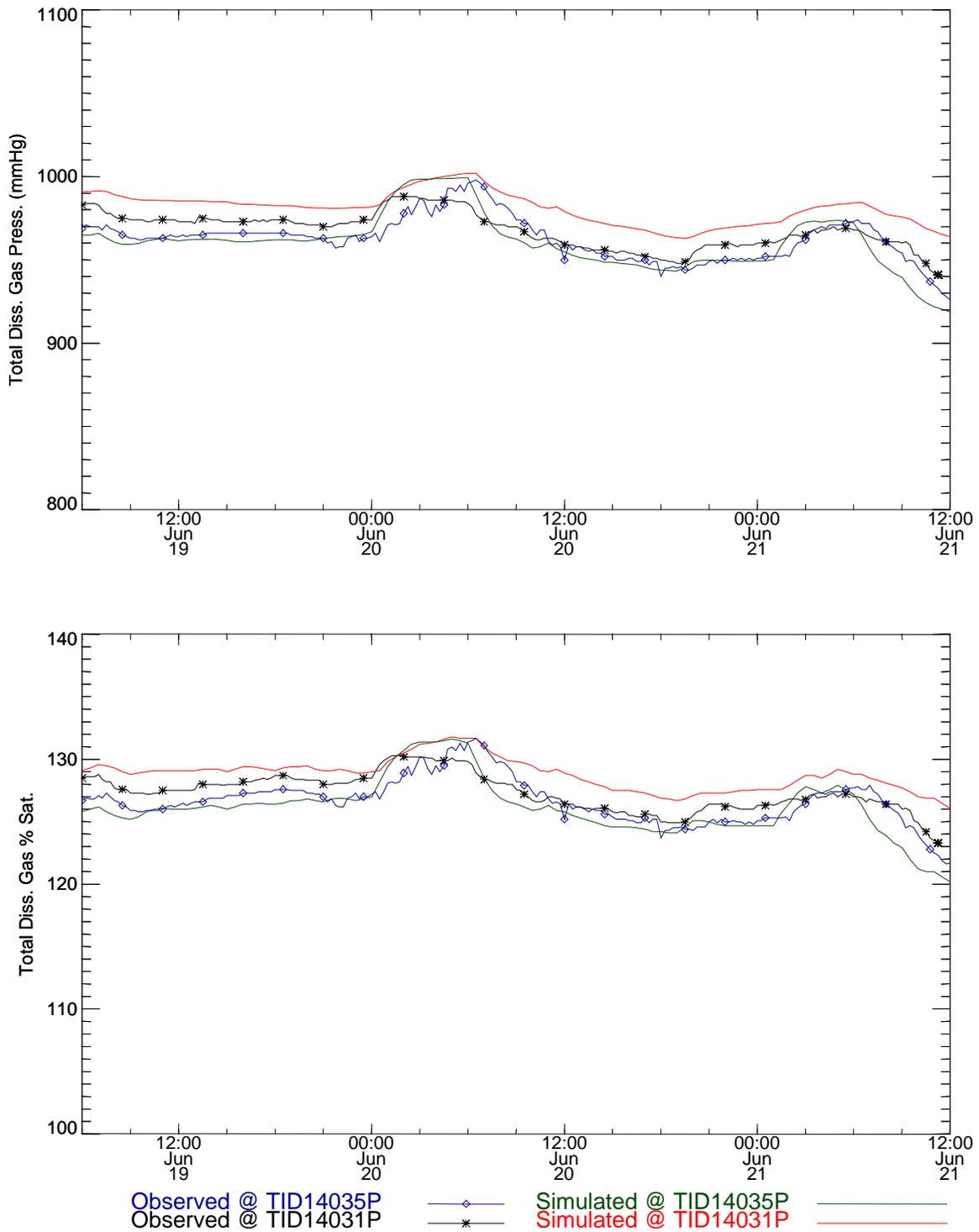


Figure 77. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 140.3 for the Spring 1996 study period (TM-BC).

Table 23. Statistical summary of measurements and simulations near Columbia River mile 140.3 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14031P	15.12	15.13	0.14	0.08	0.09
TID14035P	15.15	15.08	0.14	0.11	0.11
Concentration					
TID14031P	35.28	35.69	0.42	0.39	0.43
TID14035P	35.08	34.98	0.53	0.62	0.33
Gas Pressure					
TID14031P	967.48	981.02	11.1	9.64	14.32
TID14035P	962.67	960.81	13.41	16.79	8.61
% Saturation					
TID14031P	127.28	128.8	1.53	1.26	1.66
TID14035P	126.65	126.14	1.87	2.28	1.26

Table 24. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 140.3 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID14031P	100	100	100	100
TID14035P	100	100	100	100

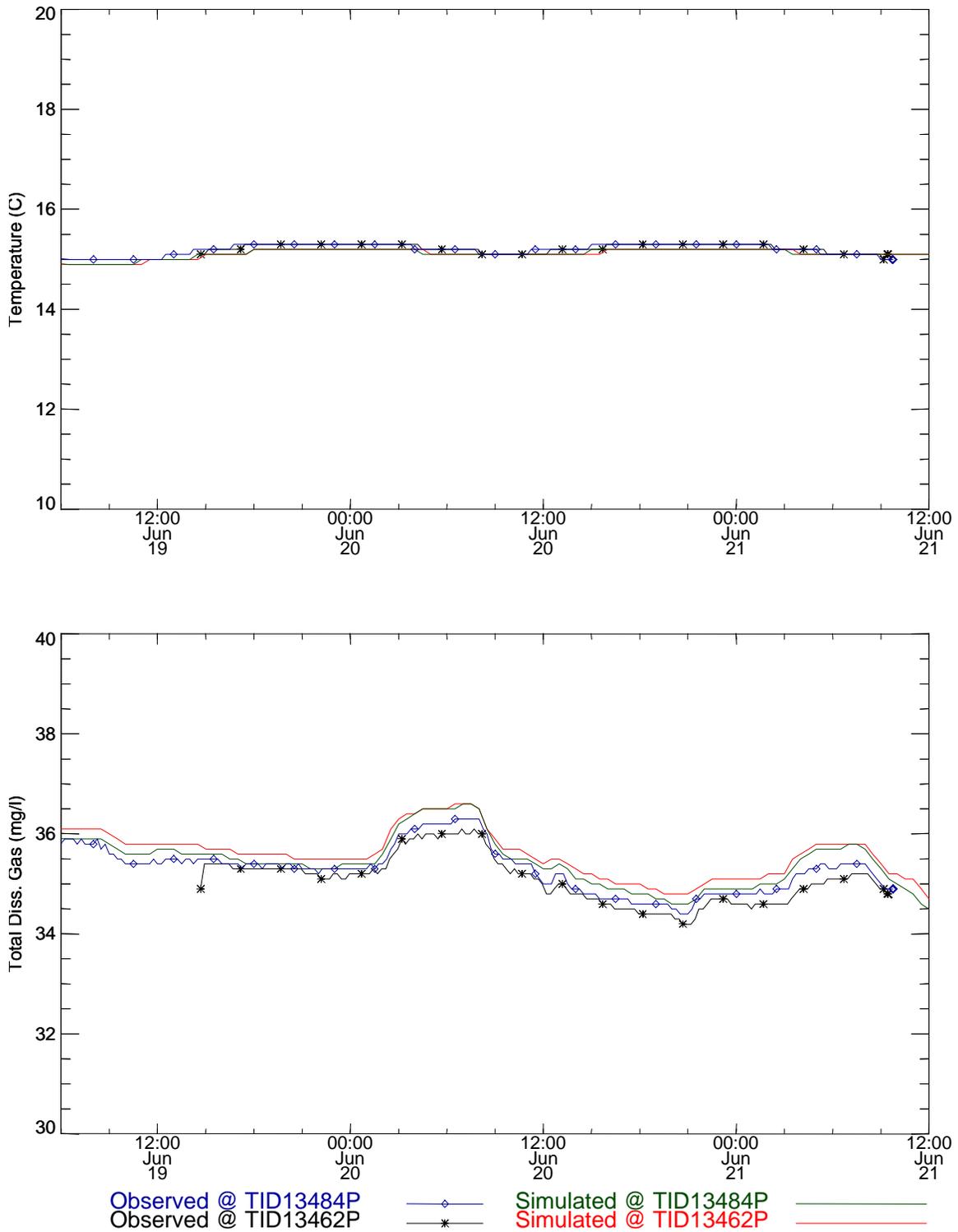


Figure 78. Temperature and total dissolved gas time series near Columbia River mile 134.6 for the Spring 1996 study (TM-BC).

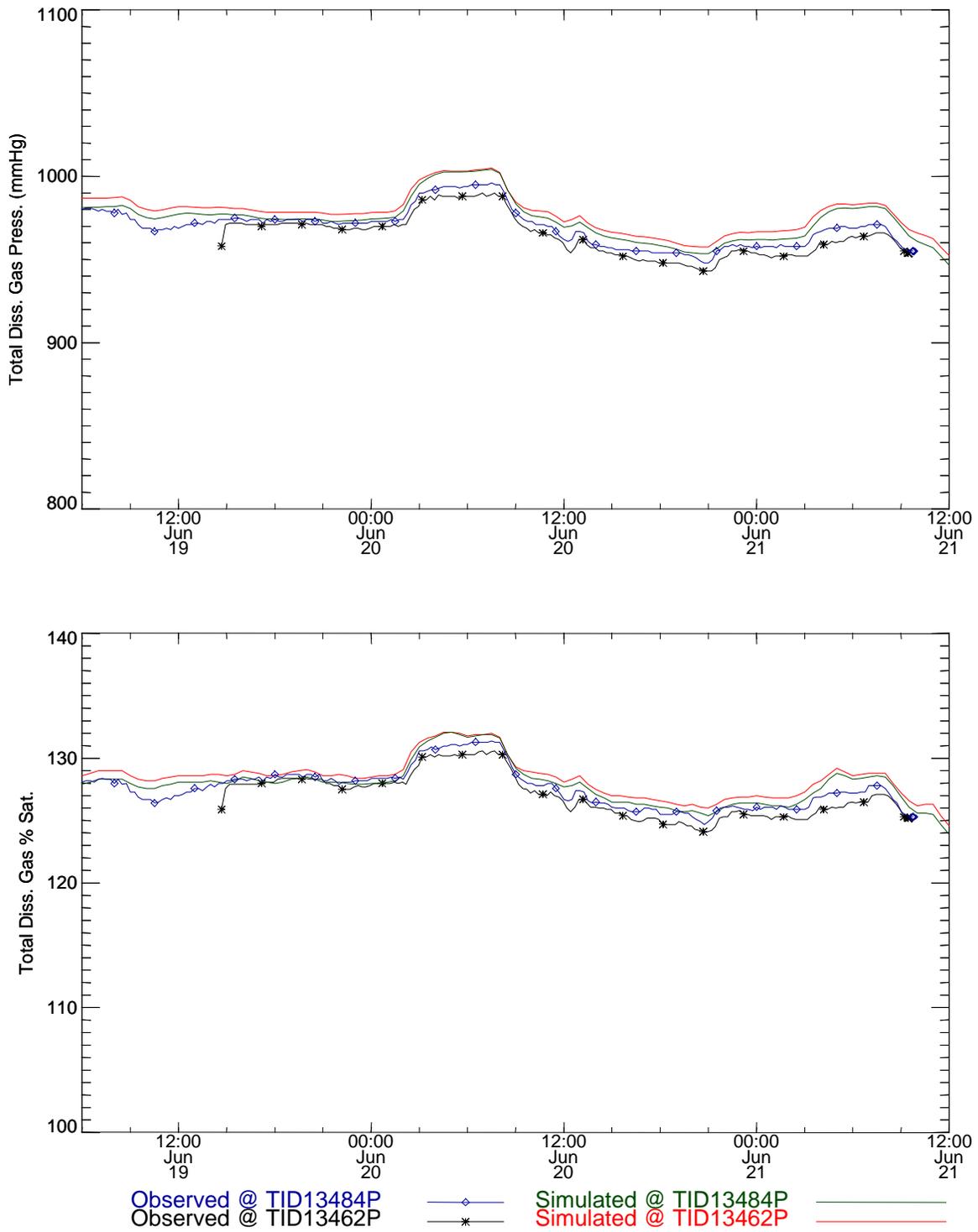


Figure 79. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 134.6 for the Spring 1996 study period (TM-BC).

Table 25. Statistical summary of measurements and simulations near Columbia River mile 134.6 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID13462P	15.23	15.15	0.08	0.05	0.09
TID13484P	15.23	15.15	0.08	0.05	0.09
Concentration					
TID13462P	35.08	35.55	0.48	0.47	0.49
TID13484P	35.25	35.43	0.48	0.51	0.2
Gas Pressure					
TID13462P	964.48	977.68	12.48	12.29	13.77
TID13484P	969.14	974.34	12.29	13.28	6.14
% Saturation					
TID13462P	127.04	128.48	1.76	1.62	1.55
TID13484P	127.66	128.04	1.72	1.74	0.6

Table 26. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 134.6 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID13462P	100	100	100	100
TID13484P	100	100	100	100

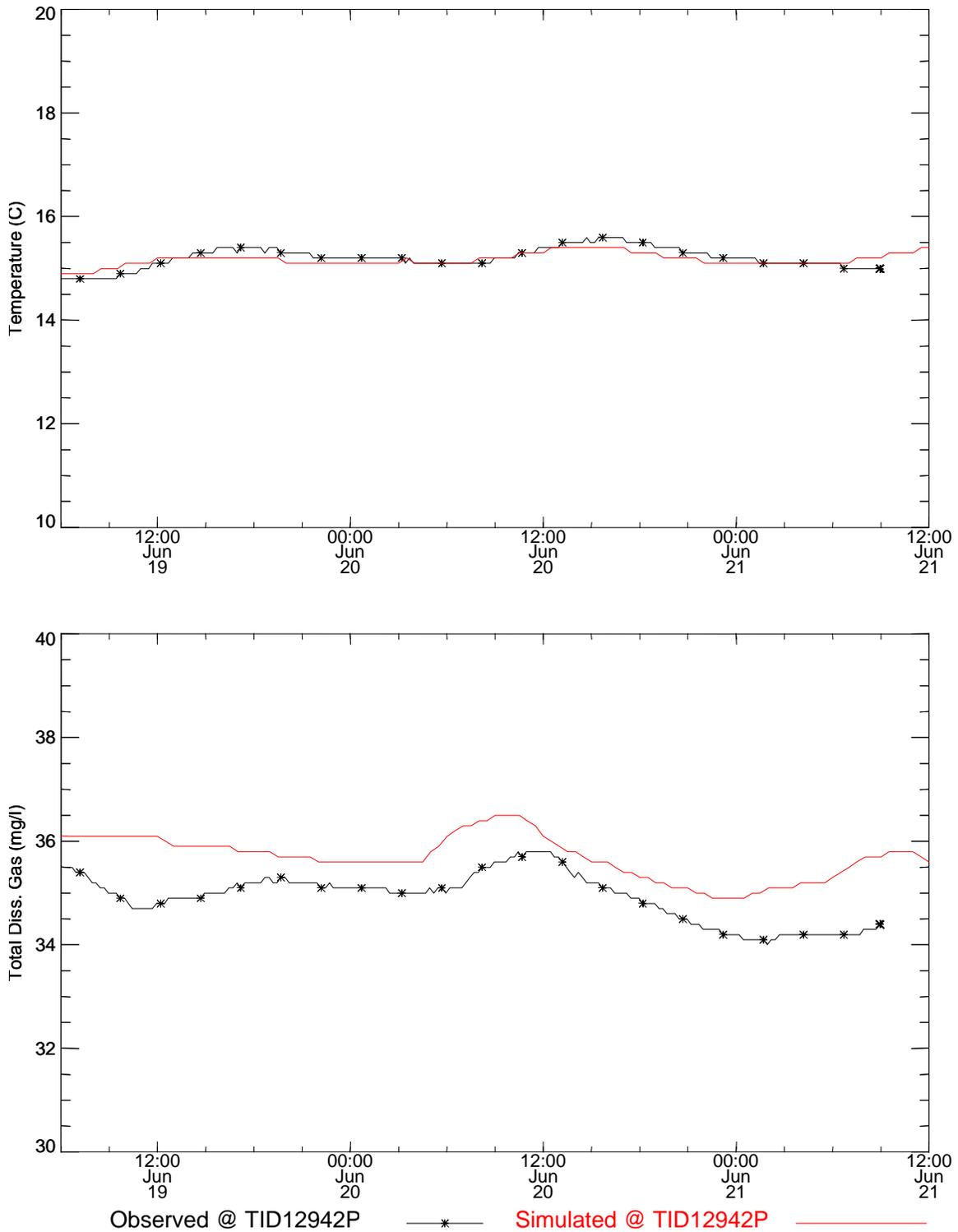


Figure 80. Temperature and total dissolved gas time series near Columbia River mile 129.4 for the Spring 1996 study (TM-BC).

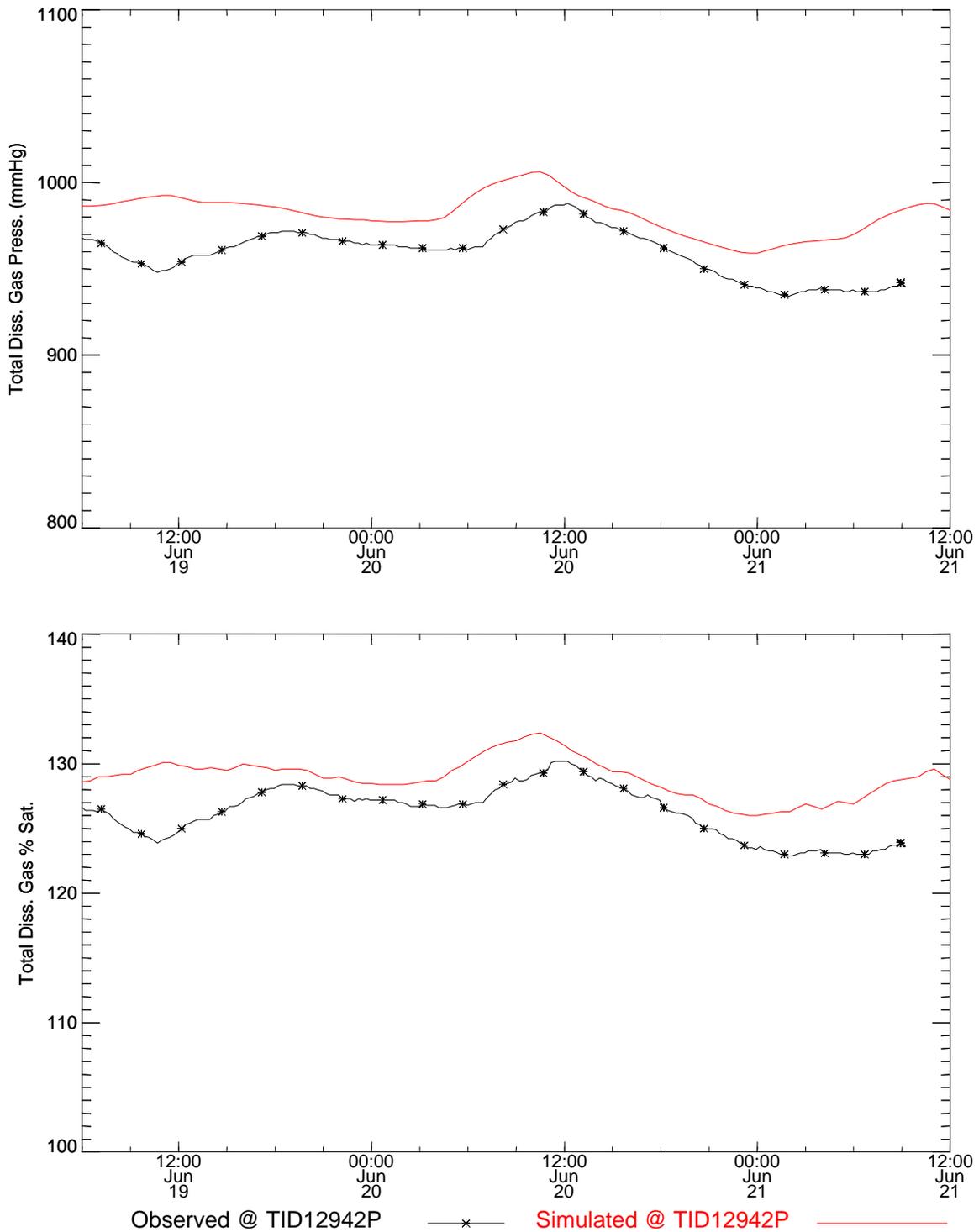


Figure 81. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 129.4 for the Spring 1996 study period (TM-BC).

Table 27. Statistical summary of measurements and simulations near Columbia River mile 129.4 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID12942P	15.19	15.17	0.2	0.12	0.15
Concentration TID12942P	34.89	35.69	0.47	0.41	0.86
Gas Pressure TID12942P	958.59	982.01	14.18	11.46	25.82
% Saturation TID12942P	126.13	128.93	2.03	1.53	3.13

Table 28. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 129.4 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12942P	100	77.06	85.32	90.83

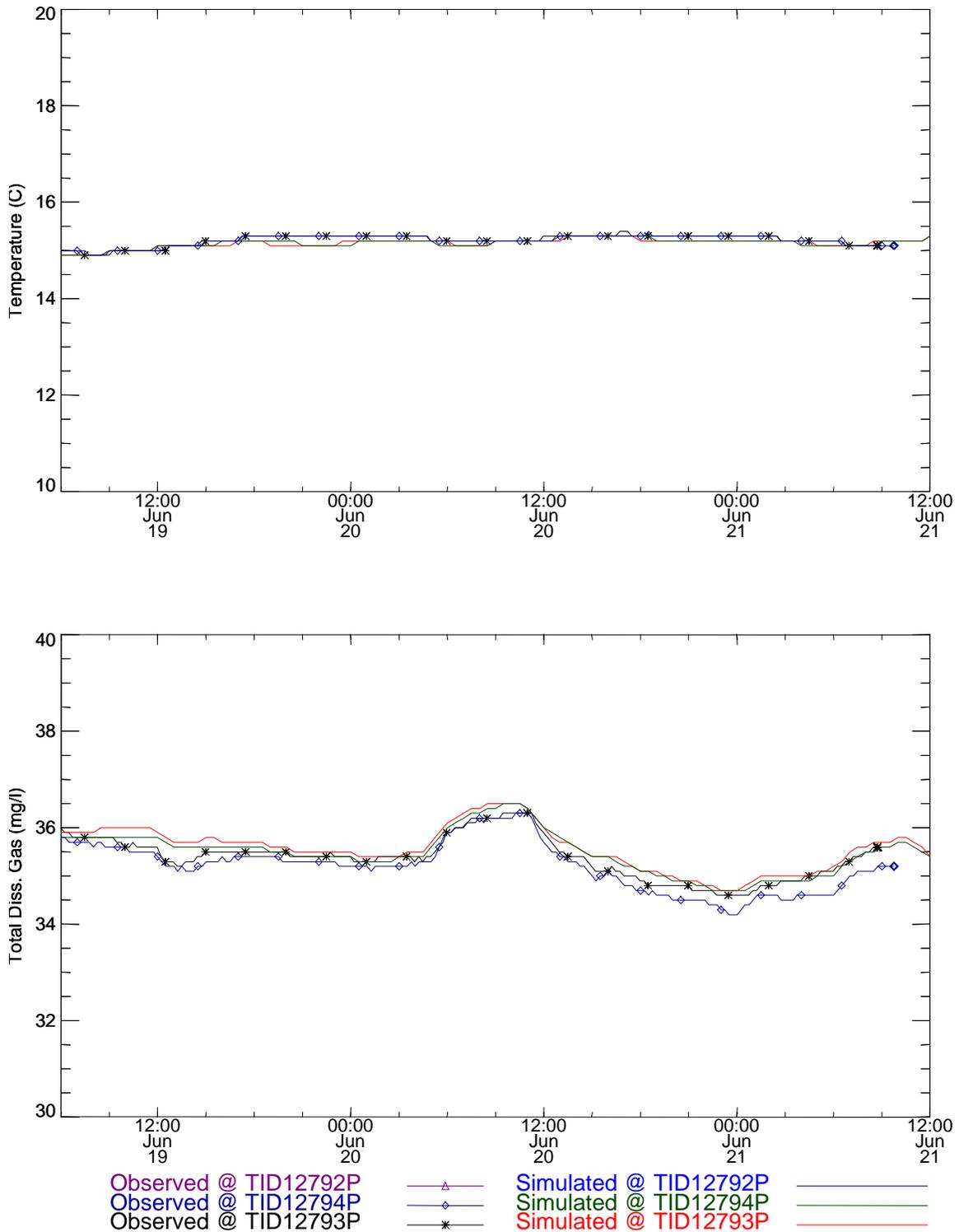


Figure 82. Temperature and total dissolved gas time series near Columbia River mile 127.9 for the Spring 1996 study (TM-BC).

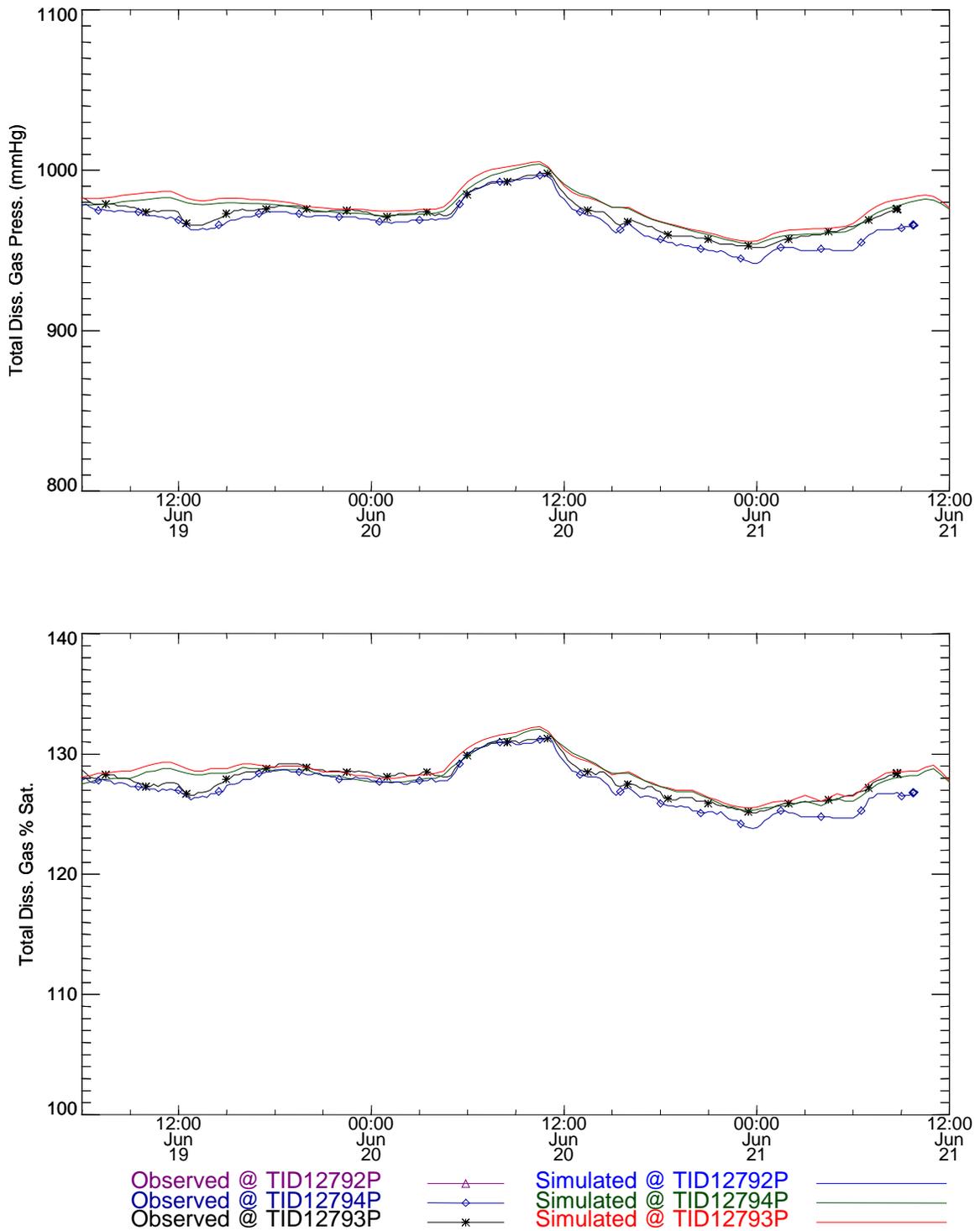


Figure 83. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 127.9 for the Spring 1996 study period (TM-BC).

Table 29. Statistical summary of measurements and simulations near Columbia River mile 127.9 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID12793P	15.21	15.15	0.12	0.09	0.1
TID12794P	15.21	15.16	0.11	0.1	0.09
Concentration					
TID12793P	35.4	35.57	0.42	0.44	0.21
TID12794P	35.21	35.48	0.5	0.44	0.3
Gas Pressure					
TID12793P	972.45	978.24	10.67	11.64	6.73
TID12794P	967.34	975.89	12.69	11.52	9.44
% Saturation					
TID12793P	127.96	128.43	1.5	1.55	0.73
TID12794P	127.27	128.12	1.77	1.56	1.05

Table 30. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 127.9 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12793P	100	100	100	100
TID12794P	100	100	100	100

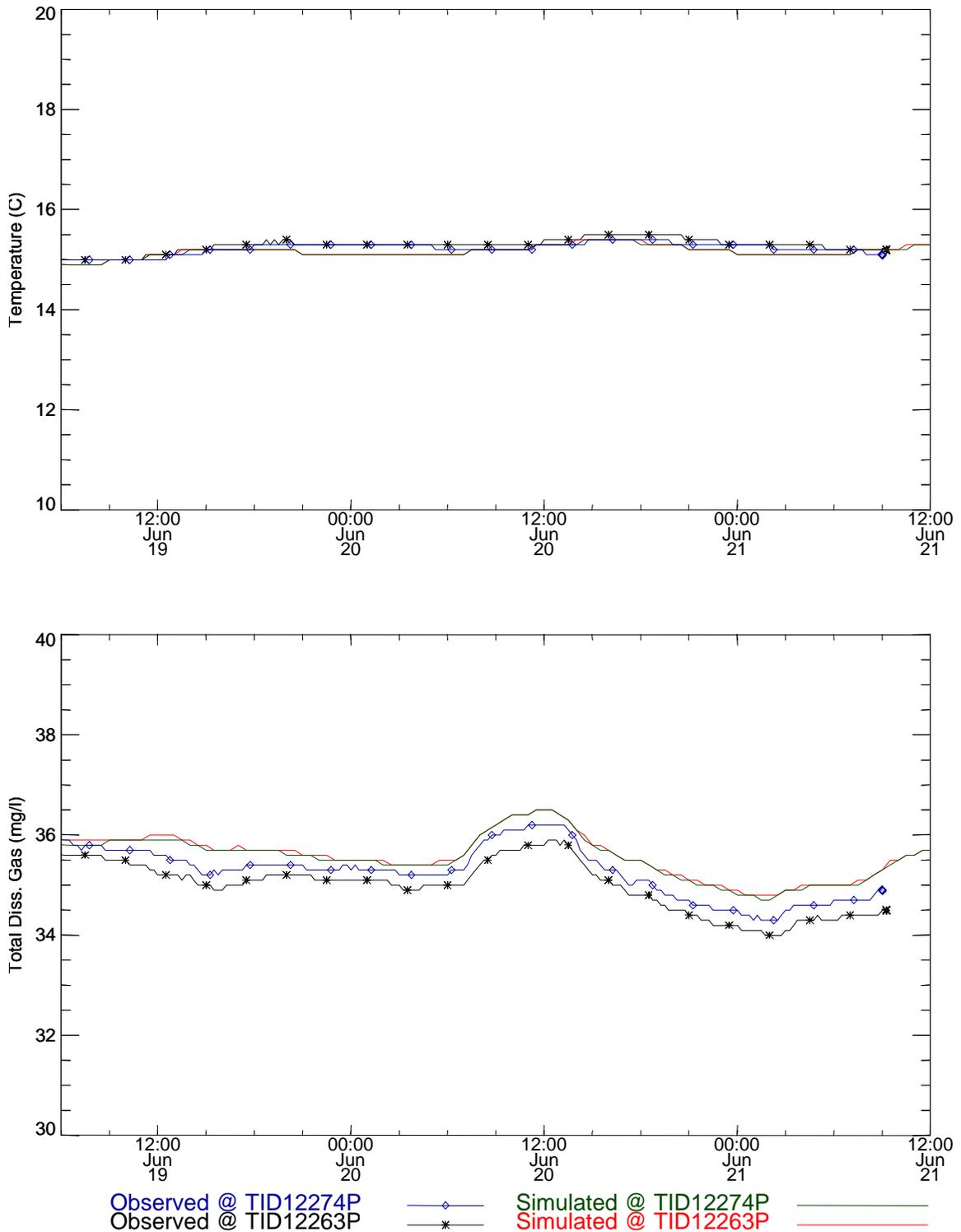


Figure 84. Temperature and total dissolved gas time series near Columbia River mile 122.6 for the Spring 1996 study (TM-BC).

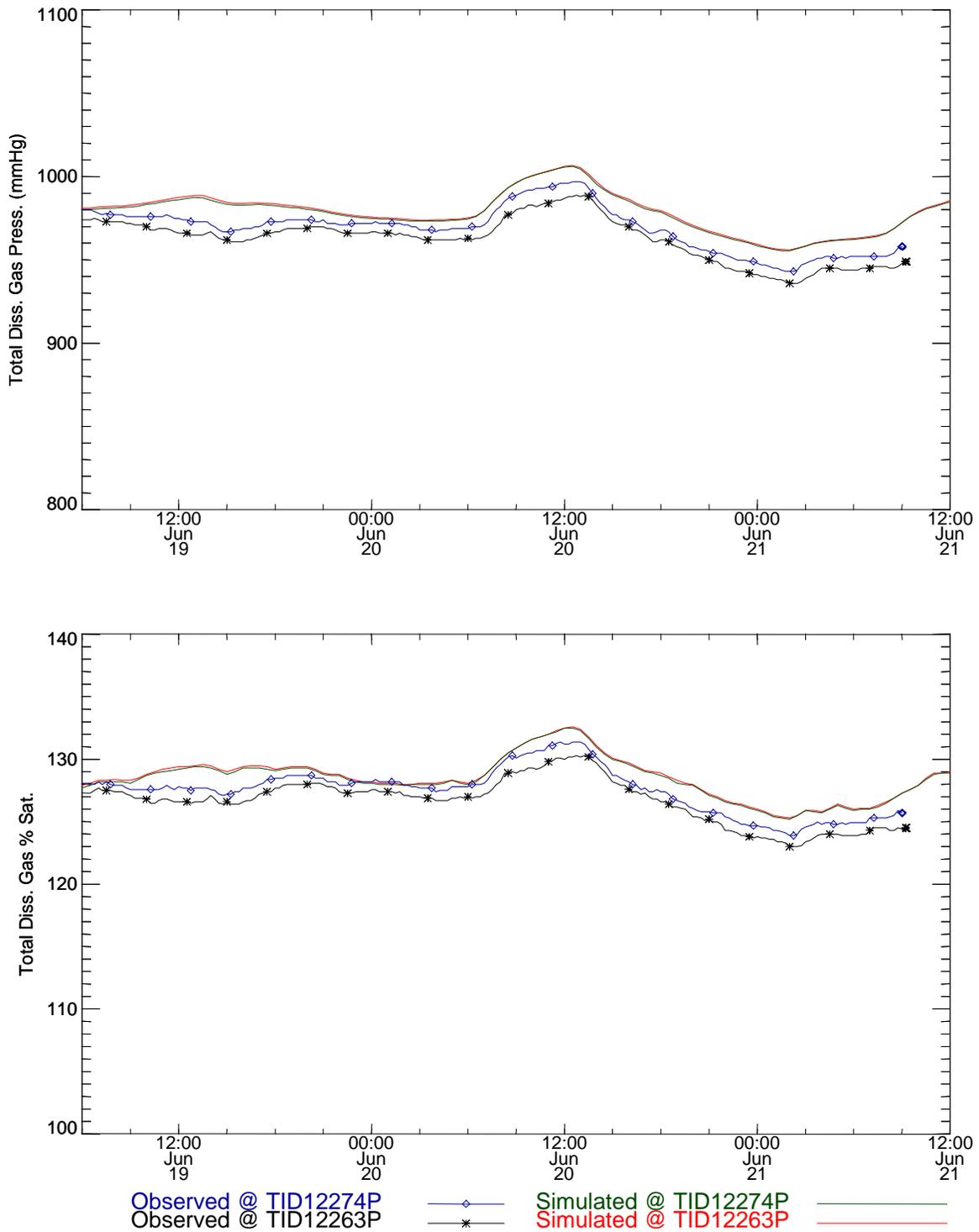


Figure 85. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 122.6 for the Spring 1996 study period (TM-BC).

Table 31. Statistical summary of measurements and simulations near Columbia River mile 122.6 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID12263P	15.28	15.17	0.13	0.12	0.14
TID12274P	15.22	15.16	0.12	0.11	0.12
Concentration					
TID12263P	34.96	35.58	0.5	0.43	0.65
TID12274P	35.25	35.55	0.5	0.43	0.34
Gas Pressure					
TID12263P	961.93	978.87	13.14	12.06	17.86
TID12274P	968.42	978.13	13.1	12.02	10.85
% Saturation					
TID12263P	126.55	128.52	1.83	1.67	2.12
TID12274P	127.41	128.42	1.82	1.68	1.22

Table 32. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 122.7 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12263P	100	96.33	100	100
TID12274P	100	100	100	100

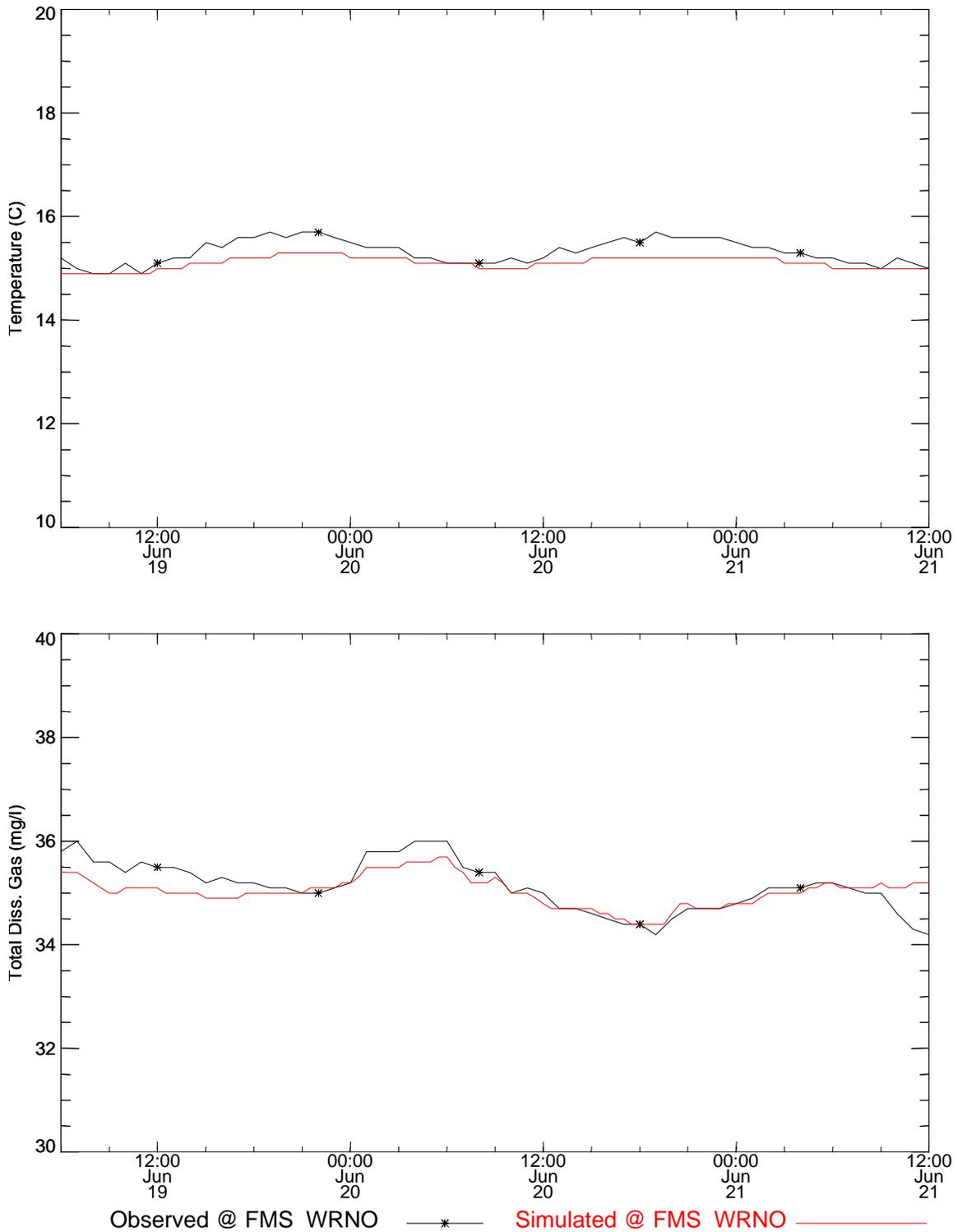


Figure 86. Temperature and total dissolved gas time series near fixed monitor WRNO for the Spring 1996 study (TM-BC).

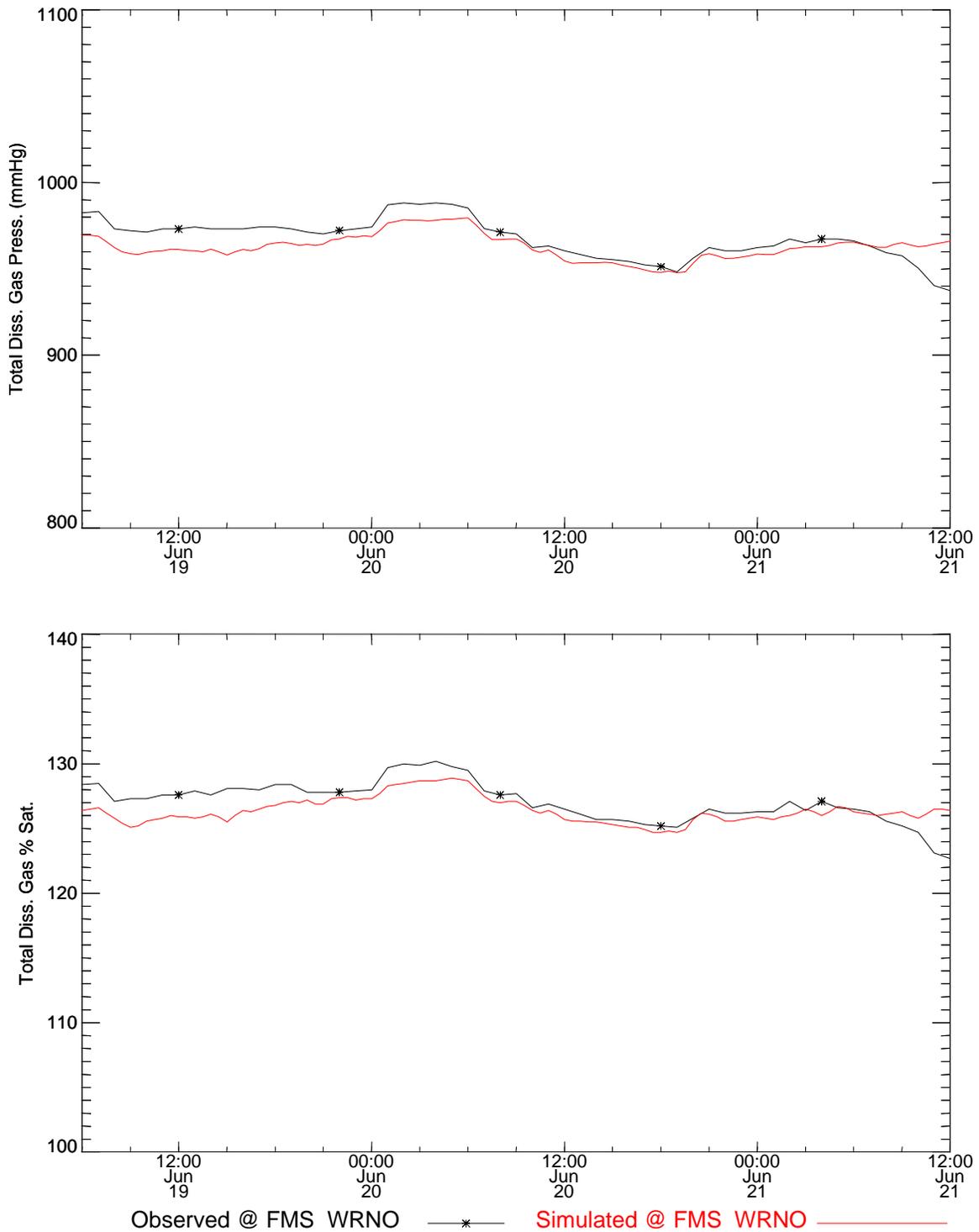


Figure 87. Total dissolved gas pressure and saturation time series comparisons near fixed monitor WRNO for the Spring 1996 study period (TM-BC).

Table 33. Statistical summary of measurements and simulations near fixed monitor WRNO for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_WRNO	15.32	15.11	0.23	0.12	0.25
Concentration					
FMS_WRNO	35.13	35.03	0.46	0.29	0.3
Gas Pressure					
FMS_WRNO	967.66	962.87	11.26	7.55	9.02
% Saturation					
FMS_WRNO	127.09	126.41	1.52	1.01	1.26

Table 34. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor WRNO for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_WRNO	100	100	100	100

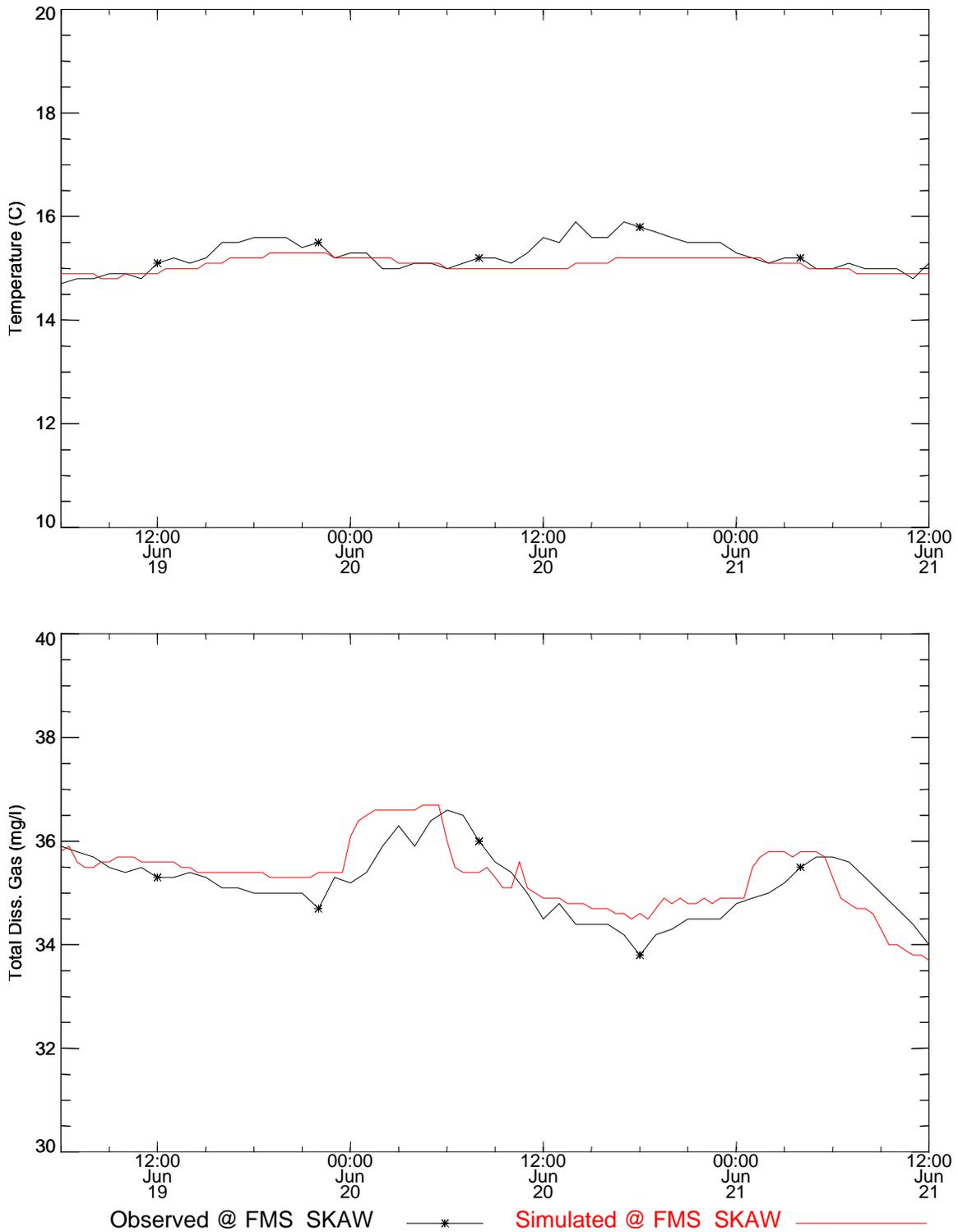


Figure 88. Temperature and total dissolved gas time series near fixed monitor SKAW for the Spring 1996 study (TM-BC).

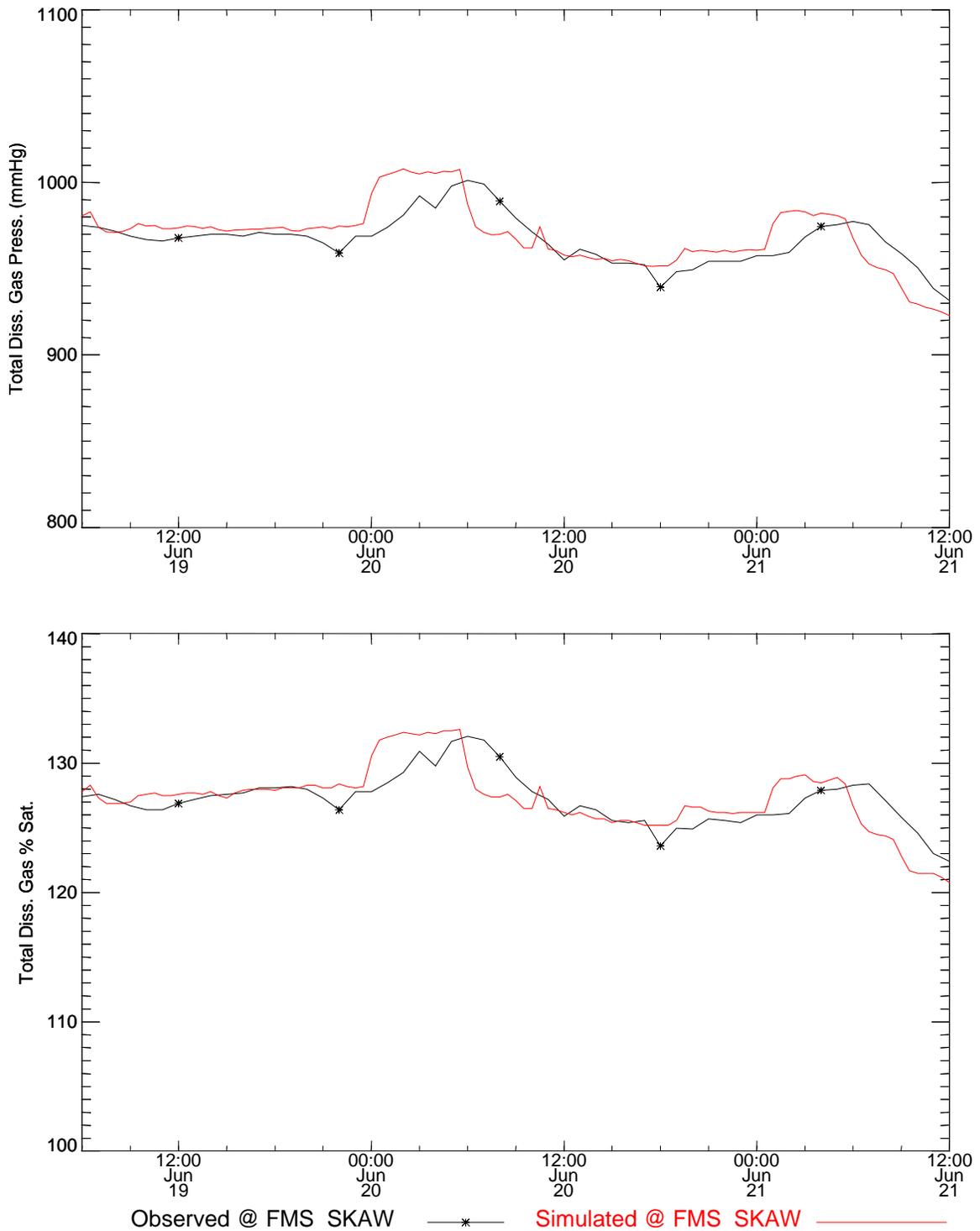


Figure 89. Total dissolved gas pressure and saturation time series comparisons near fixed monitor SKAW for the Spring 1996 study period (TM-BC).

Table 35. Statistical summary of measurements and simulations near Columbia River mile 143.7 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_SKAW	15.25	15.07	0.29	0.13	0.28
Concentration FMS_SKAW	35.16	35.31	0.62	0.66	0.48
Gas Pressure FMS_SKAW	966.89	969.57	13.85	18.14	12.61
% Saturation FMS_SKAW	127.21	127.3	1.92	2.45	1.68

Table 36. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor SKAW for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_SKAW	100	96.33	100	100

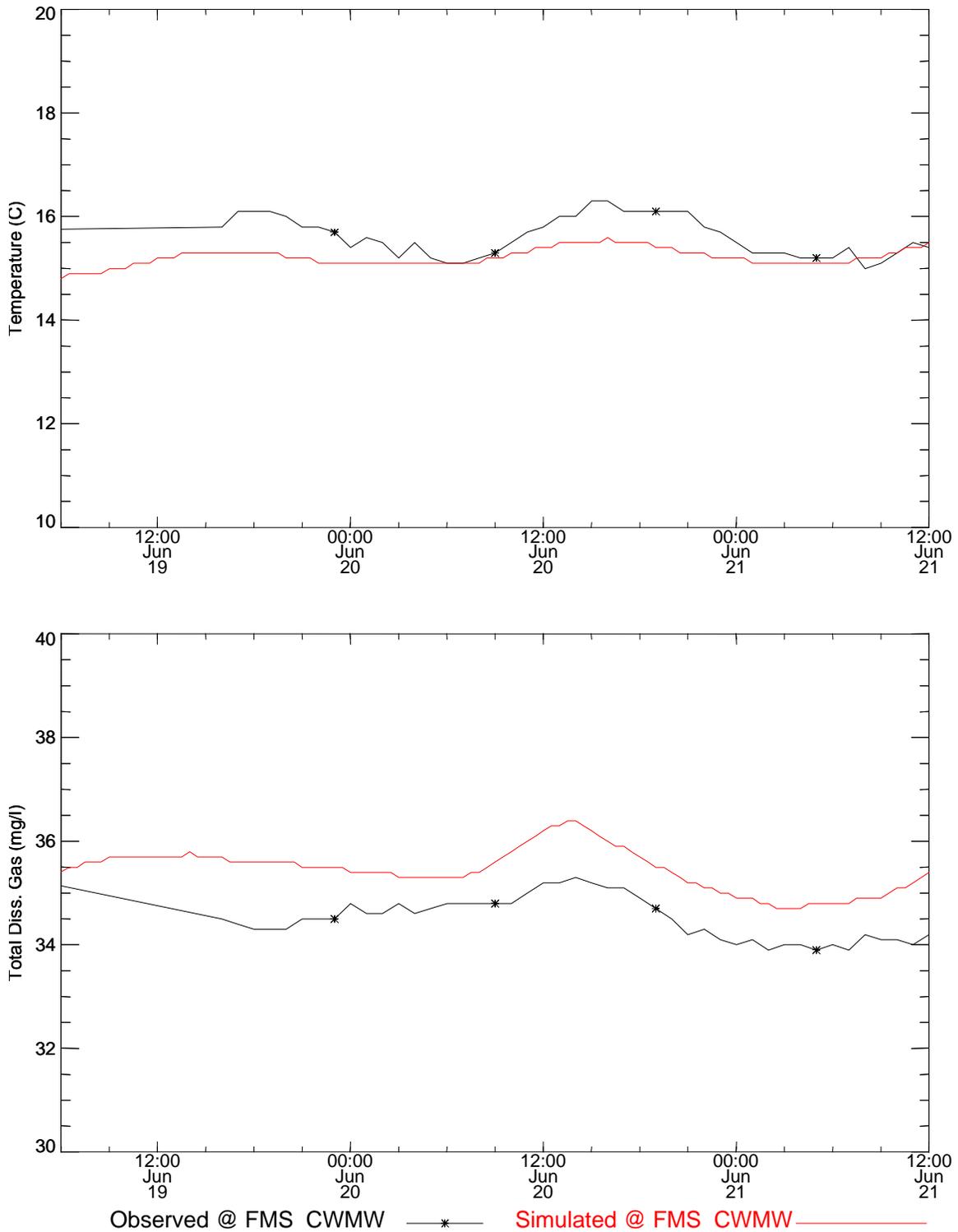


Figure 90. Temperature and total dissolved gas time series near fixed monitor CWMW for the Spring 1996 study (TM-BC).

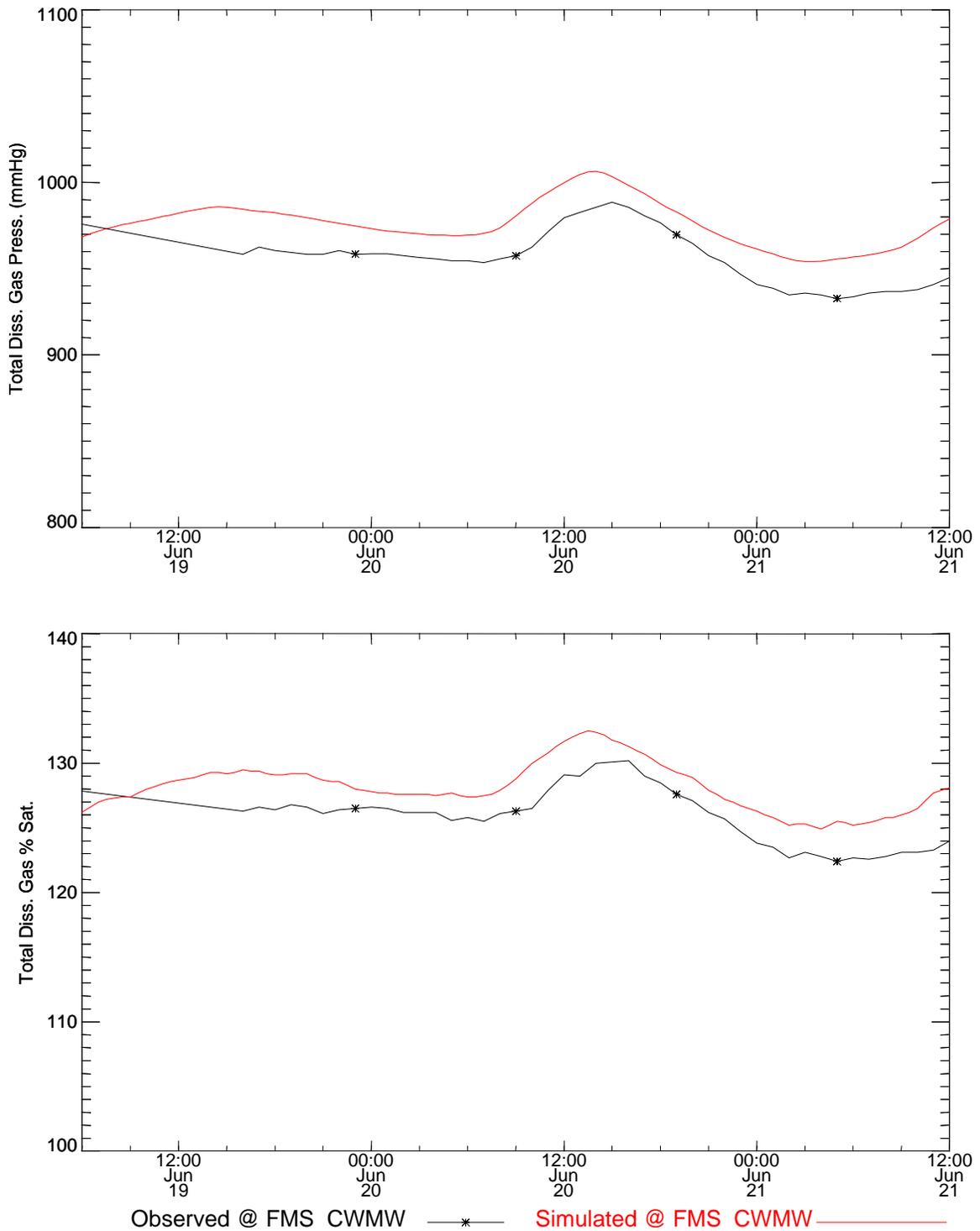


Figure 91. Total dissolved gas pressure and saturation time series comparisons near fixed monitor CWMW for the Spring 1996 study period (TM-BC).

Table 37. Statistical summary of measurements and simulations near fixed monitor CWMW for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_CWMW	15.65	15.22	0.34	0.16	0.52
Concentration					
FMS_CWMW	34.56	35.45	0.39	0.41	0.91
Gas Pressure					
FMS_CWMW	958.36	976.17	14.71	12.95	19.15
% Saturation					
FMS_CWMW	126.11	128.16	2.02	1.85	2.29

Table 38. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor CWMW for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_CWMW	100	77.06	100	100

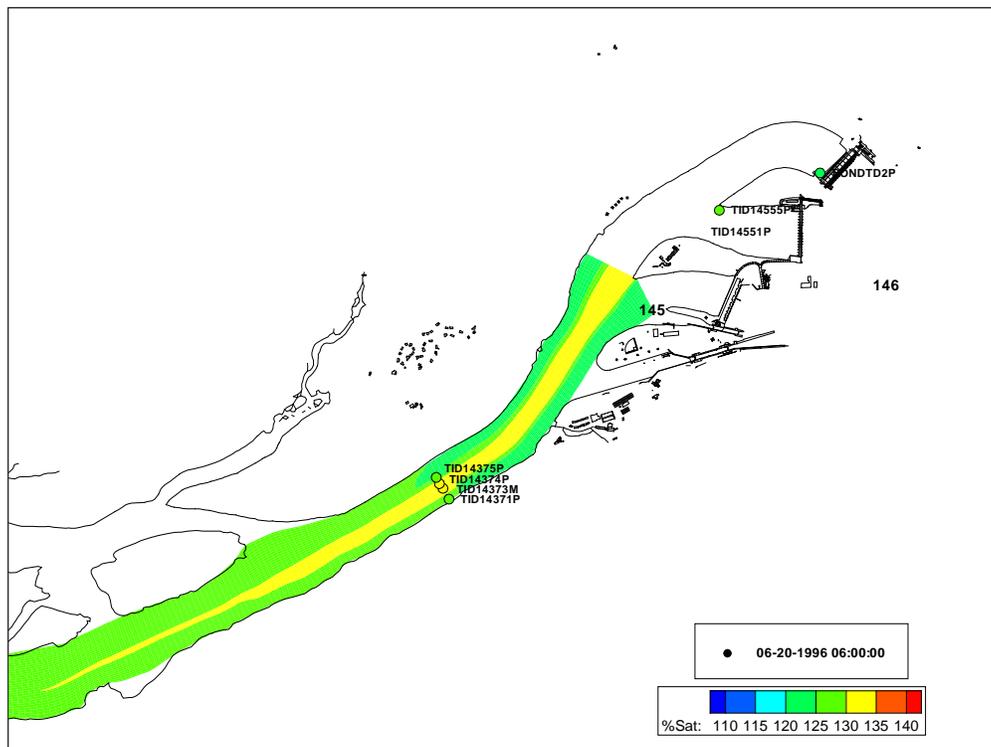


Figure 92. Spatial distribution of dissolved gas near Columbia river mile 145 during the Spring 1996 study period.

1.4.2 Summer 1996 Simulation

Boundary Conditions using Bonneville Sourcing Function and Forebay FMS Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.

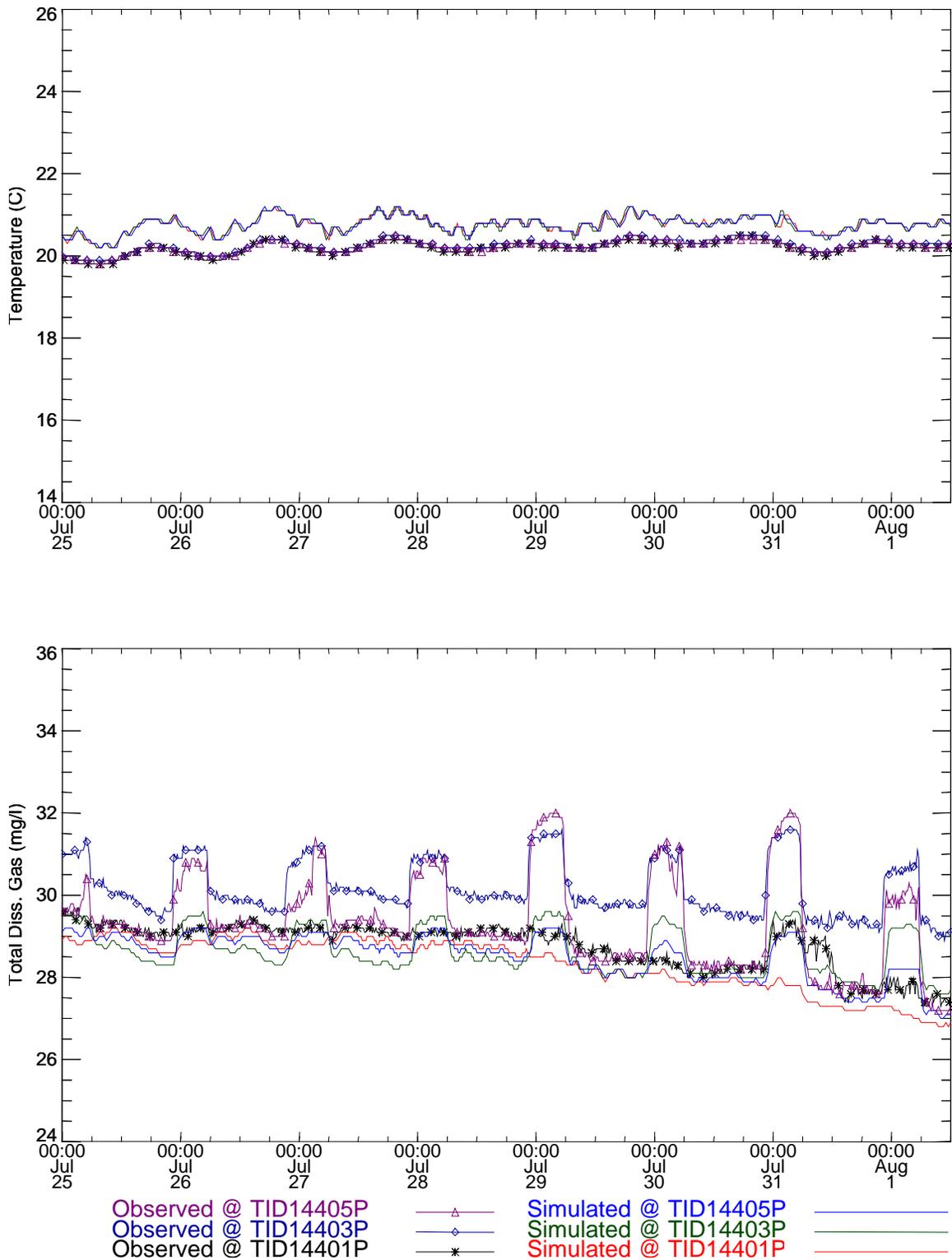


Figure 93. Temperature and total dissolved gas time series near Columbia River mile 144.0 for the Summer 1996 study (FMS-BC).

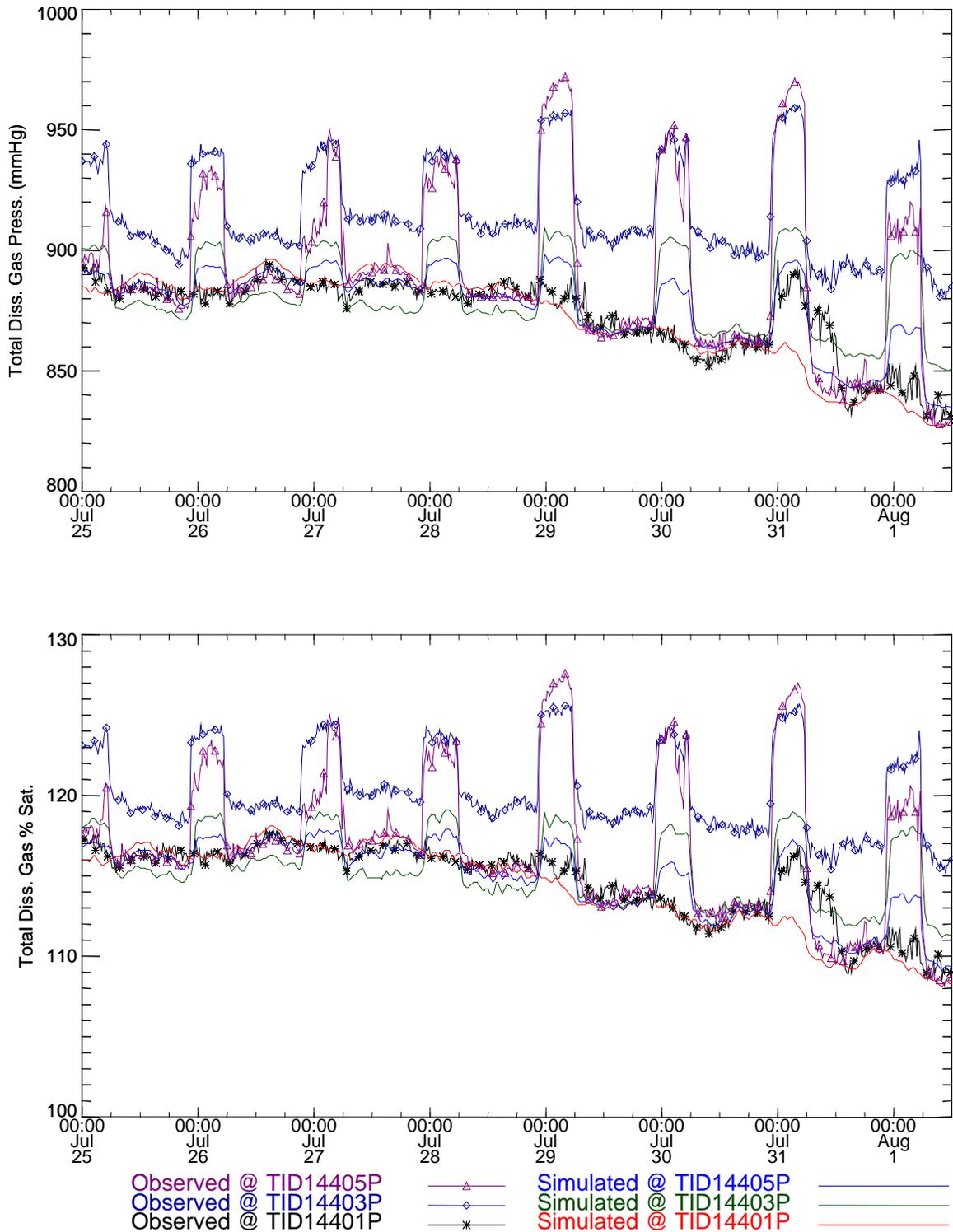


Figure 94. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 144.0 for the Summer 1996 study period (FMS-BC).

Table 39. Statistical summary of measurements and simulations near Columbia River mile 144.0 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14401P	20.2	20.78	0.15	0.2	0.59
TID14403P	20.27	20.77	0.14	0.2	0.52
TID14405P	20.24	20.77	0.14	0.2	0.55
Concentration					
TID14401P	28.82	28.4	0.53	0.61	0.51
TID14403P	30.21	28.65	0.65	0.54	1.59
TID14405P	29.42	28.56	1.14	0.52	1.18
Gas Pressure					
TID14401P	875.11	873.83	15.01	18.3	8.86
TID14403P	917.37	881.08	19.38	15.71	37.09
TID14405P	893.39	878.51	33.79	15.27	28.12
% Saturation					
TID14401P	114.91	114.48	2.17	2.6	1.2
TID14403P	120.45	115.43	2.59	2.14	5.13
TID14405P	117.3	115.1	4.5	2.16	3.85

Table 40. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 144.0 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID14401P	100	95.19	99.78	99.56
TID14403P	100	0.88	67.18	52.08
TID14405P	100	71.99	81.18	79.65

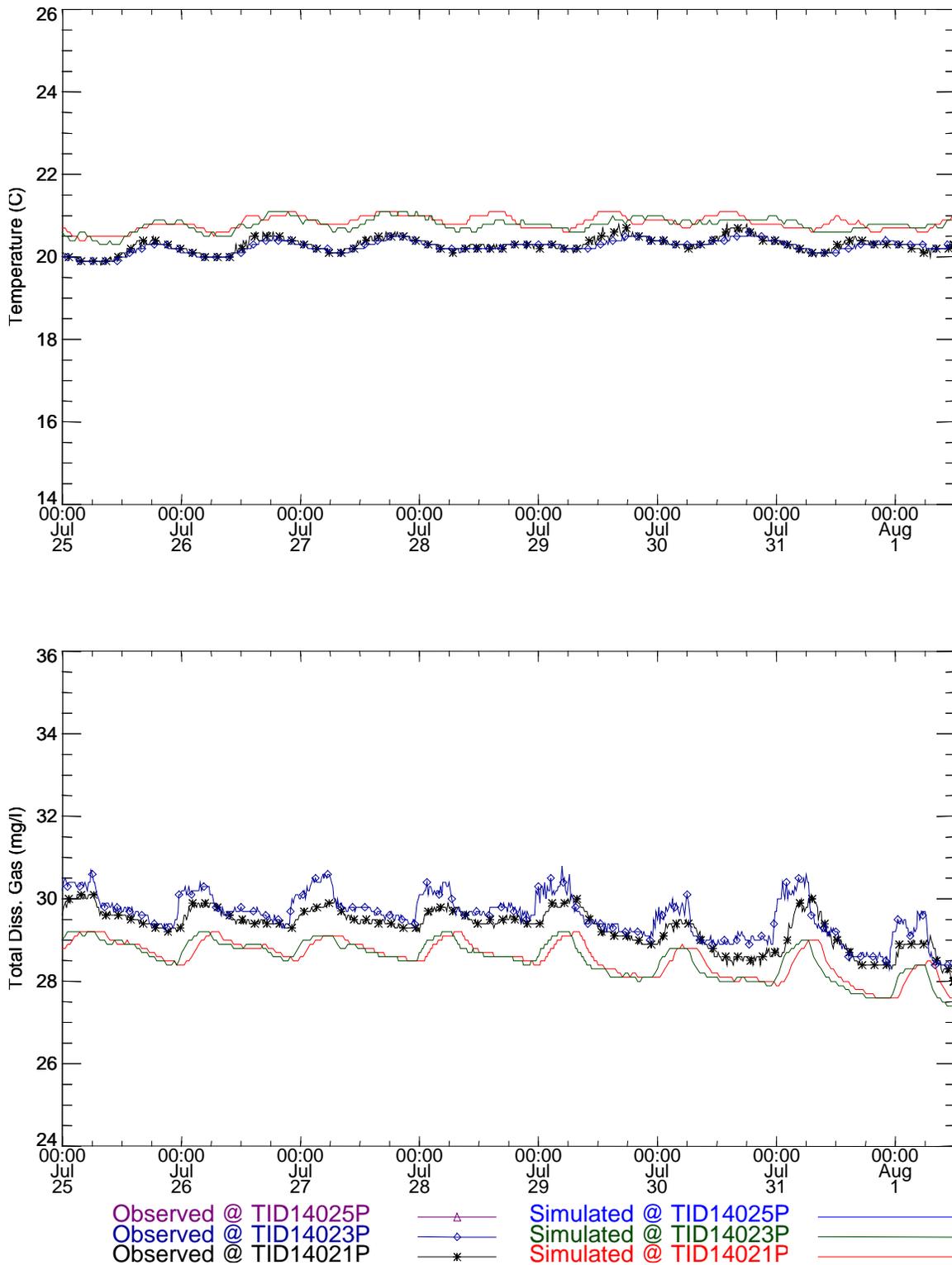


Figure 95. Temperature and total dissolved gas time series near Columbia River mile 140.2 for the Summer 1996 study (FMS-BC).

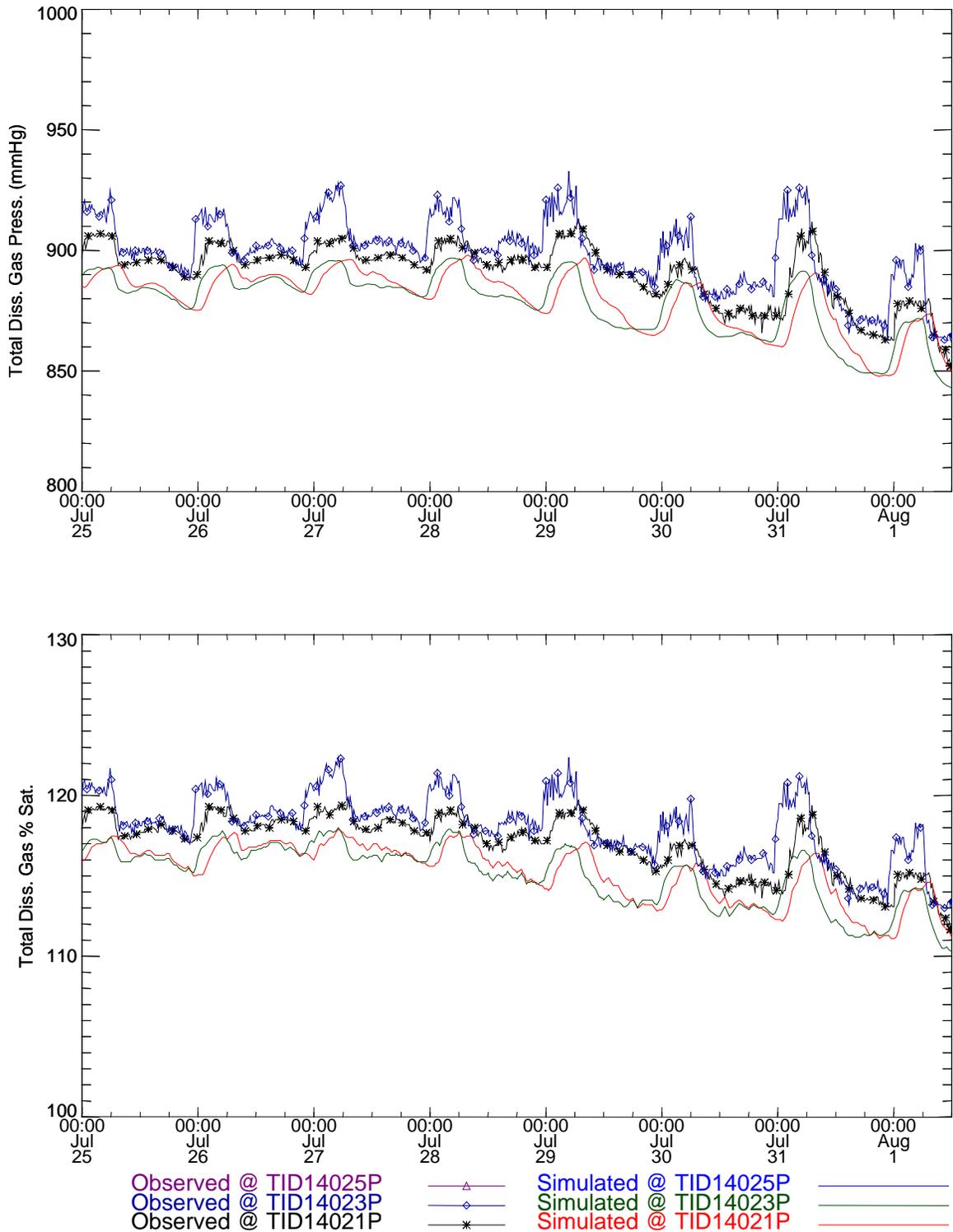


Figure 96. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 140.2 for the Summer 1996 study period (FMS-BC).

Table 41. Statistical summary of measurements and simulations near Columbia River mile 140.2 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14021P	20.29	20.82	0.18	0.17	0.55
TID14023P	20.25	20.78	0.15	0.17	0.54
Concentration					
TID14021P	29.32	28.57	0.46	0.42	0.77
TID14023P	29.6	28.55	0.52	0.45	1.07
Gas Pressure					
TID14021P	891.13	879.69	12.26	12.32	12.65
TID14023P	899.03	878.25	14.44	13	21.62
% Saturation					
TID14021P	117	115.27	1.8	1.77	1.89
TID14023P	118.04	115.08	2.05	1.88	3.07

Table 42. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 140.2 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID14021P	100	93.75	100	100
TID14023P	100	54.86	98.75	97.78

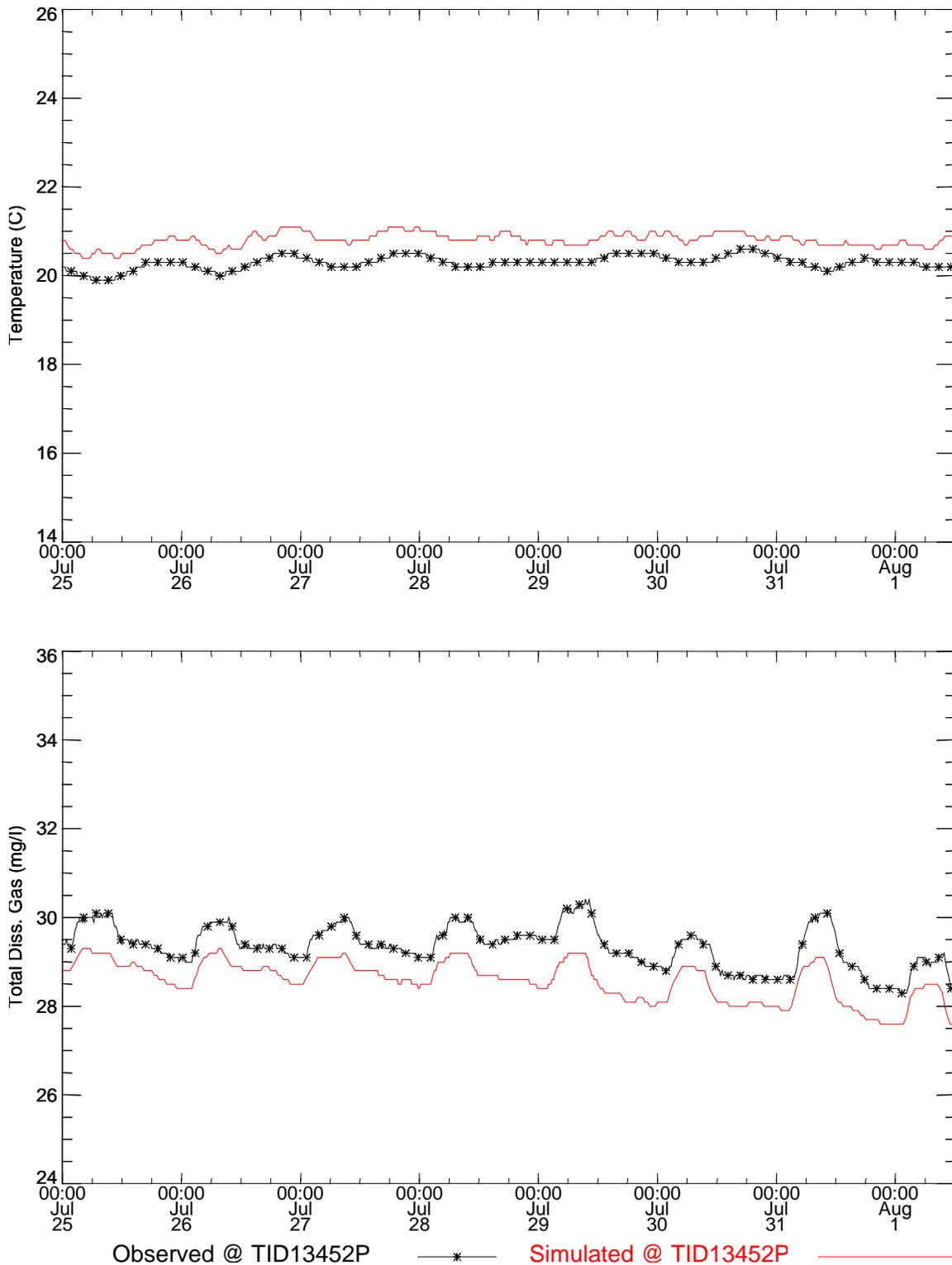


Figure 97. Temperature and total dissolved gas time series near Columbia River mile 134.5 for the Summer 1996 study (FMS-BC).

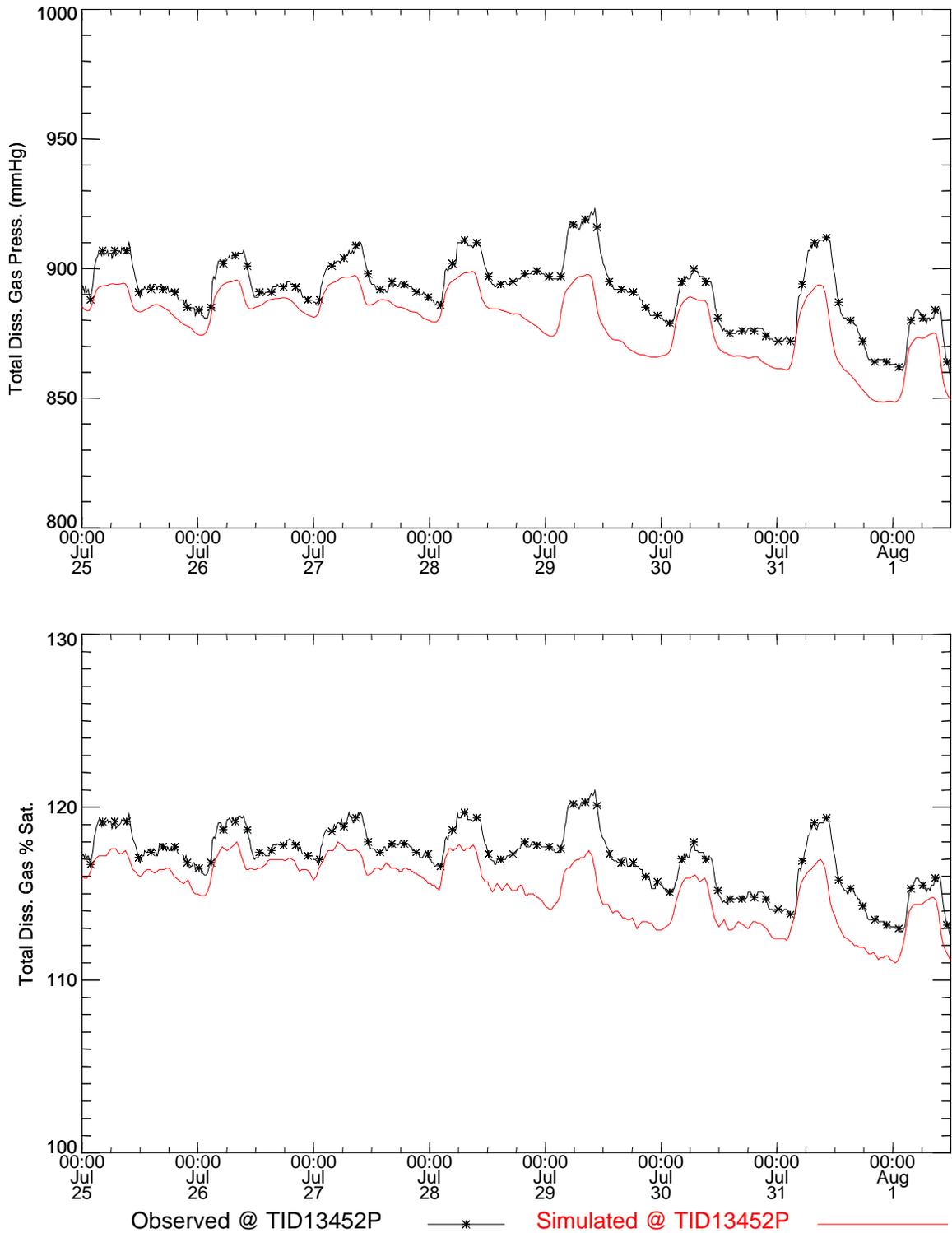


Figure 98. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 134.5 for the Summer 1996 study period (FMS-BC).

Table 43. Statistical summary of measurements and simulations near Columbia River mile 134.5 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID13452P	20.3	20.81	0.15	0.16	0.52
Concentration TID13452P	29.33	28.58	0.47	0.44	0.77
Gas Pressure TID13452P	891.75	879.7	12.81	12.7	13.43
% Saturation TID13452P	117.09	115.27	1.78	1.82	1.99

Table 44. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 134.5 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID13452P	100	91.12	100	100

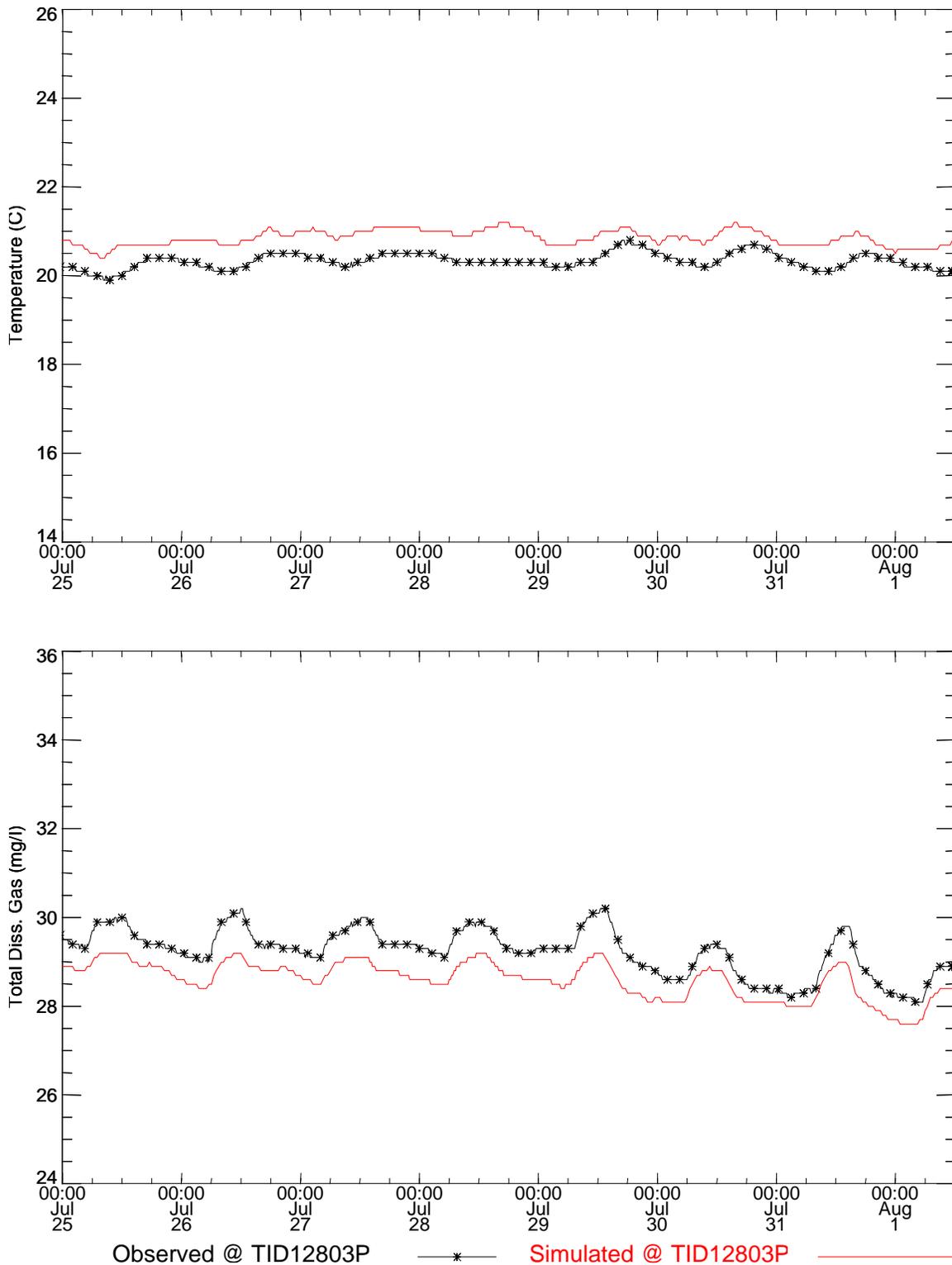


Figure 99. Temperature and total dissolved gas time series near Columbia River mile 128.0 for the Summer 1996 study (FMS-BC).

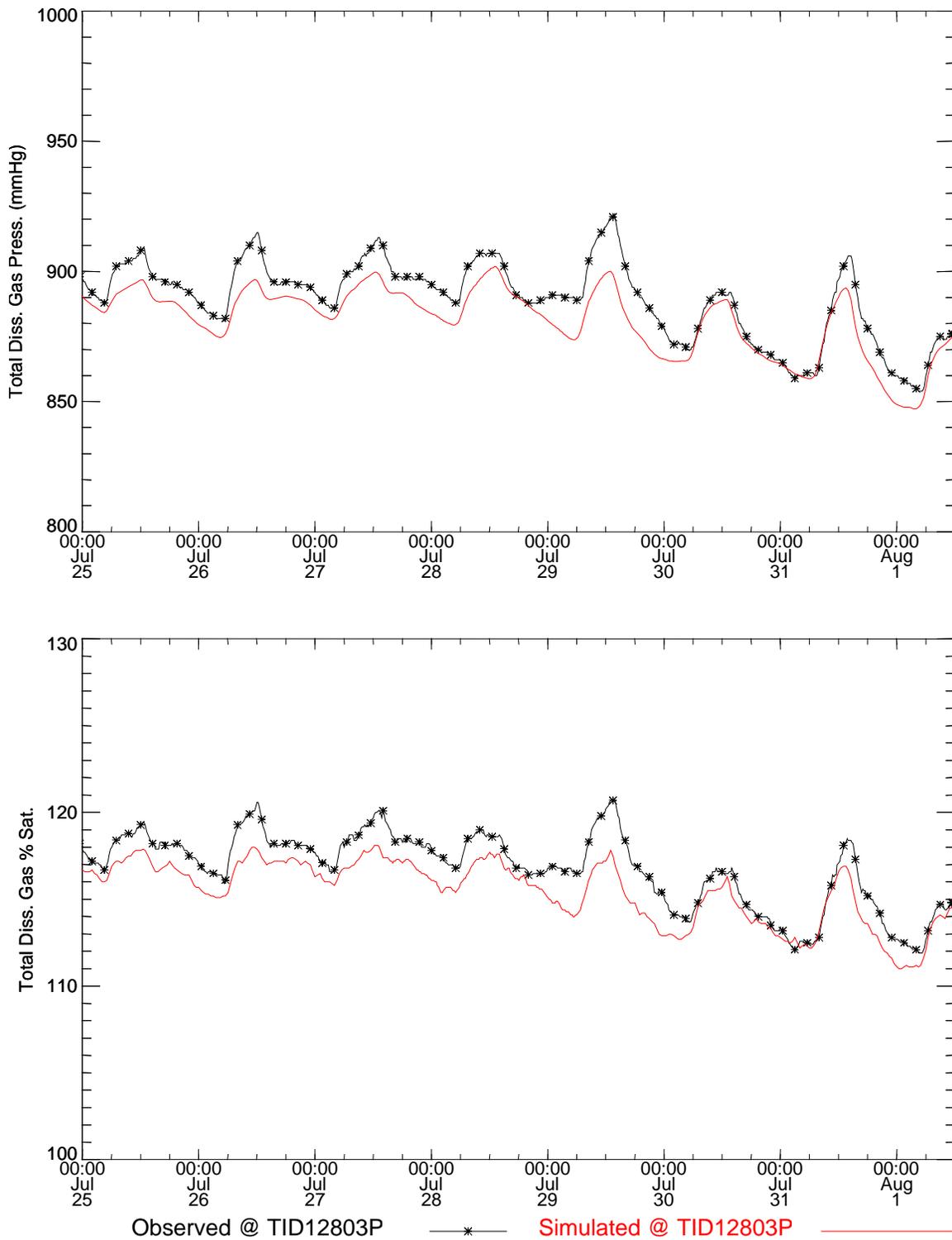


Figure 100. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 128.0 for the Summer 1996 study period (FMS-BC).

Table 45. Statistical summary of measurements and simulations near Columbia River mile 128.0 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID12803P	20.33	20.85	0.17	0.17	0.54
Concentration TID12803P	29.23	28.6	0.52	0.41	0.65
Gas Pressure TID12803P	889.28	881.14	14.94	12.89	9.54
% Saturation TID12803P	116.76	115.46	2.13	1.82	1.49

Table 46. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 128.0 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12803P	100	99.03	100	100

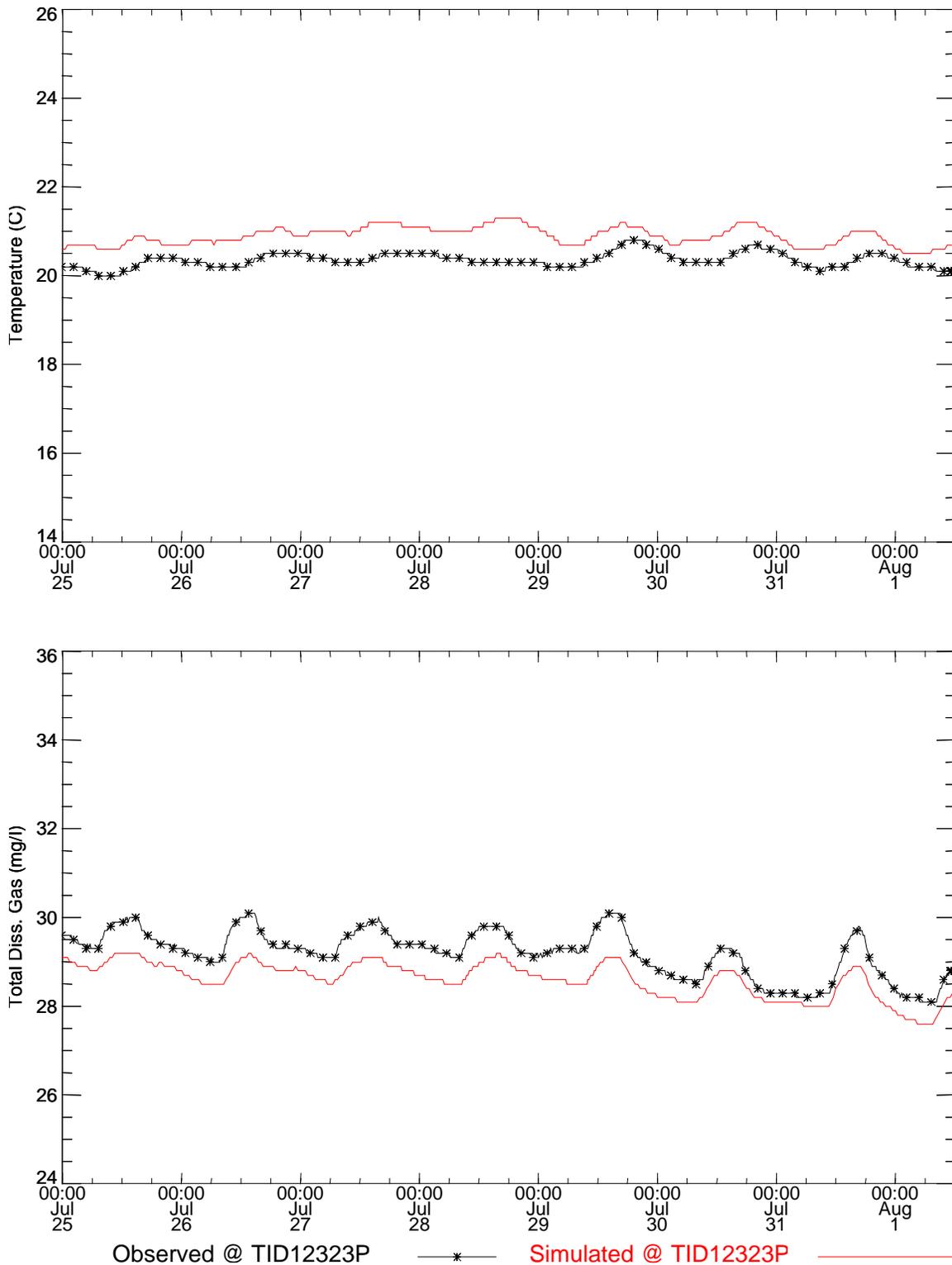


Figure 101. Temperature and total dissolved gas time series near Columbia River mile 123.2 for the Summer 1996 study (FMS-BC).

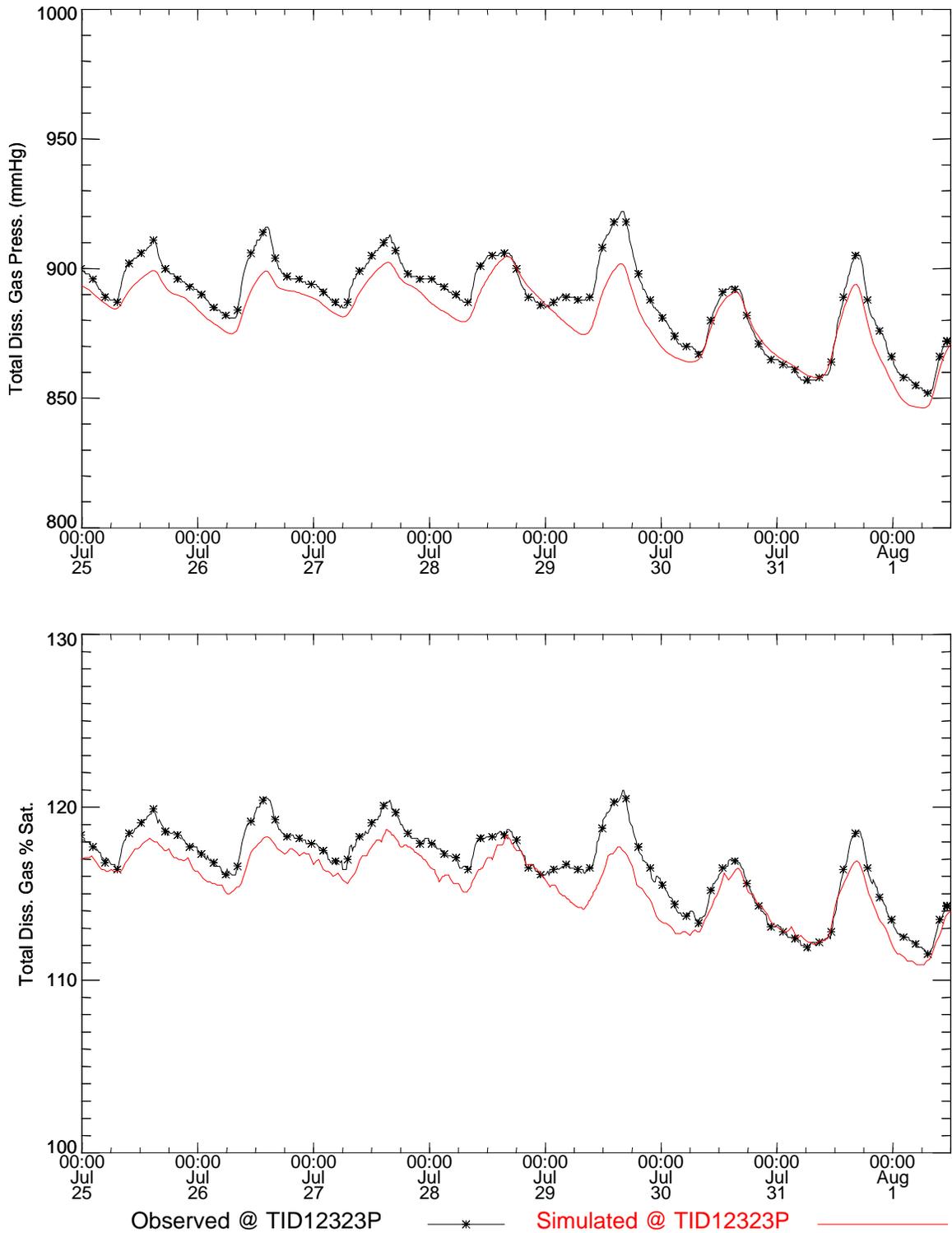


Figure 102. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 123.2 for the Summer 1996 study period (FMS-BC).

Table 47. Statistical summary of measurements and simulations near Columbia River mile 123.2 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID12323P	20.36	20.9	0.17	0.2	0.57
Concentration TID12323P	29.19	28.61	0.53	0.4	0.61
Gas Pressure TID12323P	888.59	882.05	15.92	13.83	8.32
% Saturation TID12323P	116.67	115.58	2.28	1.95	1.32

Table 48. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 144.0 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12323P	100	100	100	100

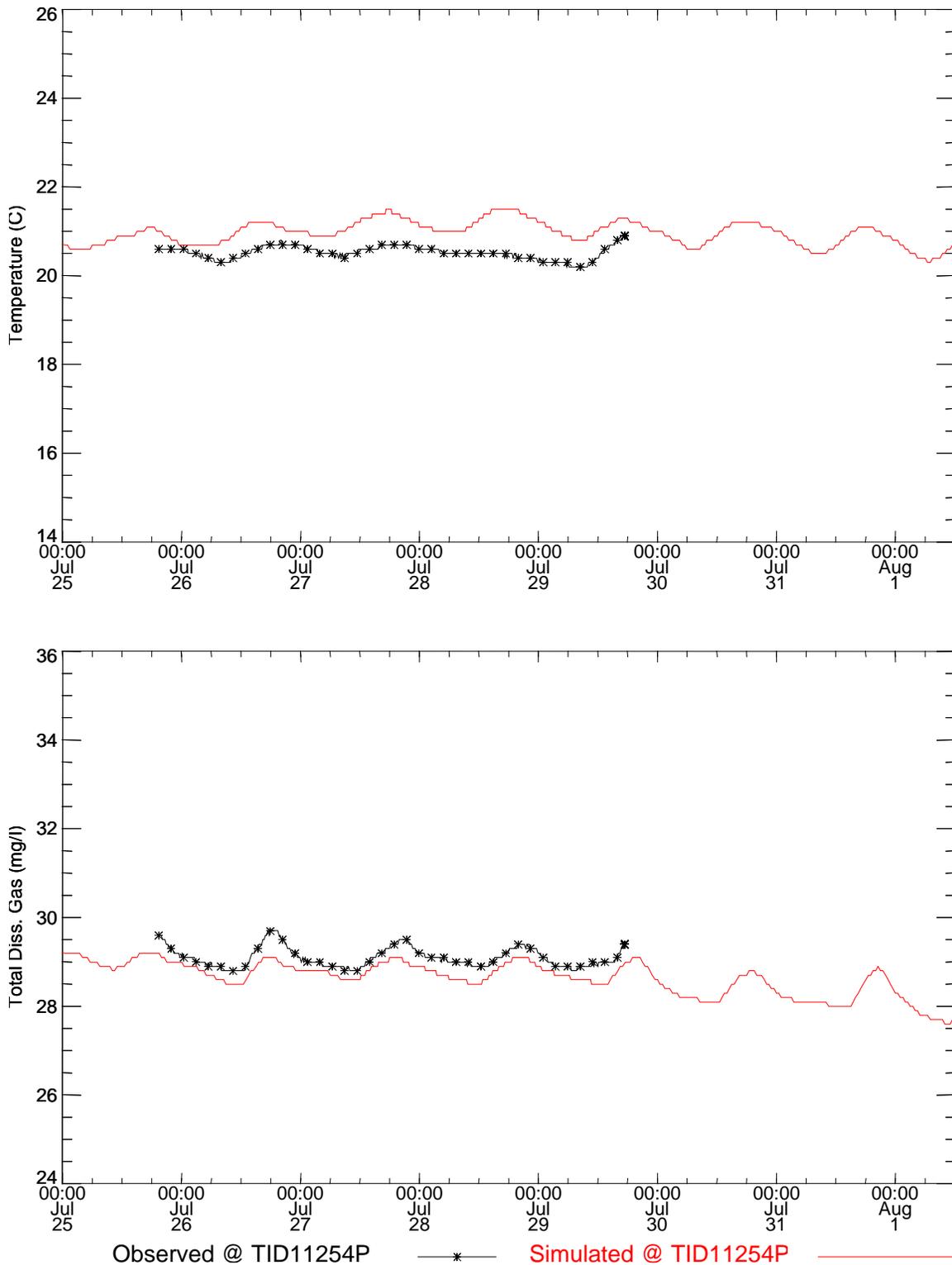


Figure 103. Temperature and total dissolved gas time series near Columbia River mile 112.5 for the Summer 1996 study (FMS-BC).

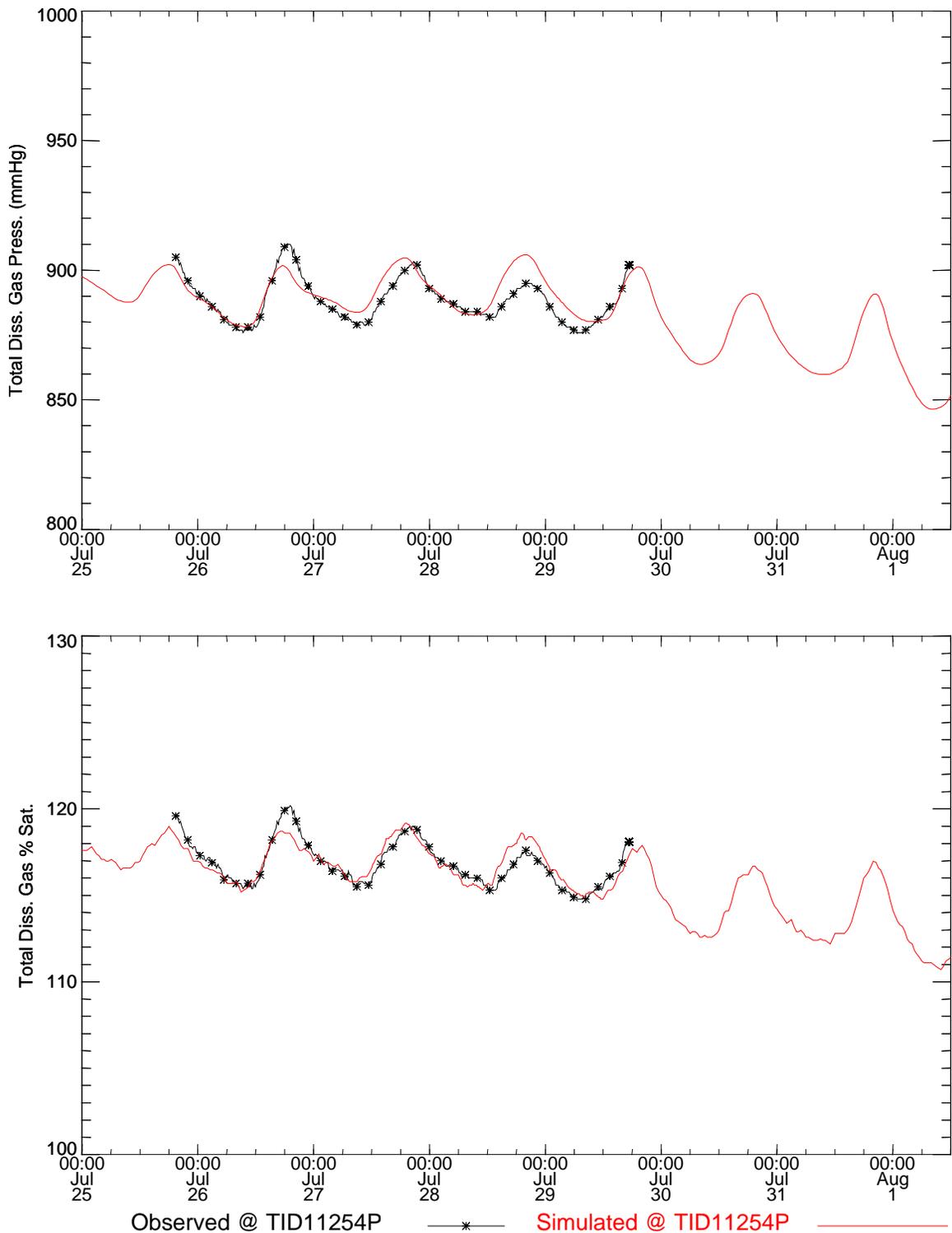


Figure 104. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 112.5 for the Summer 1996 study period (FMS-BC).

Table 49. Statistical summary of measurements and simulations near Columbia River mile 112.5 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID11254P	20.52	21.09	0.15	0.23	0.61
Concentration TID11254P	29.1	28.79	0.22	0.19	0.33
Gas Pressure TID11254P	888.42	890.51	8.19	7.74	5.31
% Saturation TID11254P	116.84	116.81	1.26	1.14	0.62

Table 50. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 112.5 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID11254P	98.41	100	100	100

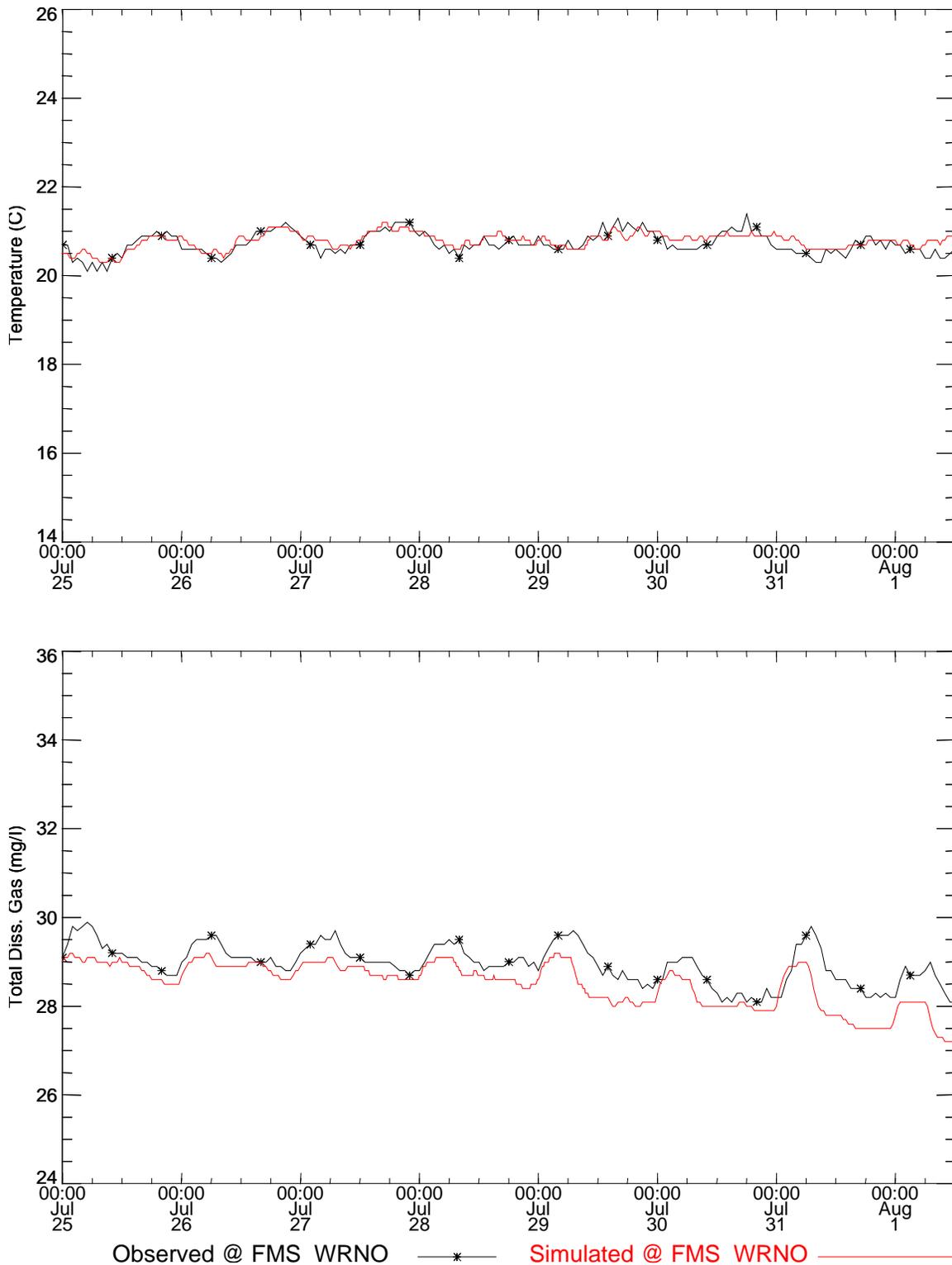


Figure 105. Temperature and total dissolved gas time series near fixed monitor WRNO for the Summer 1996 study (FMS-BC).

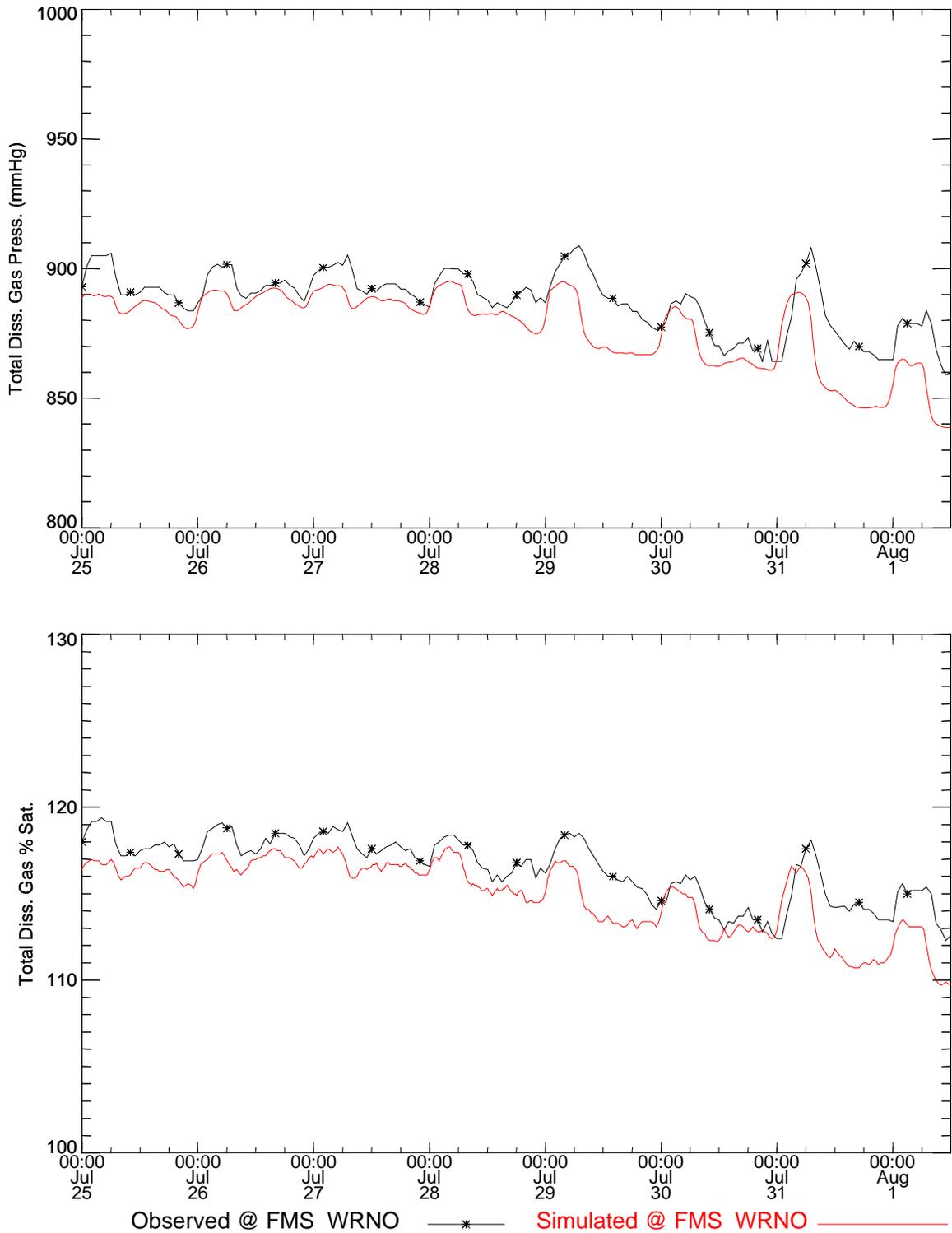


Figure 106. Total dissolved gas pressure and saturation time series comparisons near fixed monitor WRNO for the Summer 1996 study period (FMS-BC).

Table 51. Statistical summary of measurements and simulations near fixed monitor WRNO for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_WRNO	20.74	20.8	0.23	0.18	0.16
Concentration FMS_WRNO	28.99	28.56	0.41	0.47	0.52
Gas Pressure FMS_WRNO	888.87	878.84	10.96	13.73	12.91
% Saturation FMS_WRNO	116.63	115.14	1.69	1.97	1.8

Table 52. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor WRNO for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_WRNO	100	96.5	100	100

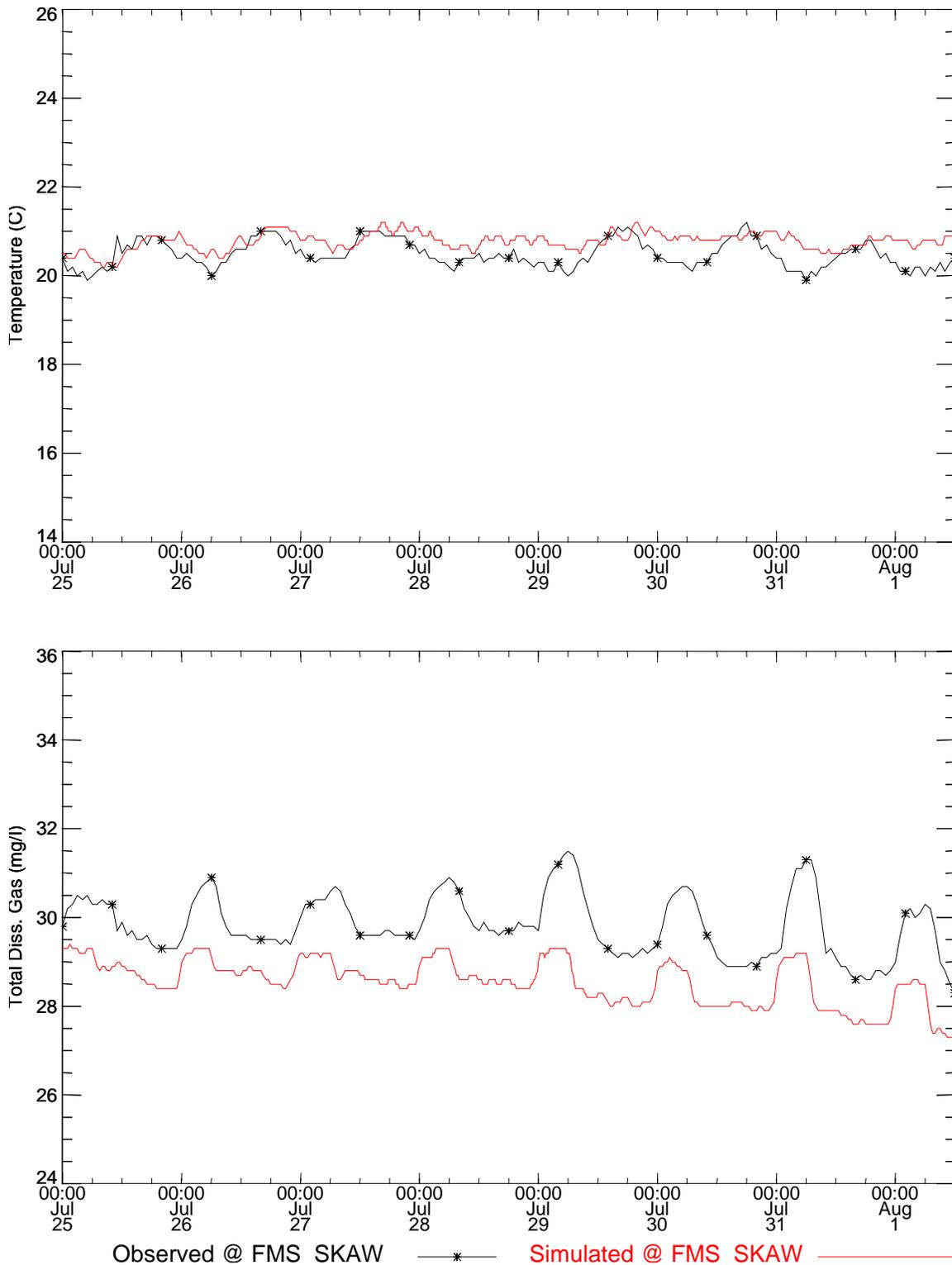


Figure 107. Temperature and total dissolved gas time series near fixed monitor SKAW for the Summer 1996 study (FMS-BC).

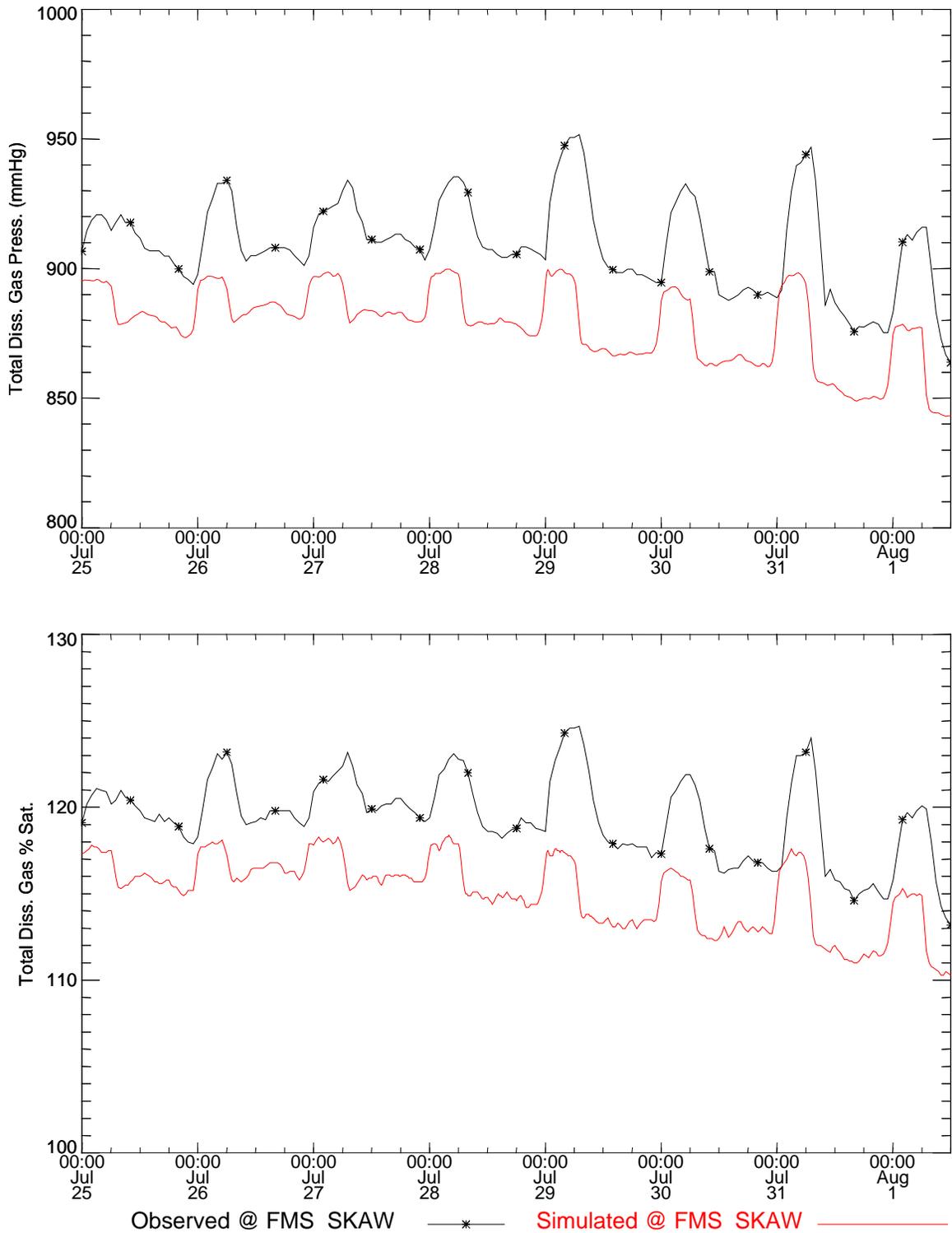


Figure 108. Total dissolved gas pressure and saturation time series comparisons near fixed monitor SKAW for the Summer 1996 study period (FMS-BC).

Table 53. Statistical summary of measurements and simulations near fixed monitor SKAW for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_SKAW	20.48	20.79	0.3	0.19	0.39
Concentration FMS_SKAW	29.88	28.59	0.67	0.48	1.38
Gas Pressure FMS_SKAW	911.33	879.42	17.24	13.85	34.23
% Saturation FMS_SKAW	119.66	115.21	2.32	1.95	4.74

Table 54. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor SKAW for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_SKAW	100	29.32	78.56	75.49

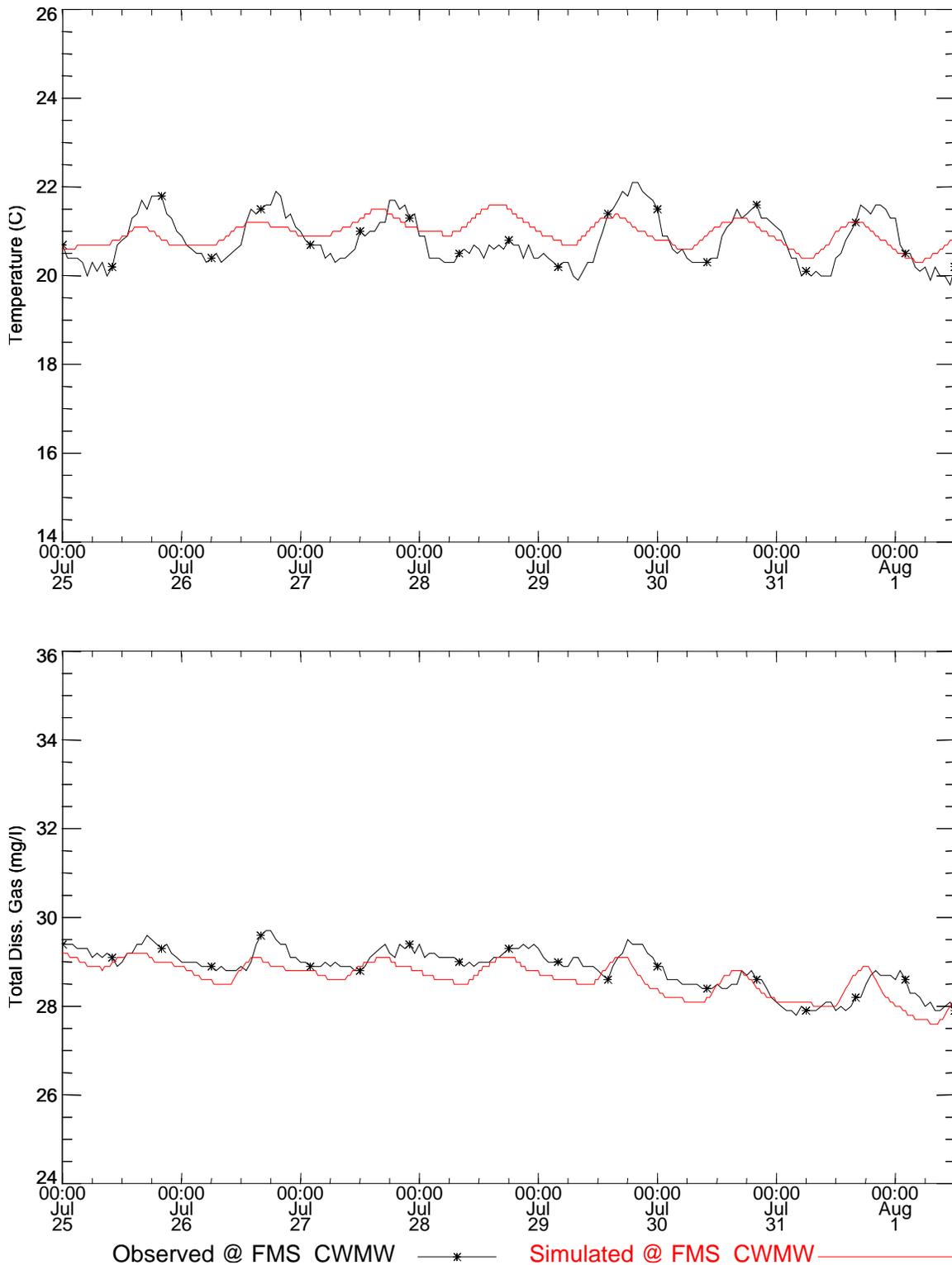


Figure 109. Temperature and total dissolved gas time series near fixed monitor CWMW for the Summer 1996 study (FMS-BC).

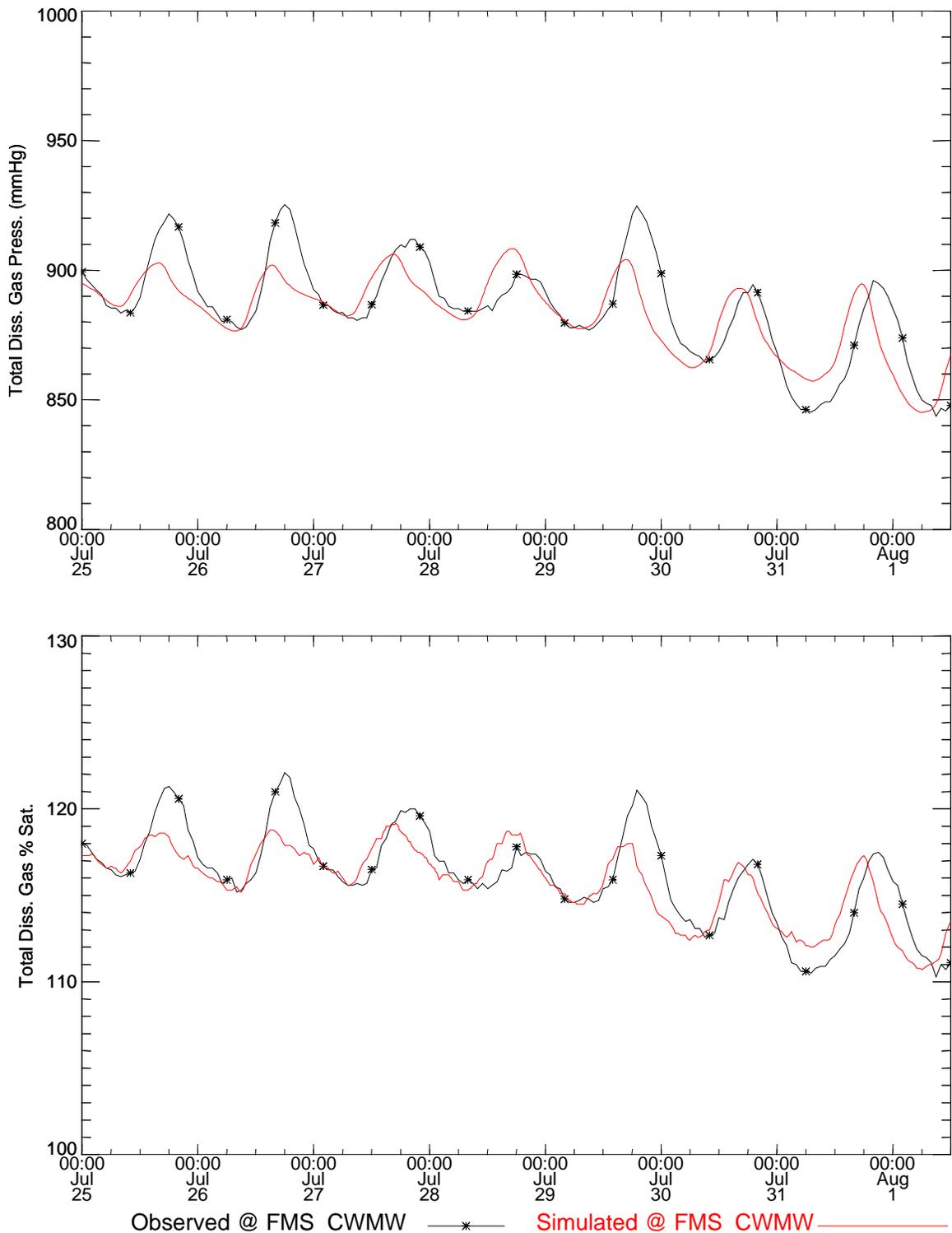


Figure 110. Total dissolved gas pressure and saturation time series comparisons near fixed monitor CWMW for the Summer 1996 study period (FMS-BC).

Table 55. Statistical summary of measurements and simulations near fixed monitor CWMW for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_CWMW	20.78	21	0.53	0.3	0.53
Concentration FMS_CWMW	28.91	28.66	0.43	0.36	0.36
Gas Pressure FMS_CWMW	887.06	884.98	17.73	14.46	11.6
% Saturation FMS_CWMW	116.25	115.94	2.52	2.03	1.53

Table 56. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor CWMW for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_CWMW	99.12	100	100	100

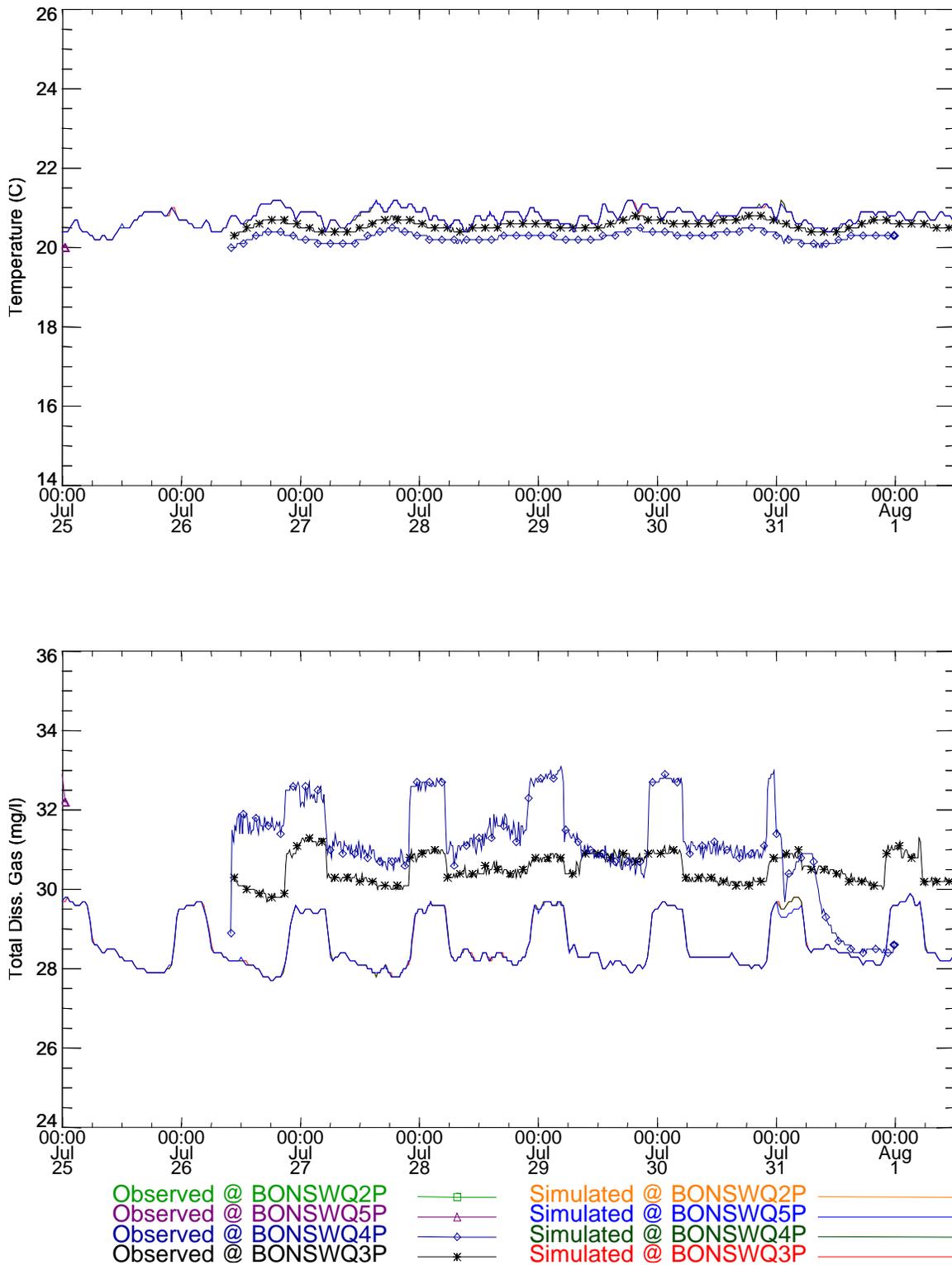


Figure 111. Temperature and total dissolved gas time series near fixed monitor BONSWQ for the Summer 1996 study (FMS-BC).

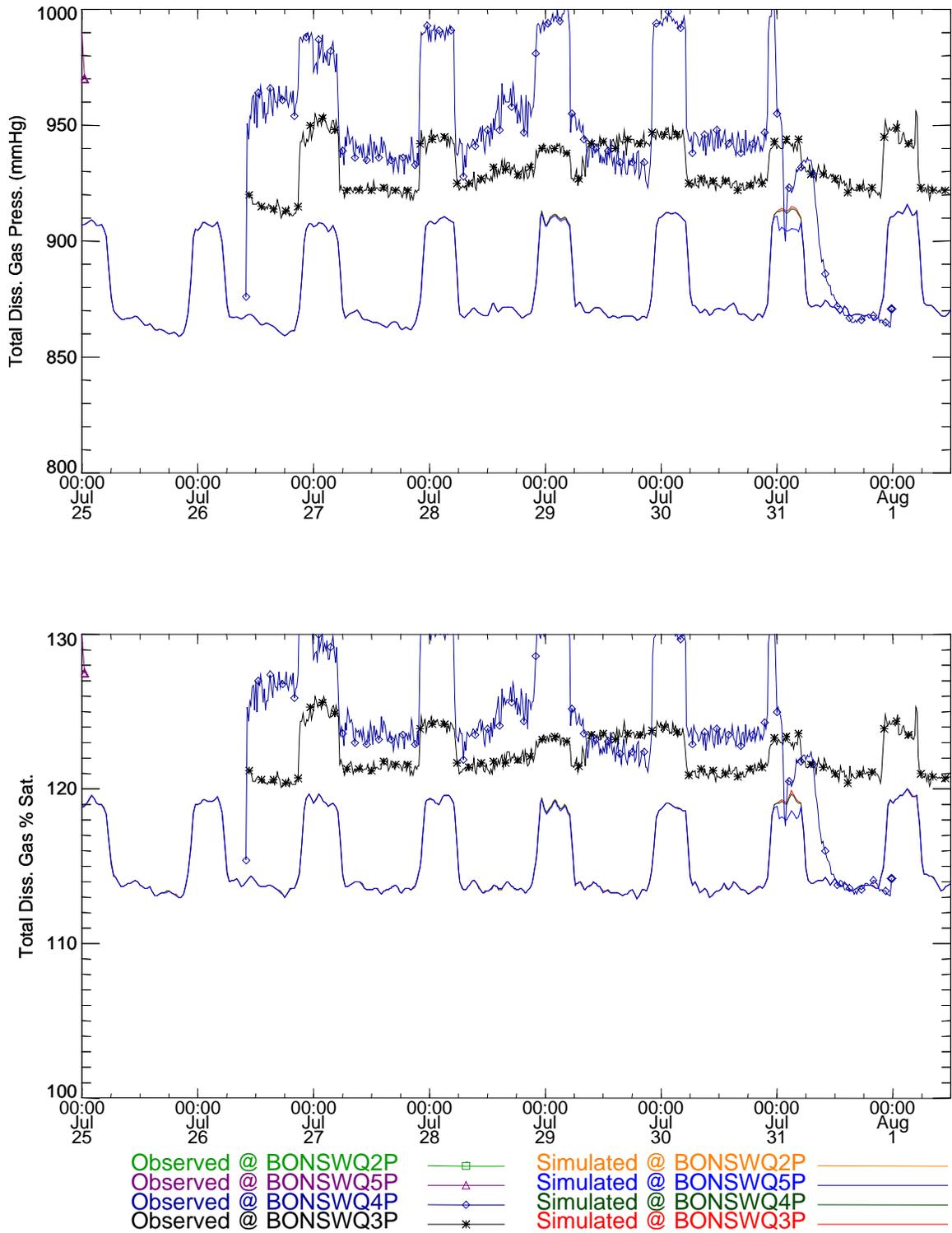


Figure 112. Total dissolved gas pressure and saturation time series comparisons near fixed monitor BONSWQ for the Summer 1996 study period (FMS-BC).

Table 57. Statistical summary of measurements and simulations near fixed monitor BONSWQ for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BONSWQ3P	20.57	20.81	0.11	0.18	0.27
BONSWQ4P	20.28	20.82	0.11	0.18	0.55
BONSWQ5P	20	20.82	0	0.18	0.84
Concentration					
BONSWQ3P	30.51	28.62	0.36	0.63	1.94
BONSWQ4P	30.95	28.62	1.32	0.63	2.66
BONSWQ5P	32.2	28.61	0	0.61	3.64
Gas Pressure					
BONSWQ3P	931.73	880.92	10.76	18.54	52.36
BONSWQ4P	939.78	880.89	39.13	18.51	69.9
BONSWQ5P	970	880.59	0	18.05	91.21
% Saturation					
BONSWQ3P	122.25	115.34	1.4	2.43	7.11
BONSWQ4P	123.32	115.34	5.25	2.43	9.44
BONSWQ5P	127.5	115.3	0	2.37	12.43

Table 58. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor BONSWQ for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
BONSWQ3P	100	1.57	22.26	18.43
BONSWQ4P	100	17.22	17.74	17.91
BONSWQ5P	87.65	0	0	0

Boundary Conditions using Temporary Monitored Field Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.

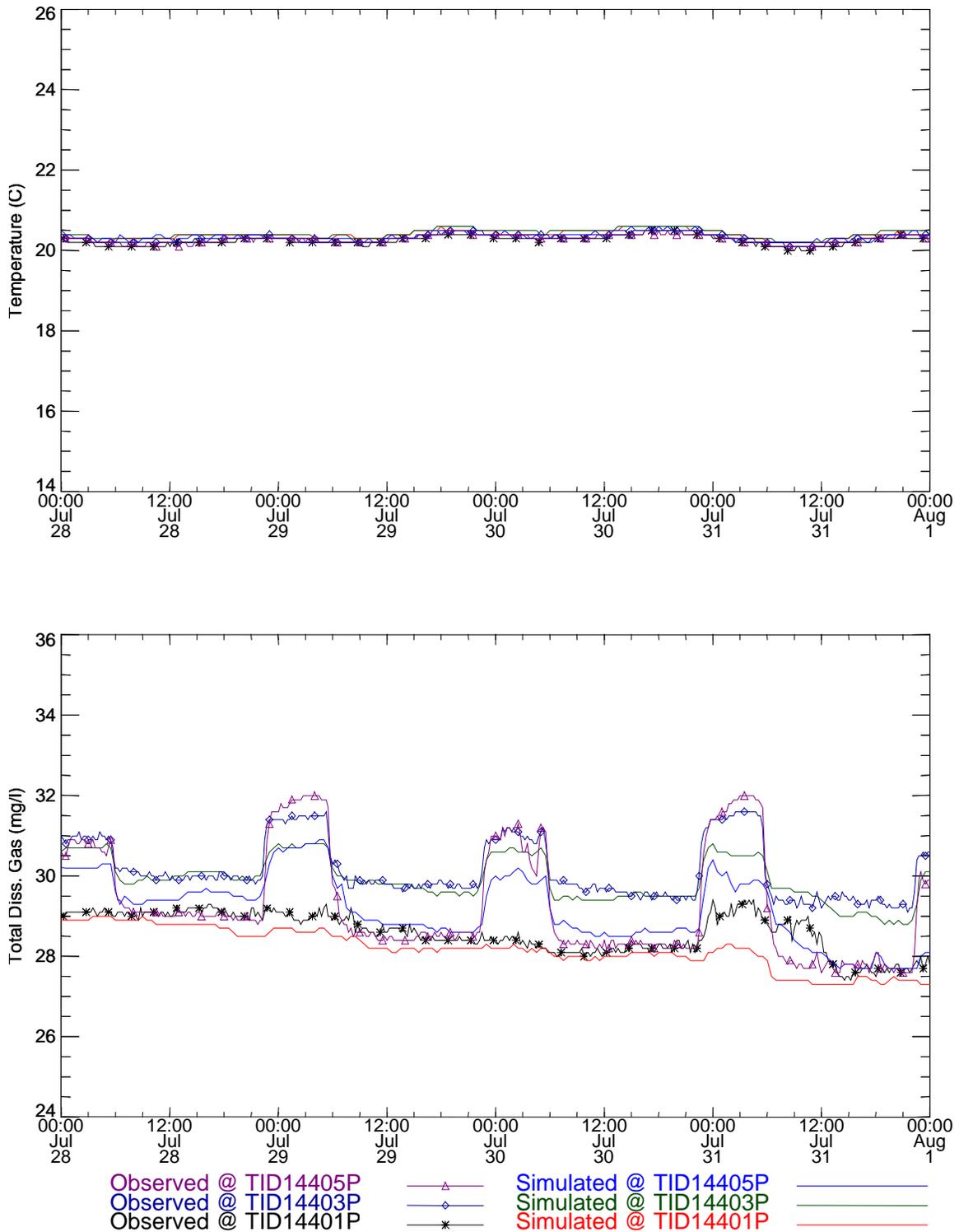


Figure 113. Temperature and total dissolved gas time series near Columbia River mile 144.0 for the Summer 1996 study period (TM-BC).

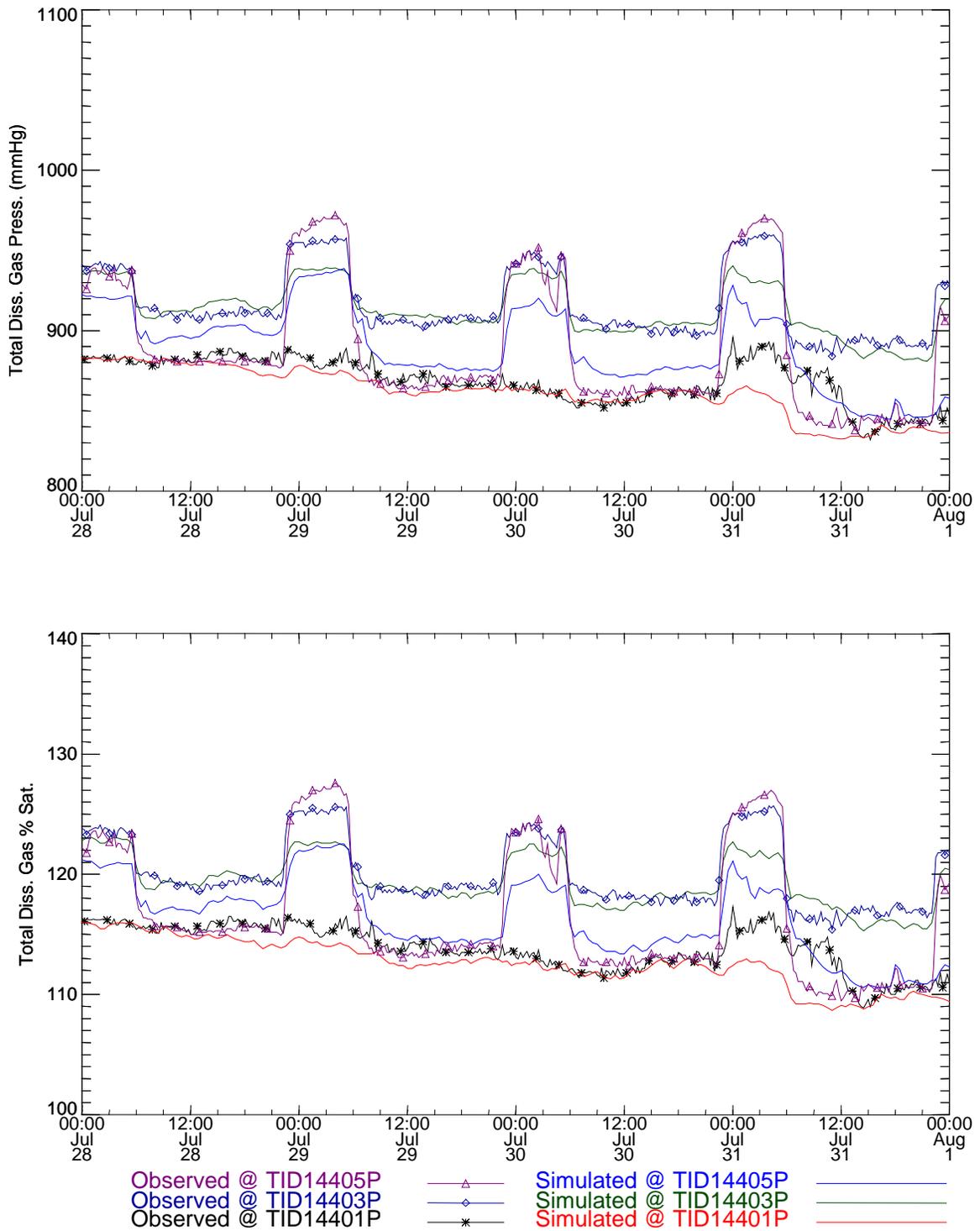


Figure 114. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 144.0 for the Summer 1996 study period (TM-BC).

Table 59. Statistical summary of measurements and simulations near Columbia River Mile 144.0 for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14401P	20.25	20.4	0.12	0.11	0.15
TID14403P	20.32	20.42	0.11	0.11	0.11
TID14405P	20.29	20.34	0.11	0.1	0.1
Concentration					
TID14401P	28.59	28.19	0.5	0.5	0.53
TID14403P	30.15	29.91	0.72	0.55	0.4
TID14405P	29.29	29.16	1.36	0.84	0.76
Gas Pressure					
TID14401P	869.01	861.7	14.31	14.8	12.64
TID14403P	916.54	913.34	21.8	16.18	10.29
TID14405P	890.33	889.41	40.48	24.75	22.63
% Saturation					
TID14401P	113.85	112.63	1.92	1.95	1.77
TID14403P	120.08	119.38	2.89	2.11	1.47
TID14405P	116.64	116.25	5.33	3.22	2.98

Table 60. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 144.0 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID14401P	100	91.19	98.45	98.45
TID14403P	100	96.89	100	100
TID14405P	100	84.97	92.75	91.71

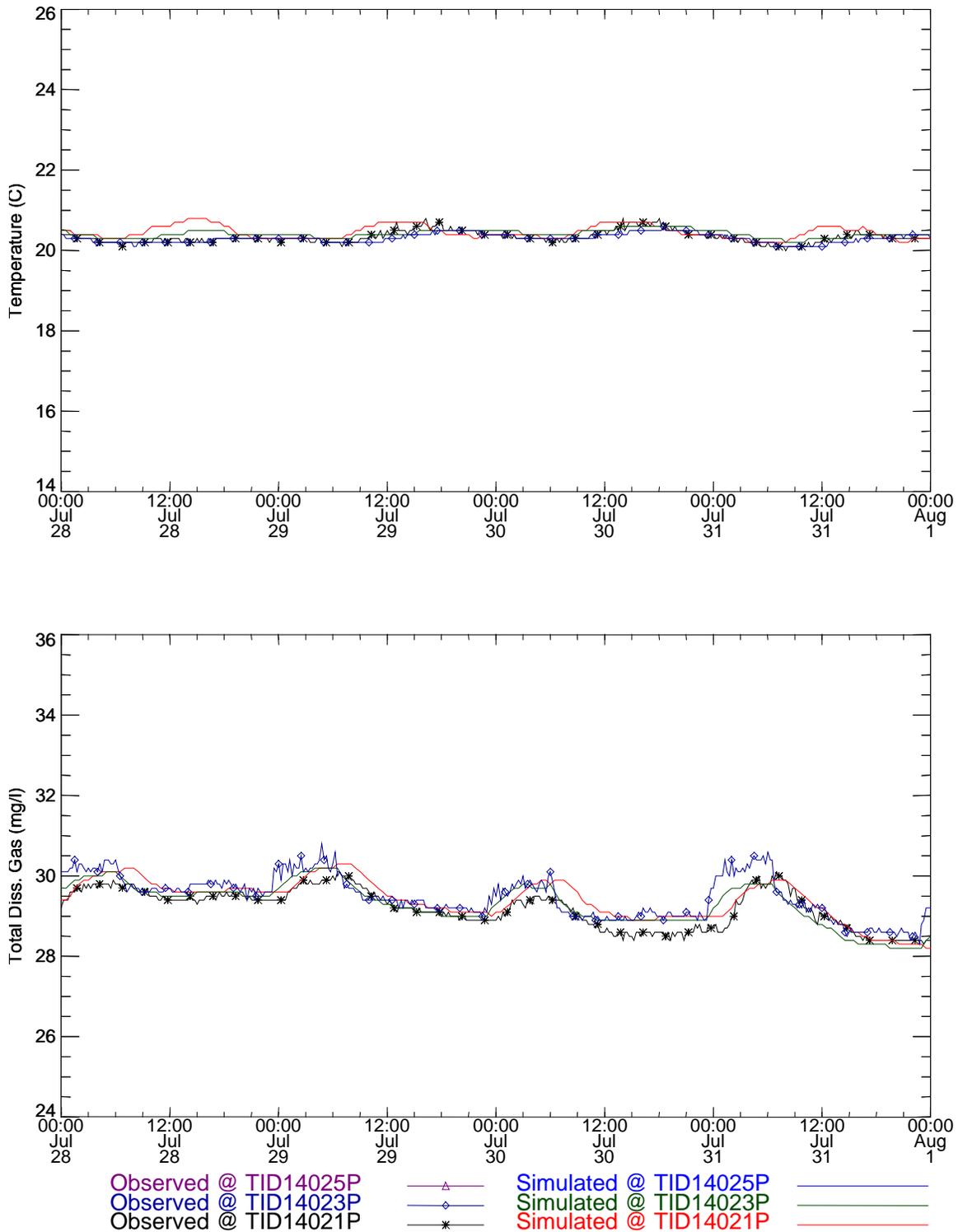


Figure 115. Temperature and total dissolved gas time series near Columbia River mile 140.2 for the Summer 1996 study period (TM-BC).

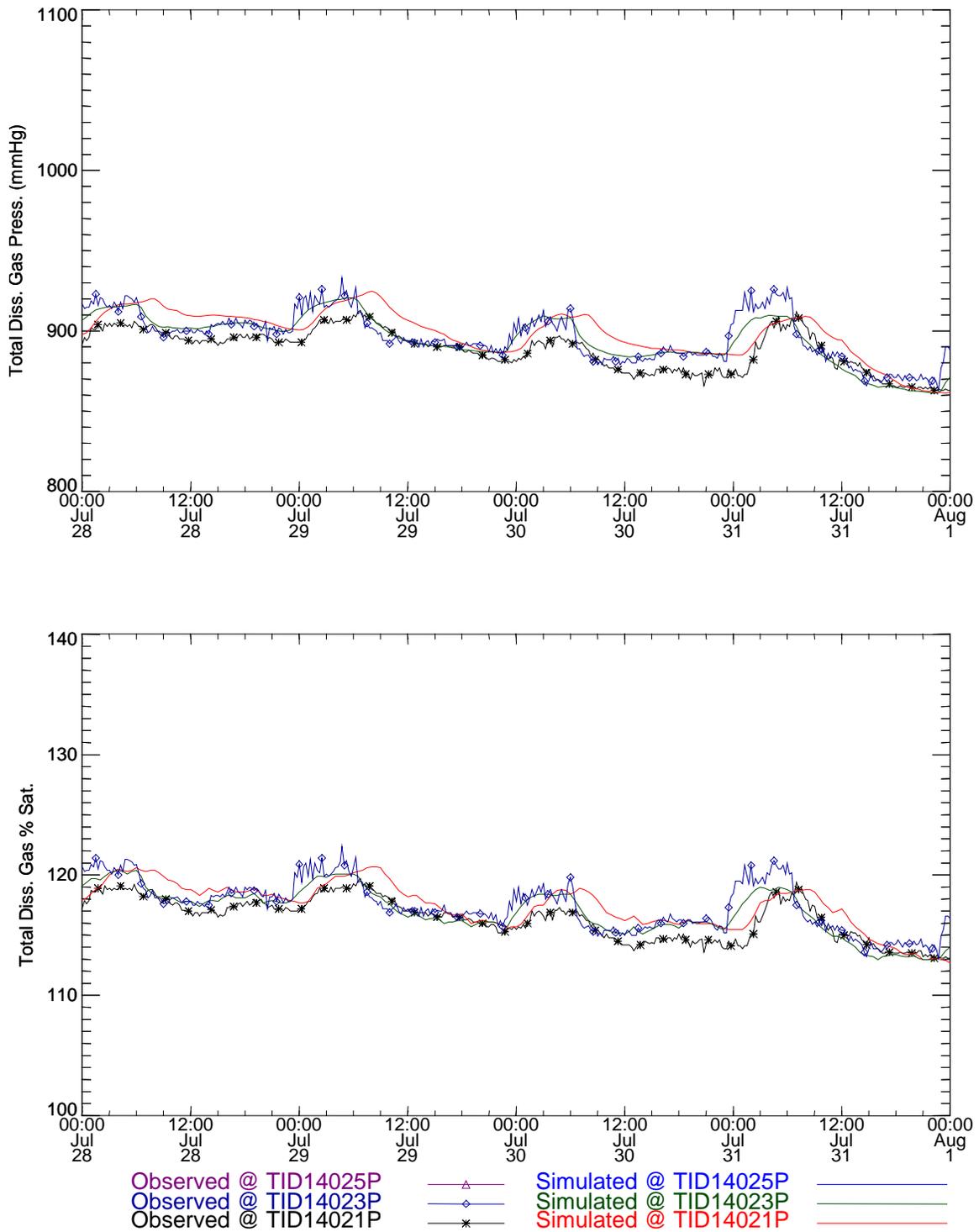


Figure 116. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 140.2 for the Summer 1996 study period (TM-BC).

Table 61. Statistical summary of measurements and simulations near Columbia River Mile 140.2 for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14021P	20.34	20.45	0.15	0.16	0.2
TID14023P	20.31	20.42	0.11	0.09	0.13
Concentration					
TID14021P	29.2	29.41	0.48	0.51	0.28
TID14023P	29.49	29.31	0.53	0.52	0.27
Gas Pressure					
TID14021P	888.52	898.76	12.94	15	11.91
TID14023P	896.66	895.12	15.19	15.17	6.13
% Saturation					
TID14021P	116.4	117.47	1.75	1.94	1.32
TID14023P	117.47	117	2.04	1.98	0.88

Table 62. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 140.2 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID14021P	100	100	100	100
TID14023P	100	100	100	100

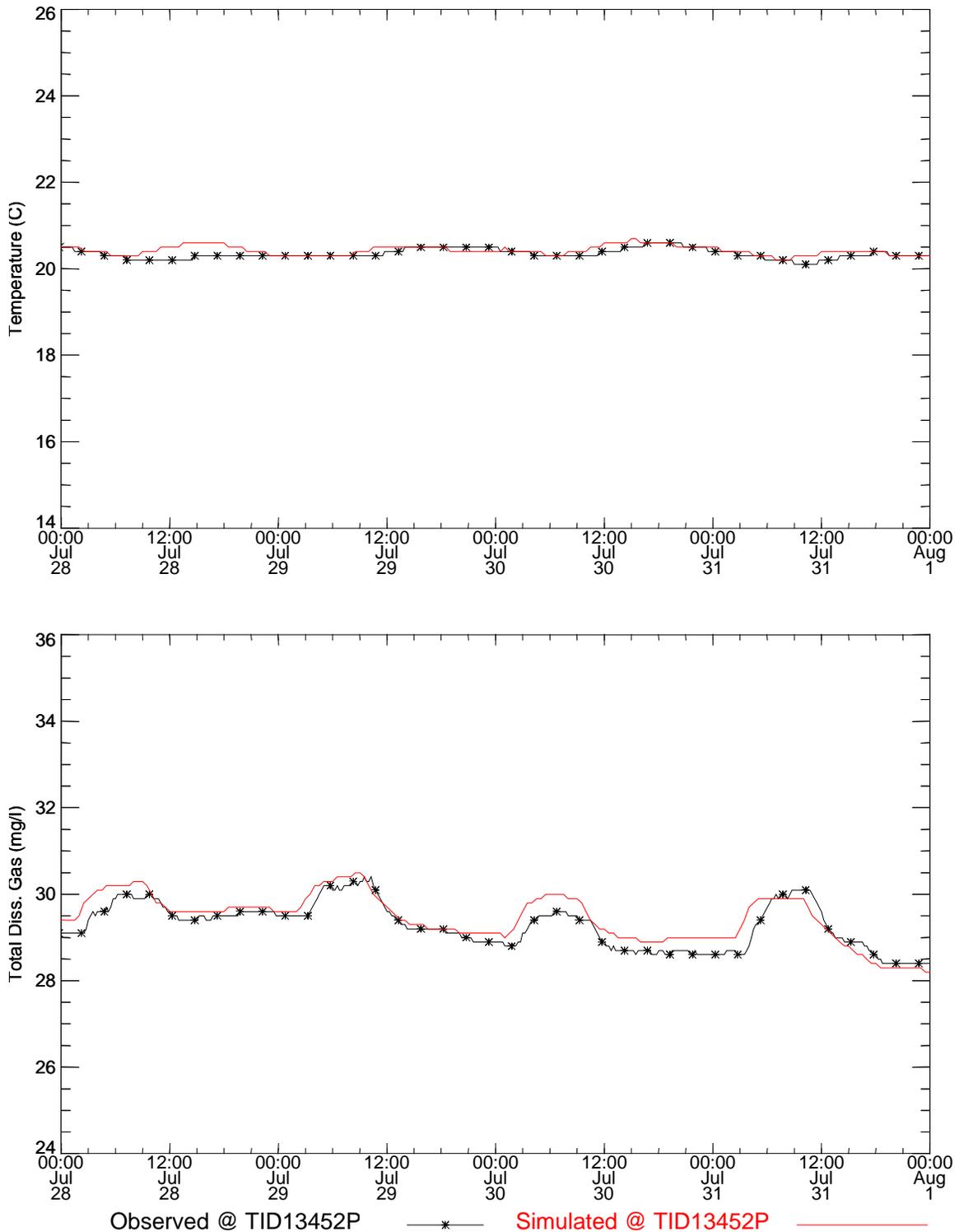


Figure 117. Temperature and total dissolved gas time series near Columbia River mile 134.5 for the Summer 1996 study period (TM-BC).

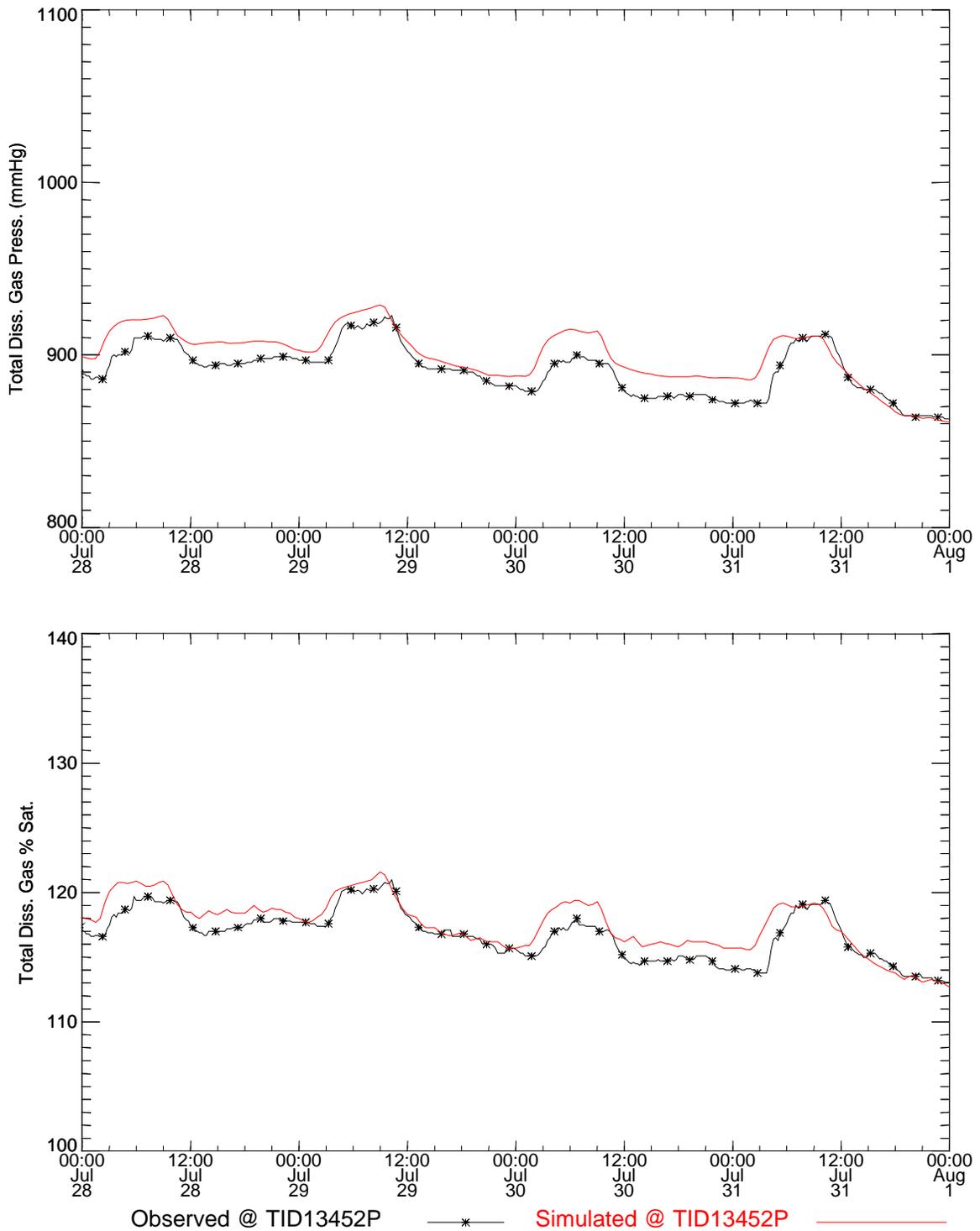


Figure 118. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 134.5 for the Summer 1996 study period (TM-BC).

Table 63. Statistical summary of measurements and simulations near Columbia River Mile 134.5 for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID13452P	20.35	20.42	0.12	0.11	0.13
Concentration TID13452P	29.28	29.45	0.52	0.55	0.29
Gas Pressure TID13452P	891.01	899.58	14.46	15.99	10.98
% Saturation TID13452P	116.73	117.58	1.92	2.06	1.23

Table 64. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 134.5 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID13452P	100	100	100	100

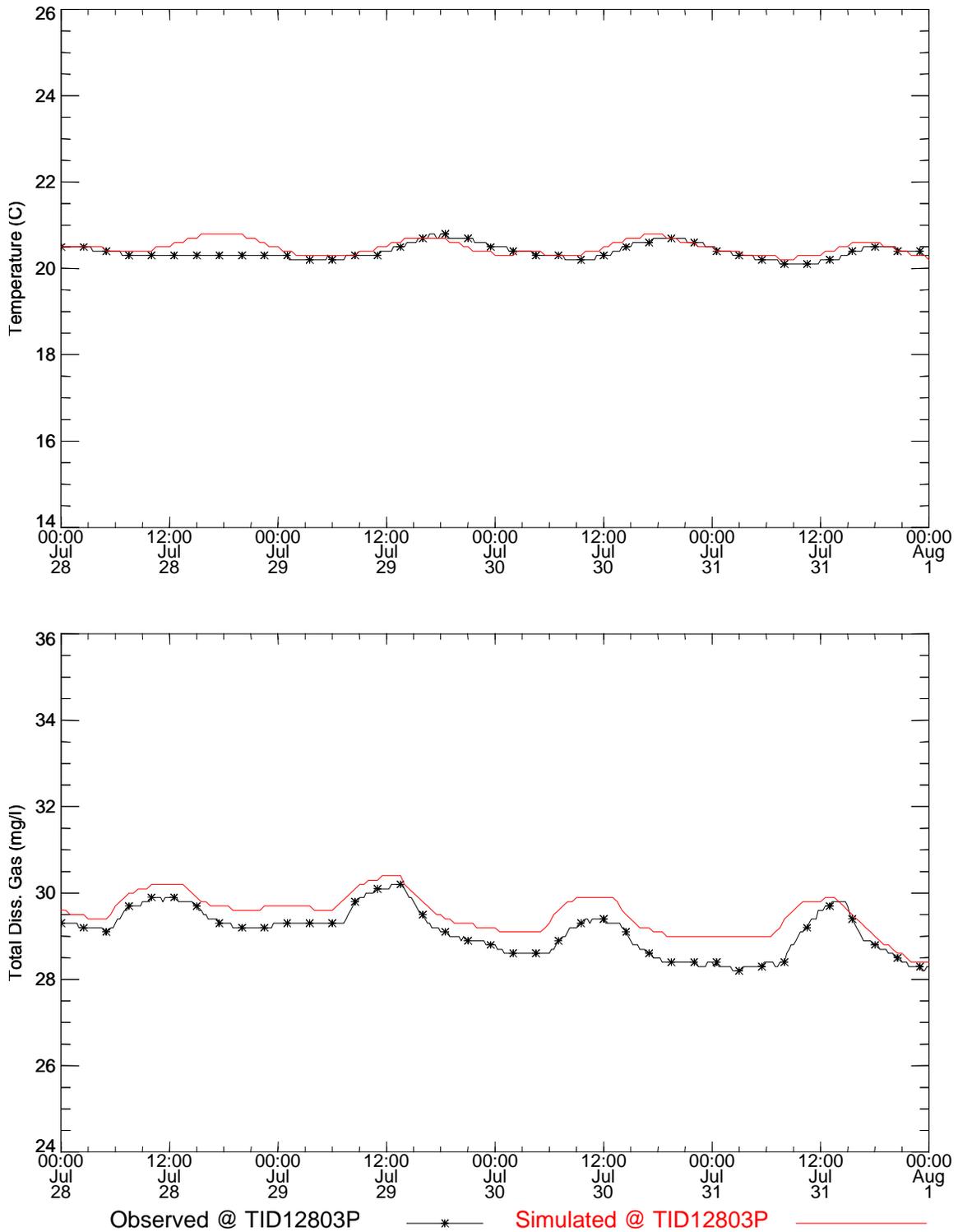


Figure 119. Temperature and total dissolved gas time series near Columbia River mile 128.0 for the Summer 1996 study period (TM-BC).

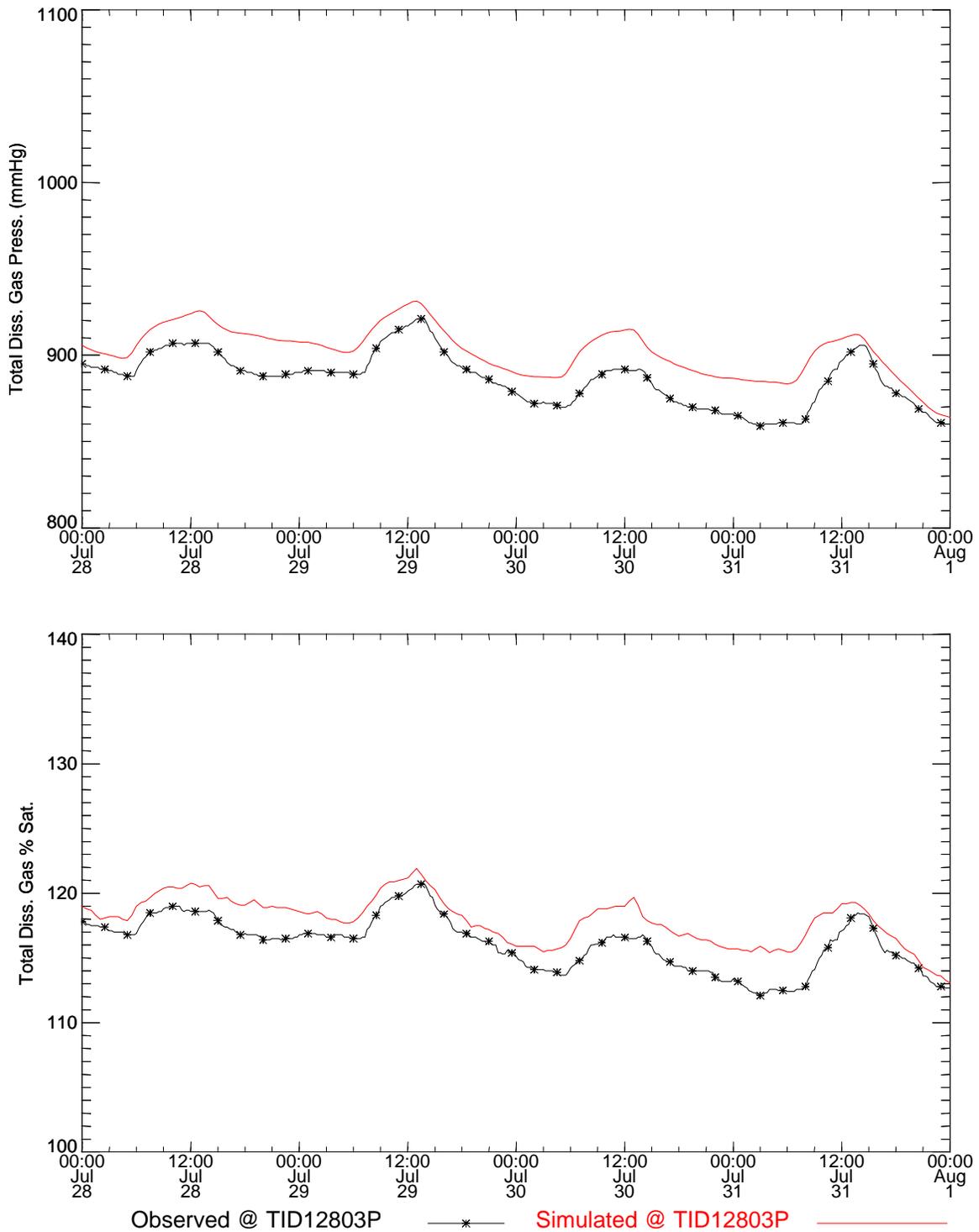


Figure 120. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 128.0 for the Summer 1996 study period (TM-BC).

Table 65. Statistical summary of measurements and simulations near Columbia River Mile 128.0 for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID12803P	20.38	20.48	0.17	0.16	0.18
Concentration TID12803P	29.1	29.51	0.53	0.46	0.45
Gas Pressure TID12803P	886.35	902.29	15.34	14.37	17.03
% Saturation TID12803P	116.12	117.93	2.07	1.83	1.99

Table 66. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 128.0 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12803P	100	100	100	100

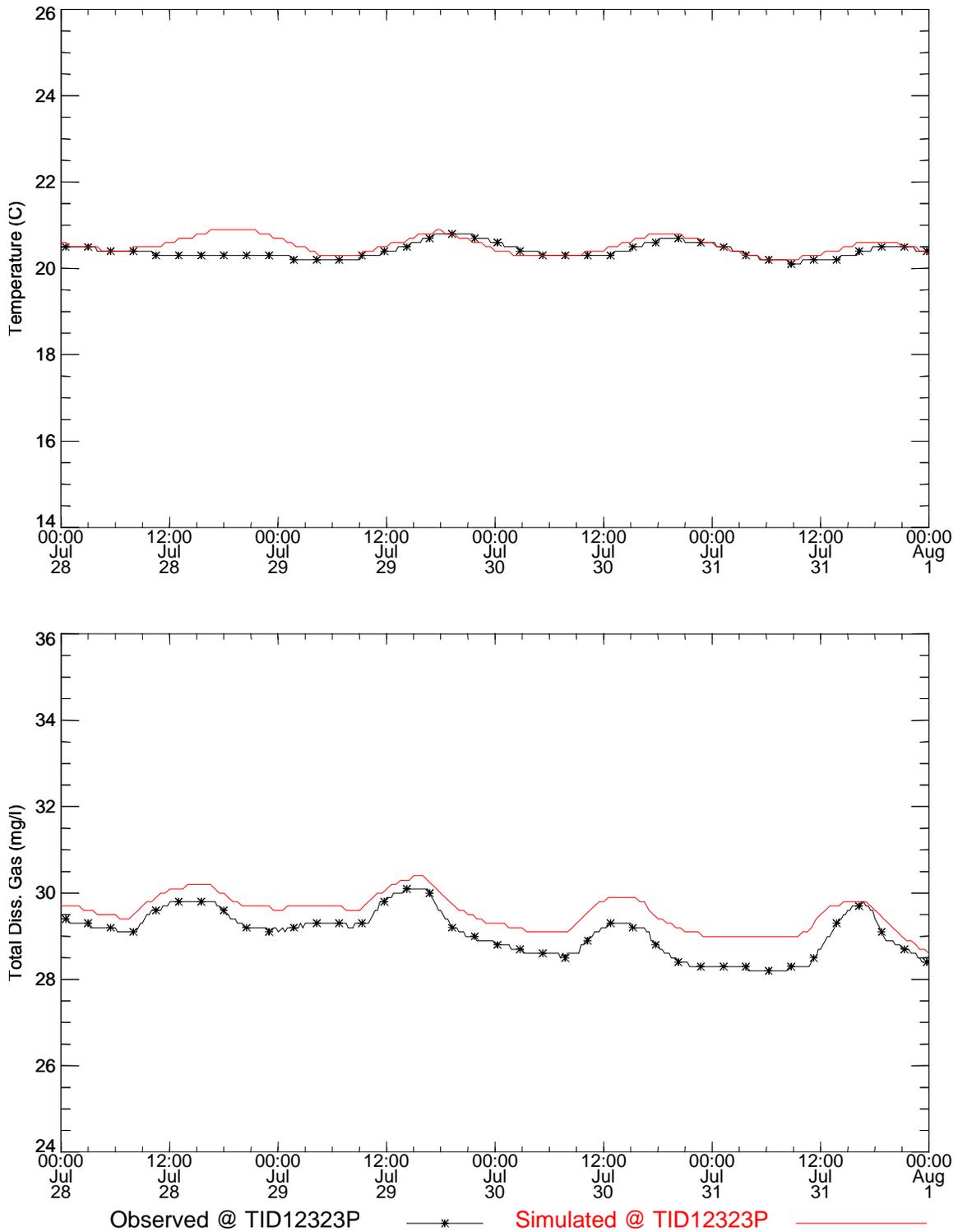


Figure 121. Temperature and total dissolved gas time series near Columbia River mile 123.2 for the Summer 1996 study period (TM-BC).

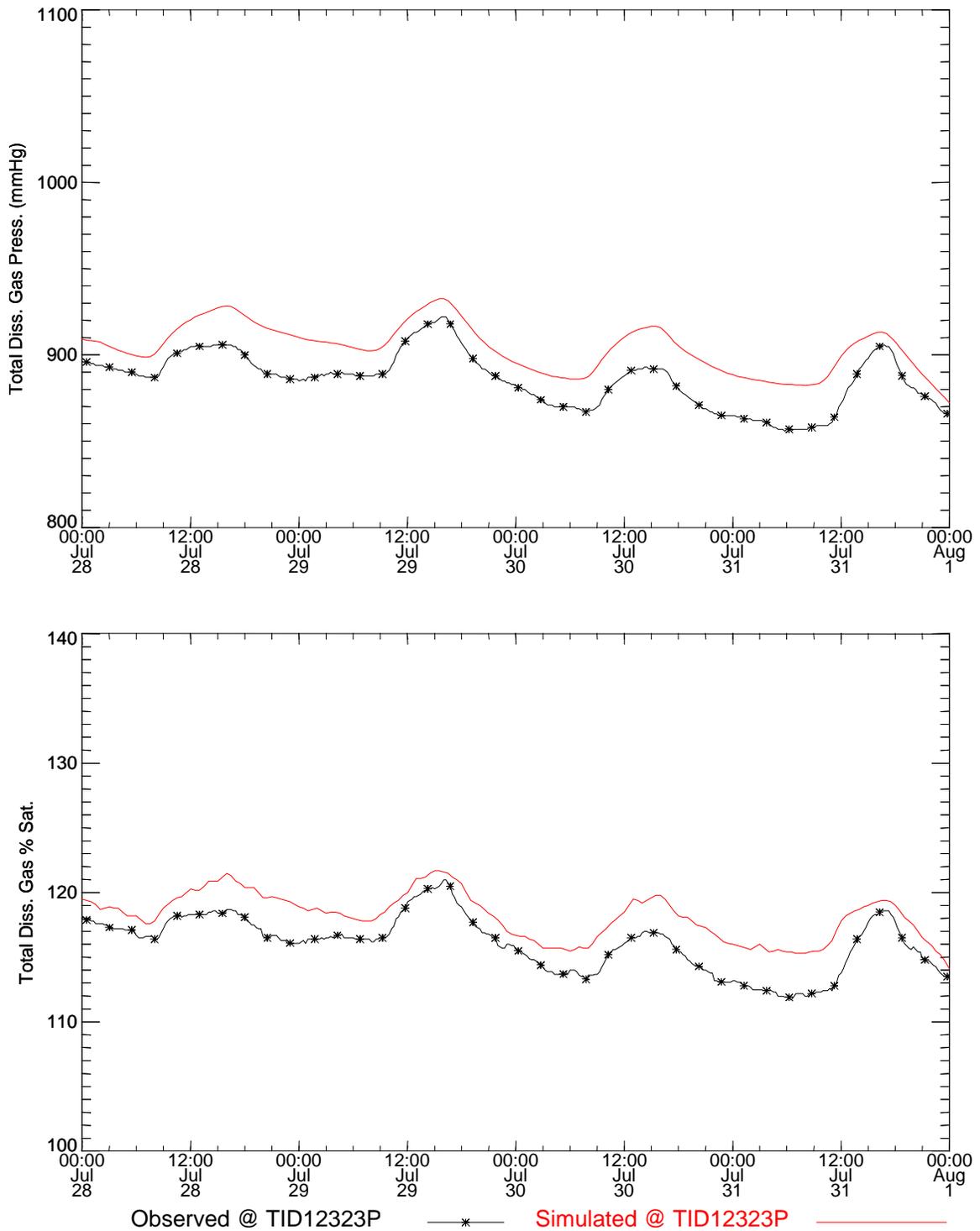


Figure 122. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 123.2 for the Summer 1996 study period (TM-BC).

Table 67. Statistical summary of measurements and simulations near Columbia River Mile 123.2 for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID12323P	20.4	20.53	0.17	0.2	0.22
Concentration TID12323P	29.08	29.55	0.52	0.4	0.51
Gas Pressure TID12323P	885.7	904.1	15.74	13.85	19.27
% Saturation TID12323P	116.03	118.17	2.15	1.8	2.28

Table 68. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 123.2 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12323P	100	100	100	100

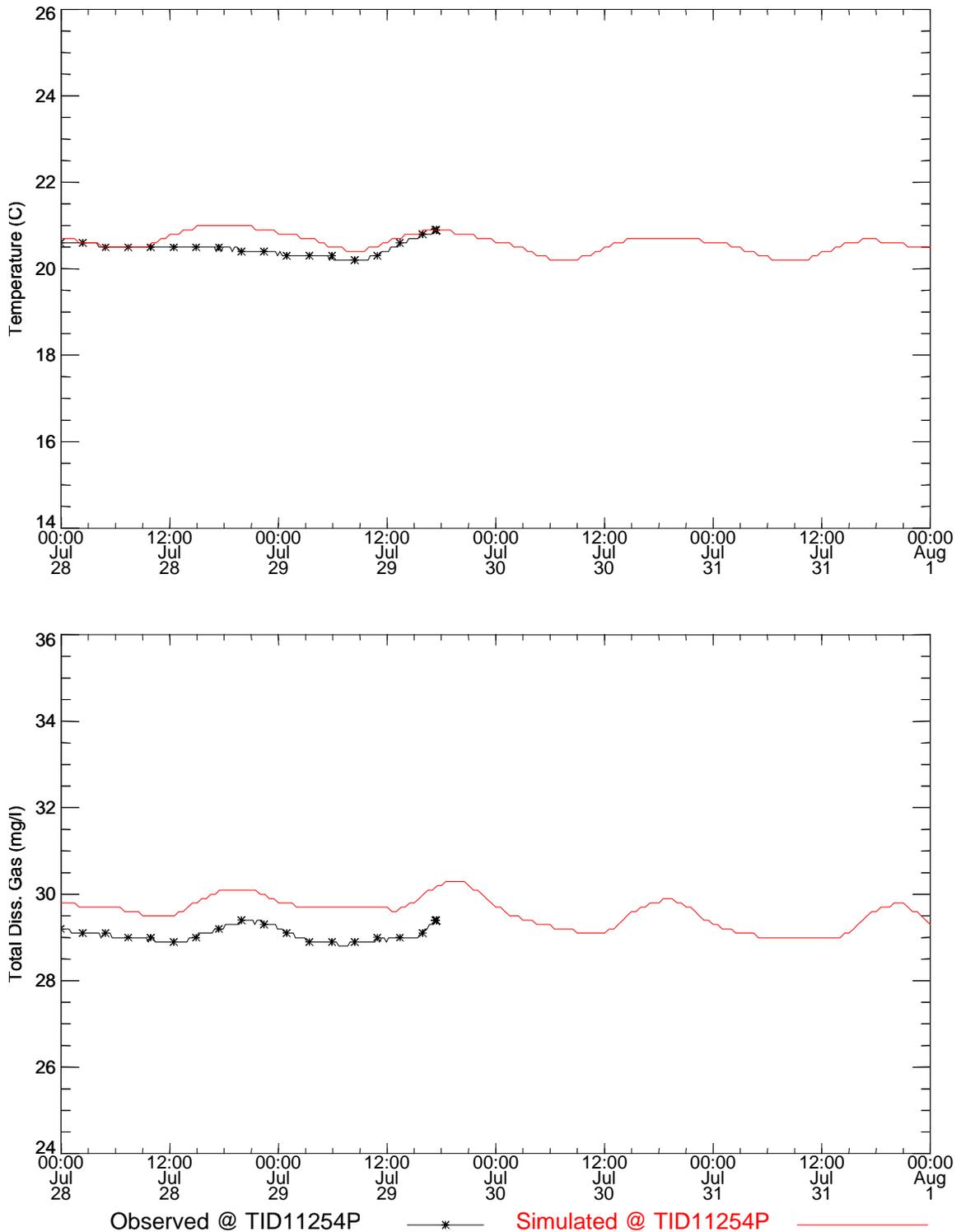


Figure 123. Temperature and total dissolved gas time series near Columbia River mile 112.5 for the Summer 1996 study period (TM-BC).

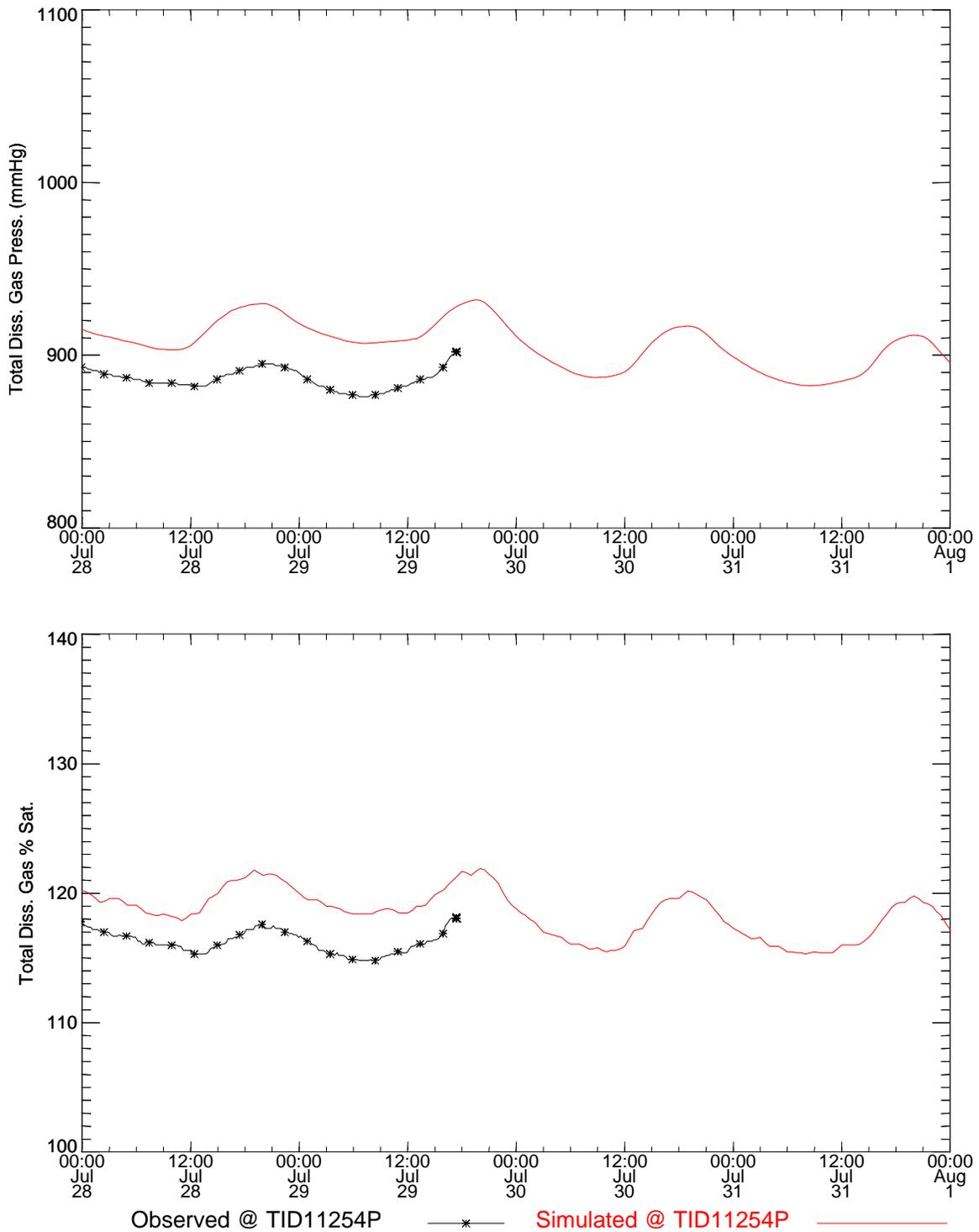


Figure 124. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 112.5 for the Summer 1996 study period (TM-BC).

Table 69. Statistical summary of measurements and simulations near Columbia River Mile 112.5 for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID11254P	20.71	20.6	0.24	0.22	0.39
Concentration TID11254P	29.25	29.58	0.2	0.35	0.55
Gas Pressure TID11254P	895.13	906.52	8.74	13.39	21.35
% Saturation TID11254P	117.28	118.49	1.09	1.81	2.64

Table 70. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 112.5 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID11254P	100	100	100	100

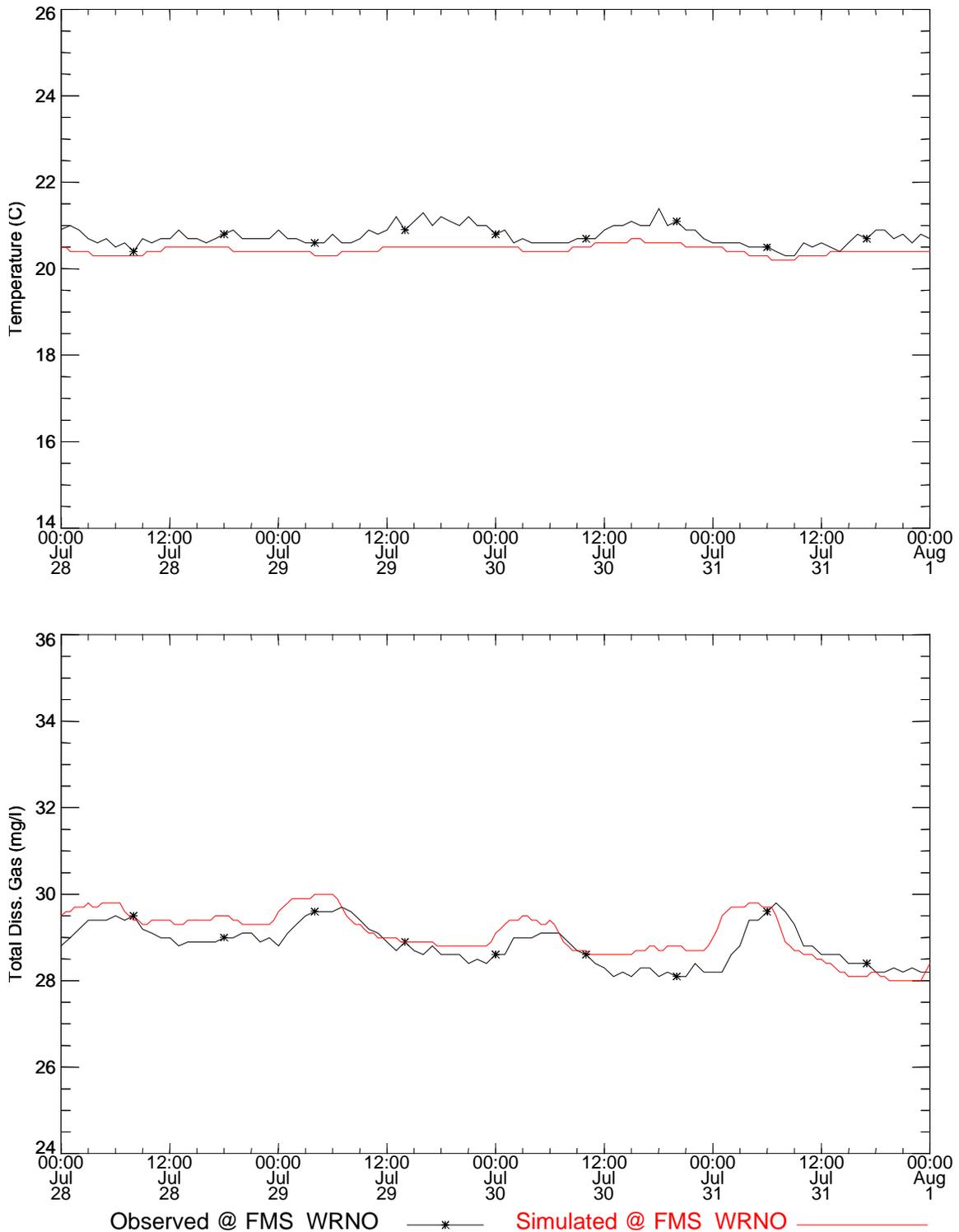


Figure 125. Temperature and total dissolved gas time series near fixed monitor WRNO for the Summer 1996 study period (TM-BC).

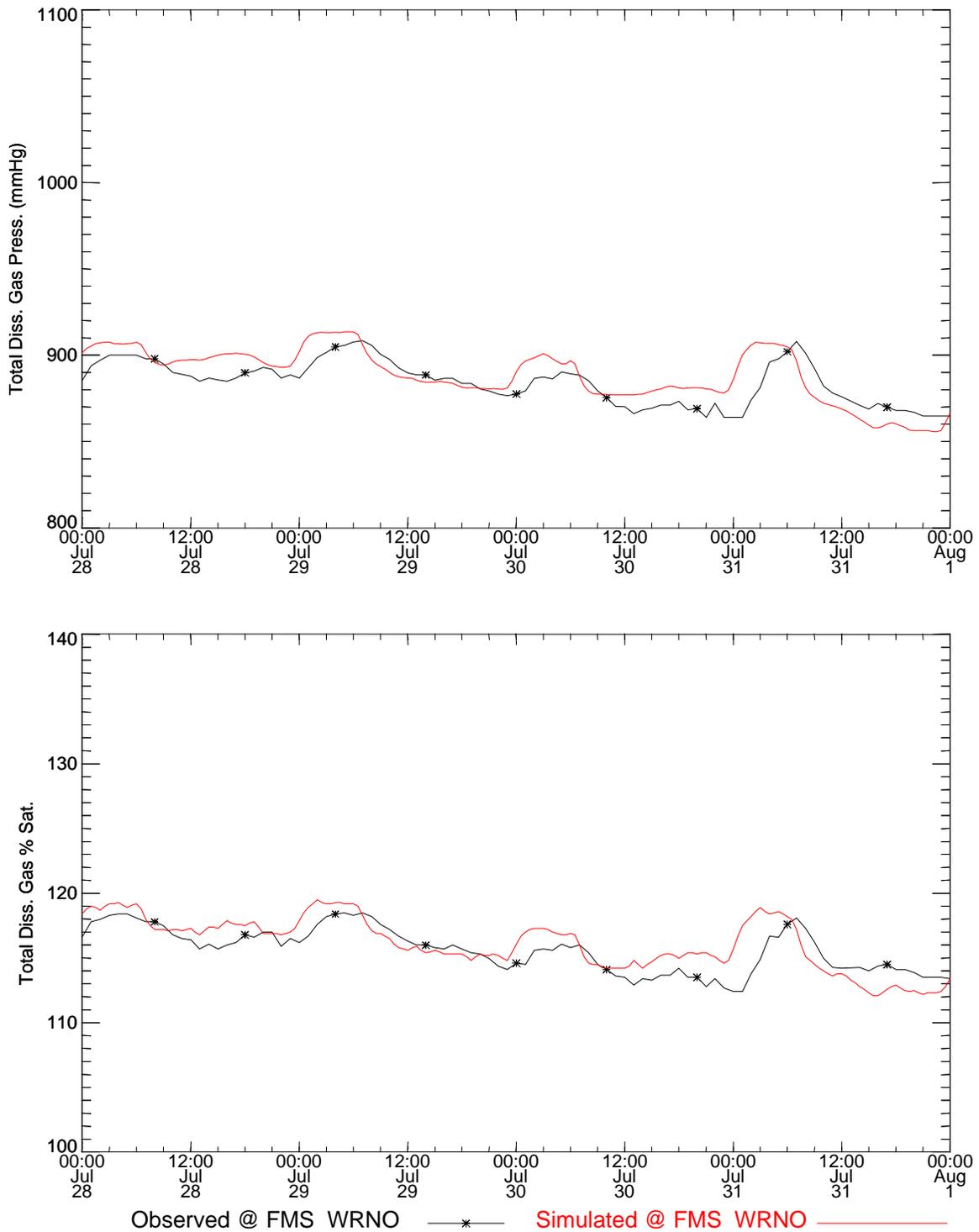


Figure 126. Total dissolved gas pressure and saturation time series comparisons near fixed monitor WRNO for the Summer 1996 study period (TM-BC).

Table 71. Statistical summary of measurements and simulations near Columbia River Mile 144.0 for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_WRNO	20.76	20.43	0.21	0.1	0.36
Concentration FMS_WRNO	28.83	29.08	0.46	0.54	0.43
Gas Pressure FMS_WRNO	884.34	888.5	12.37	15.49	10.91
% Saturation FMS_WRNO	115.62	116.13	1.68	2.02	1.46

Table 72. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor WRNO for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_WRNO	100	98.45	100	99.48

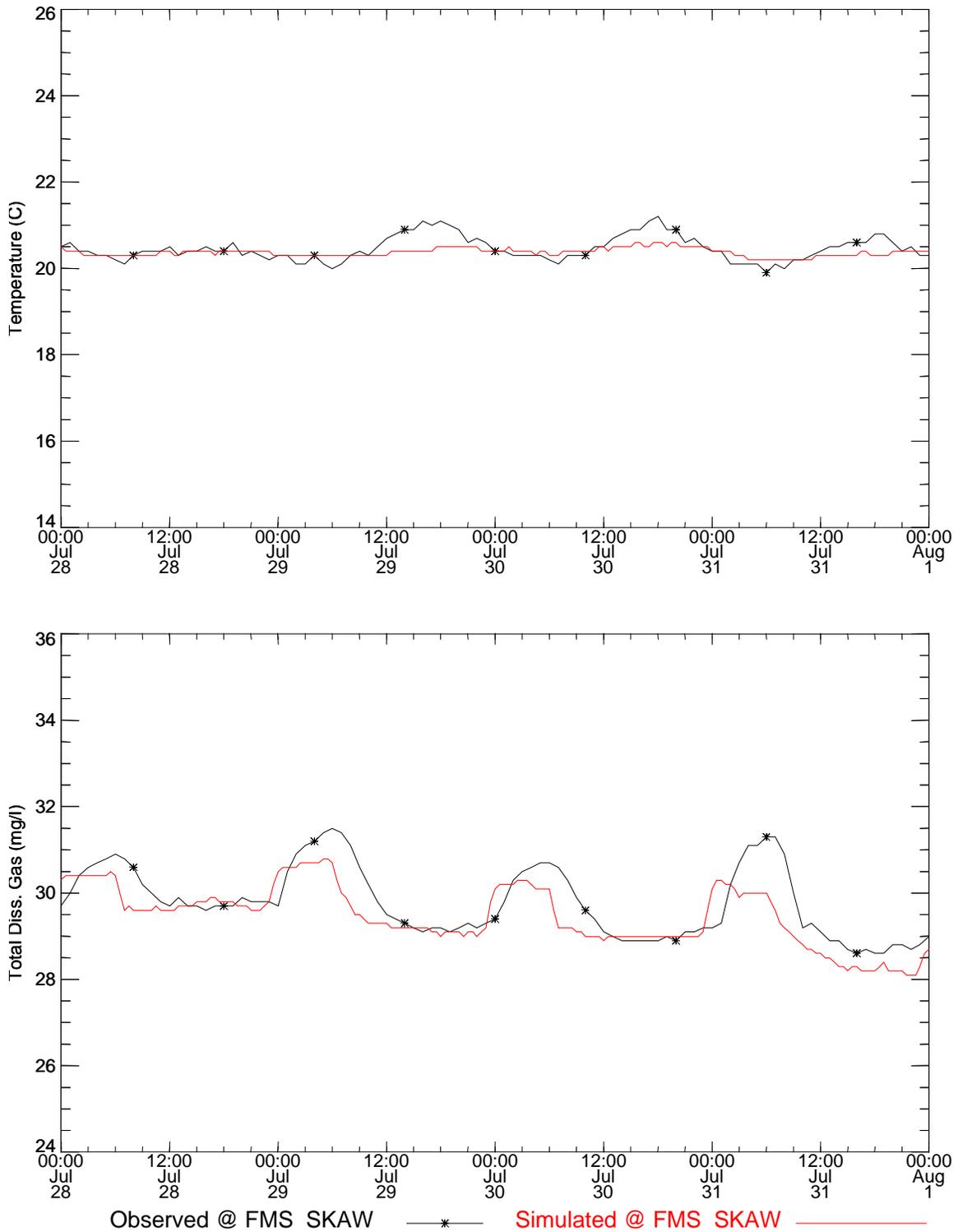


Figure 127. Temperature and total dissolved gas time series near fixed monitor SKAW for the Summer 1996 study period (TM-BC).

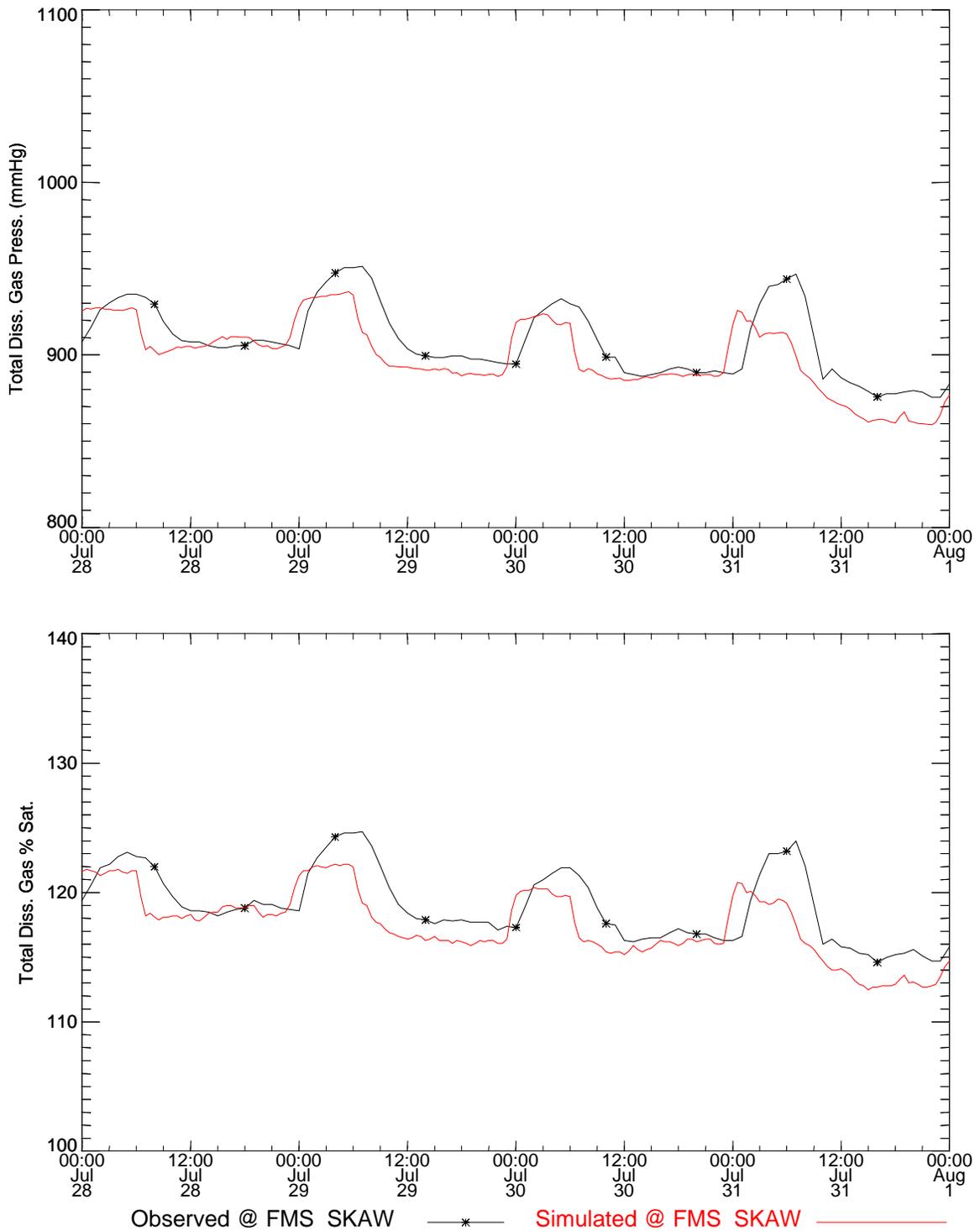


Figure 128. Total dissolved gas pressure and saturation time series comparisons near fixed monitor SKAW for the Summer 1996 study period (TM-BC).

Table 73. Statistical summary of measurements and simulations near fixed monitor SKAW for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_SKAW	20.46	20.37	0.28	0.09	0.24
Concentration FMS_SKAW	29.79	29.47	0.8	0.7	0.6
Gas Pressure FMS_SKAW	908.23	899.25	20.65	20.31	16.68
% Saturation FMS_SKAW	118.99	117.53	2.73	2.64	2.31

Table 74. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor SKAW for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_SKAW	100	88.08	96.89	95.85

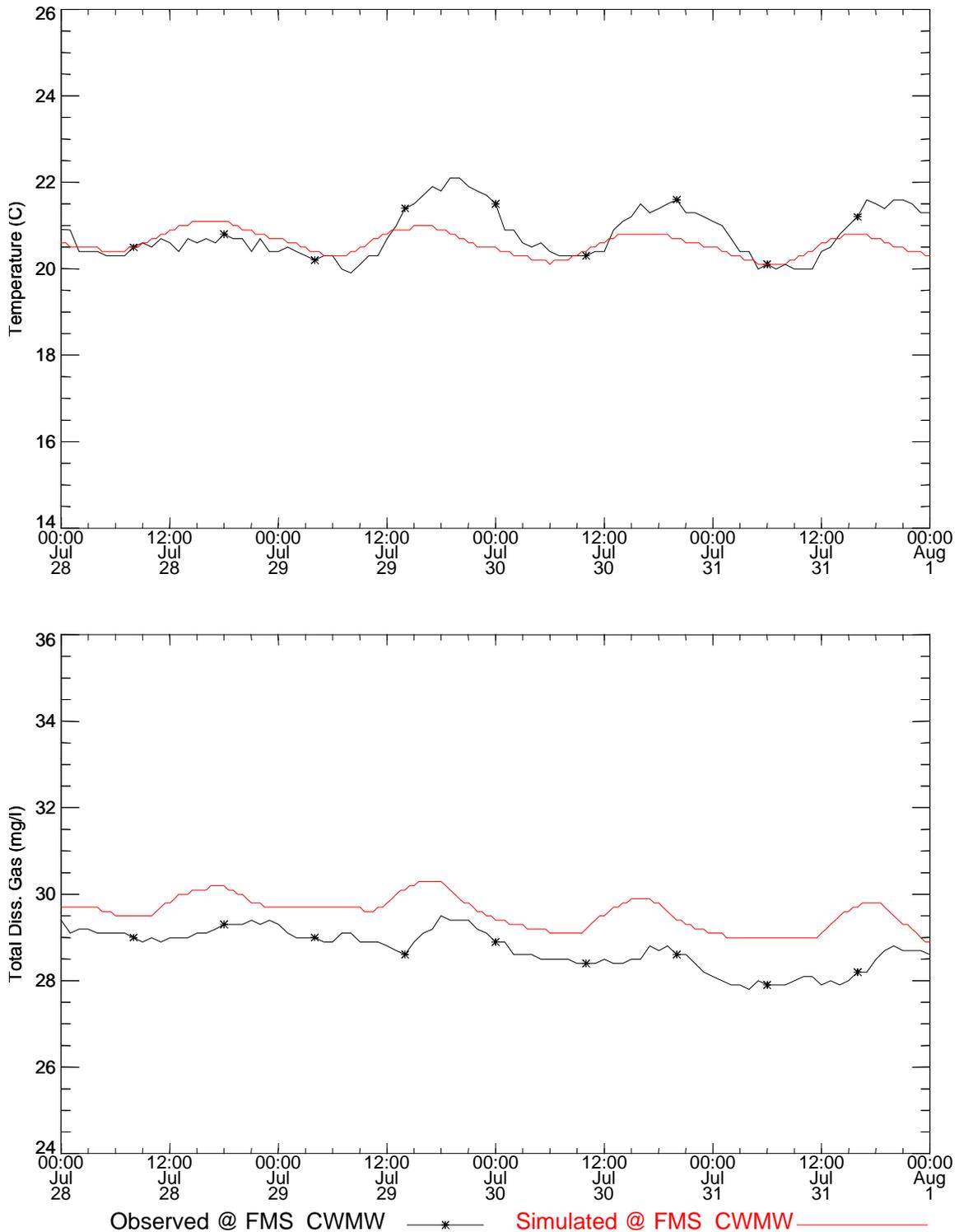


Figure 129. Temperature and total dissolved gas time series near fixed monitor CWMW 144.0 for the Summer 1996 study period (TM-BC).

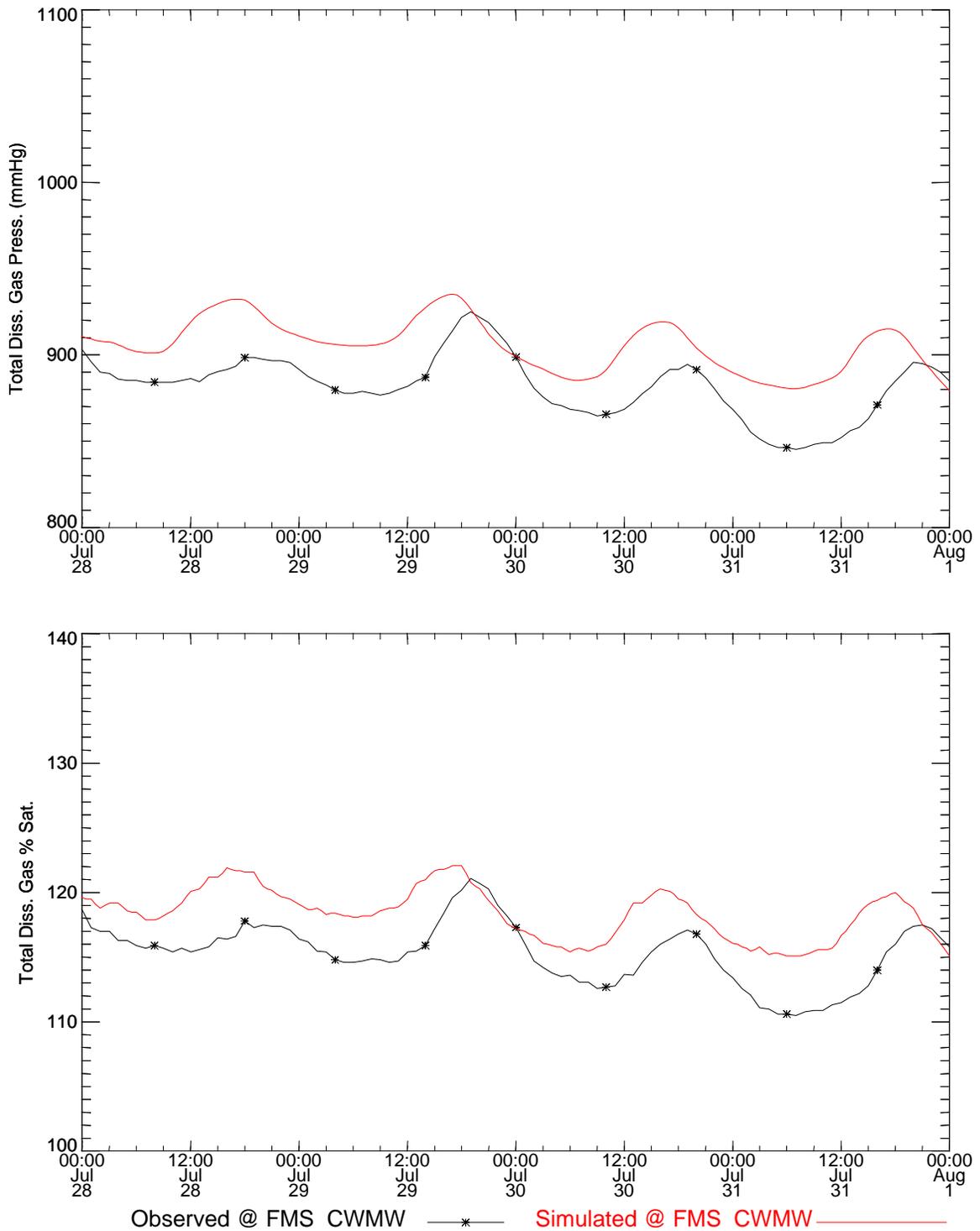


Figure 130. Total dissolved gas pressure and saturation time series comparisons near fixed monitor CWMW for the Summer 1996 study period (TM-BC).

Table 75. Statistical summary of measurements and simulations near fixed monitor CWMW for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_CWMW	20.8	20.59	0.56	0.26	0.54
Concentration FMS_CWMW	28.73	29.57	0.45	0.37	0.9
Gas Pressure FMS_CWMW	881.84	905.67	17.74	14.81	27.01
% Saturation FMS_CWMW	115.29	118.38	2.37	1.95	3.5

Table 76. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor CWMW for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_CWMW	91.71	71.5	88.08	89.64

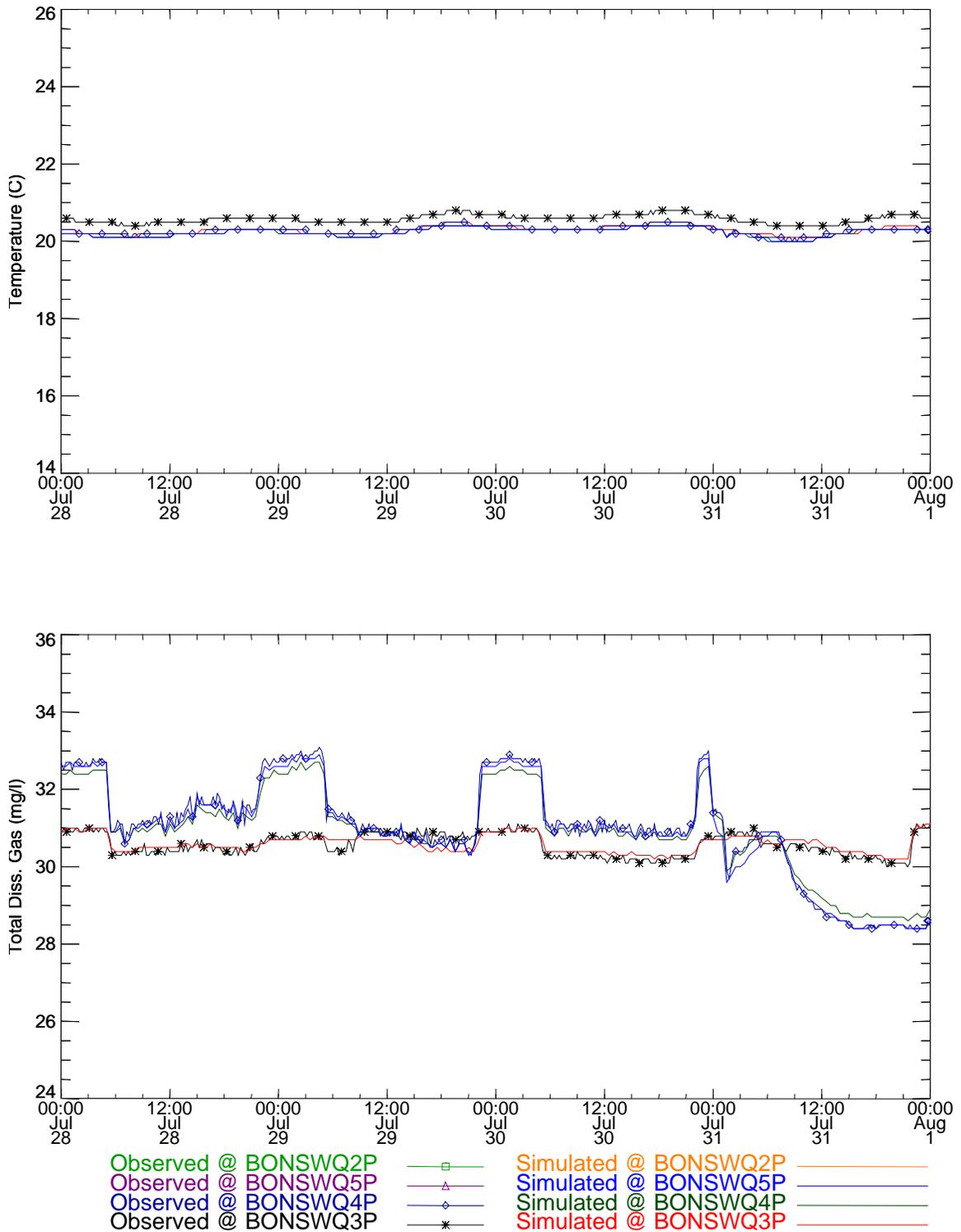


Figure 131. Temperature and total dissolved gas time series near fixed monitor BONSQW for the Summer 1996 study period (TM-BC).

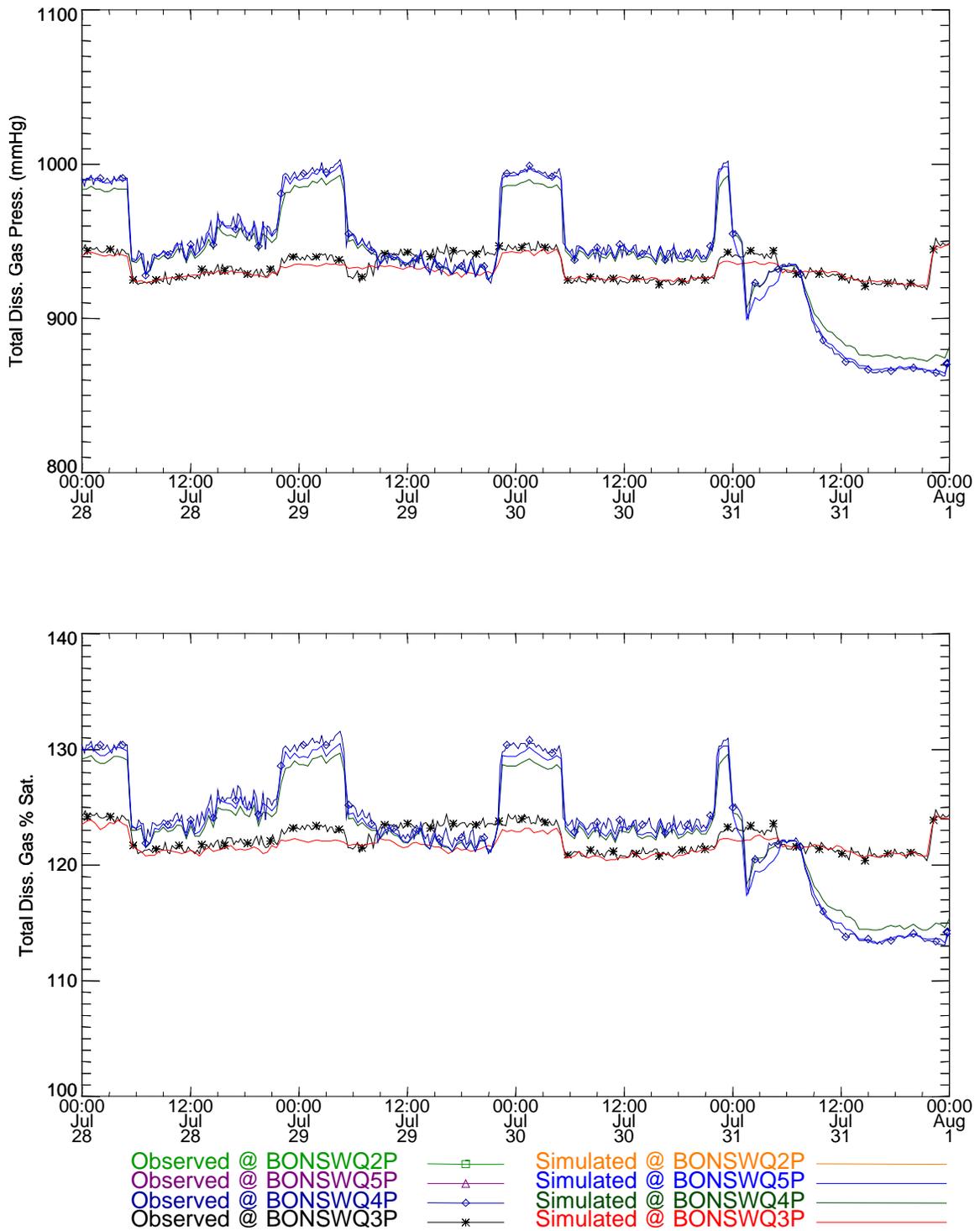


Figure 132. Total dissolved gas pressure and saturation time series comparisons near fixed monitor BONSQ for the Summer 1996 study period (TM-BC).

Table 77. Statistical summary of measurements and simulations near fixed monitor BONSWQ for the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BONSWQ3P	20.58	20.29	0.11	0.11	0.29
BONSWQ4P	20.28	20.24	0.11	0.11	0.07
BONSWQ5P	20	20.24	0	0.11	0.26
Concentration					
BONSWQ3P	30.57	30.59	0.29	0.22	0.16
BONSWQ4P	31.02	30.92	1.3	1.11	0.22
BONSWQ5P	32.2	30.95	0	1.26	1.78
Gas Pressure					
BONSWQ3P	933.64	931.33	8.59	6.28	5.03
BONSWQ4P	941.95	940.08	38.82	33.32	6.02
BONSWQ5P	970	940.95	0	37.84	47.7
% Saturation					
BONSWQ3P	122.32	121.73	1.17	0.87	0.89
BONSWQ4P	123.41	122.87	5.14	4.31	1.04
BONSWQ5P	127.5	122.99	0	4.9	6.66

Table 78. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor BONSWQ for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
BONSWQ3P	100	100	100	100
BONSWQ4P	100	100	100	100
BONSWQ5P	100	35.75	74.61	64.25

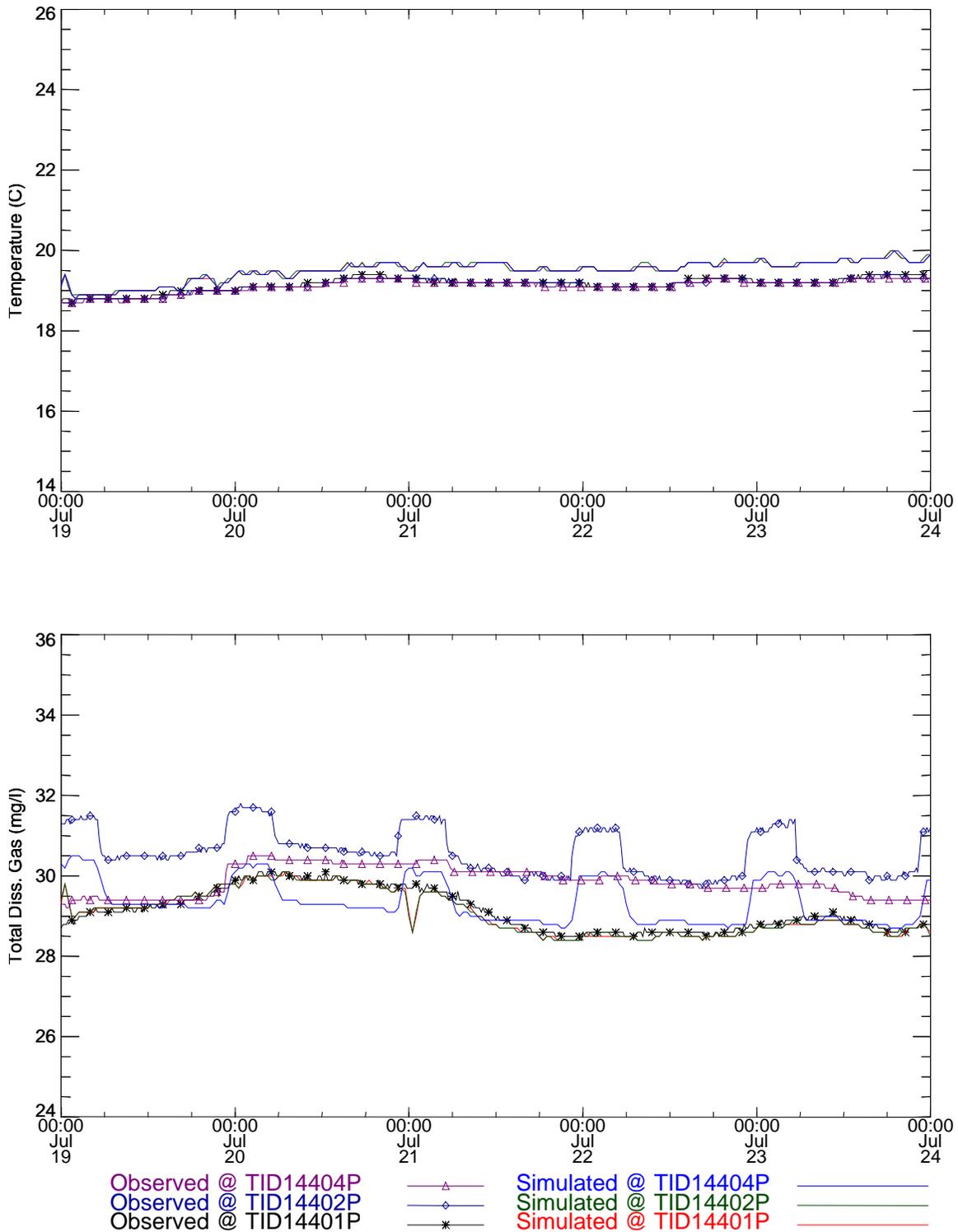


Figure 134. Temperature and total dissolved gas time series near Columbia River mile 144.0 for the Summer 1997 study period (FMS-BC).

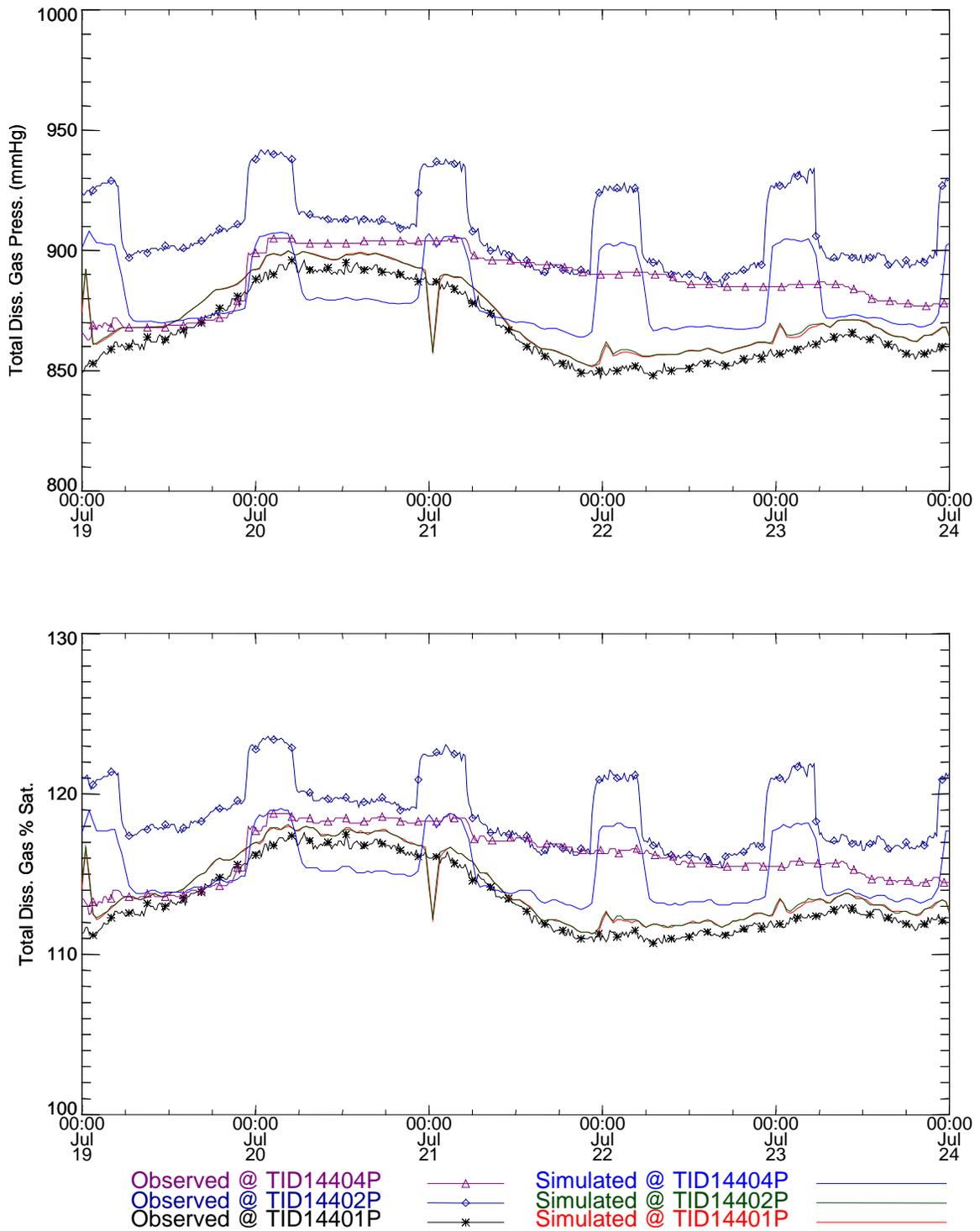


Figure 135. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 144.0 for the Summer 1997 study period (FMS-BC).

Table 79. Statistical summary of measurements and simulations near Columbia River mile 144.0 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14401P	19.16	19.5	0.17	0.25	0.36
TID14402P	19.14	19.51	0.17	0.25	0.39
TID14404P	19.12	19.5	0.16	0.25	0.4
Concentration					
TID14401P	29.13	29.08	0.51	0.54	0.17
TID14402P	30.57	29.08	0.56	0.54	1.59
TID14404P	29.87	29.34	0.37	0.52	0.78
Gas Pressure					
TID14401P	867.33	873.12	14.99	14.89	7.25
TID14402P	908.93	873.23	15.73	14.77	38.89
TID14404P	888.09	881	11.97	14.32	17.9
% Saturation					
TID14401P	113.43	114.14	2.13	2.11	0.92
TID14402P	118.86	114.16	2.17	2.1	5.12
TID14404P	116.14	115.17	1.66	1.94	2.36

Table 80. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 144.0 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID14401P	100	99.59	99.59	100
TID14402P	100	17.84	68.88	70.12
TID14404P	100	73.86	99.17	99.17

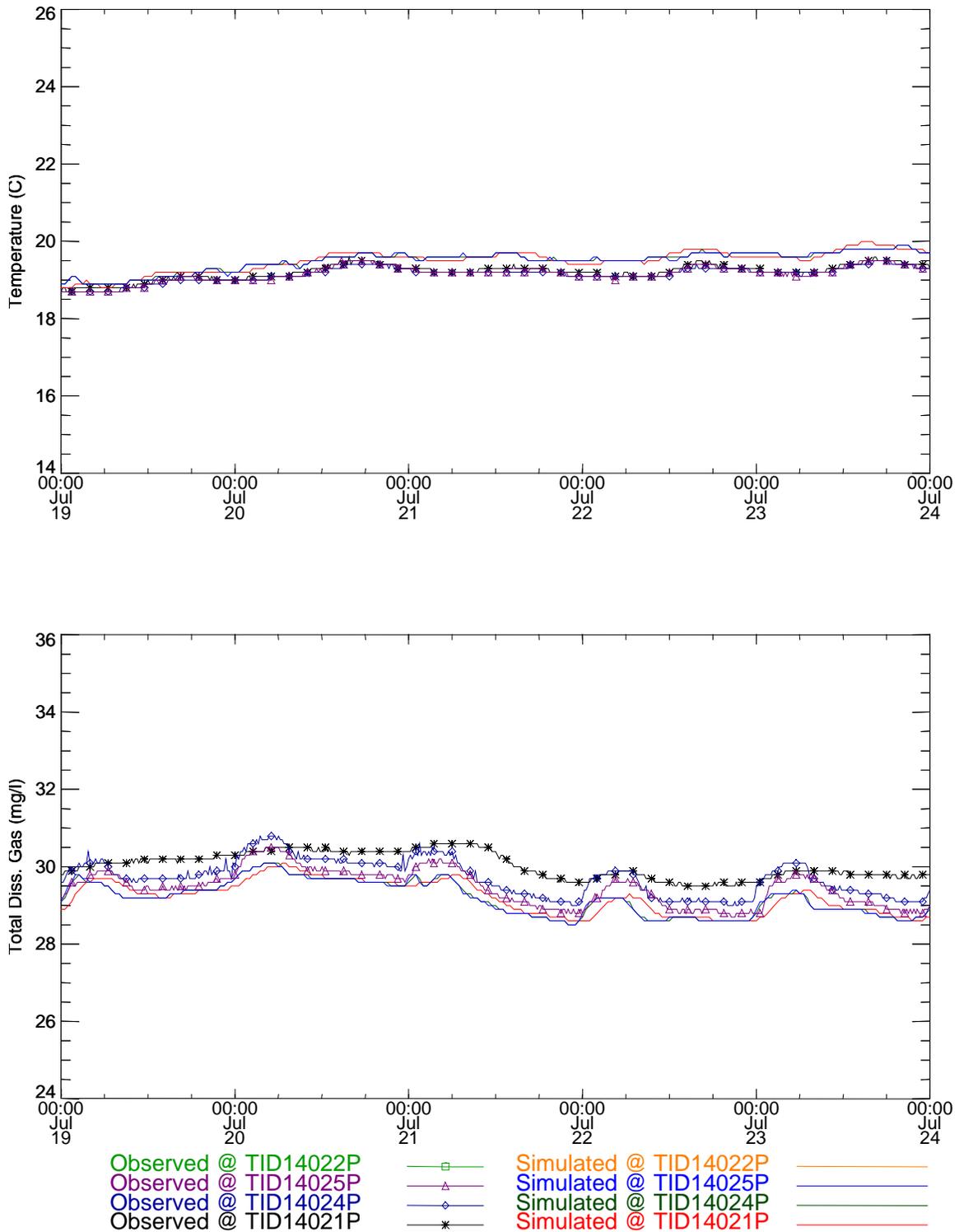


Figure 136. Temperature and total dissolved gas time series near Columbia River mile 140.2 for the Summer 1997 study period (FMS-BC).

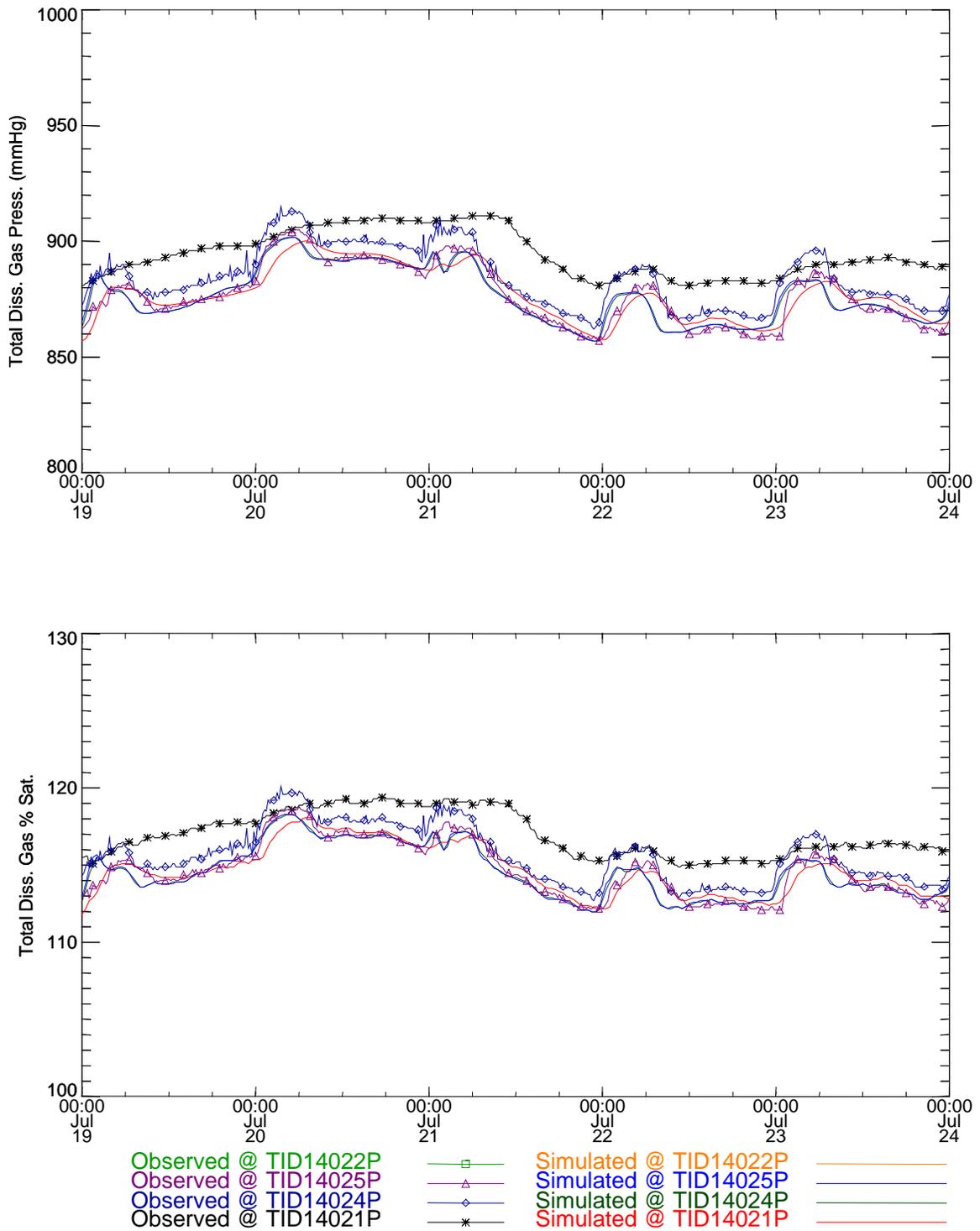


Figure 137. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 140.2 for the Summer 1997 study period (FMS-BC).

Table 81. Statistical summary of measurements and simulations near Columbia River mile 140.2 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14021P	19.21	19.5	0.19	0.28	0.31
TID14024P	19.15	19.5	0.19	0.26	0.36
TID14025P	19.17	19.49	0.2	0.26	0.35
Concentration					
TID14021P	30.04	29.21	0.34	0.43	0.85
TID14024P	29.72	29.19	0.47	0.44	0.54
TID14025P	29.47	29.19	0.47	0.44	0.33
Gas Pressure					
TID14021P	894.54	877.17	10.02	11.38	18.12
TID14024P	884.39	876.56	12.96	11.85	8.37
TID14025P	877.06	876.65	12.82	11.83	4.82
% Saturation					
TID14021P	116.98	114.68	1.47	1.63	2.4
TID14024P	115.65	114.59	1.84	1.7	1.14
TID14025P	114.7	114.61	1.82	1.7	0.65

Table 82. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 140.2 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID14021P	100	89.21	100	100
TID14024P	100	100	100	100
TID14025P	100	100	100	100

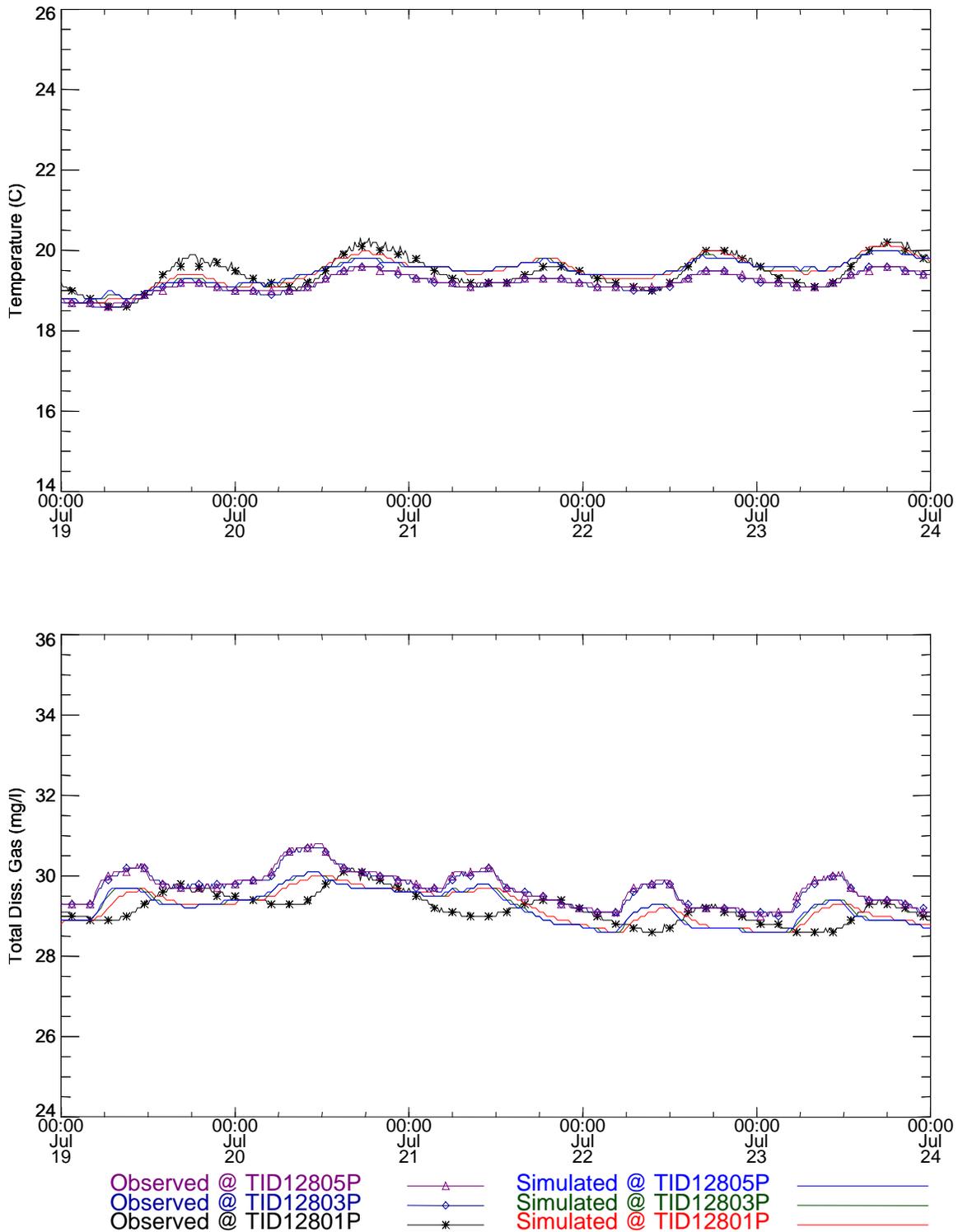


Figure 138. Temperature and total dissolved gas time series near Columbia River mile 128.0 for the Summer 1997 study period (FMS-BC).

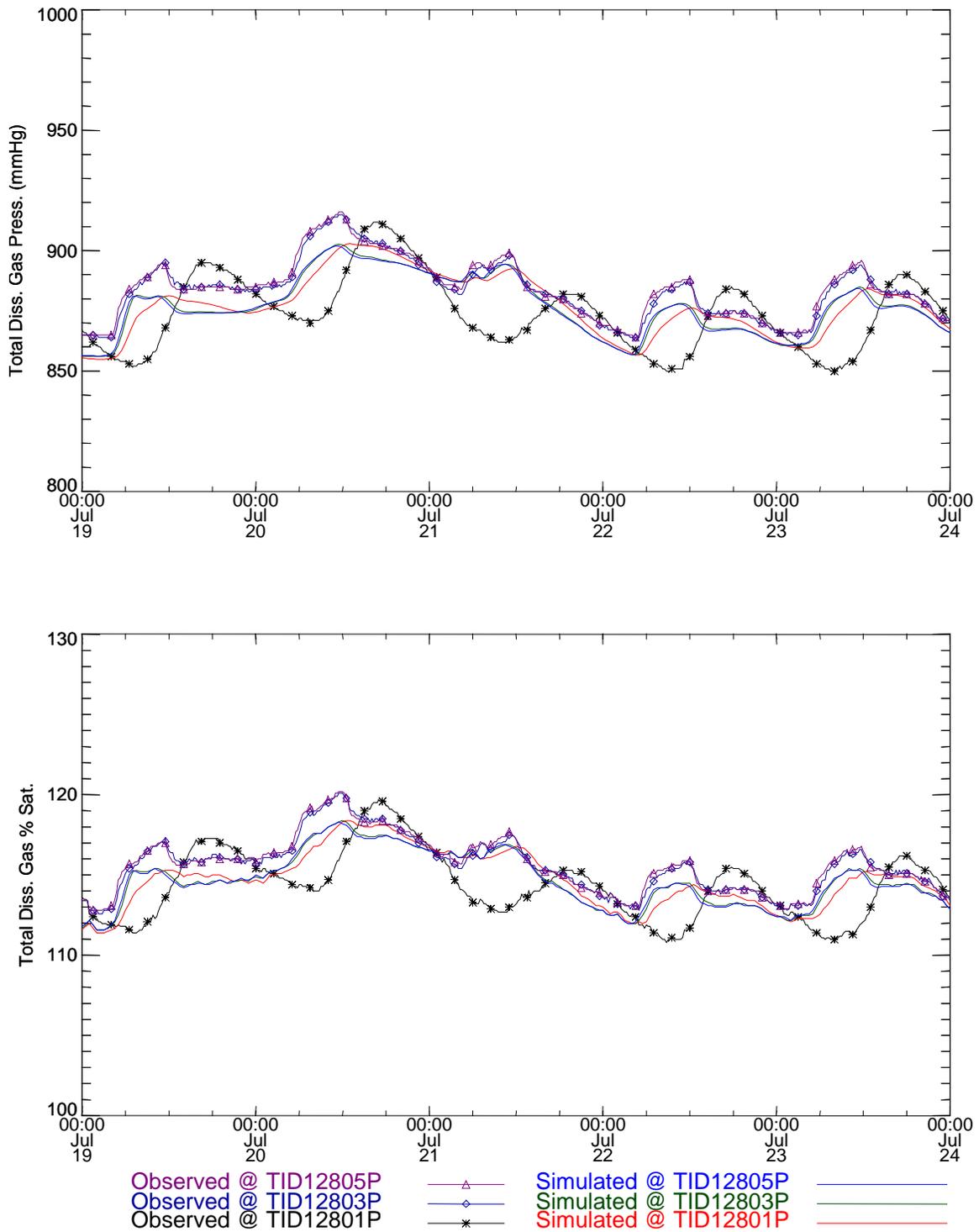


Figure 139. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 128.0 for the Summer 1997 study period (FMS-BC).

Table 83. Statistical summary of measurements and simulations near Columbia River mile 128.0 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID12801P	19.45	19.49	0.4	0.35	0.22
TID12803P	19.18	19.48	0.25	0.31	0.32
TID12805P	19.2	19.48	0.24	0.3	0.31
Concentration					
TID12801P	29.2	29.23	0.37	0.4	0.35
TID12803P	29.68	29.23	0.42	0.42	0.47
TID12805P	29.7	29.23	0.43	0.42	0.49
Gas Pressure					
TID12801P	874.22	877.53	15.37	12.5	13.29
TID12803P	883.74	877.37	12.17	12.15	7.25
TID12805P	884.39	877.31	12.24	11.99	7.83
% Saturation					
TID12801P	114.33	114.72	2.11	1.75	1.74
TID12803P	115.57	114.7	1.71	1.7	1
TID12805P	115.66	114.69	1.72	1.69	1.07

Table 84. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 128.0 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID12801P	100	100	100	100
TID12803P	100	100	100	100
TID12805P	100	100	100	100

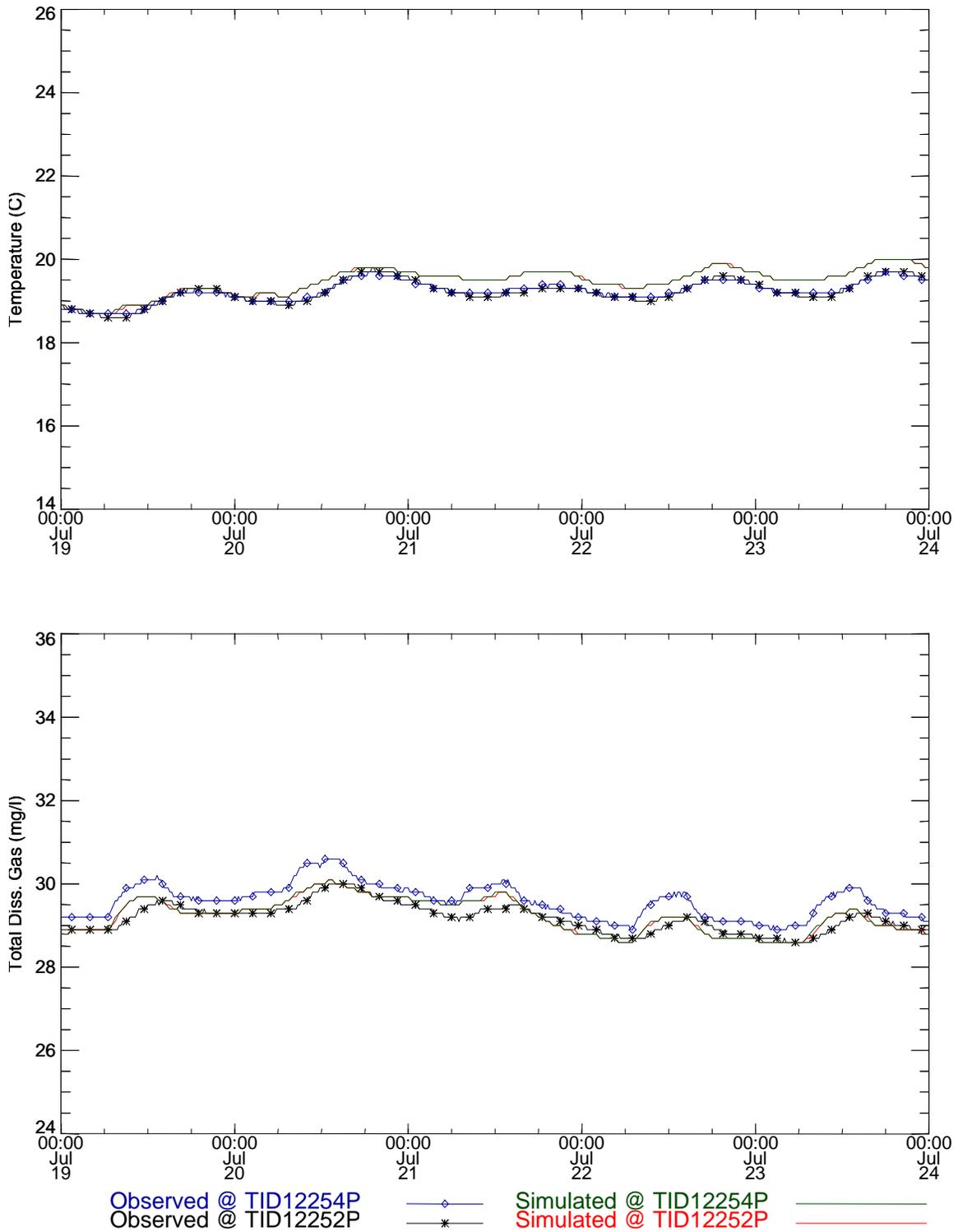


Figure 140. Temperature and total dissolved gas time series near Columbia River mile 122.5 for the Summer 1997 study period (FMS-BC).

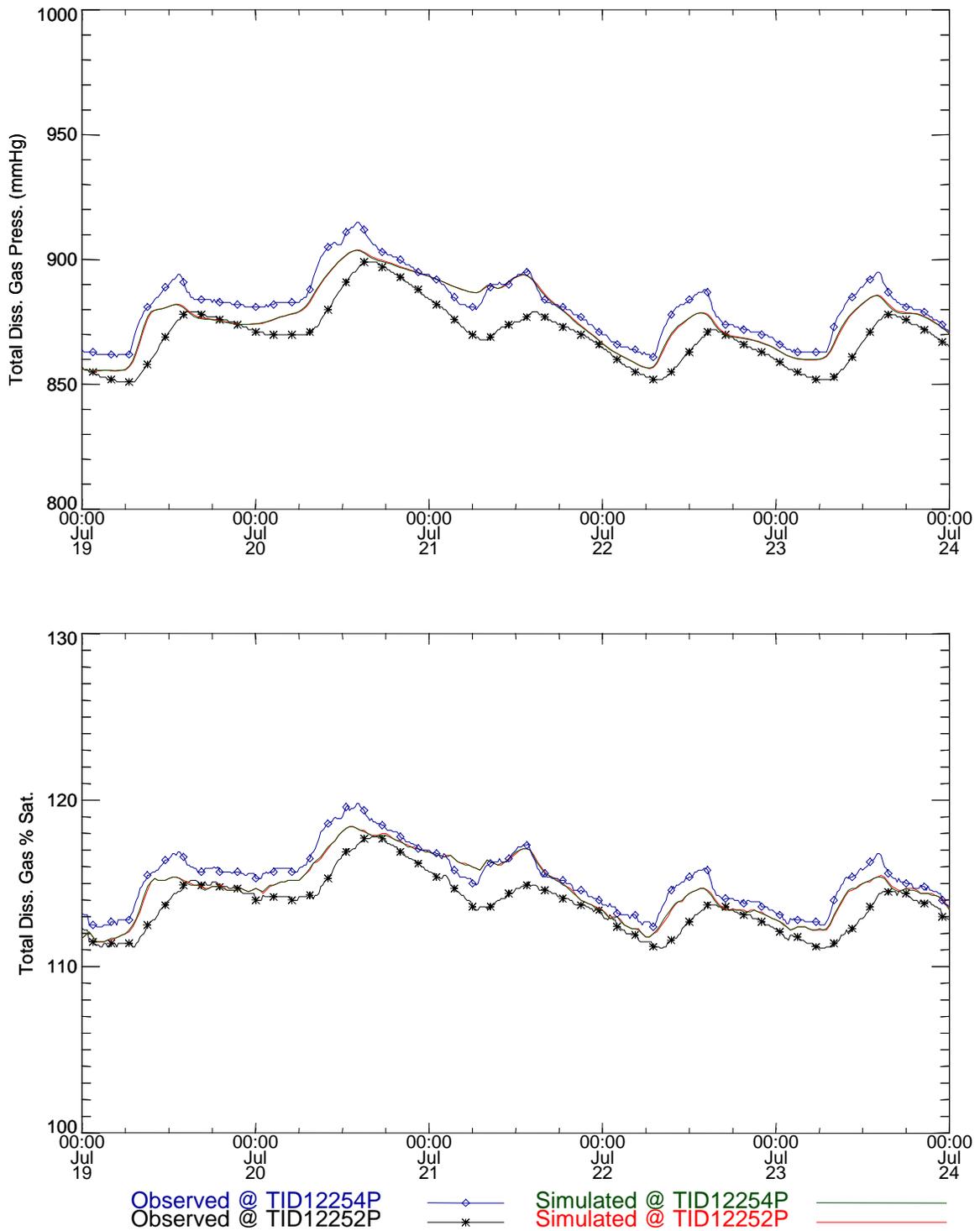


Figure 141. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 122.5 for the Summer 1997 study period (FMS-BC).

Table 85. Statistical summary of measurements and simulations near Columbia River mile 122.5 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID12252P	19.22	19.47	0.28	0.33	0.28
TID12254P	19.23	19.47	0.25	0.32	0.26
Concentration					
TID12252P	29.18	29.23	0.34	0.41	0.18
TID12254P	29.59	29.23	0.41	0.41	0.37
Gas Pressure					
TID12252P	869.86	877.32	11.8	12.73	9.34
TID12254P	881.64	877.3	12.61	12.66	5.63
% Saturation					
TID12252P	113.76	114.7	1.66	1.77	1.2
TID12254P	115.29	114.69	1.76	1.76	0.78

Table 86. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 122.5 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12252P	100	100	100	100
TID12254P	100	100	100	100

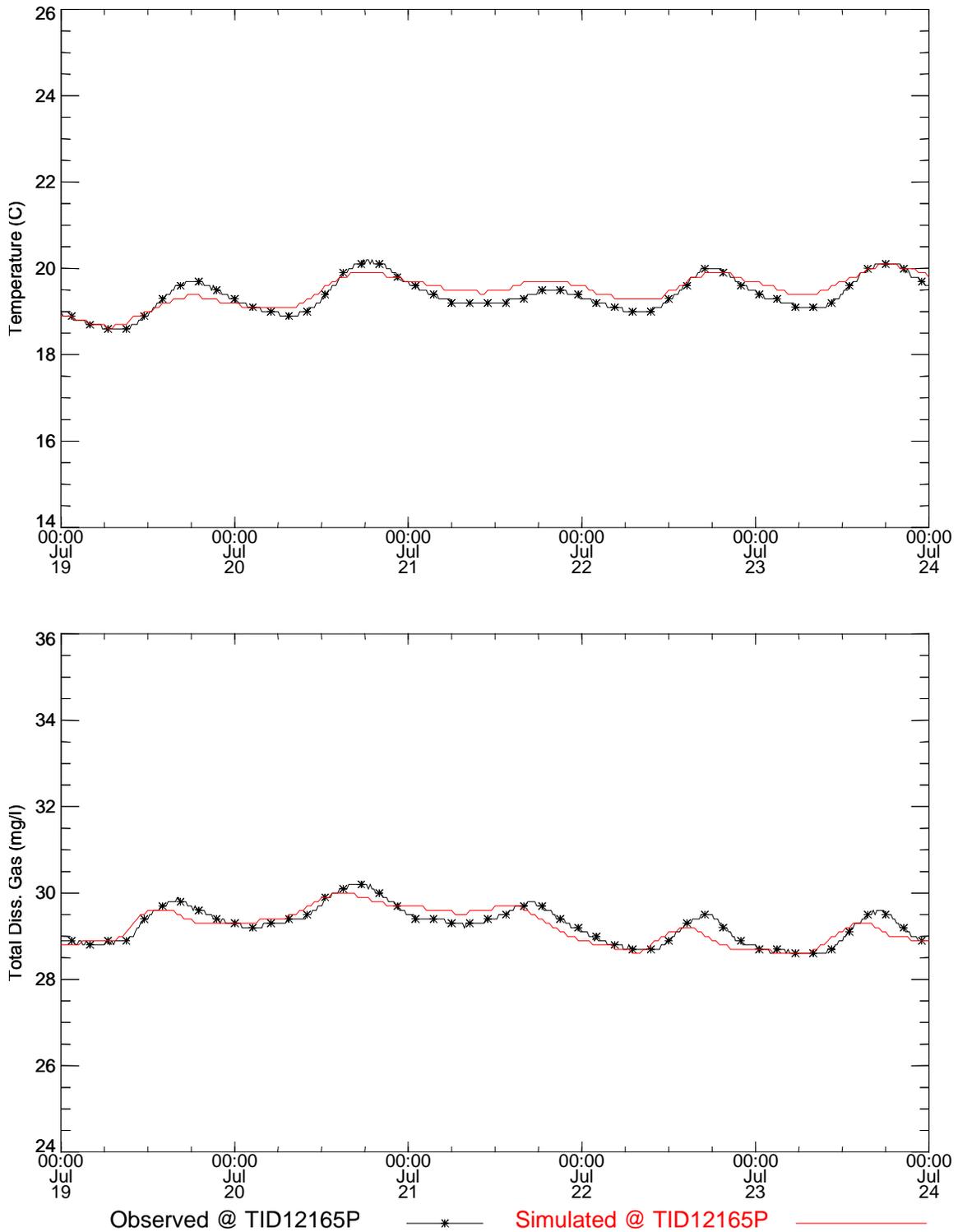


Figure 142. Temperature and total dissolved gas time series near Columbia River mile 121.6 for the Summer 1997 study period (FMS-BC).

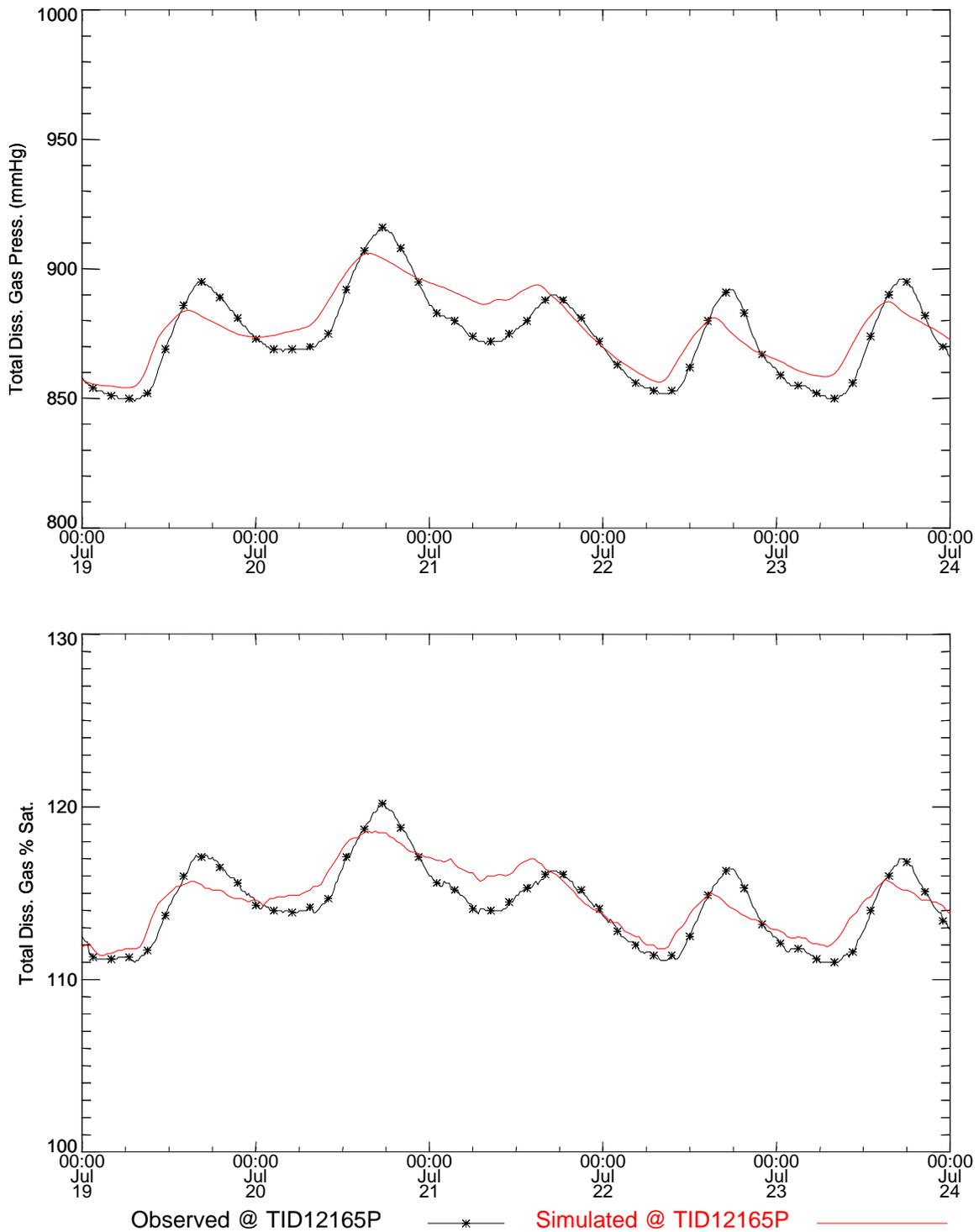


Figure 143. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 121.6 for the Summer 1997 study period (FMS-BC).

Table 87. Statistical summary of measurements and simulations near Columbia River mile 121.6 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID12165P	19.38	19.48	0.4	0.35	0.21
Concentration TID12165P	29.26	29.23	0.41	0.4	0.21
Gas Pressure TID12165P	874.59	877.35	16.45	13.52	8.42
% Saturation TID12165P	114.37	114.7	2.23	1.86	1.11

Table 88. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 121.6 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12165P	100	100	100	100

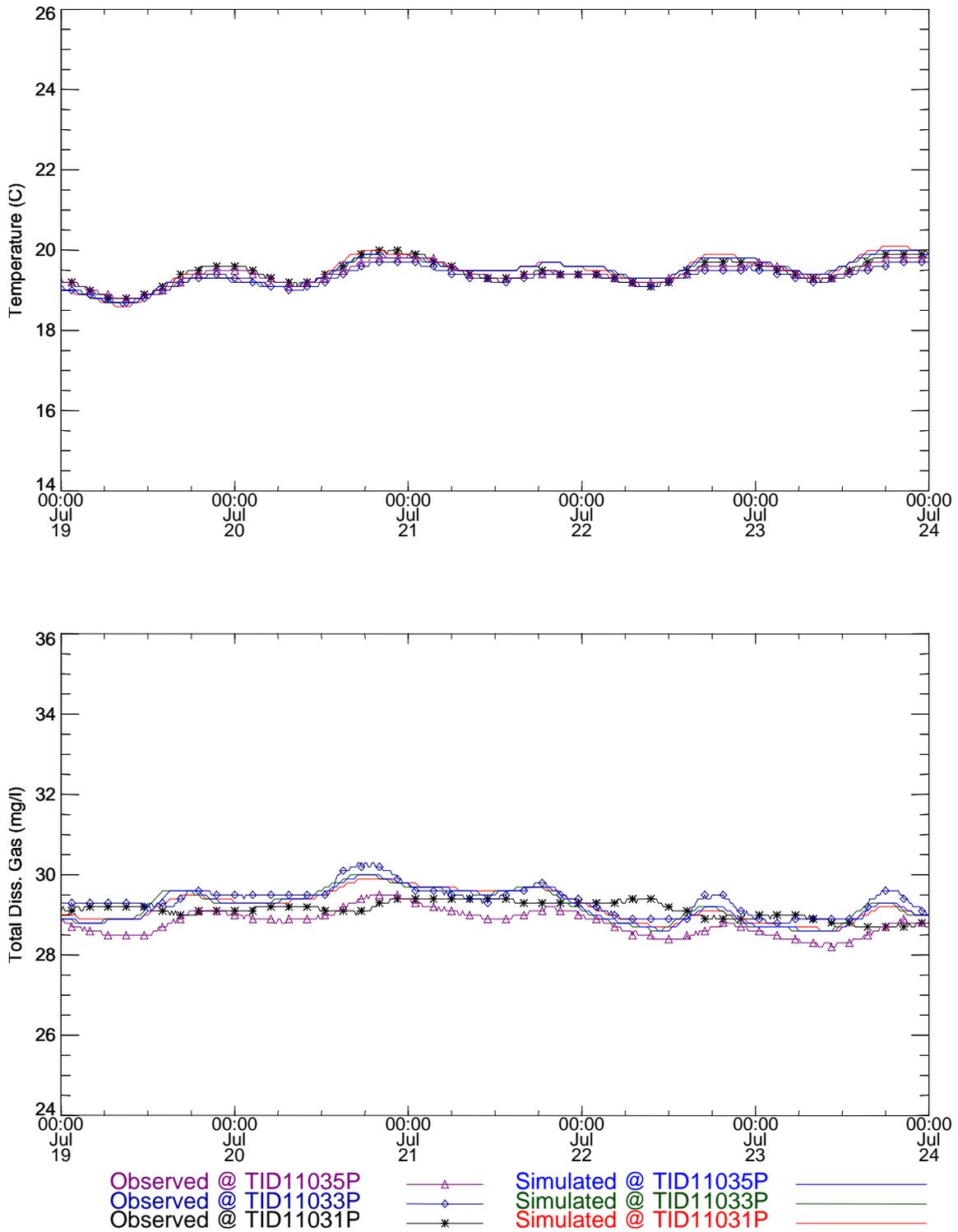


Figure 144. Temperature and total dissolved gas time series near Columbia River mile 110.3 for the Summer 1997 study period (FMS-BC).

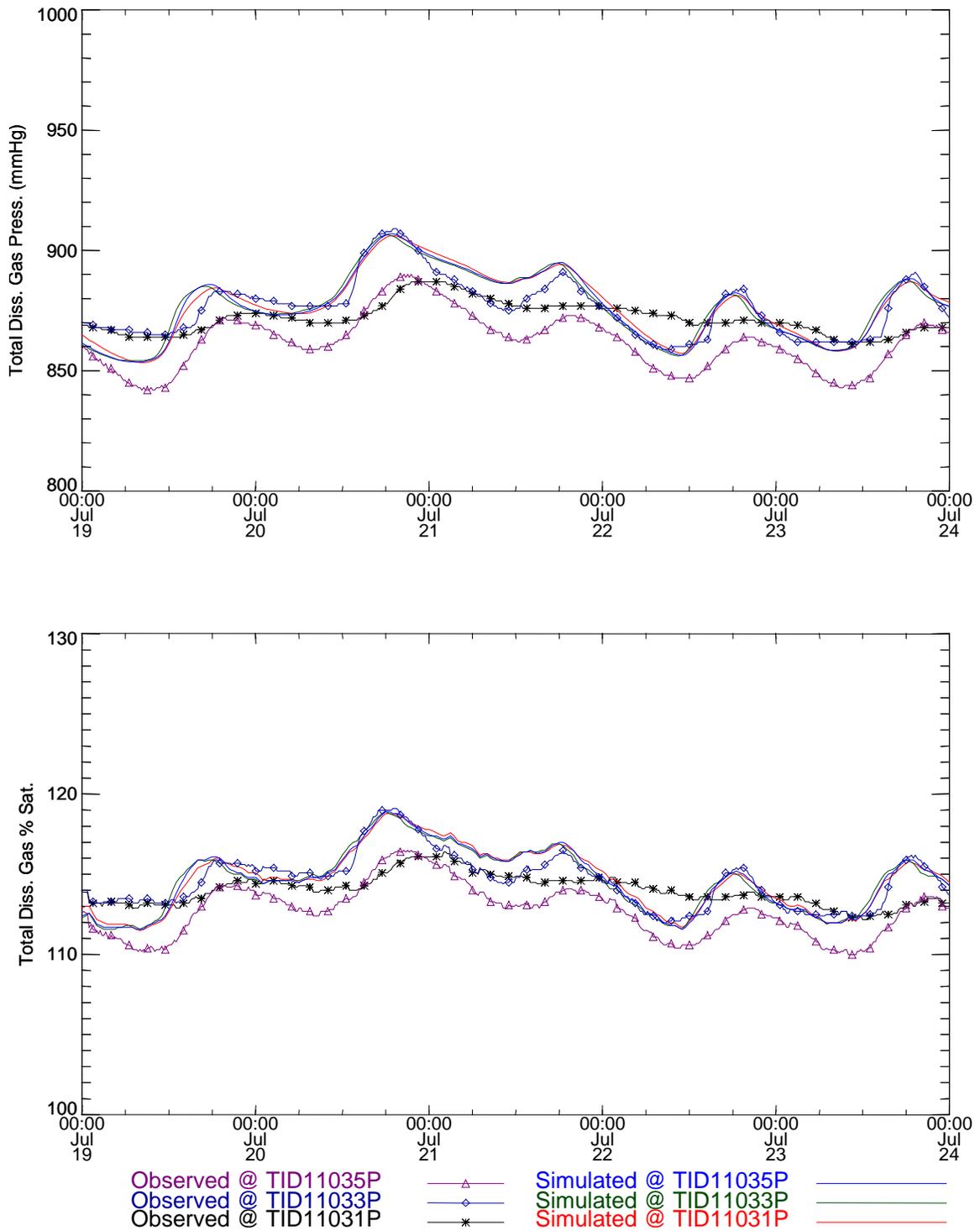


Figure 145. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 110.3 for the Summer 1997 study period (FMS-BC).

Table 89. Statistical summary of measurements and simulations near Columbia River mile 110.3 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID11031P	19.44	19.48	0.3	0.36	0.16
TID11033P	19.31	19.46	0.25	0.33	0.2
TID11035P	19.41	19.47	0.26	0.33	0.16
Concentration					
TID11031P	29.13	29.23	0.21	0.37	0.34
TID11033P	29.36	29.23	0.35	0.4	0.24
TID11035P	28.82	29.22	0.31	0.4	0.45
Gas Pressure					
TID11031P	871.95	877.47	6.41	13.82	11.5
TID11033P	876.56	877.1	11.98	13.92	6.22
TID11035P	862.09	877.12	11.62	14.15	16.22
% Saturation					
TID11031P	114.03	114.72	0.94	1.9	1.49
TID11033P	114.63	114.66	1.67	1.91	0.83
TID11035P	112.74	114.67	1.63	1.94	2.09

Table 90. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 110.3 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID11031P	100	100	100	100
TID11033P	100	100	100	100
TID11035P	100	100	100	100

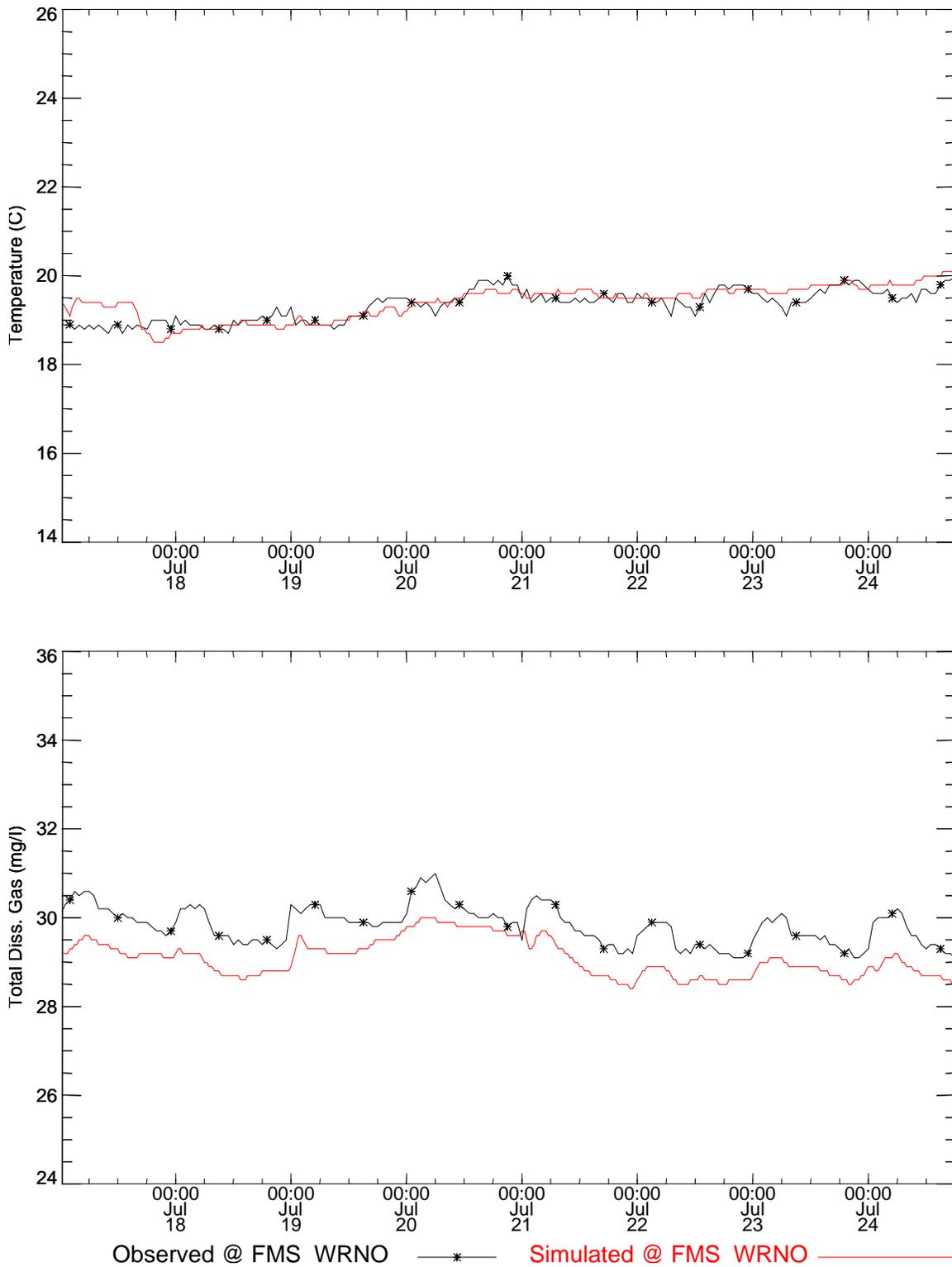


Figure 146. Temperature and total dissolved gas time series near fixed monitor WRNO for the Summer 1997 study period (FMS-BC).

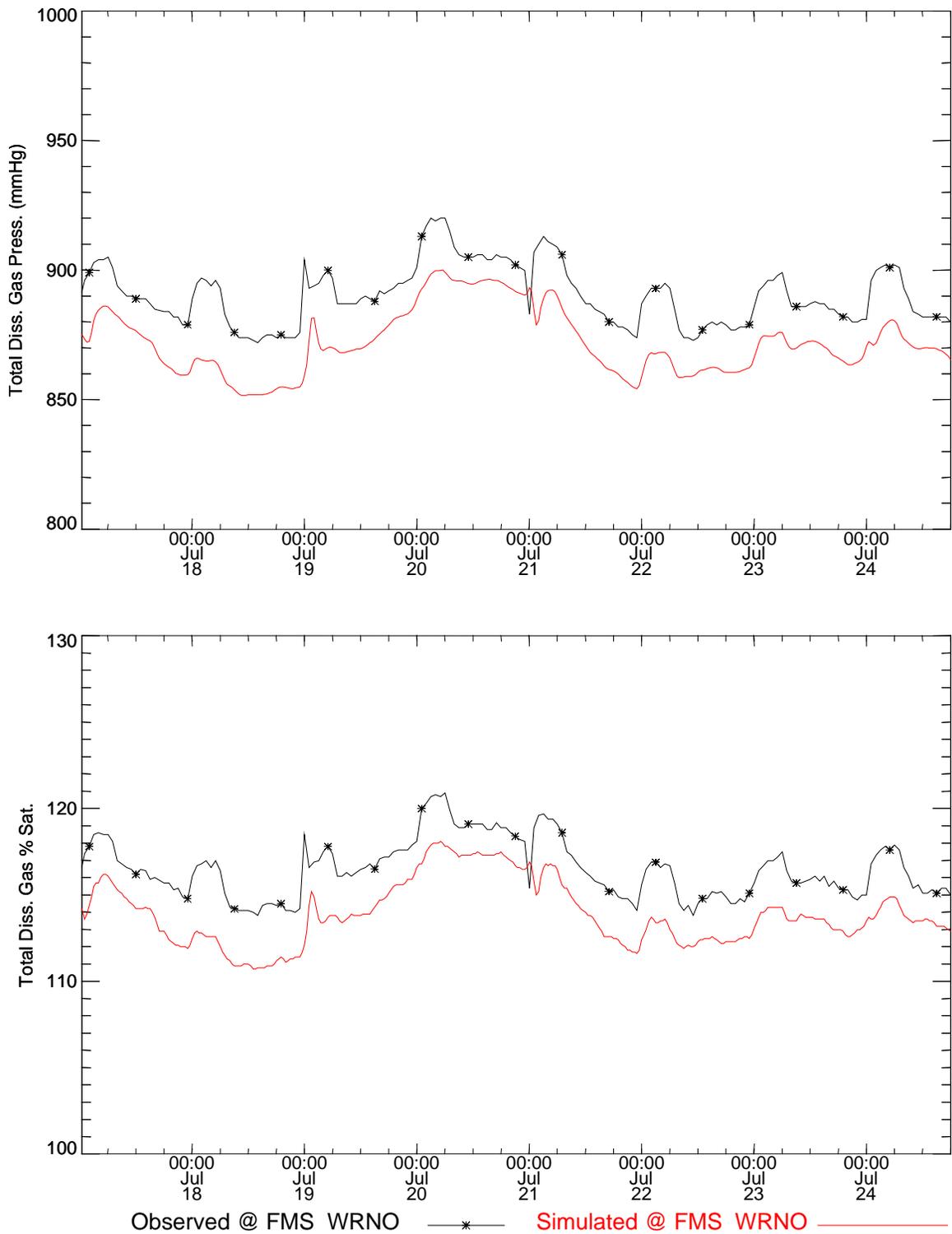


Figure 147. Total dissolved gas pressure and saturation time series comparisons near fixed monitor WRNO for the Summer 1997 study period (FMS-BC).

Table 91. Statistical summary of measurements and simulations near fixed monitor WRNO for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_WRNO	19.34	19.41	0.34	0.37	0.25
Concentration FMS_WRNO	29.82	29.09	0.42	0.42	0.77
Gas Pressure FMS_WRNO	890.4	872.13	11.36	12.58	19.14
% Saturation FMS_WRNO	116.52	113.91	1.65	1.85	2.71

Table 92. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor WRNO for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_WRNO	100	91.94	99.73	99.73

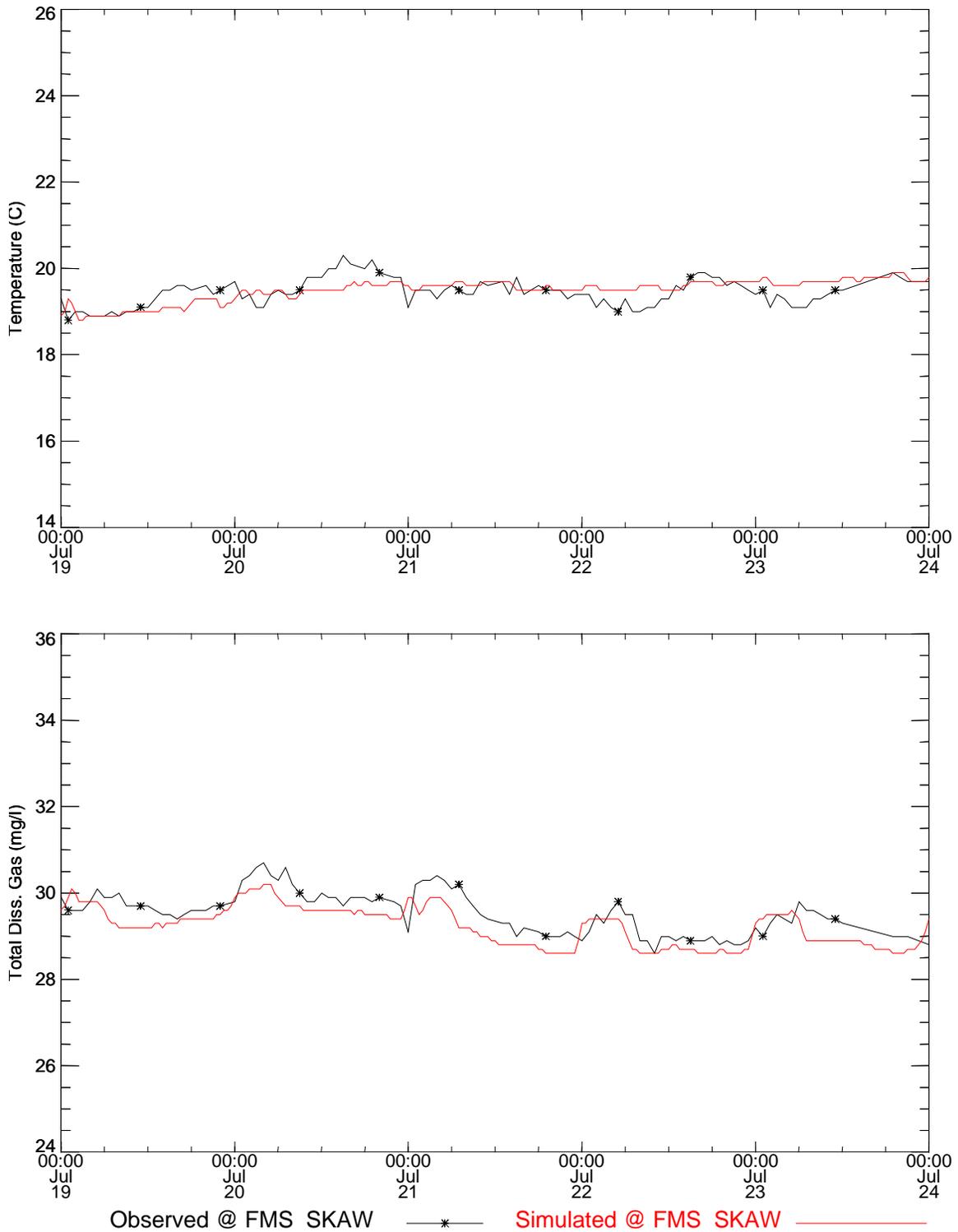


Figure 148. Temperature and total dissolved gas time series near fixed monitor SKAW for the Summer 1997 study period (FMS-BC).

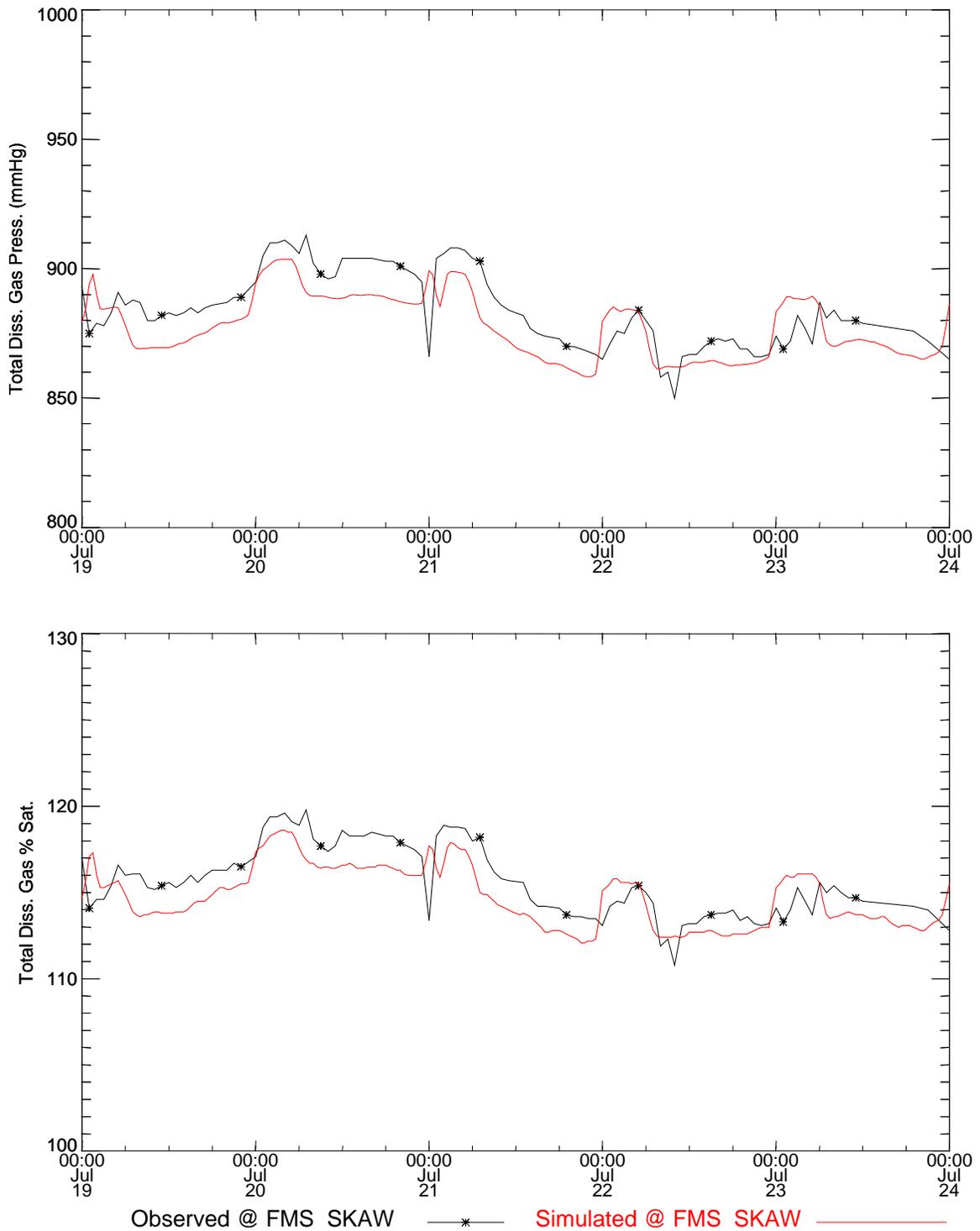


Figure 149. Total dissolved gas pressure and saturation time series comparisons near fixed monitor SKAW for the Summer 1997 study period (FMS-BC).

Table 93. Statistical summary of measurements and simulations near fixed monitor SKAW for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_SKAW	19.47	19.5	0.3	0.25	0.28
Concentration FMS_SKAW	29.51	29.23	0.47	0.45	0.39
Gas Pressure FMS_SKAW	883.71	877.71	13.79	12.08	10.76
% Saturation FMS_SKAW	115.55	114.74	1.96	1.72	1.43

Table 94. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor SKAW for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_SKAW	100	100	100	100

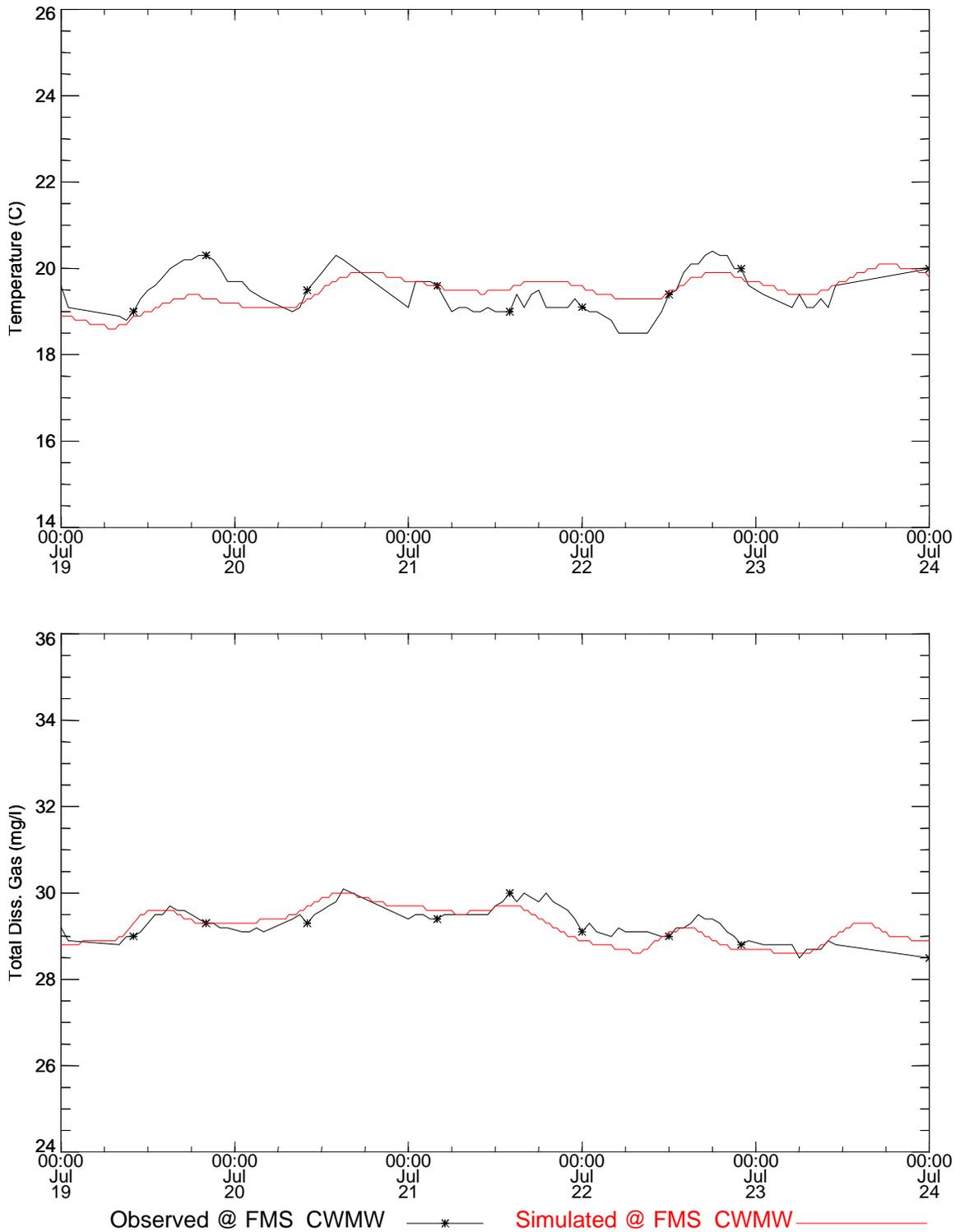


Figure 150. Temperature and total dissolved gas time series near fixed monitor CWMW for the Summer 1997 study period (FMS-BC).

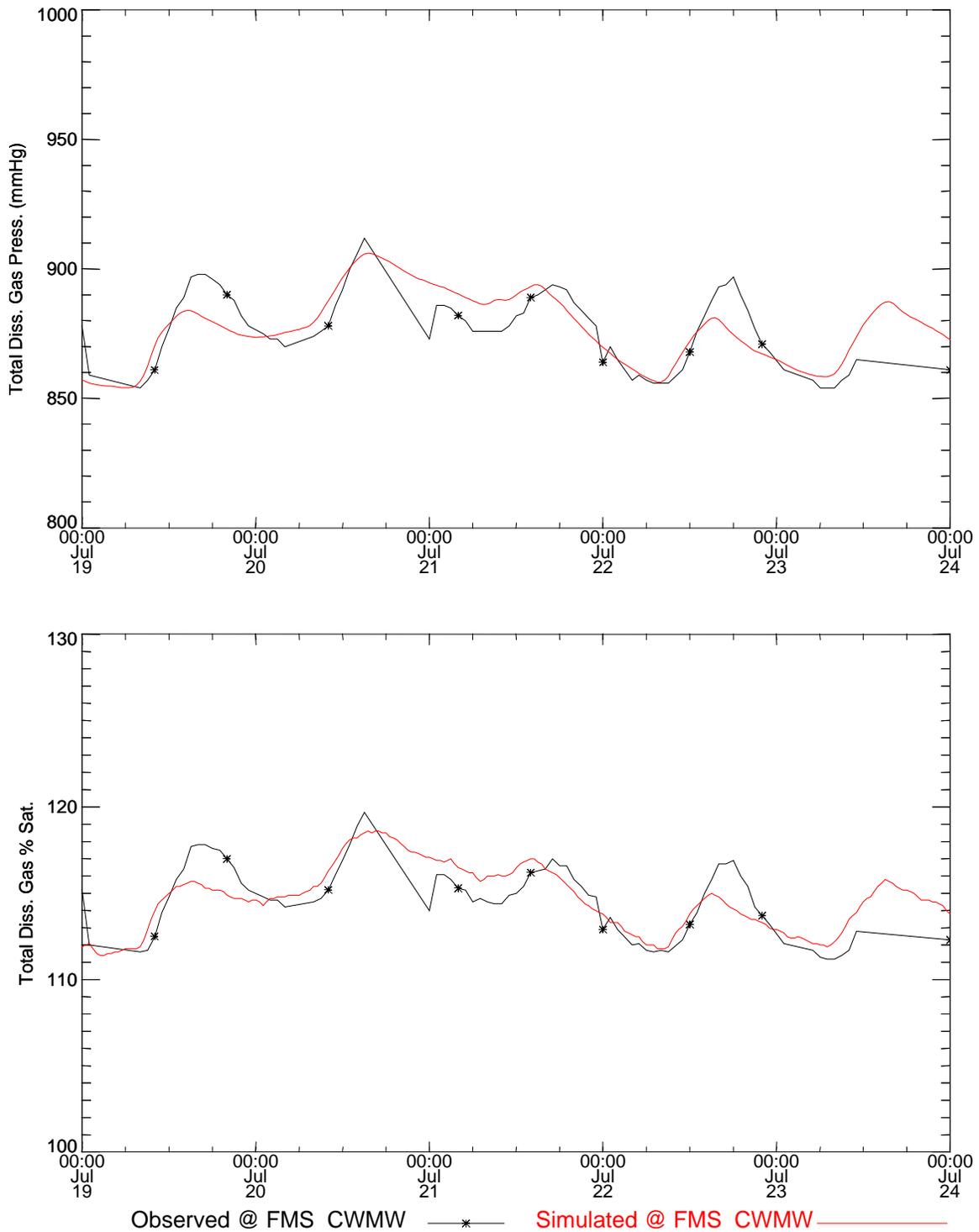


Figure 151. Total dissolved gas pressure and saturation time series comparisons near fixed monitor CWMW for the Summer 1997 study period (FMS-BC).

Table 95. Statistical summary of measurements and simulations near fixed monitor CWMW for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_CWMW	19.45	19.48	0.47	0.35	0.43
Concentration FMS_CWMW	29.23	29.23	0.4	0.4	0.28
Gas Pressure FMS_CWMW	874.9	877.35	14.49	13.53	9.79
% Saturation FMS_CWMW	114.34	114.7	2.09	1.86	1.35

Table 96. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor CWMW for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_CWMW	100	100	100	100

Boundary Conditions using Temporary Monitored Field Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.

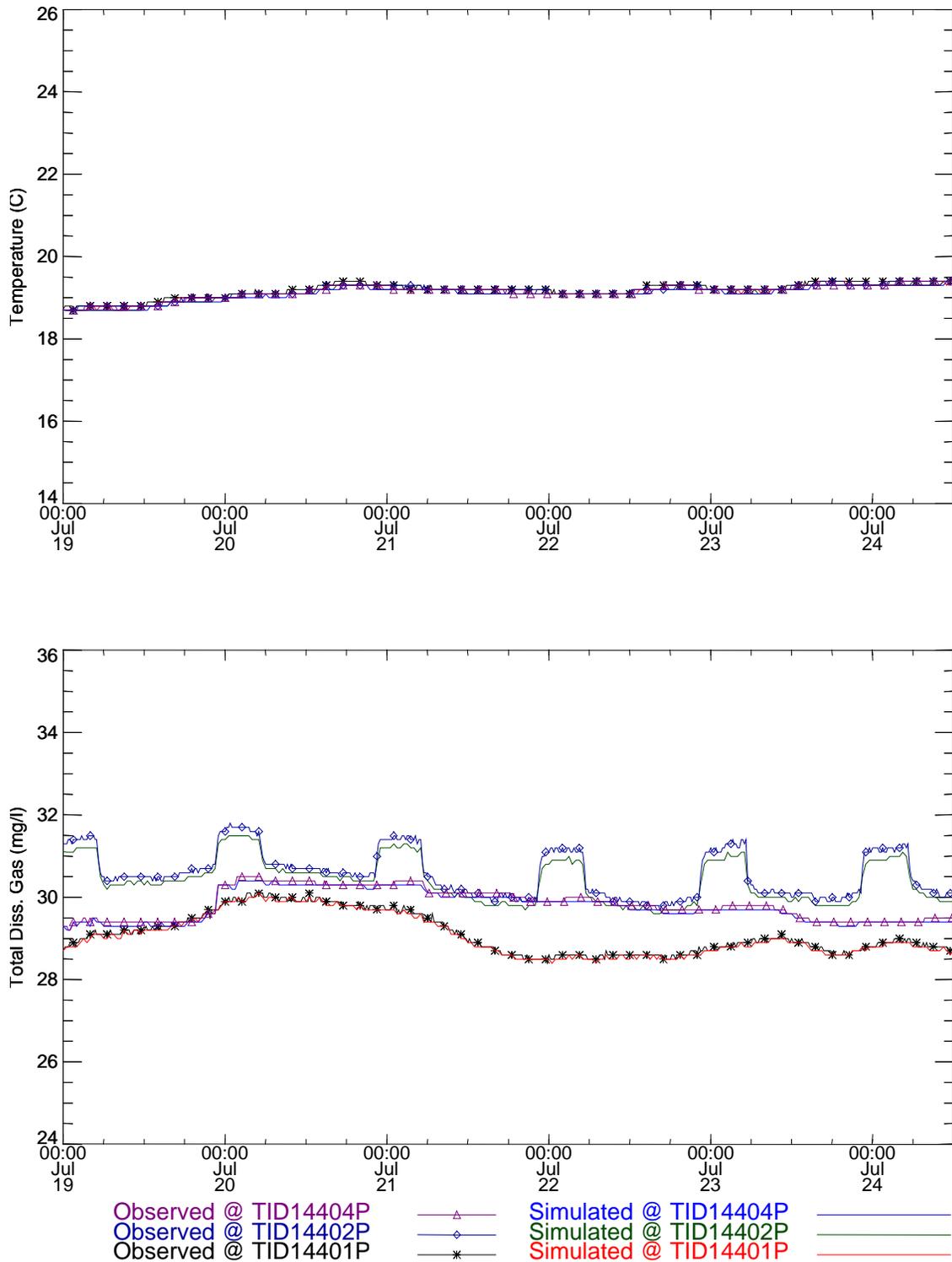


Figure 152. Temperature and total dissolved gas time series near Columbia River mile 144.0 for the Summer 1997 study period (TM-BC).

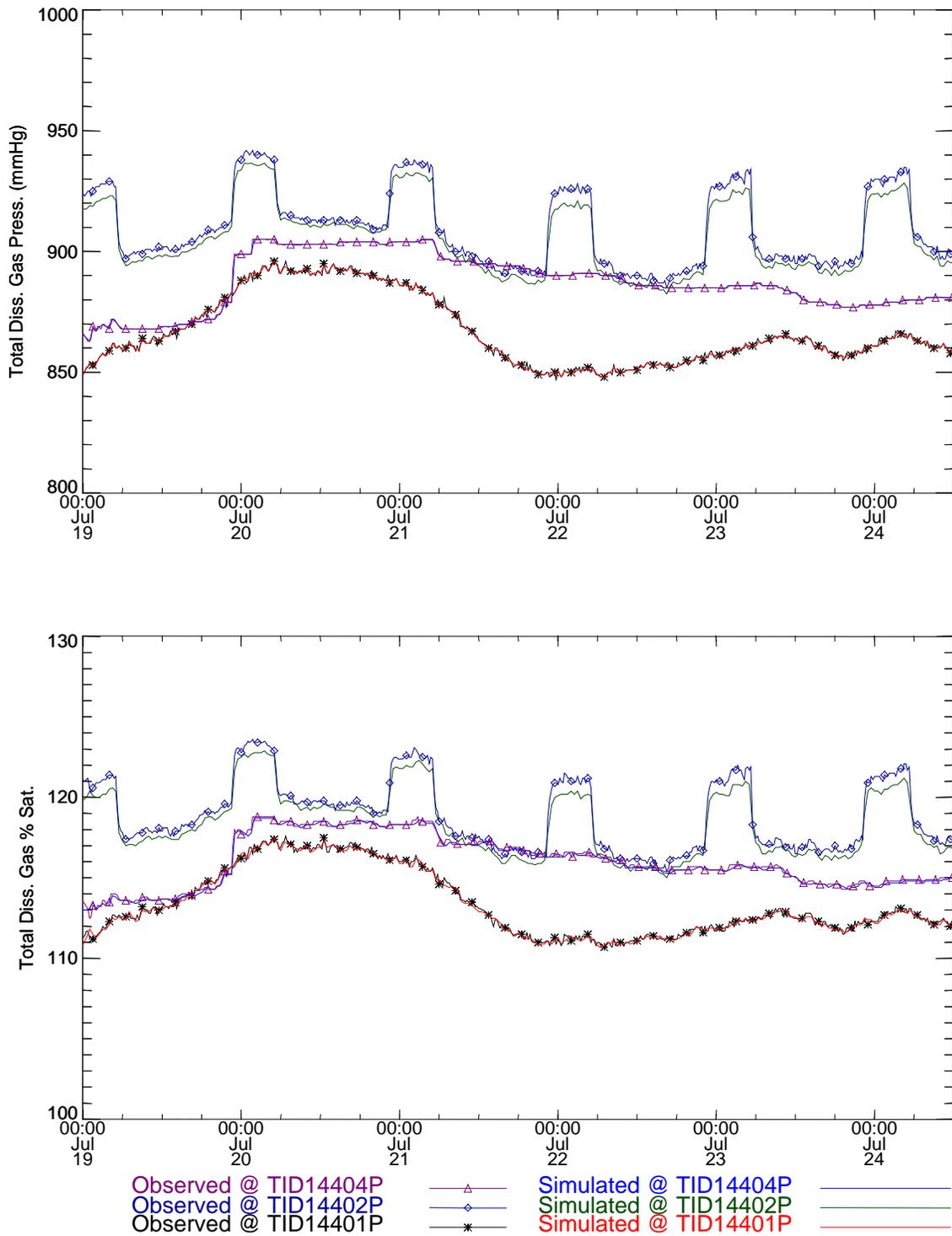


Figure 153. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 144.0 for the Summer 1997 study period (TM-BC).

Table 97. Statistical summary of measurements and simulations near Columbia River mile 144.0 during the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14401P	19.18	19.14	0.18	0.17	0.06
TID14402P	19.16	19.11	0.17	0.18	0.07
TID14404P	19.15	19.1	0.17	0.18	0.07
Concentration					
TID14401P	29.11	29.06	0.49	0.49	0.07
TID14402P	30.57	30.41	0.55	0.53	0.18
TID14404P	29.83	29.78	0.37	0.37	0.07
Gas Pressure					
TID14401P	866.89	866.83	14.38	14.36	0.21
TID14402P	909.43	905.71	15.71	14.95	3.99
TID14404P	887.35	887.3	11.65	11.65	0.12
% Saturation					
TID14401P	113.35	113.3	2.05	2.04	0.14
TID14402P	118.91	118.38	2.15	2.06	0.57
TID14404P	116.02	115.98	1.63	1.64	0.14

Table 98. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 144.0 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID14401P	100	100	100	100
TID14402P	100	100	100	100
TID14404P	100	100	100	100

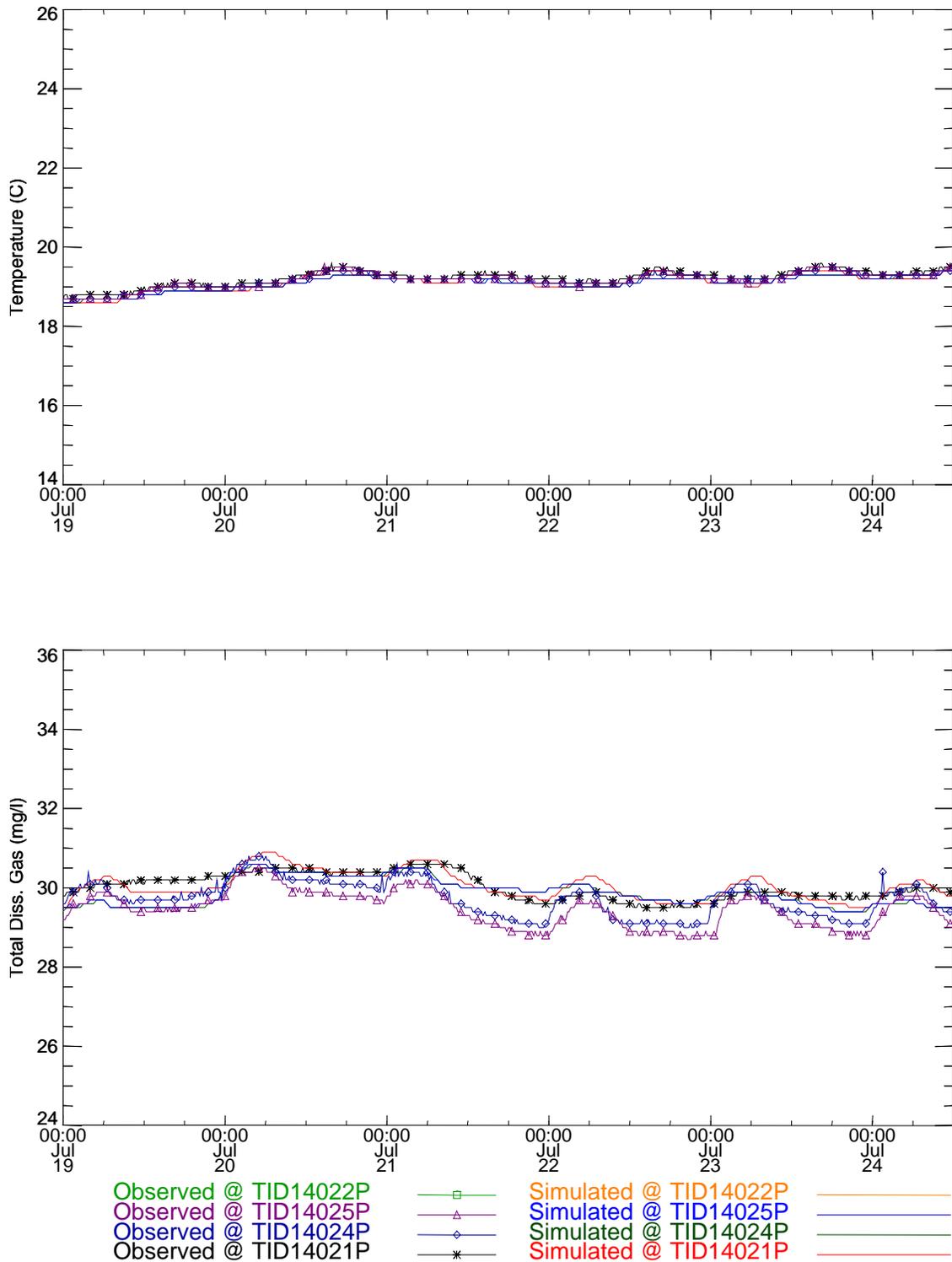


Figure 154. Temperature and total dissolved gas time series near Columbia River mile 140.2 for the Summer 1997 study period (TM-BC).

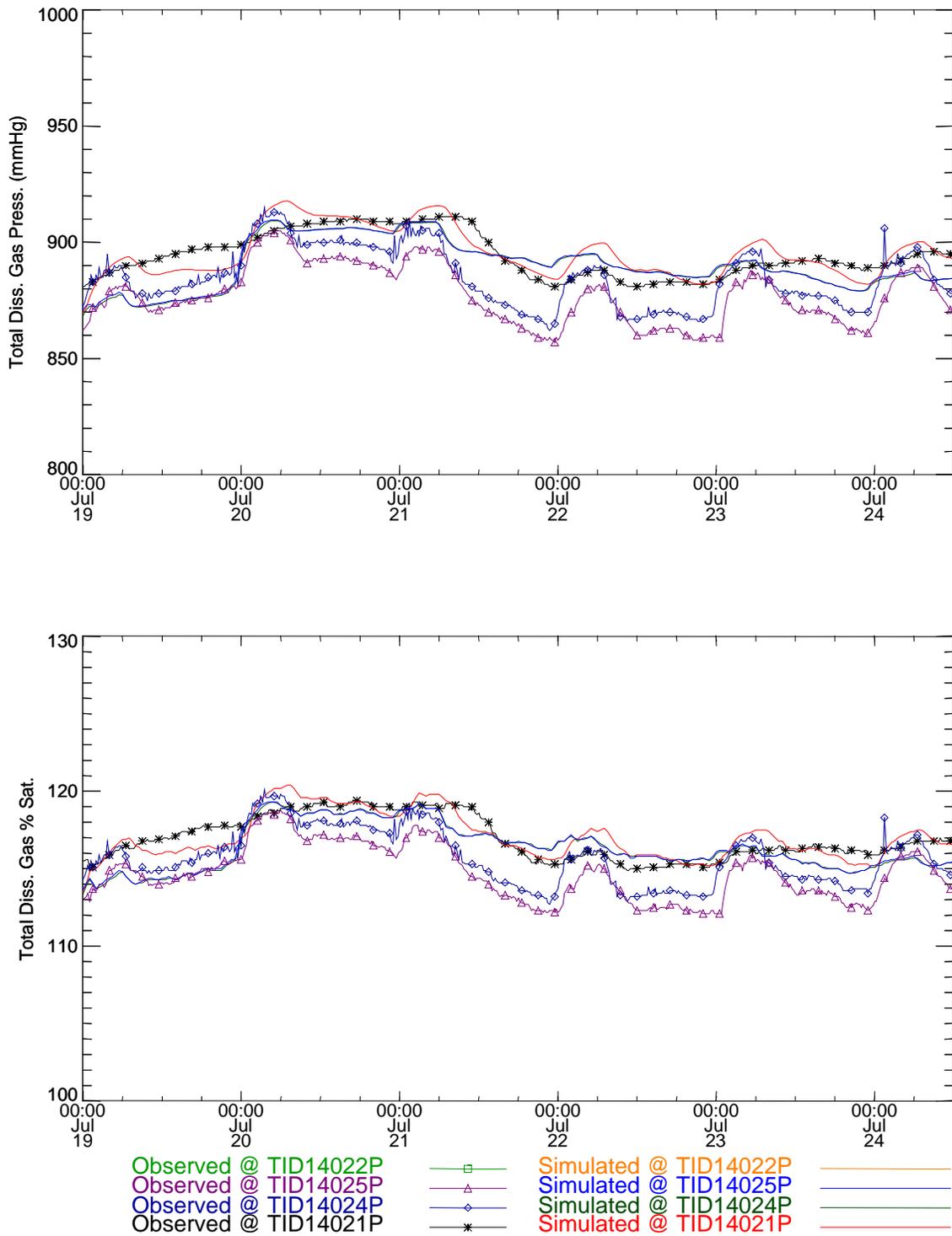


Figure 155. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 140.2 for the Summer 1997 study period (TM-BC).

Table 99. Statistical summary of measurements and simulations near Columbia River mile 140.2 during the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID14021P	19.22	19.11	0.19	0.21	0.12
TID14024P	19.16	19.1	0.19	0.18	0.09
TID14025P	19.18	19.1	0.2	0.18	0.11
Concentration					
TID14021P	30.03	30.06	0.33	0.35	0.21
TID14024P	29.72	29.88	0.45	0.35	0.4
TID14025P	29.47	29.89	0.45	0.35	0.54
Gas Pressure					
TID14021P	894.44	895.59	9.59	10.37	5.92
TID14024P	884.82	890.17	12.63	10.83	11.59
TID14025P	877.44	890.4	12.45	10.72	16.3
% Saturation					
TID14021P	116.95	117.06	1.41	1.48	0.79
TID14024P	115.69	116.35	1.78	1.53	1.51
TID14025P	114.73	116.38	1.76	1.52	2.1

Table 100. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 140.2 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID14021P	100	100	100	100
TID14024P	100	100	100	100
TID14025P	100	96.6	100	100

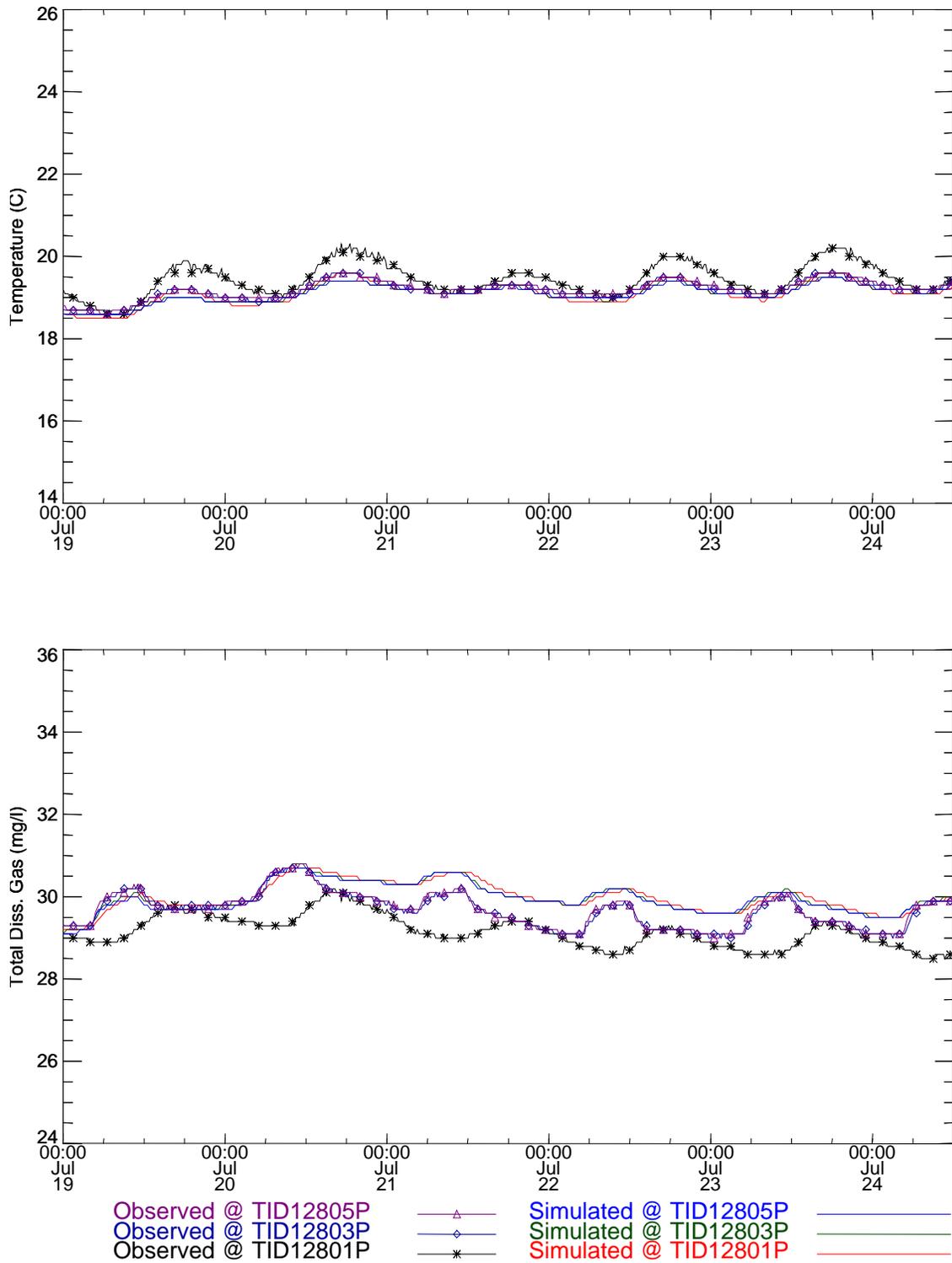


Figure 156. Temperature and total dissolved gas time series near Columbia River mile 128.0 for the Summer 1997 study period (TM-BC).

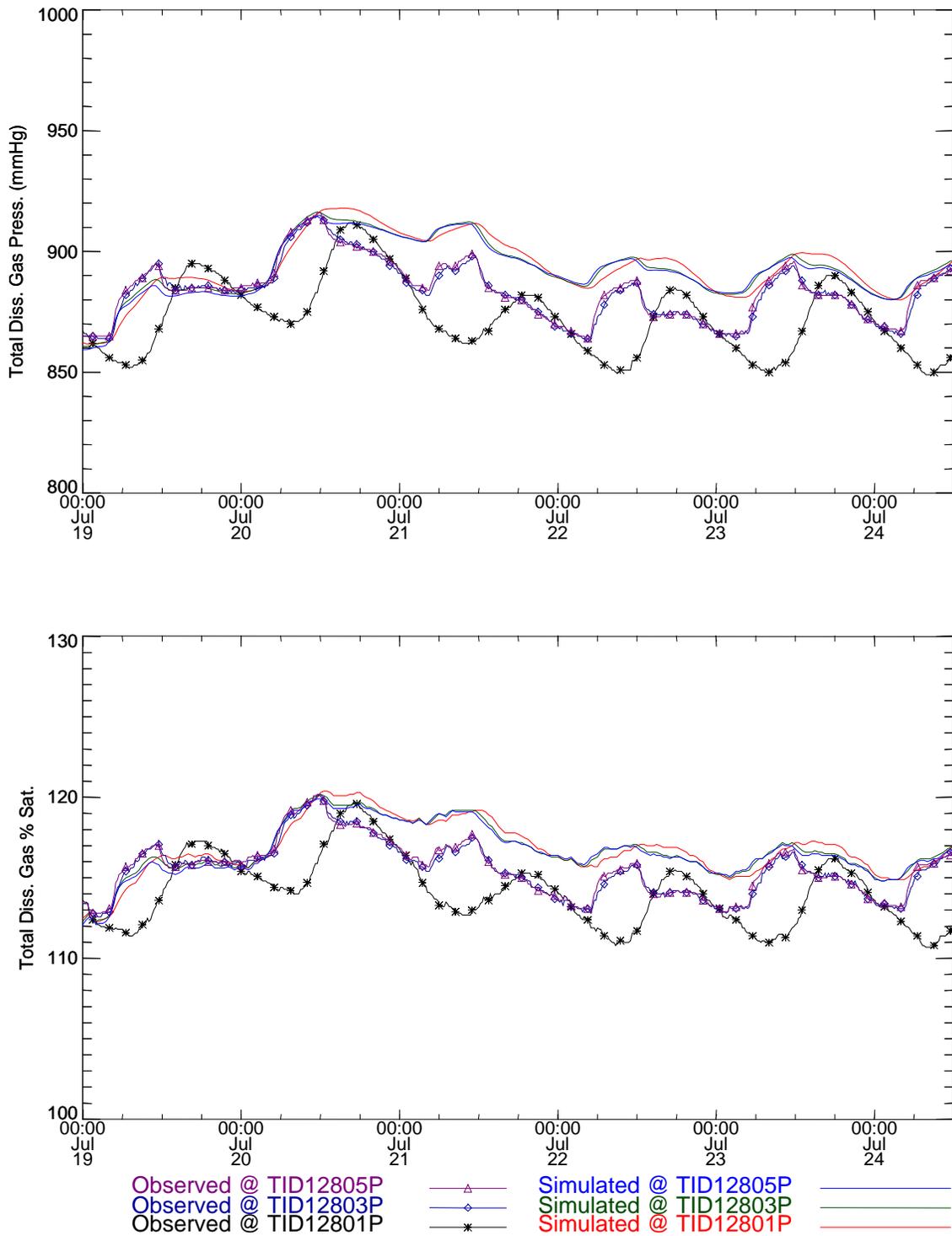


Figure 157. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 128.0 for the Summer 1997 study period (TM-BC).

Table 101. Statistical summary of measurements and simulations near Columbia River mile 128.0 during the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID12801P	19.45	19.11	0.39	0.27	0.39
TID12803P	19.19	19.1	0.24	0.22	0.11
TID12805P	19.2	19.1	0.23	0.22	0.12
Concentration					
TID12801P	29.16	29.99	0.38	0.35	0.92
TID12803P	29.67	29.98	0.42	0.36	0.41
TID12805P	29.69	29.96	0.43	0.36	0.4
Gas Pressure					
TID12801P	872.68	893.51	15.56	12.59	25.05
TID12803P	883.32	893.1	12.09	11.98	12.58
TID12805P	884.03	892.48	12.12	11.92	12
% Saturation					
TID12801P	114.1	116.79	2.15	1.72	3.24
TID12803P	115.5	116.74	1.7	1.65	1.62
TID12805P	115.59	116.65	1.7	1.64	1.55

Table 102. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 128.0 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID12801P	100	69.43	83.77	84.91
TID12803P	100	100	100	100
TID12805P	100	100	100	100

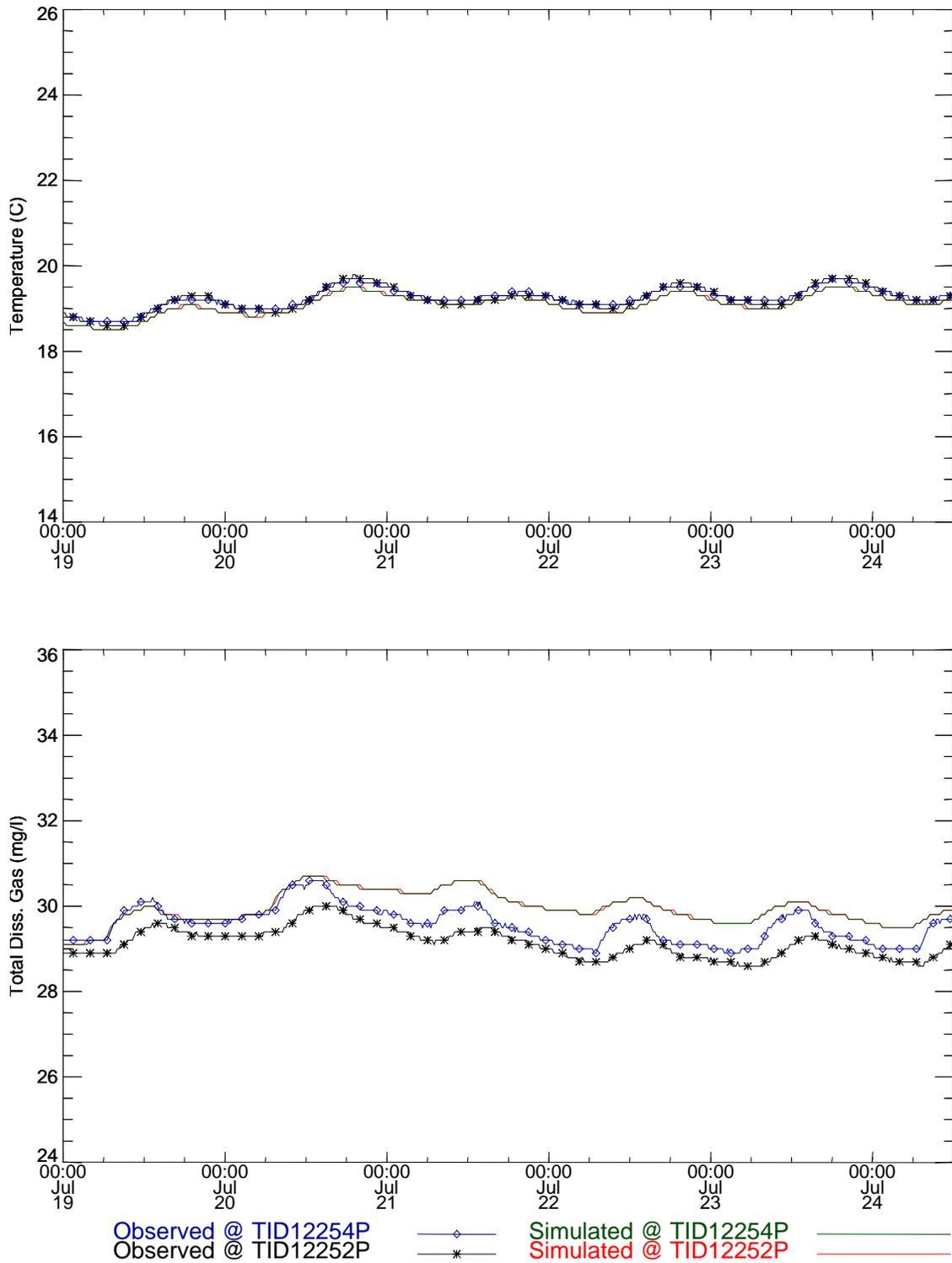


Figure 158. Temperature and total dissolved gas time series near Columbia River mile 122.5 for the Summer 1997 study period (TM-BC).

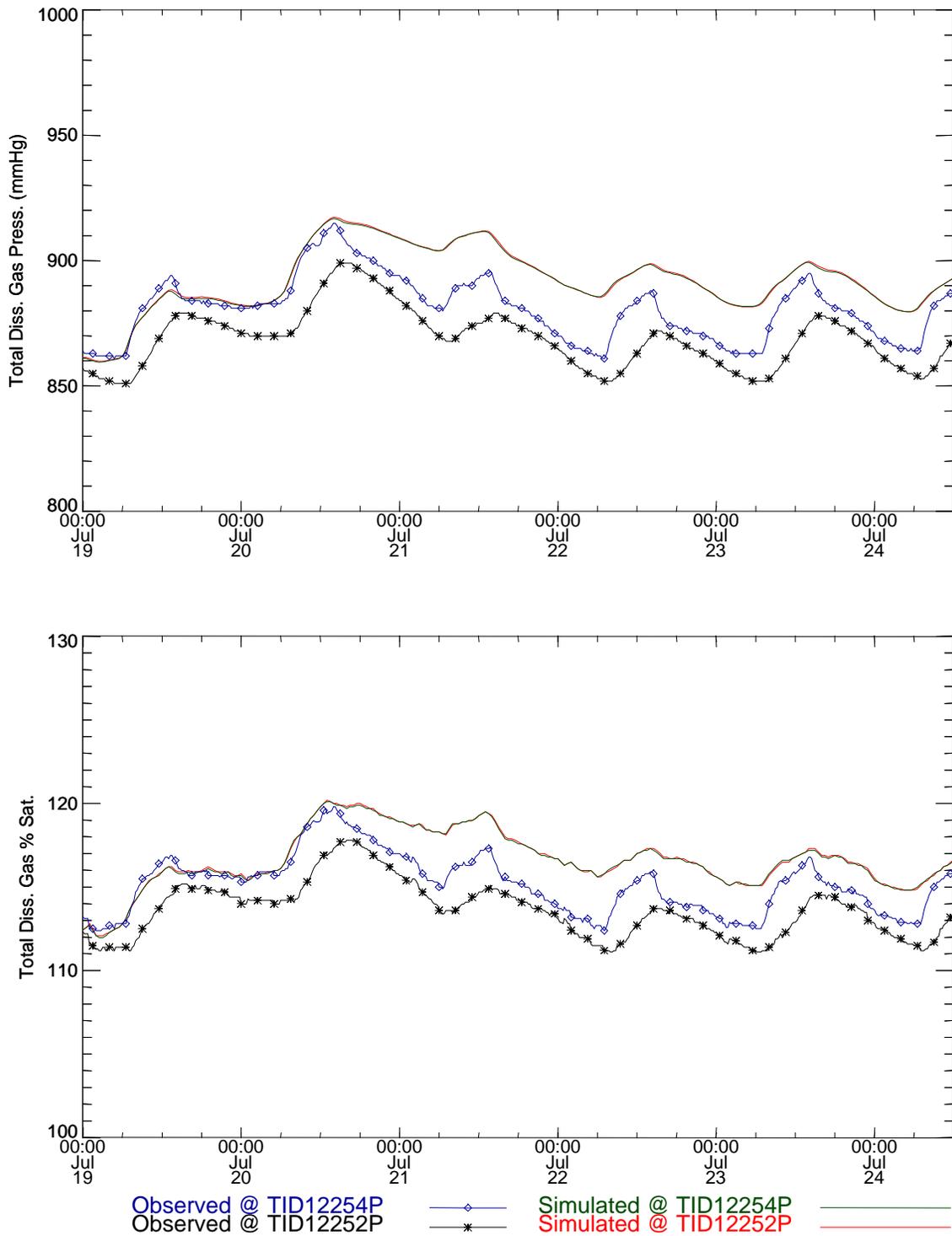


Figure 159. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 122.5 for the Summer 1997 study period (TM-BC).

Table 103. Statistical summary of measurements and simulations near Columbia River mile 122.5 during the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID12252P	19.23	19.09	0.27	0.25	0.15
TID12254P	19.24	19.09	0.24	0.24	0.16
Concentration					
TID12252P	29.15	29.96	0.35	0.38	0.85
TID12254P	29.56	29.95	0.41	0.37	0.49
Gas Pressure					
TID12252P	868.85	892.44	11.77	13.04	25.04
TID12254P	880.84	892.29	12.57	12.99	14.28
% Saturation					
TID12252P	113.6	116.65	1.66	1.77	3.24
TID12254P	115.17	116.63	1.76	1.76	1.85

Table 104. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 122.5 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12252P	100	80.38	98.49	98.87
TID12254P	100	100	100	100

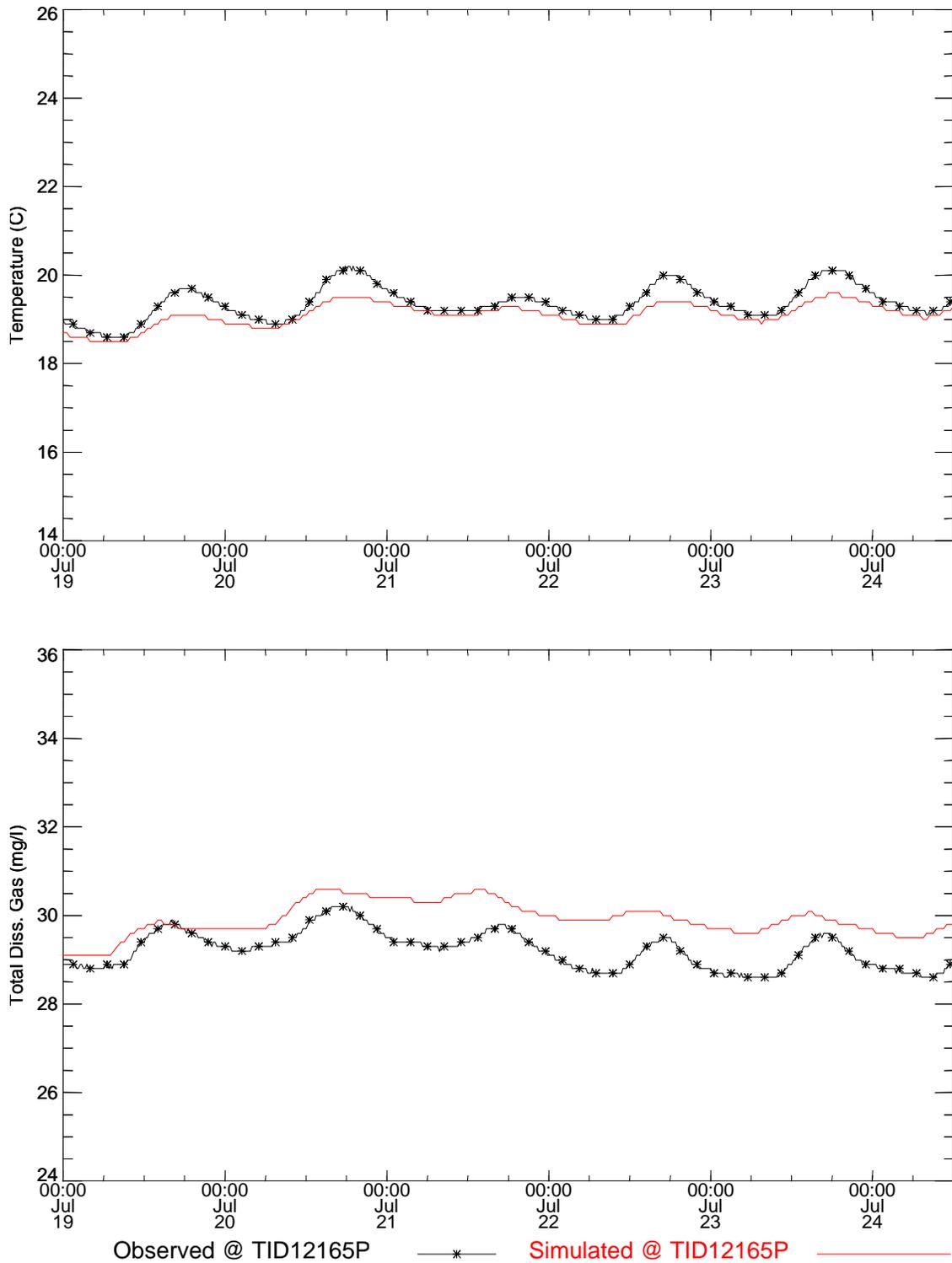


Figure 160. Temperature and total dissolved gas time series near Columbia River mile 121.6 for the Summer 1997 study period (TM-BC).

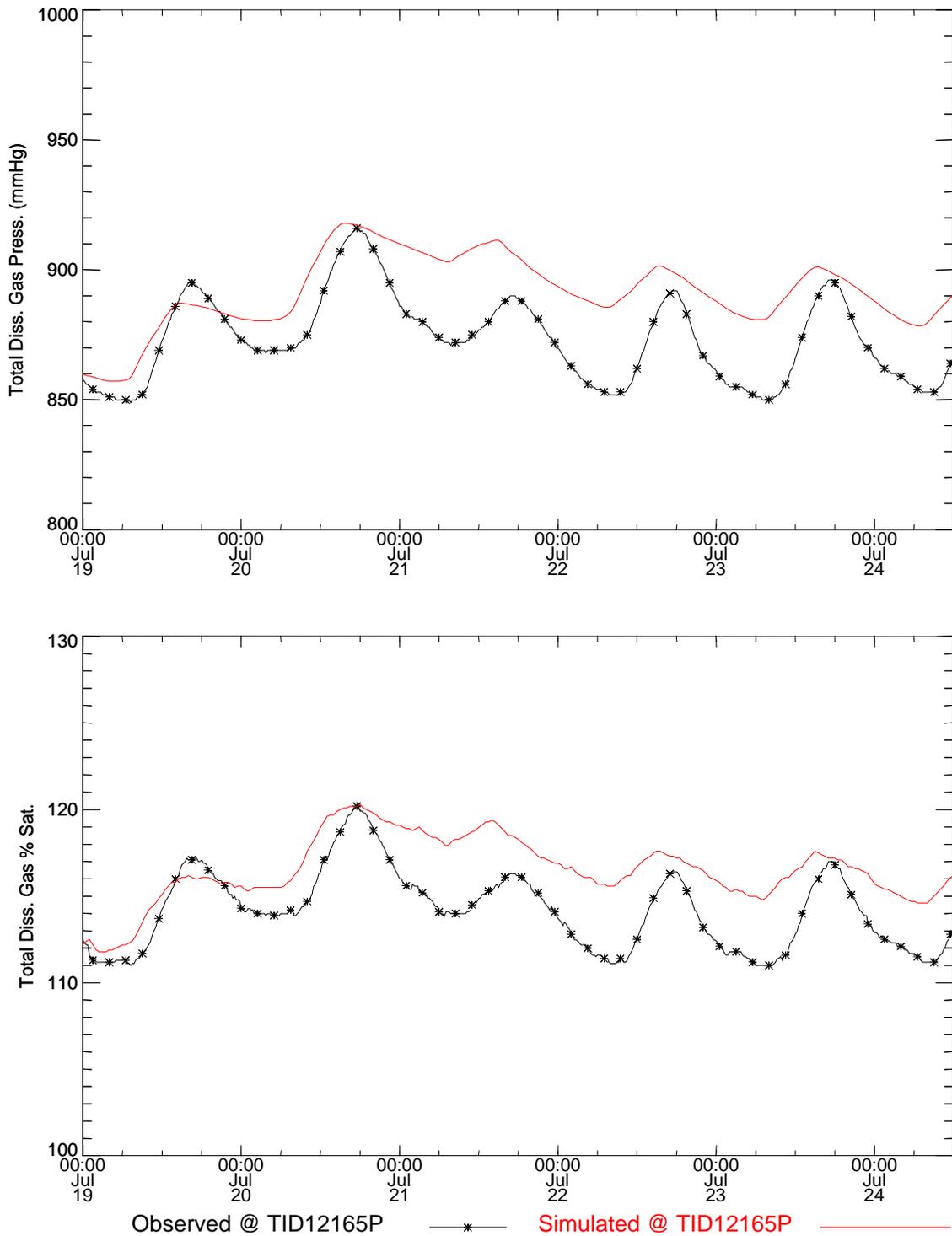


Figure 161. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 121.6 for the Summer 1997 study period (TM-BC).

Table 105. Statistical summary of measurements and simulations near Columbia River mile 137.4 during the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature TID12165P	19.37	19.11	0.38	0.26	0.31
Concentration TID12165P	29.21	29.92	0.42	0.38	0.78
Gas Pressure TID12165P	873.09	891.52	16.43	14.2	21.49
% Saturation TID12165P	114.15	116.53	2.24	1.9	2.78

Table 106. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 121.6 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TID12165P	100	84.91	100	100

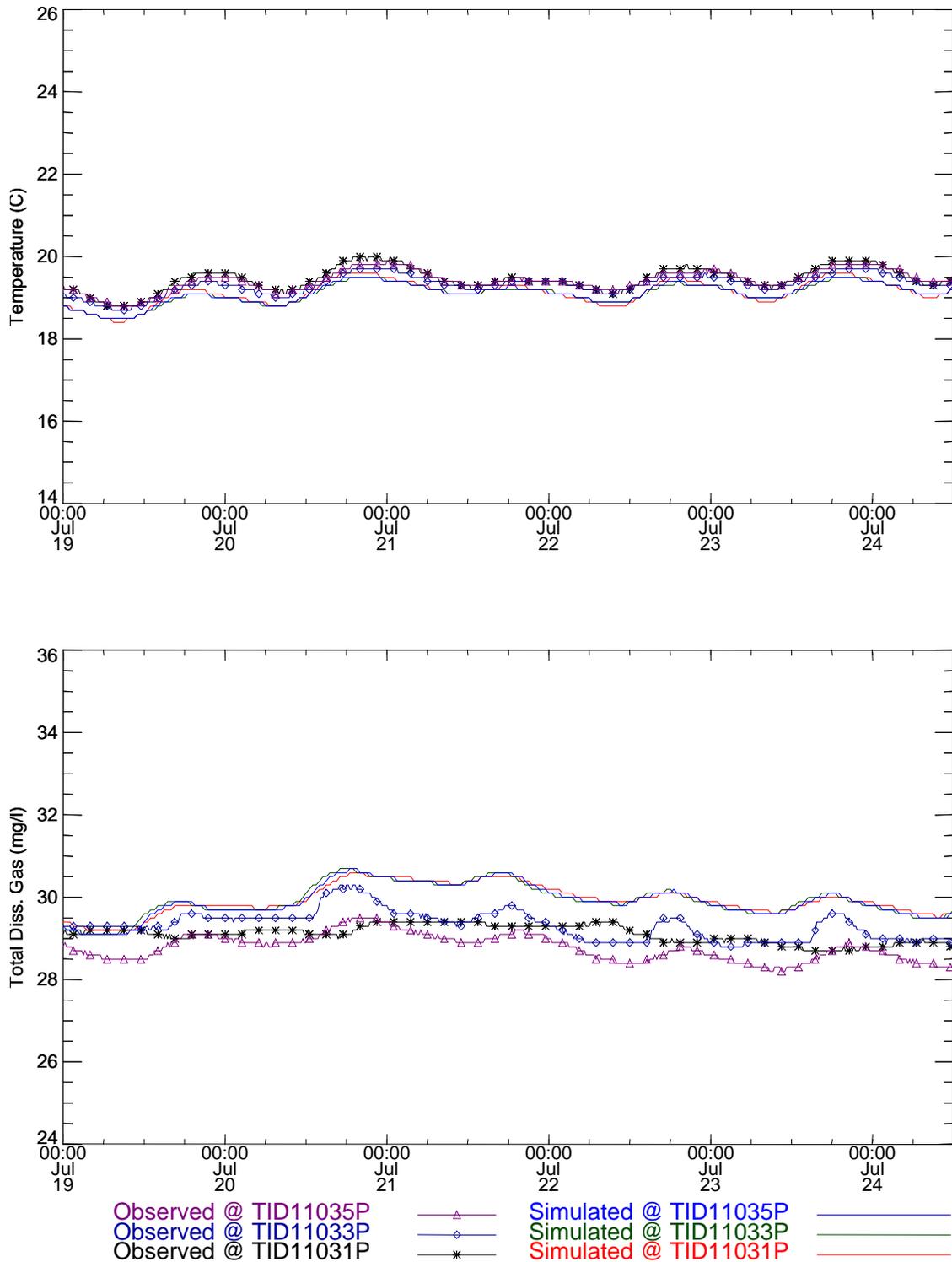


Figure 162. Temperature and total dissolved gas time series near Columbia River mile 110.3 for the Summer 1997 study period (TM-BC).

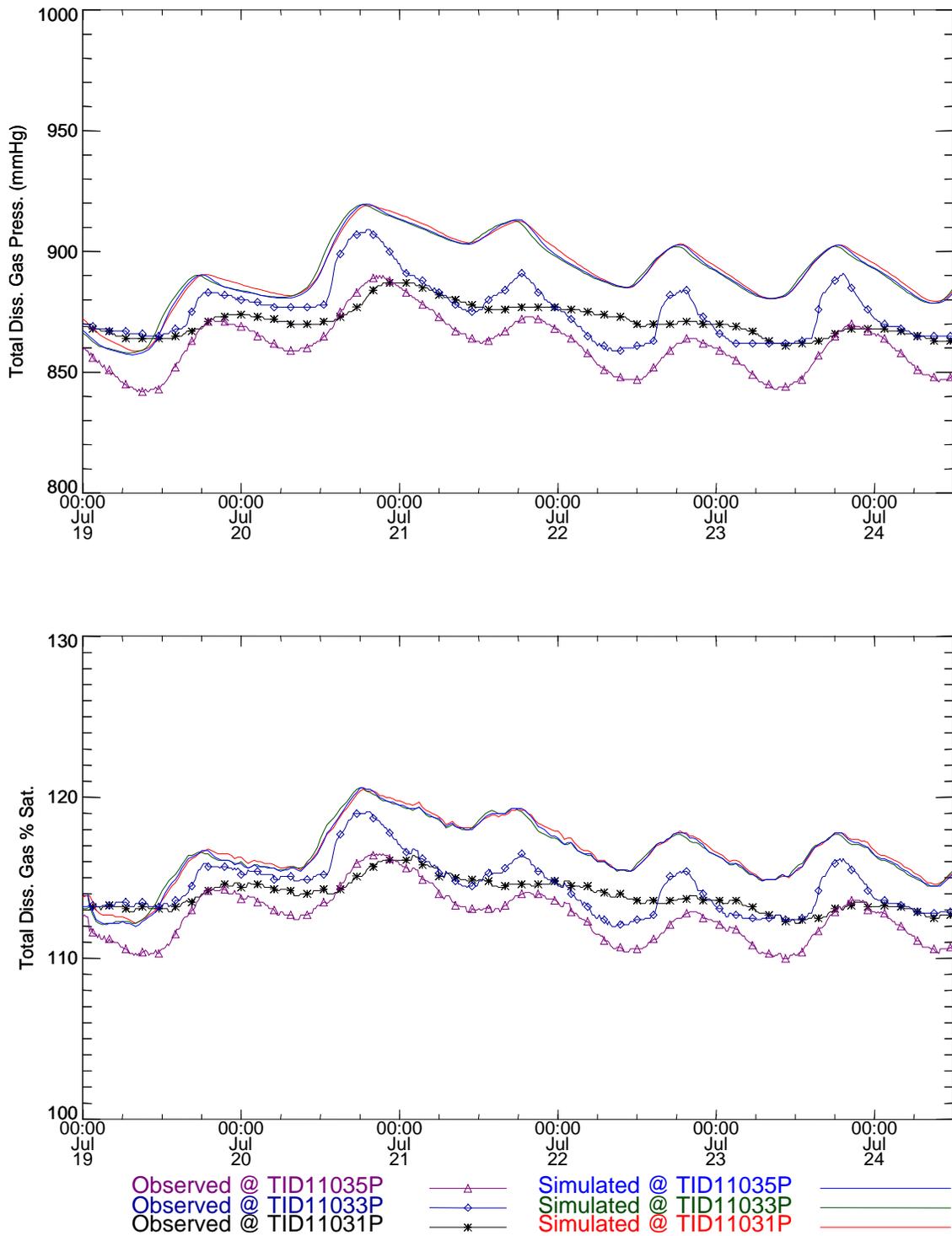


Figure 163. Total dissolved gas pressure and saturation time series comparisons near Columbia River mile 110.3 for the Summer 1997 study period (TM-BC).

Table 107. Statistical summary of measurements and simulations near Columbia River mile 110.3 during the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TID11031P	19.45	19.13	0.29	0.29	0.33
TID11033P	19.32	19.1	0.24	0.25	0.22
TID11035P	19.42	19.11	0.25	0.25	0.32
Concentration					
TID11031P	29.11	29.94	0.21	0.36	0.9
TID11033P	29.33	29.92	0.35	0.4	0.68
TID11035P	28.78	29.92	0.32	0.4	1.17
Gas Pressure					
TID11031P	871.35	892.4	6.44	14.44	23.58
TID11033P	875.66	891.64	11.79	14.62	18.86
TID11035P	861.34	891.51	11.5	14.9	31.54
% Saturation					
TID11031P	113.93	116.64	0.95	1.93	3.05
TID11033P	114.49	116.54	1.66	1.95	2.44
TID11035P	112.62	116.52	1.62	1.98	4.09

Table 108. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 110.3 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
TID11031P	100	71.32	97.74	98.87
TID11033P	100	97.74	100	100
TID11035P	100	29.06	80.38	82.26

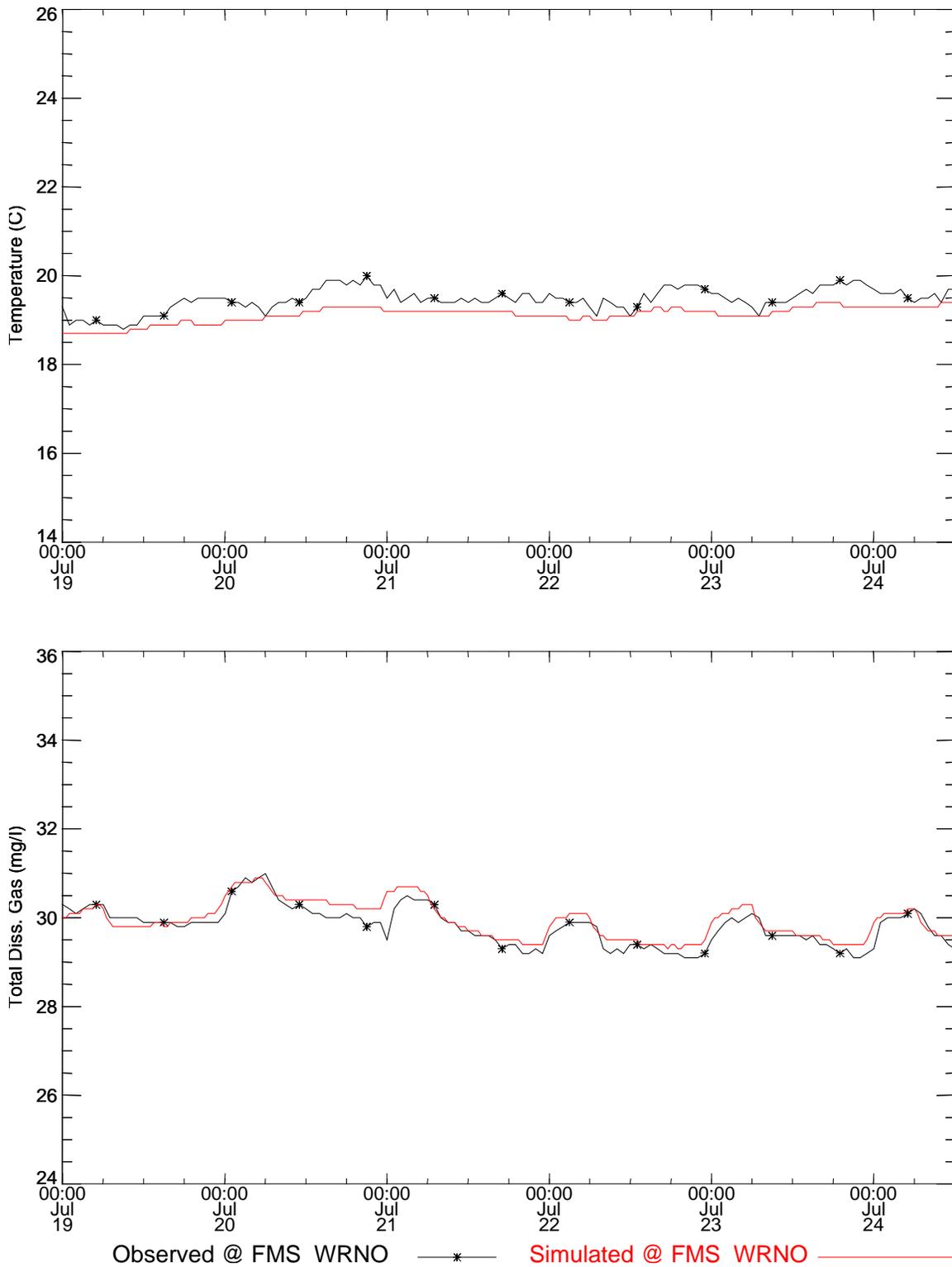


Figure 164. Temperature and total dissolved gas time series near fixed monitor WRNO for the Summer 1997 study period (TM-BC).

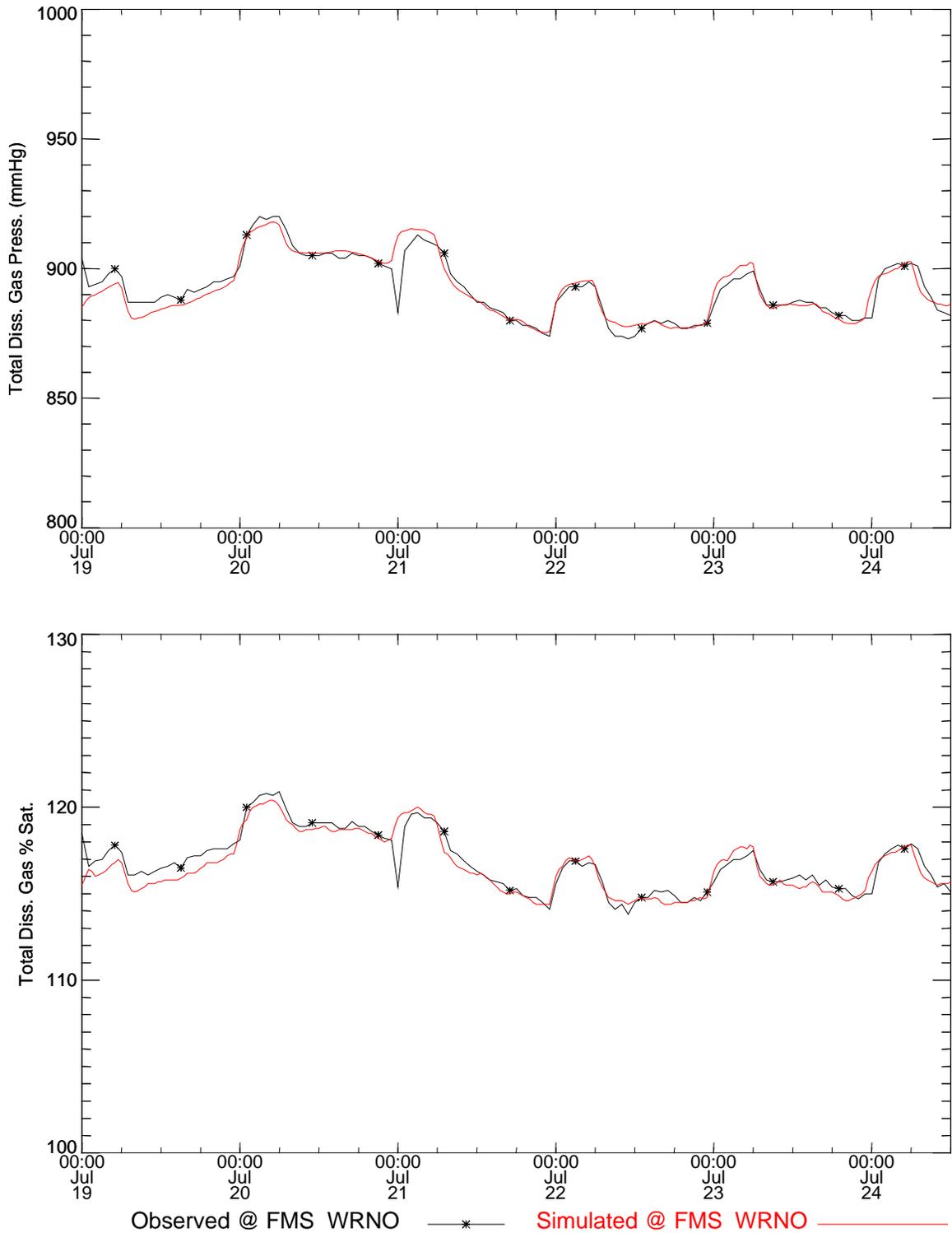


Figure 165. Total dissolved gas pressure and saturation time series comparisons near fixed monitor WRNO for the Summer 1997 study period (TM-BC).

Table 109. Statistical summary of measurements and simulations near fixed monitor WRNO during the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_WRNO	19.47	19.13	0.25	0.18	0.38
Concentration FMS_WRNO	29.82	29.94	0.43	0.41	0.21
Gas Pressure FMS_WRNO	892.46	892.24	11.42	11.65	4.01
% Saturation FMS_WRNO	116.83	116.62	1.67	1.66	0.61

Table 110. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor WRNO for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_WRNO	100	99.62	100	100

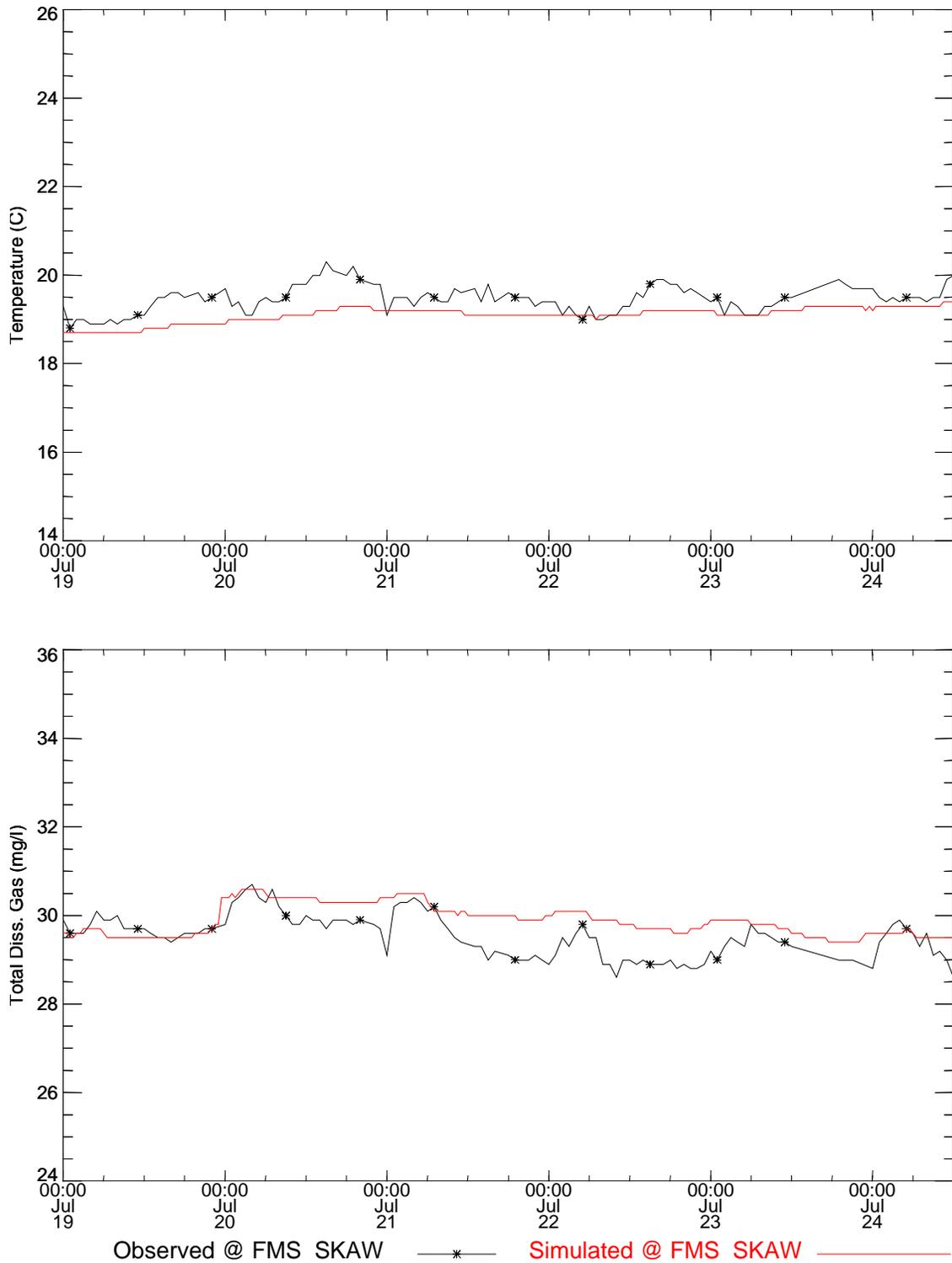


Figure 166. Temperature and total dissolved gas time series near fixed monitor SKAW for the Summer 1997 study period (TM-BC).

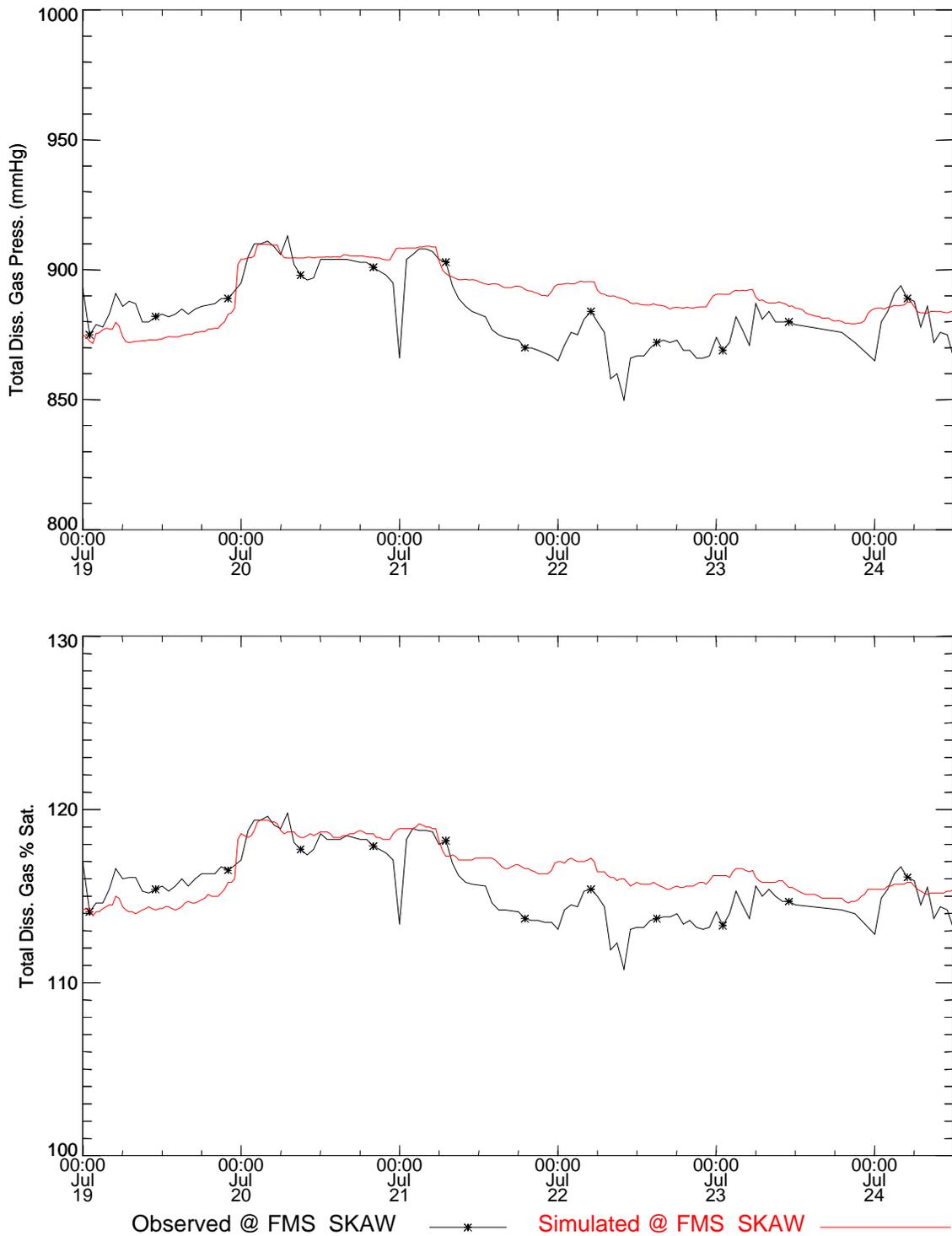


Figure 167. Total dissolved gas pressure and saturation time series comparisons near fixed monitor SKAW for the Summer 1997 study period (TM-BC).

Table 111. Statistical summary of measurements and simulations near fixed monitor SKAW during the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_SKAW	19.48	19.1	0.29	0.18	0.44
Concentration FMS_SKAW	29.5	29.89	0.46	0.35	0.54
Gas Pressure FMS_SKAW	883.51	890.37	13.36	10.75	13.2
% Saturation FMS_SKAW	115.51	116.38	1.9	1.53	1.72

Table 112. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor SKAW for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_SKAW	99.62	98.11	99.25	99.25

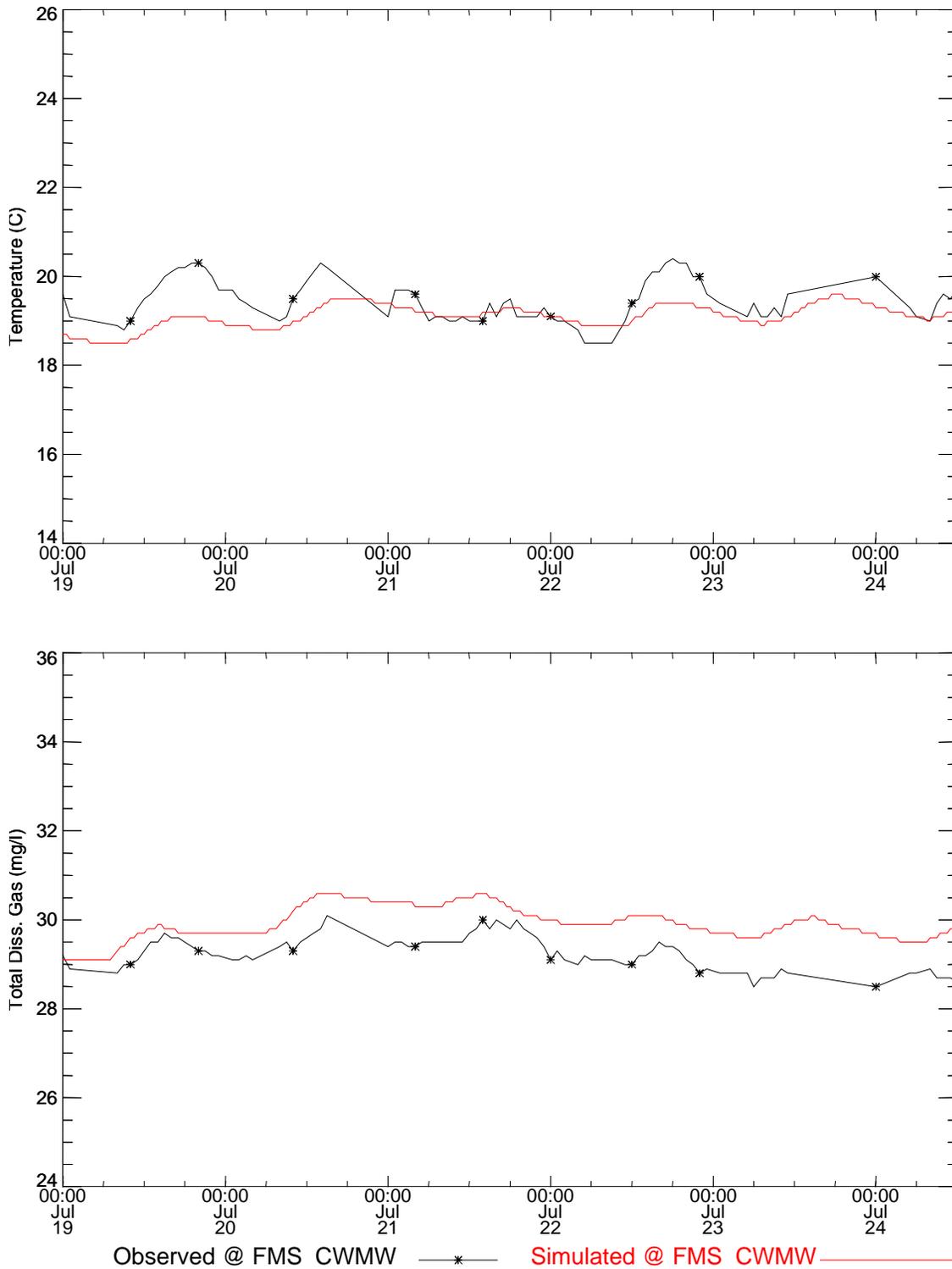


Figure 168. Temperature and total dissolved gas time series near fixed monitor CWMW for the Summer 1997 study period (TM-BC).

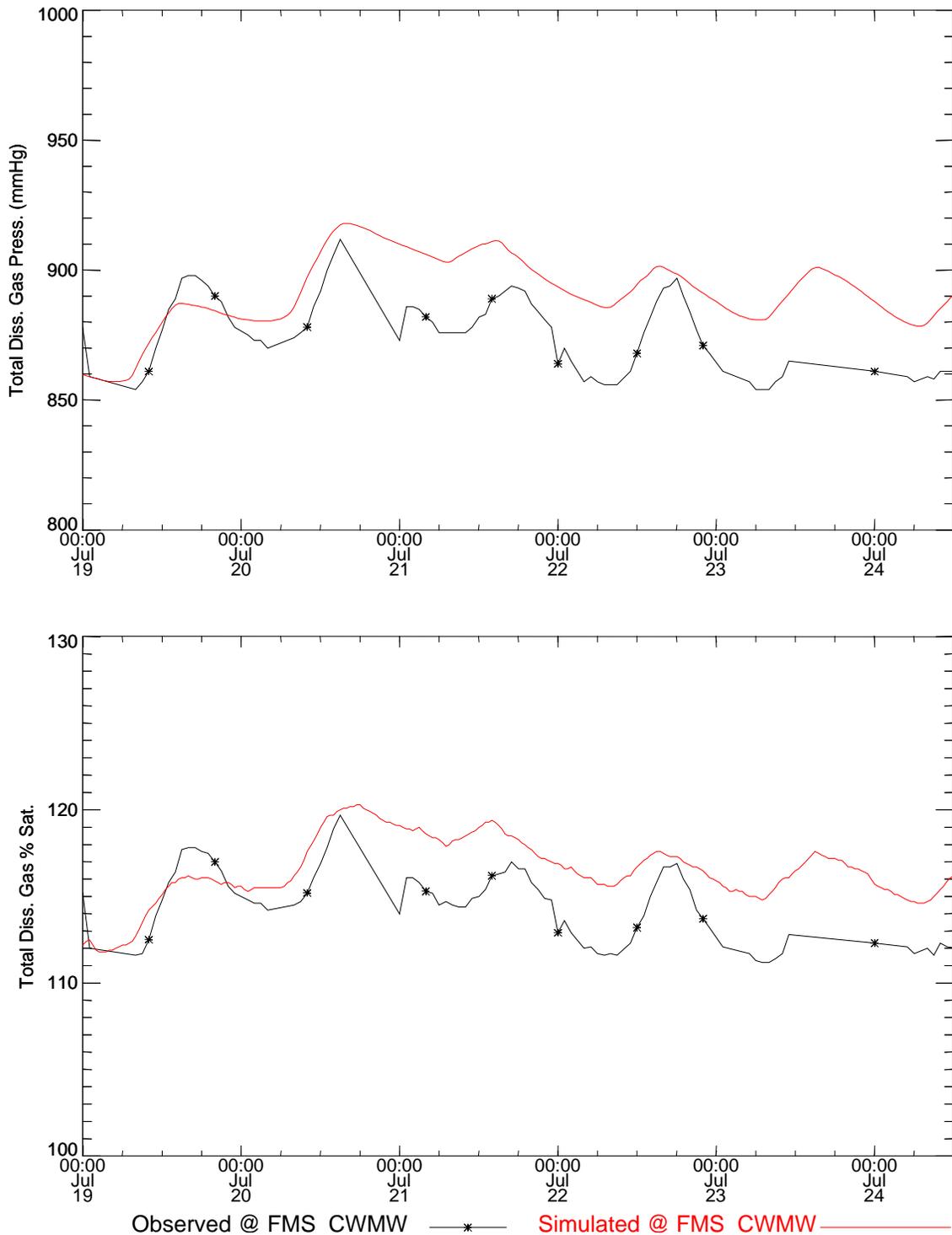


Figure 169. Total dissolved gas pressure and saturation time series comparisons near fixed monitor CWMW for the Summer 1997 study period (TM-BC).

Table 113. Statistical summary of measurements and simulations near fixed monitor CWMW during the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_CWMW	19.45	19.11	0.45	0.26	0.51
Concentration FMS_CWMW	29.18	29.92	0.41	0.38	0.8
Gas Pressure FMS_CWMW	873.51	891.52	14.51	14.21	21.75
% Saturation FMS_CWMW	114.13	116.53	2.1	1.9	2.92

Table 114. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor CWMW for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_CWMW	95.47	85.66	100	99.62

2 References

Richmond, M.C., W.A. Perkins, and T.D. Scheibe. 1998. *Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers. Part 1: Summary and Model Formulation*. Draft Final Report submitted to U.S. Army Corps of Engineers, Walla Walla District. Battelle Pacific Northwest Division, Richland, Washington.

Steinbrenner J.P., and J.R. Chawner, 1995. *The GRIDGEN Version 9 Multiple Block Grid Generation Software*. MDA Engineering, Inc., Arlington, Texas.

U.S. Army Corps of Engineers (USACE), 1996. *Dissolved Gas Abatement, Phase I*. Technical Report. North Pacific Division, Portland and Walla Walla Districts.

Appendix A. Tidal Reach Data Sources

A.1 Bathymetry

Bathymetric data for the Columbia River was gathered from the various sources shown in Table 115. The primary source was the Tidal Reach survey, during which elevations were measured at a relatively fine spacing from Bonneville dam to the mouth of the Willamette River, except in the restricted areas below Bonneville dam. The data sets near Bonneville dam are shown in Figure 171. Using the Arc/Info® GIS software system, the data was converted to a consistent coordinate system and datum, and combined to build a triangular irregular network (TIN), which represented the river bottom and shore as a three-dimensional surface. The resulting surface for the Tidal reach is shown in Figure 170. Once the surface was produced, it was “sampled” at the necessary grid locations to produce the bathymetry required by the hydrodynamic model grid

Table 115. Columbia River bathymetry data sets used to create the Tidal Reach bathymetric surface.

Bathymetric Data Set	Source	Survey Date	Approximate Rivermile	
			Start	End
Tidal Reach Survey (Tidbath)	George Kalli (Portland)	unknown	5.0	145.1
Bonneville Pool Survey	George Kalli (Portland)	unknown	148.0	191.7
Bonneville Spillway (bonn-n.xyz and bonn-s.xyz)	Kim Fodrea (Portland)	1996	145.5	145.5
Bonneville Tailrace (Bod026a.xyz)	Gregg Bertrand (Portland)	unknown	144.5	145.5
Bonneville North Powerhouse Tailrace (Bon271.xyz)	Gregg Bertrand (Portland)	unknown	145.5	145.7
Bonneville North Powerhouse Forebay (Bon227.xyz)	Gregg Bertrand (Portland)	unknown	145.7	146.0
Bonneville South Powerhouse Forebay (Bon023.xyz)	Gregg Bertrand (Portland)	unknown	145.3	146.0
Bonneville Forebay North Channel (Bon271.xyz)	Gregg Bertrand (Portland)	unknown	146.1	146.8
Bonneville Forebay Main Channel (Bon225)	Mike Cristler (Portland)	1990	146.2	148.0
Digitized NOAA Navigation Charts	Battelle	unknown	various	various

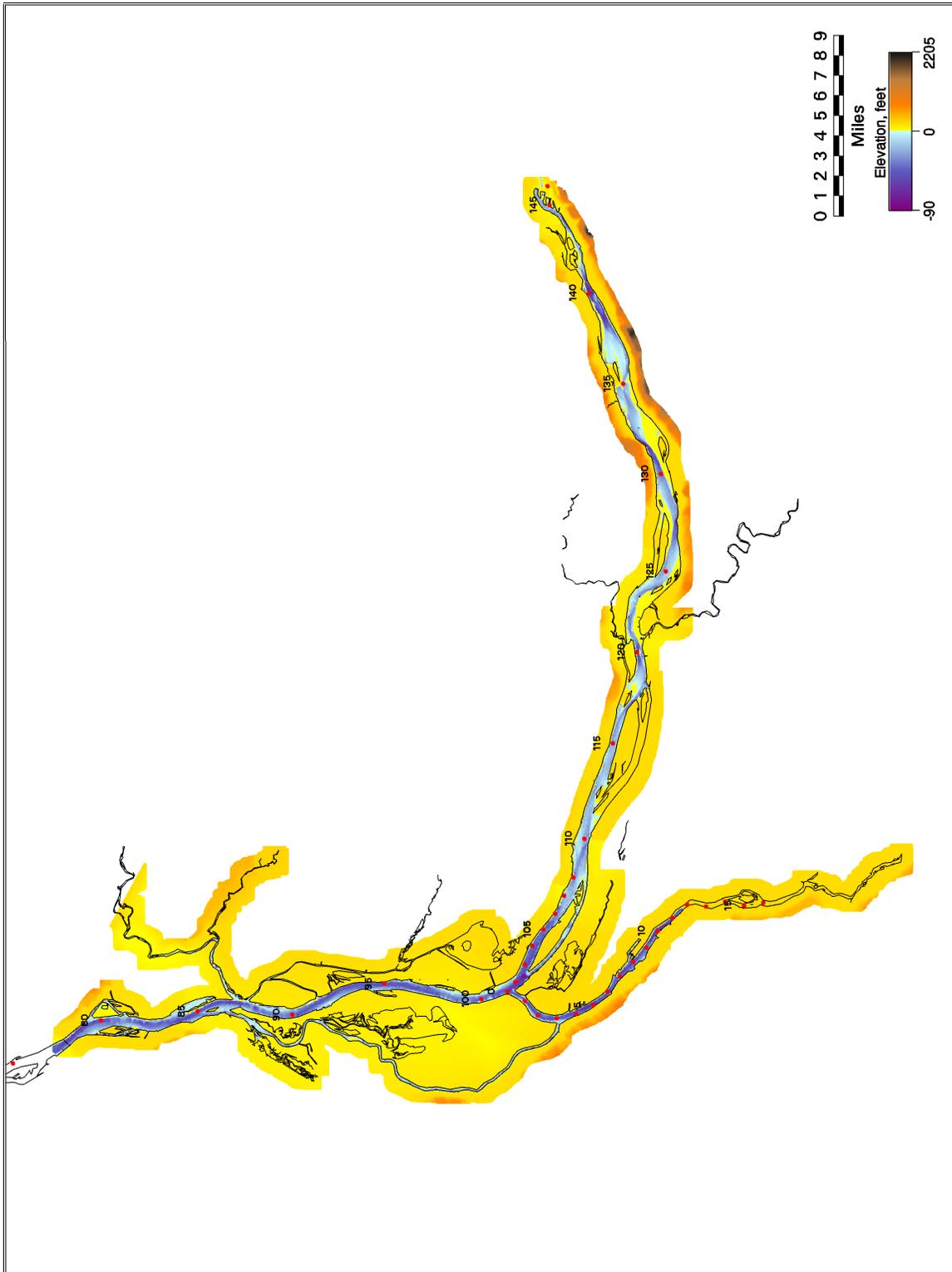


Figure 170. Color representation of Tidal Reach bathymetric surface.

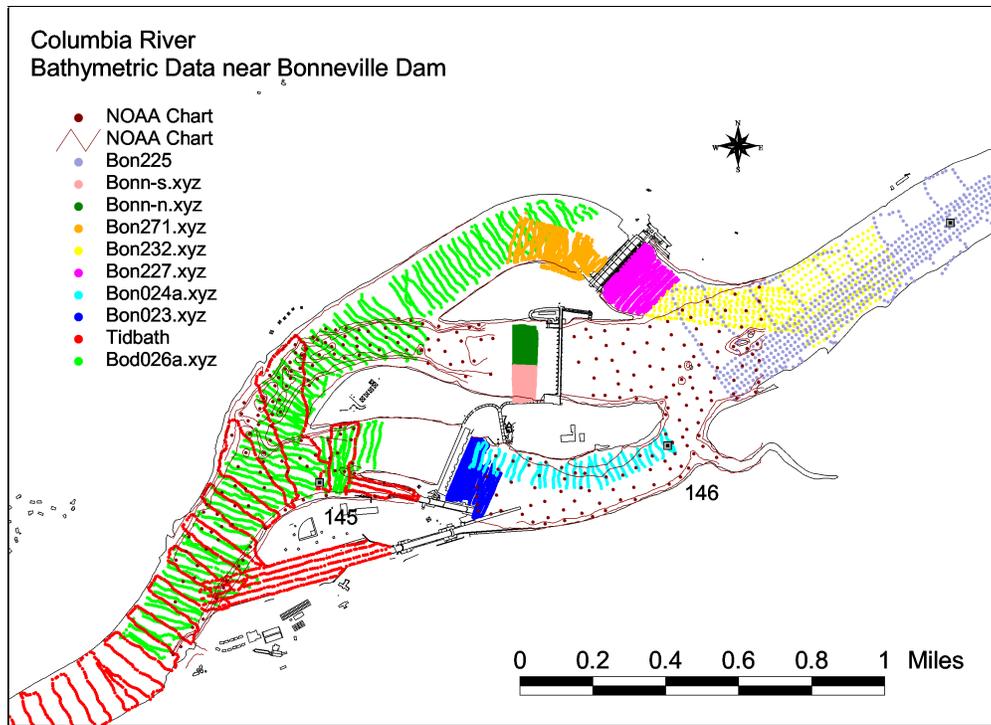


Figure 171. Bathymetric data near Bonneville dam.

A.2 Calibration/Verification Data Sources

A.2.1 Dissolved Gas Measurements

Dissolved gas measurements were available from two sources: permanent fixed monitors and dissolved gas pool studies which used temporary monitors. Fixed monitor stations (FMS) in tidal reach are shown in Figure 172. The water quality data recorded by the FMS included total dissolved gas (TDG) pressure, barometric pressure, and temperature, and was obtained from the DGAS team ftp server, `limnos.wes.army.mil`, in the file `/data3/dgas/database/FMS_data/FMS_data.zip`, dated August 25, 1998. Fixed monitor data was used to establish temperature and TDG concentration in powerhouse flow at the Lower Granite dam model boundary.

The dissolved gas pool studies performed in Columbia River tidal reach to date are shown in Table 116 and their durations are shown graphically in Figure 173. During these studies water temperature and TDG pressures were measured at several locations within the reach. These periods were used for model calibration and verification and are discussed individually below. The water quality data gathered during these studies was obtained from the DGAS team ftp server, `limnos.wes.army.mil`, in the file `/data3/dgas/database/field_data/field_data.zip`, dated August 25, 1998.

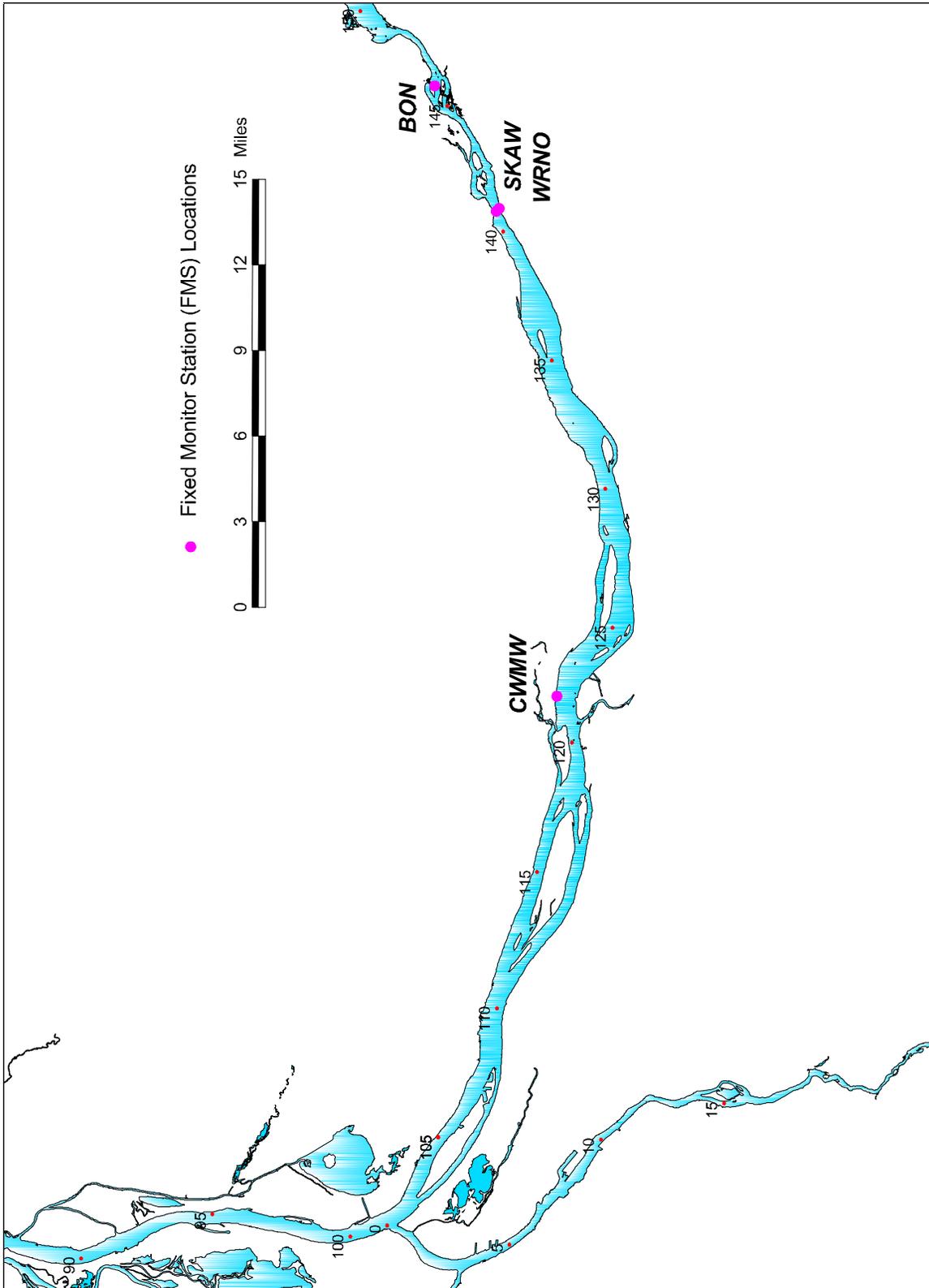


Figure 172. FMS locations in the Columbia River tidal reach.

Table 116. Dates of dissolved gas field studies in the Tidal reach.

STUDY SET	Start	End
TID SPR 96	6/16/96 2:52:00 PM	6/22/96 10:48:00 AM
TID SUM 96	7/24/96 10:05:00 AM	8/2/96 5:00:00 PM
TID SUM 97	7/15/97 3:00:00 PM	7/30/97 11:30:00 AM

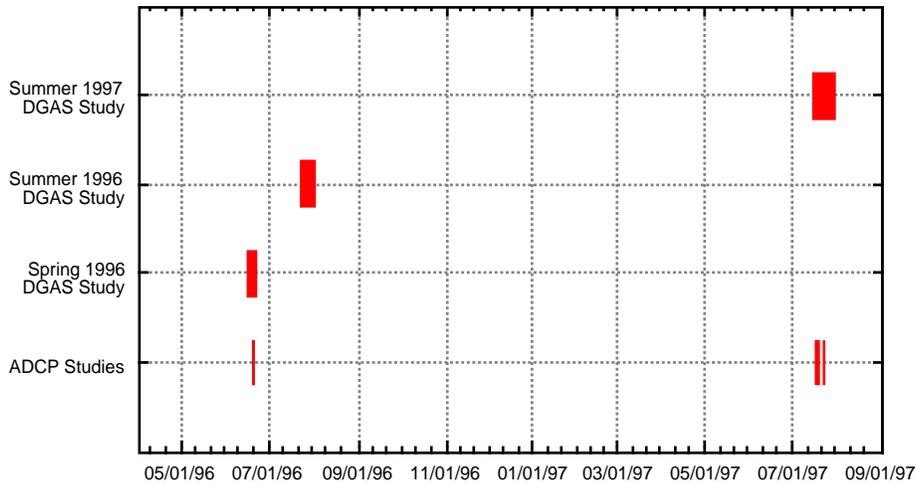


Figure 173. Dates and durations of dissolved gas and ADCP velocity studies in Little Goose Pool

A.2.2 ADCP Velocity Measurements

As shown in Figure 173, velocity measurements were taken using ADCP (Acoustic Doppler Current Profiler) instruments during two of the dissolved gas pool studies: Spring 1996 and Summer 1997. The ADCP data was obtained from the DGAS team FTP server, `limnos.wes.army.mil`, in the files `/data3/dgas/database/ADCP data/96ADCP.zip` and `/data3/dgas/database/ADCP data/97ADCP.zip`, dated April 10, 1998 and July 15, 1998, respectively. Figure 174 through Figure 180 show the measurements made, in the modeled region, as small arrows. The measurements were thinned for clarity in those figures: only one arrow in three was drawn.

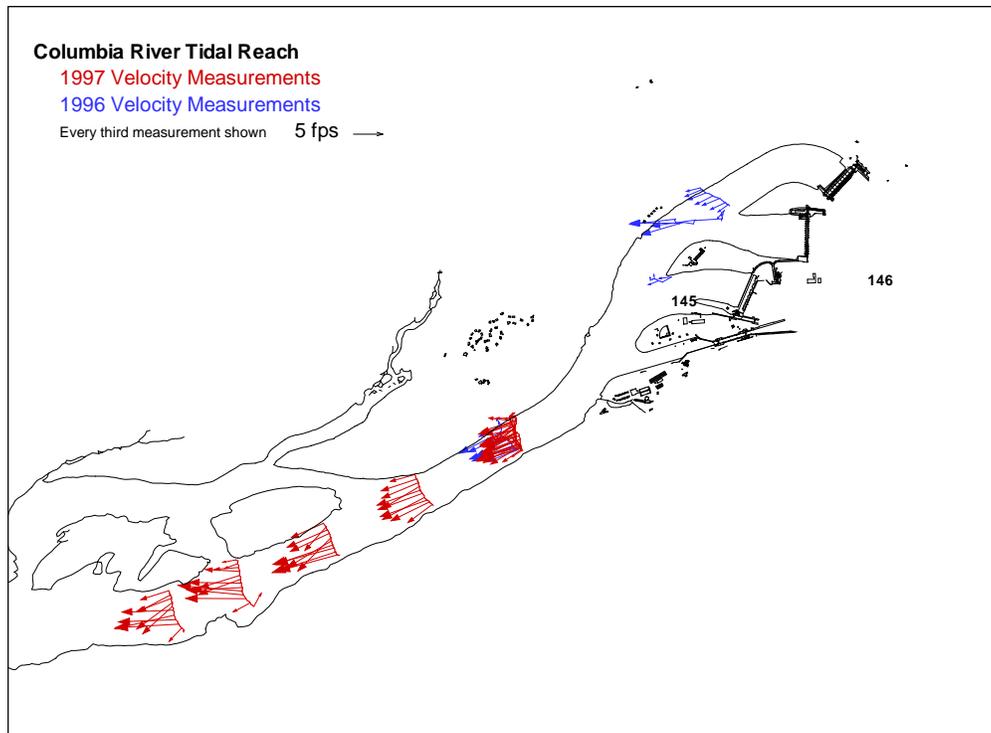


Figure 174. Columbia River tidal reach ADCP velocity measurements near Bonneville Dam.

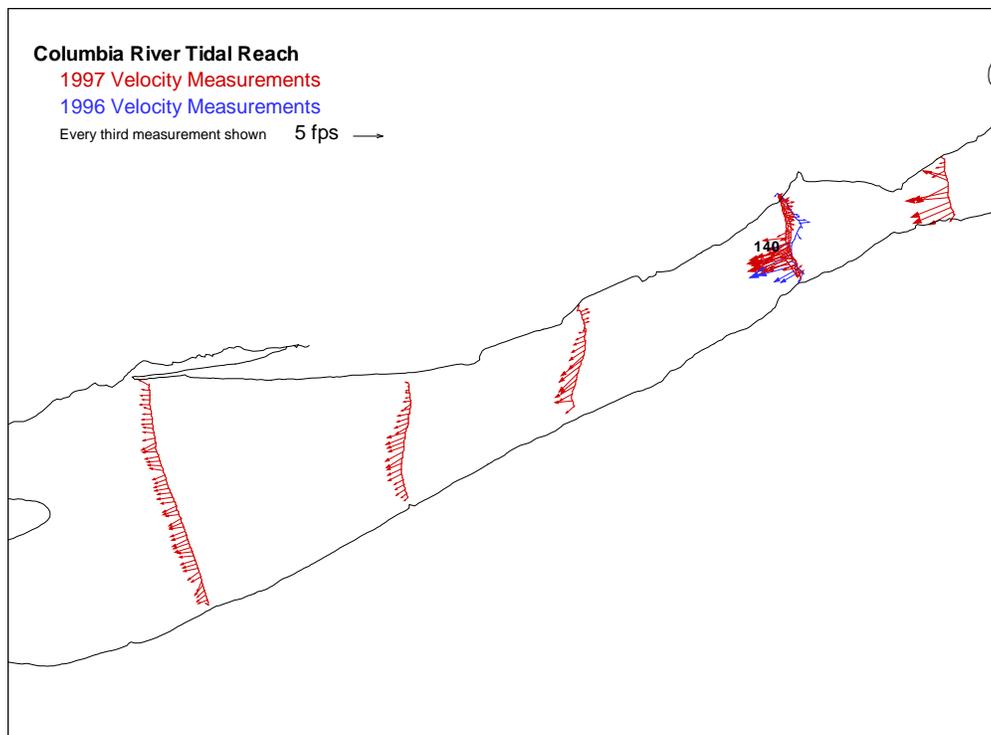


Figure 175. Columbia River tidal reach ADCP velocity measurements near .

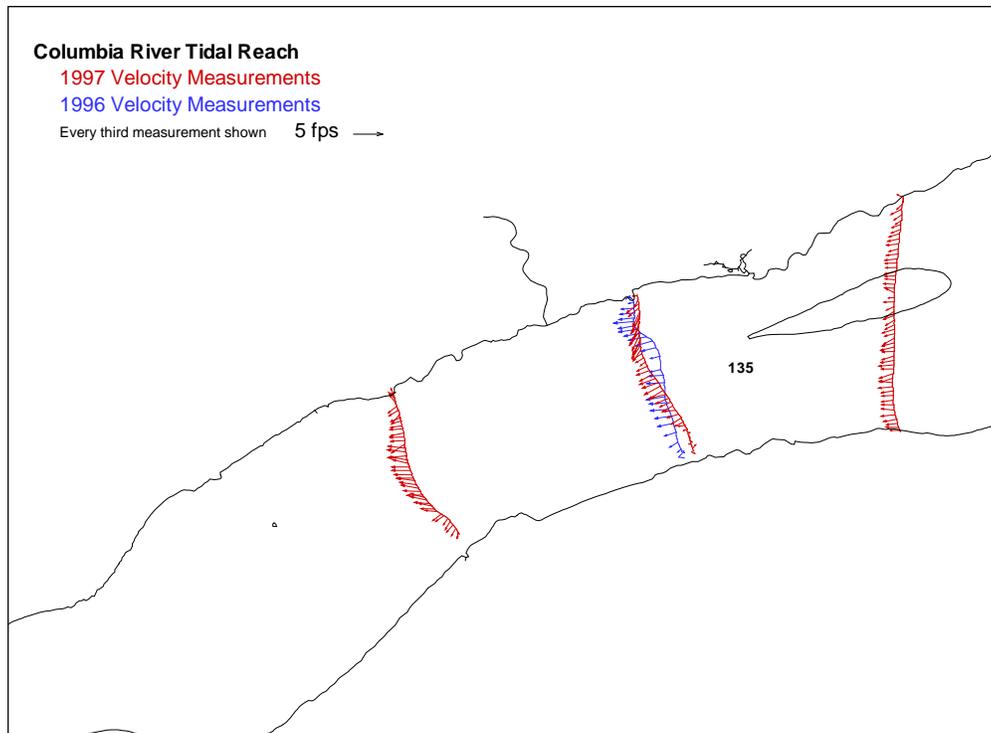


Figure 176. Columbia River tidal reach ADCP velocity measurements near .

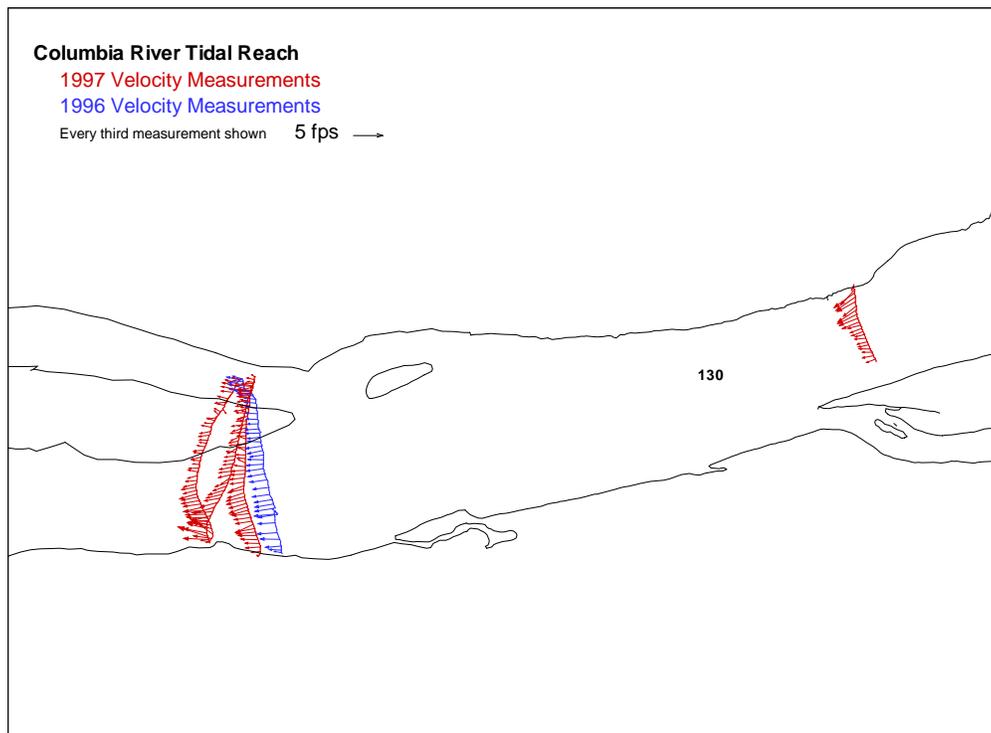


Figure 177. Columbia River tidal reach ADCP velocity measurements near .

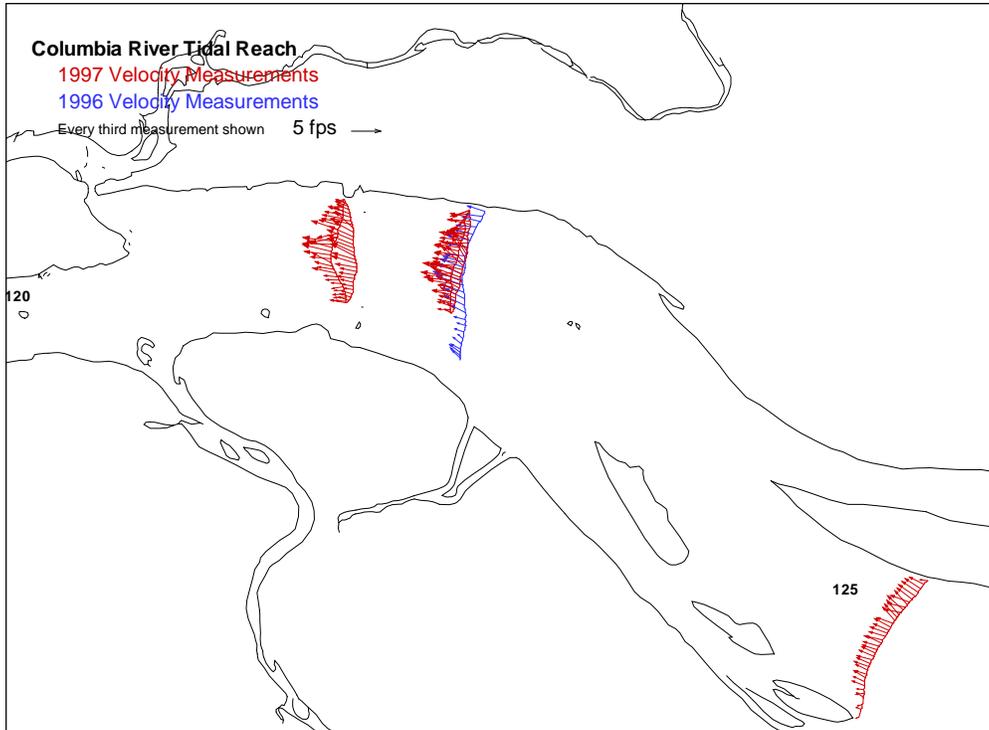


Figure 178. Columbia River tidal reach ADCP velocity measurements near .

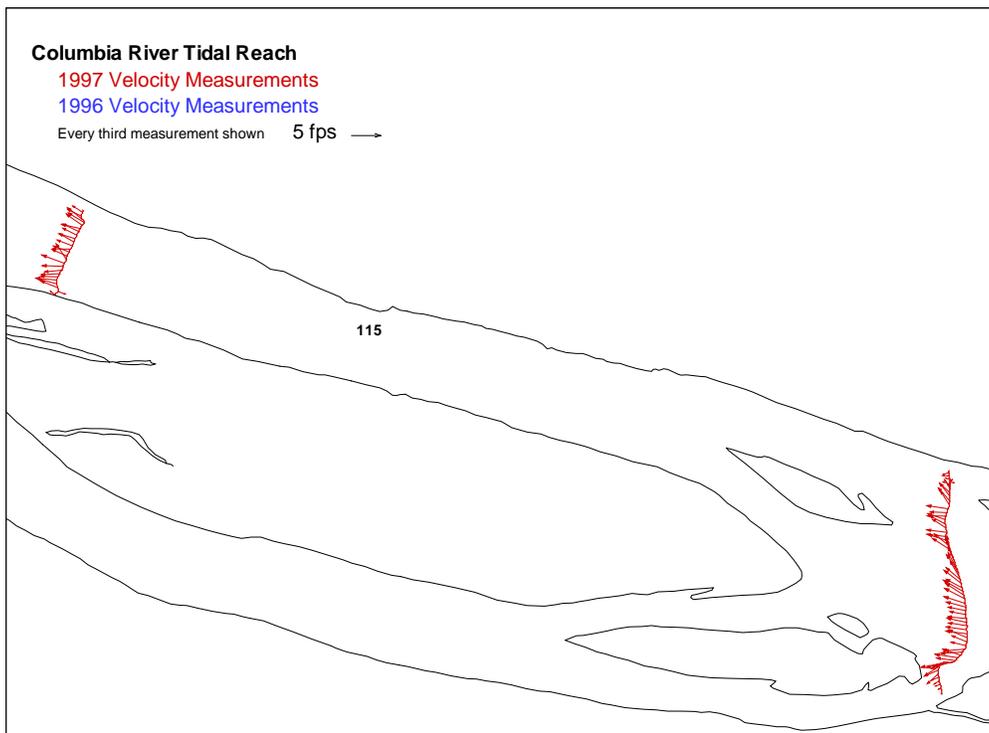


Figure 179. Columbia River tidal reach ADCP velocity measurements near .

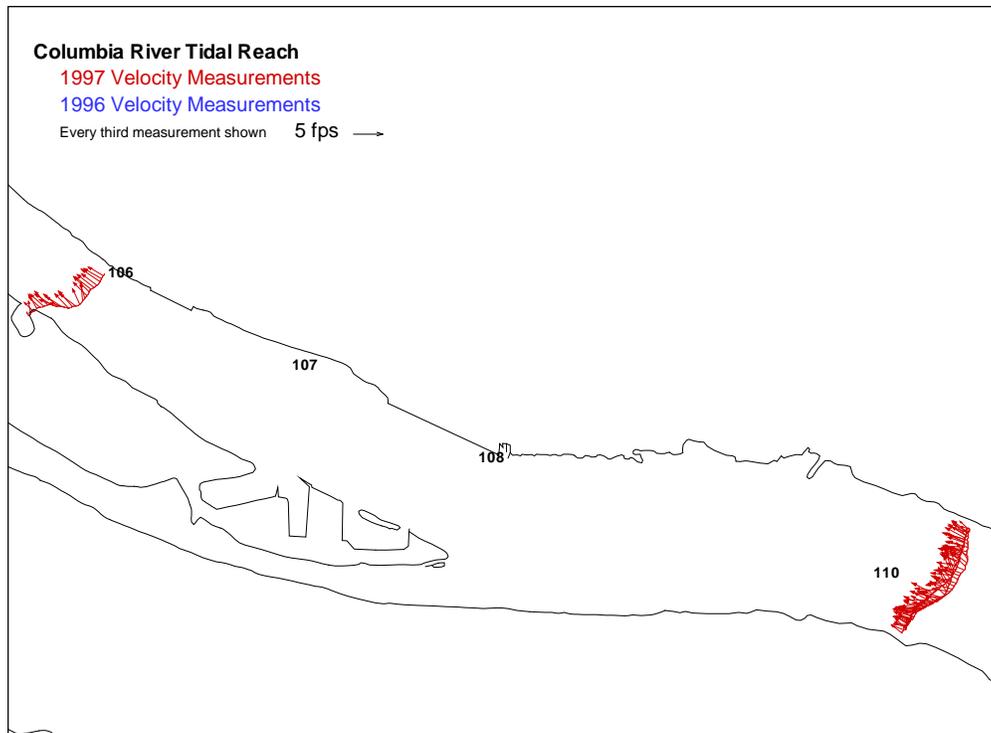


Figure 180. Columbia River tidal reach ADCP velocity measurements near .

A.2.3 Dam Operations Data

Dam operations data was used to establish model boundary conditions. Hourly CHROMS data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file /data3/dgas/database/ops_data/ops_data.zip, dated August 25, 1998. The CHROMS operations data provided hourly aggregate spill and powerhouse flows and forebay and tailwater stages.

A.2.4 Downstream Boundary Data

The downstream model boundary was located at Columbia River mile 110.0. Observed stage data was not available for this location, so stage was estimated using a one-dimensional hydrodynamic model. The model used flows at Bonneville dam (as in Section A.2.3), tributary inflows from several rivers joining the Columbia River downstream of Bonneville dam, and observed stage at Astoria, Oregon to predict stage at river mile 110.0. The various sources of data are shown in Table 117.

Table 117. Sources of data used by one-dimensional hydrodynamic model to predict stage at Columbia River mile 110.0.

Data Set	Data Source	
	1996 Studies	Summer 1997 Study
Washougal River	Constant: 600 cfs	Constant: 600 cfs
Willamette River	USGS Gage #14211720	Constant: 17000 cfs
Lewis River	Sum of USGS Gage #14220500 " and #14222500	Constant: 3500 cfs
Cowlitz River	USGS Gage #14238000 Area Scaled to USGS Gage # 14243000	Constant: 5000 cfs
Clatskanine River	Constant: 1000 cfs	Constant: 1000 cfs
Tidal Stage	NOAA NOS Gage #9439040	NOAA NOS Gage #9439040

A.2.5 Weather Data

Weather data was obtained from two DGAS team databases: one containing data from National Weather Service (NWS) stations, the other from WeatherPak instrumentation used for short periods during the pool studies. Both NWS and WeatherPak data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file `/data3/dgas/database/weather_data/weather_data.zip`, dated June 11, 1998.

Appendix B. Spring 1996 Tidal Reach Study

B.1 Dissolved Gas Data

The Spring 1996 Tidal Reach dissolved gas study started on June 16 and ended on June 21. A total of 17 water quality monitors were used. These stations, and their records, are listed in Table 118. Stations locations are shown in Figure 181.

Table 118. Dissolved gas monitor stations, and their records, used during the Summer 1996 study period.

Station	Start Date	End Date	Temperature Records	Pressure Records
BONDTD2	6/16/96 2:52:00	6/22/96 10:48:00	554	554
TID14555P	6/16/96 3:16:00	6/22/96 10:42:00	552	552
TID12793P	6/17/96 7:58:00	6/21/96 8:43:00	388	388
TID12942P	6/17/96 10:11:00	6/21/96 8:56:00	380	380
TID12263P	6/17/96 10:30:00	6/21/96 9:15:00	380	380
TID12274P	6/17/96 10:30:00	6/21/96 9:00:00	379	378
TID13484P	6/17/96 10:45:00	6/21/96 9:45:00	381	380
TID14035P	6/17/96 2:00:00	6/21/96 2:30:00	386	386
TID14031P	6/17/96 4:30:00	6/21/96 11:15:00	364	364
TID14375P	6/18/96 1:30:00	6/21/96 11:45:00	282	282
TID14371P	6/18/96 1:45:00	6/21/96 12:00:00	247	247
TID14373	6/18/96 4:30:00	6/21/96 2:15:00	280	280
TID14374P	6/18/96 4:30:00	6/21/96 2:15:00	280	280
TID12792P	6/18/96 6:00:00	6/21/96 10:15:00	258	0
TID12794P	6/18/96 6:30:00	6/21/96 9:45:00	254	254
TID14551P	6/18/96 7:19:00	6/19/96 8:49:00	101	100
TID13462P	6/19/96 2:41:00	6/21/96 9:26:00	172	172

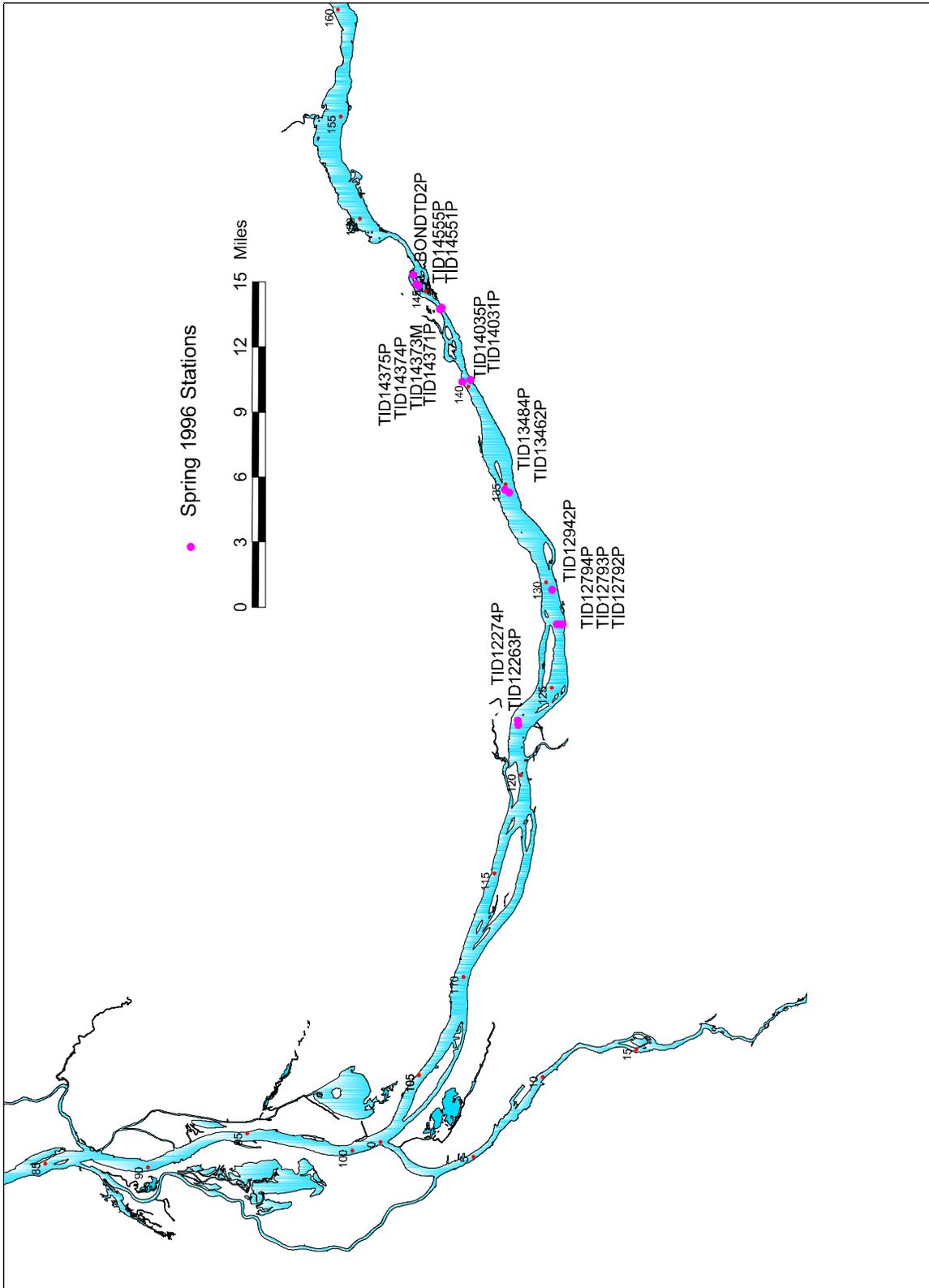


Figure 181. Temporary dissolved gas monitor locations during the Spring 1996 study period.

B.2 Velocity Data

Velocity measurements were made along a total of 8 transects during the Spring 1996 study period. The transects are summarized in Table 119. Supplied measurement locations are shown in Figure 182.

Table 119. Summary of ADCP transects made during the Spring 1996 study period.

Date Label	Average		Number of Measurements
	Velocity	Depth	
06-19-1996 13:10:00	2.8	43.2	20
06-19-1996 13:17:00	5.1	42.0	19
06-19-1996 13:35:00	1.2	29.9	10
06-20-1996 10:29:00	2.5	62.0	51
06-20-1996 11:30:00	5.6	54.4	28
06-20-1996 13:09:00	2.3	33.6	78
06-20-1996 14:31:00	2.6	25.0	119
06-20-1996 15:39:00	3.1	21.9	78

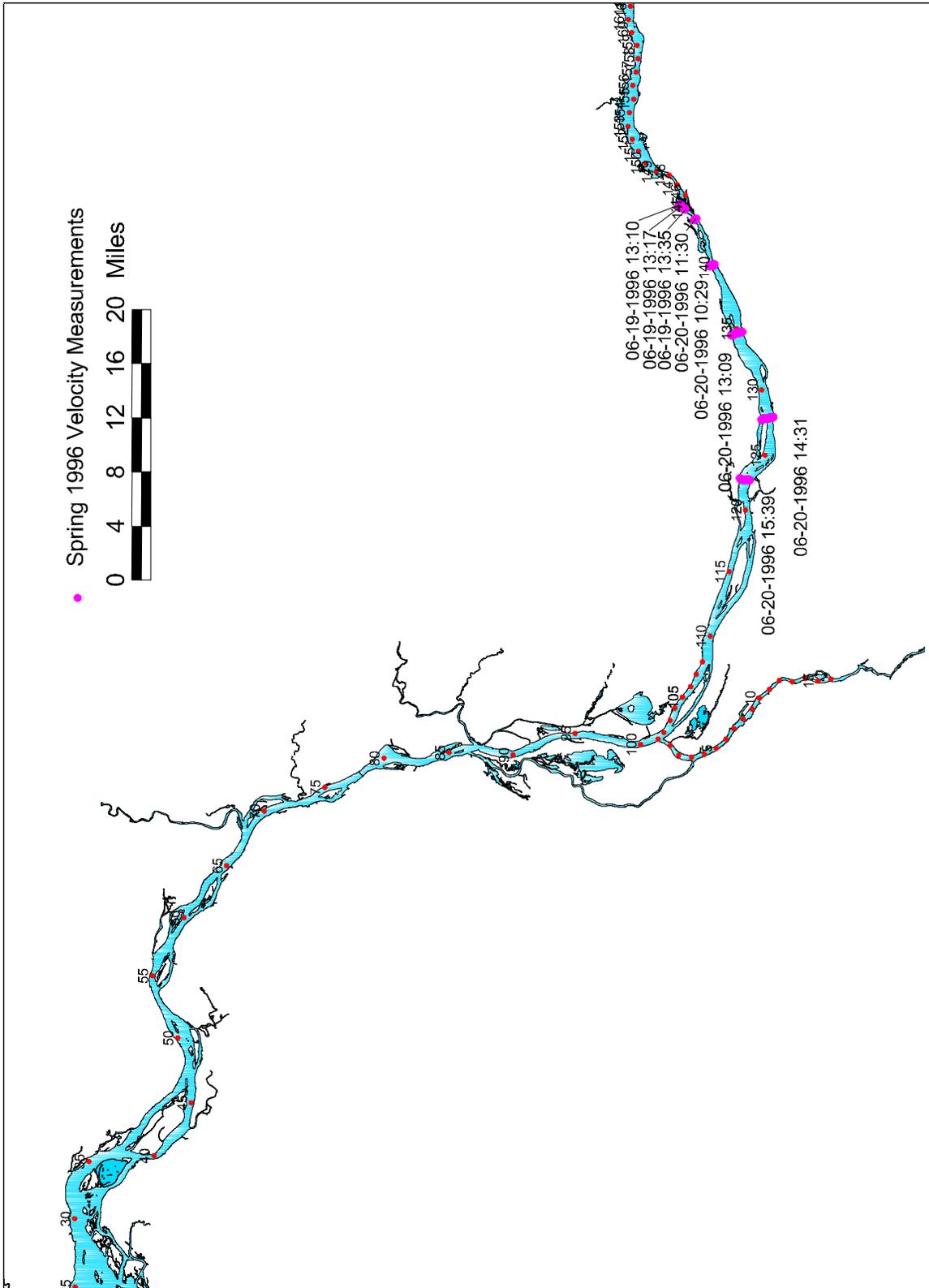


Figure 182. Locations of ADCP velocity measurements during the Spring 1996 study period.

B.3 Bonneville Dam Model Boundary

B.3.1 Dam Operations

CHROMS operations data was used to establish the flow at the Bonneville dam model boundary. This data provided hourly spillway flows and powerhouse flow. Hourly total spill and powerhouse flows for the Spring 1996 study period are shown in Figure 183. The total powerhouse flow was split according to the powerhouse flow capacities. The north powerhouse has a hydraulic capacity of 136 kcfs; the south has a capacity of 152 kcfs. The north powerhouse flows were assumed to be 136/188 of the total powerhouse flow. Similarly, the south powerhouse flow was assumed to be 152/188 of the total powerhouse flow. The partitioned powerhouse and spillway flows were uniformly distributed across the corresponding part of the model grid.

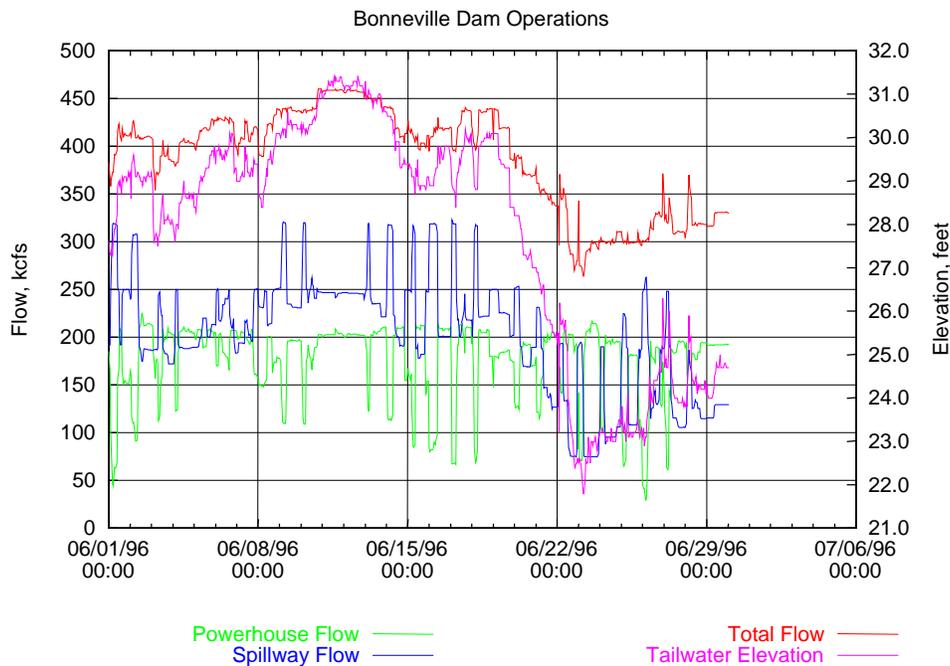


Figure 183. Bonneville dam operations during the Spring 1996 study.

B.3.2 Water Quality

Initially, data from the permanent fixed monitor located in the Bonneville dam forebay (station name "BON") was used to establish temperature at the Bonneville dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 184) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 185) was used to compute TDG concentrations (Figure 186) for the powerhouse flow. Spillway TDG gas pressures and concentrations (also shown in Figure 185 and Figure 186, respectively) were estimated using the TDG sourcing function from Bonneville dam.

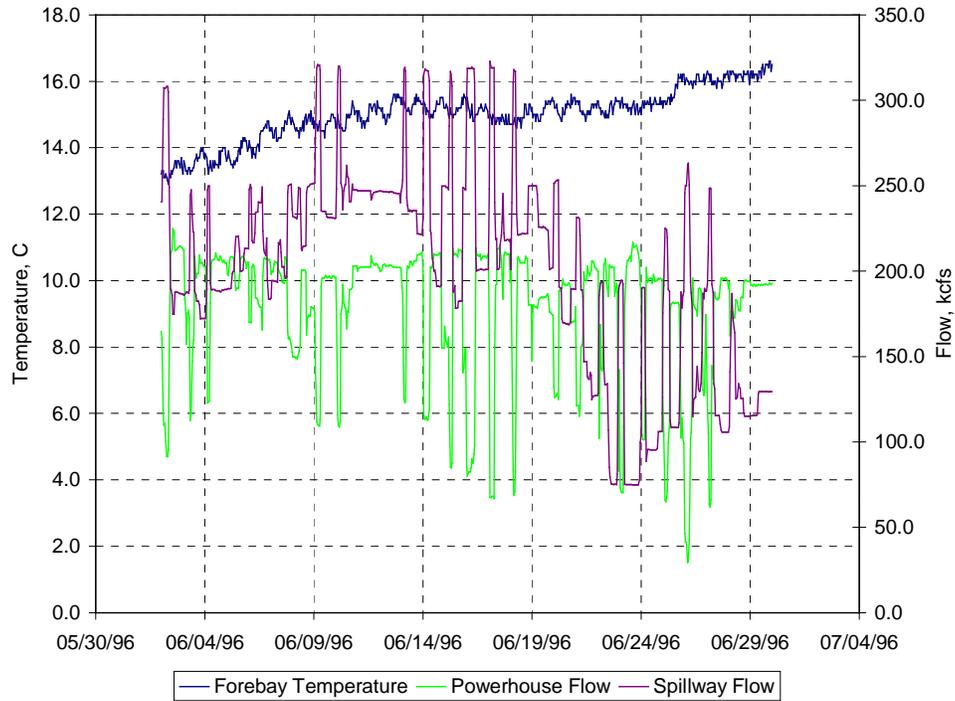


Figure 184. Bonneville forebay water temperature during the Spring 1996 study.

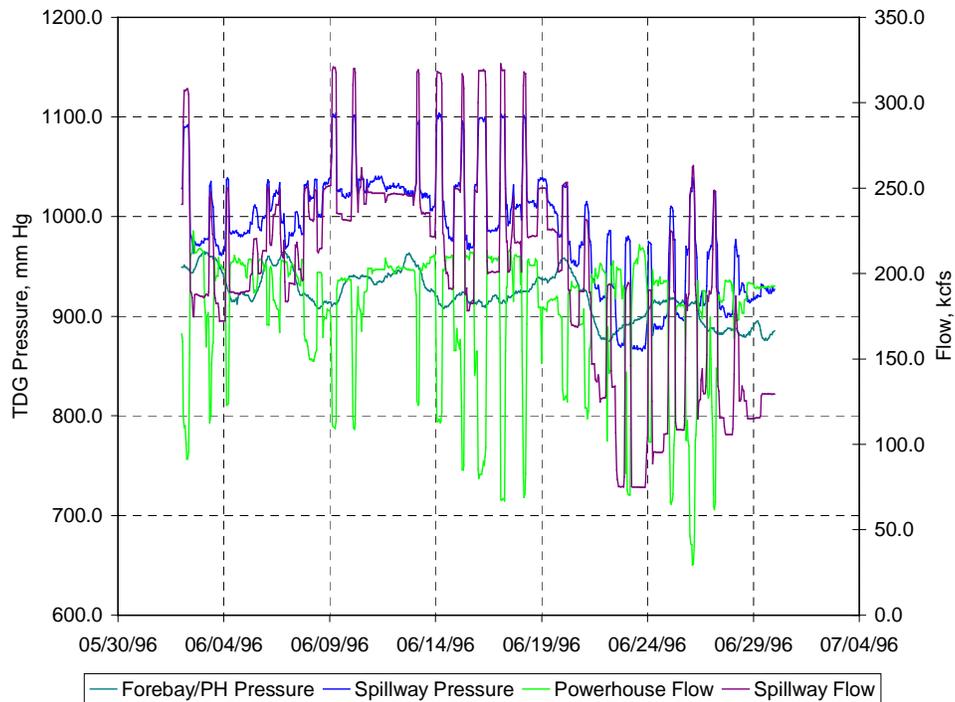


Figure 185. Bonneville forebay TDG pressure during the Spring 1996 study.

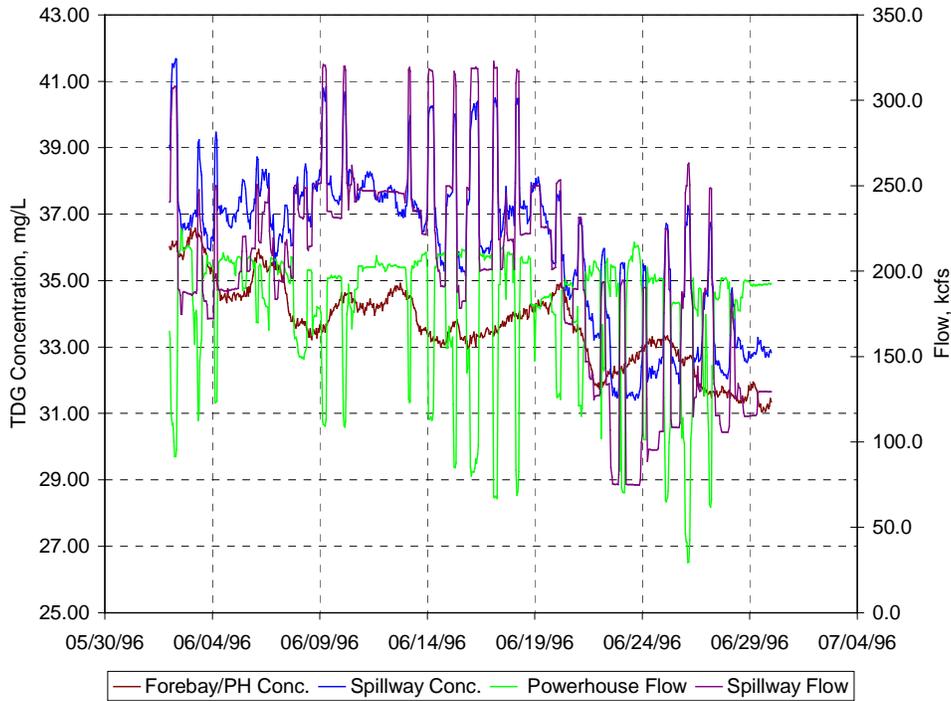


Figure 186. Computed TDG concentration in the Bonneville forebay during the Spring 1996 study.

Model boundary temperature and dissolved gas concentrations were also established at the Bonneville dam boundary using the temporary pool study monitors. Seven temporary monitors were located in the Bonneville tailrace during Spring 1996 study period, as shown in Figure 187. The temperatures and TDG pressures recorded by these monitors are shown in Figure 188 and Figure 189, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 190. The transport simulation boundary was established at grid row 56 of block 5 (shown in yellow in Figure 187). Temporary monitor TDG concentrations and temperatures as follows along the model grid:

- TID14375P: columns 1 to 12;
- TID14374P: columns 12 to 17;
- TID14373M: columns 18 to 24; and
- TID14371P: columns 22 to 24.

Stations BONDTD2P, TID14555P, and TID14551P were not used since they would have provided an incomplete description of gas levels at the dam (there was no monitor at the south powerhouse).

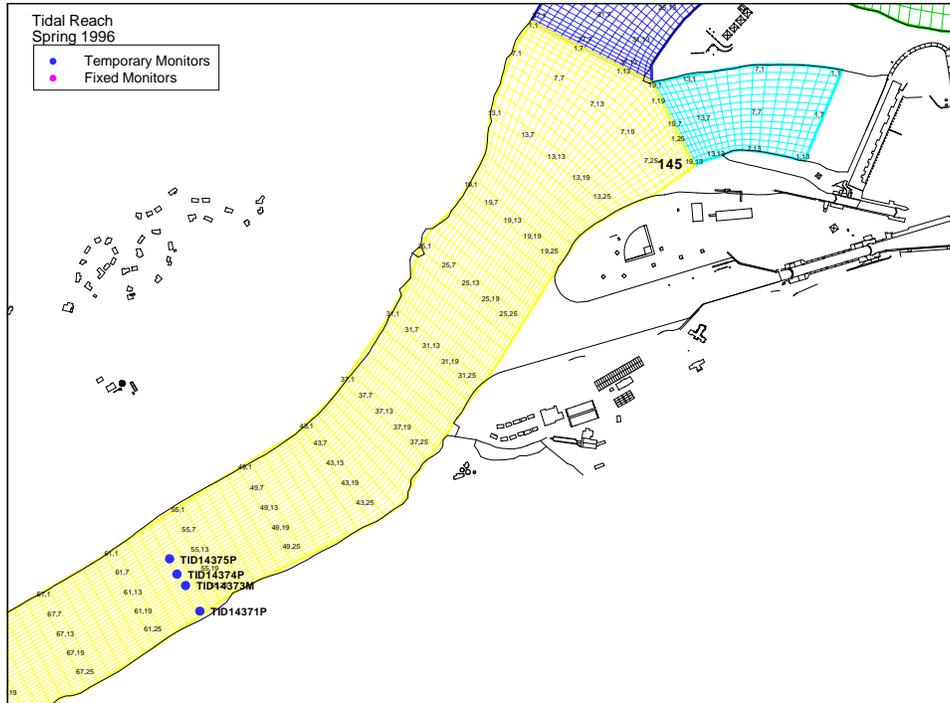


Figure 187. Locations, relative to the model grid, of temporary monitors during the Summer 1997 study period.

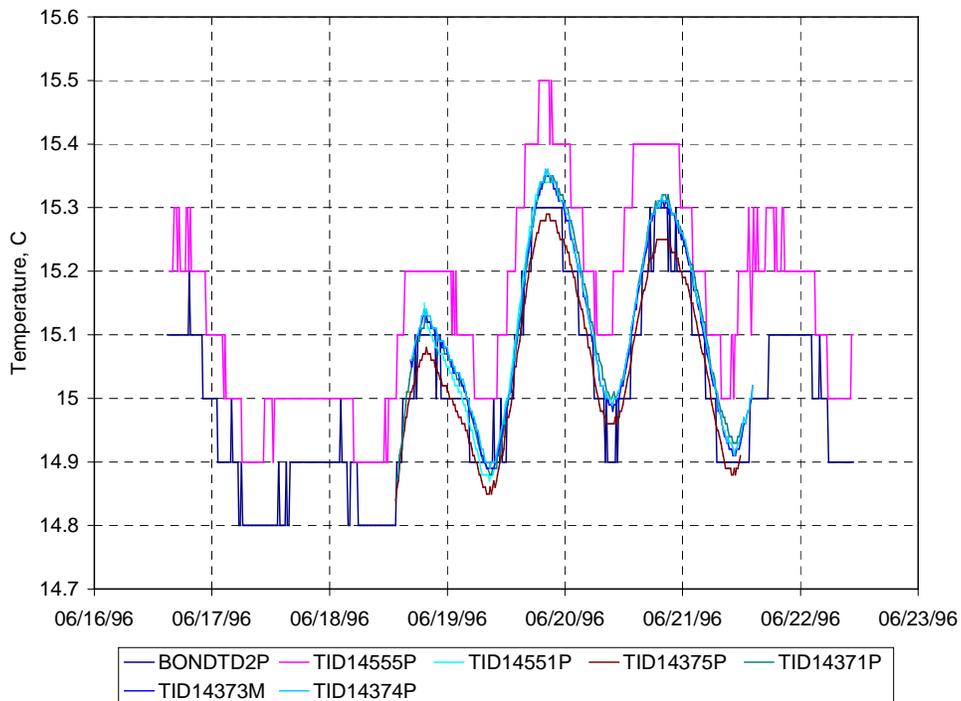


Figure 188. Temperatures measured by temporary monitors near Bonneville dam during the Spring 1996 study period.

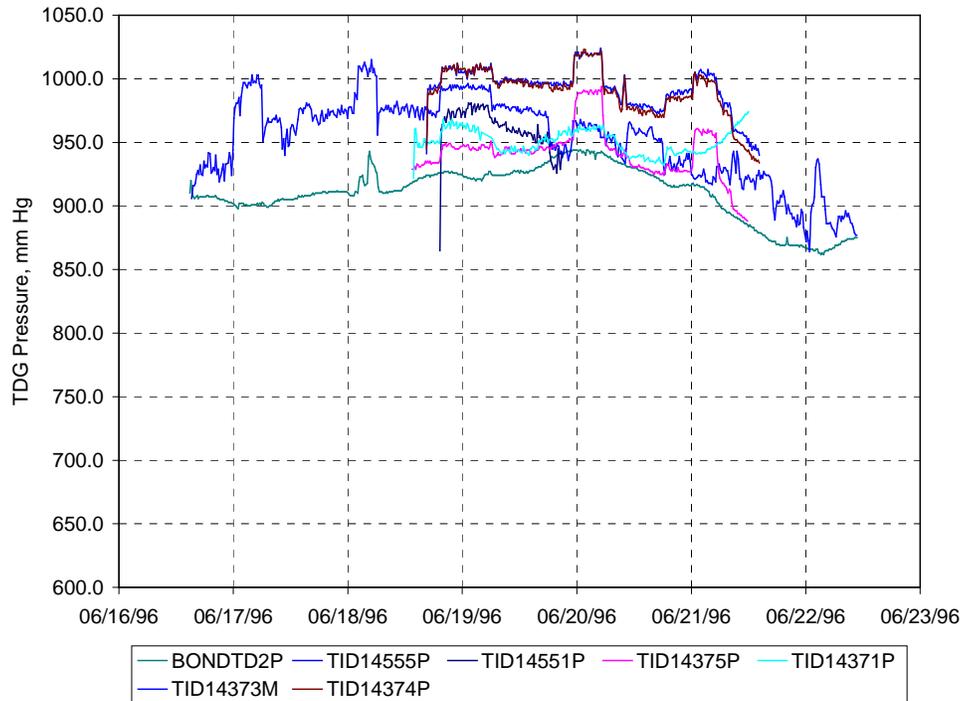


Figure 189. TDG pressures measured by temporary monitors near Bonneville dam during the Spring 1996 study period.

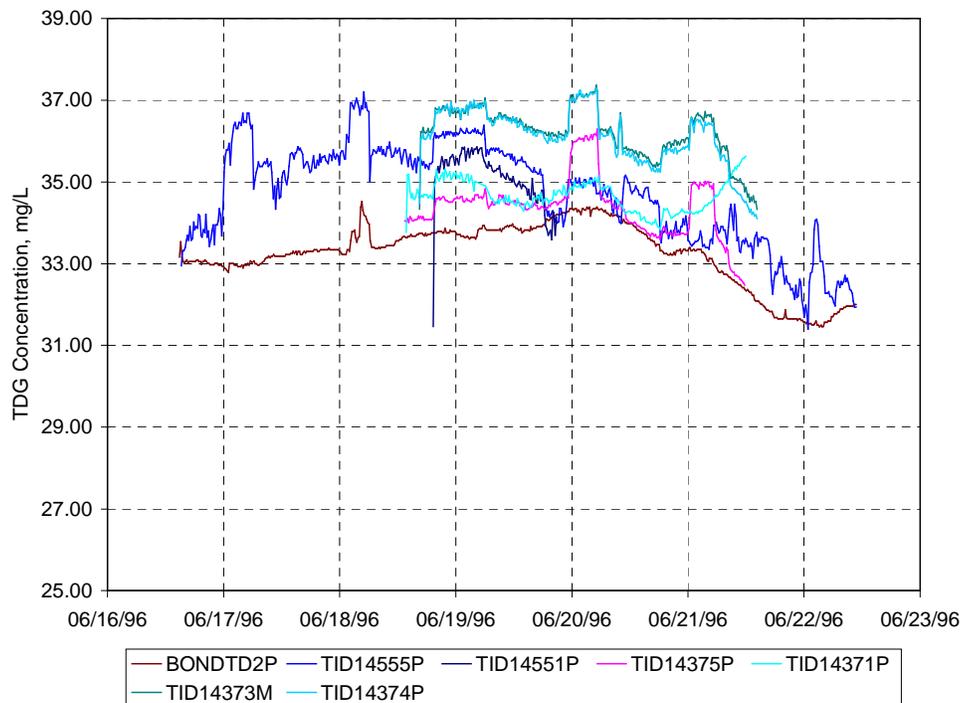


Figure 190. TDG concentrations computed from temporary monitor data near Bonneville dam during the Spring 1996 study period.

B.4 Downstream Boundary

Stage at the downstream model boundary was estimated using a one-dimensional hydrodynamic model as described in Section A.2.4. Results of the one-dimensional simulation are shown in Figure 191. Predicted stages at Columbia River model 110.0 were used for the downstream boundary of the two-dimensional model.

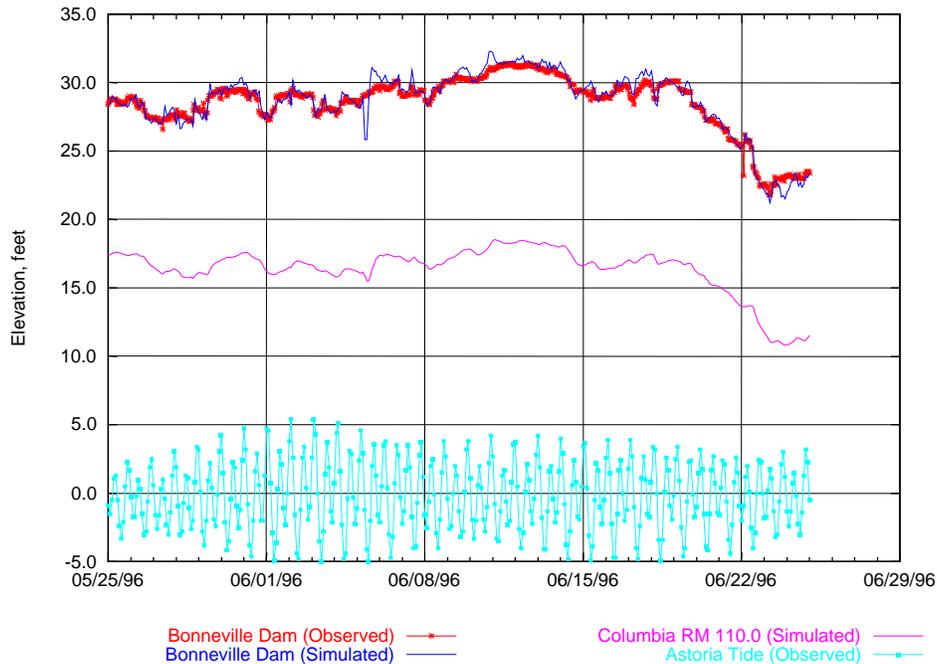


Figure 191. Predicted stage at Columbia River mile 110.0 during the Spring 1996 study period.

B.5 Weather

Atmospheric conditions were considered constant over the entire study area. Portland, Oregon, air and dew point temperature (Figure 192) and wind speed (Figure 193) were used from the NWS weather database. Barometric pressure measured by the WRNO FMS (also shown in Figure 192) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for part of the Spring 1996 study. The available radiation data was extended using NWS Portland dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 194.

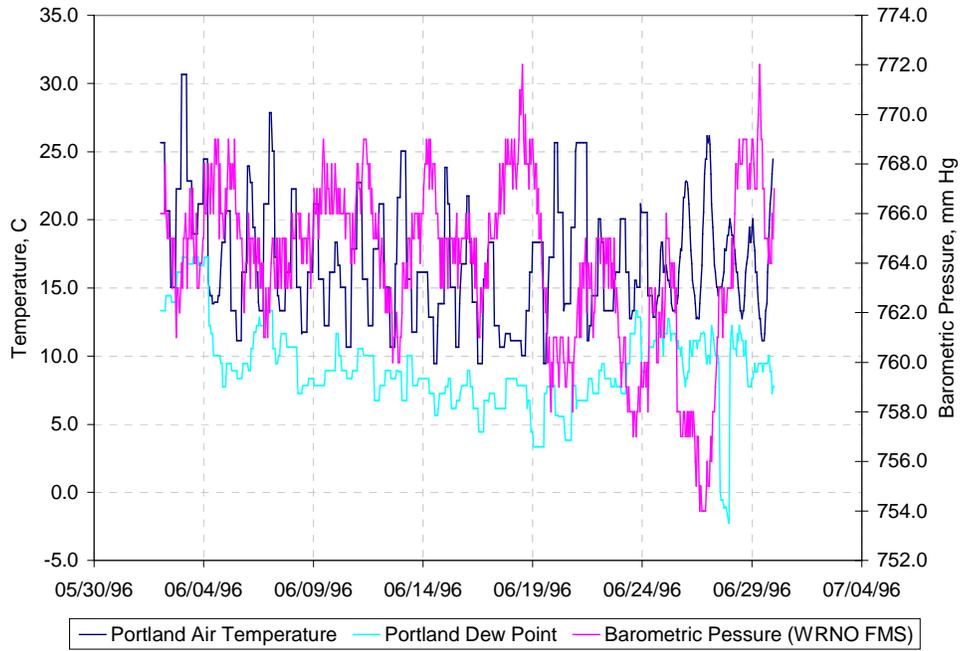


Figure 192. Air temperature, dew point, and barometric pressure used during the Spring 1996 study period.

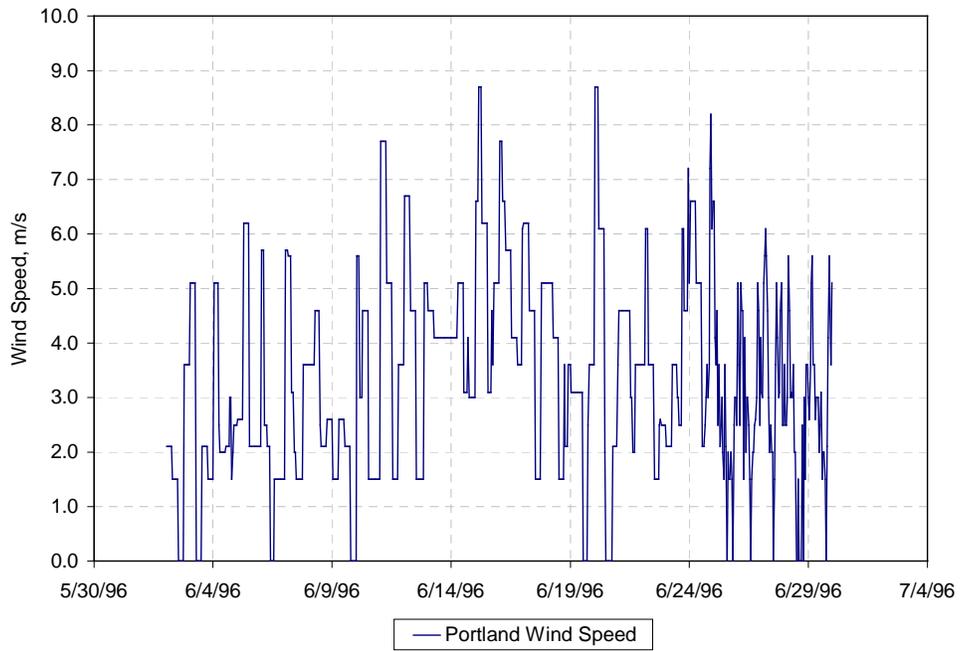


Figure 193. Wind speed used during the Spring 1996 study period.

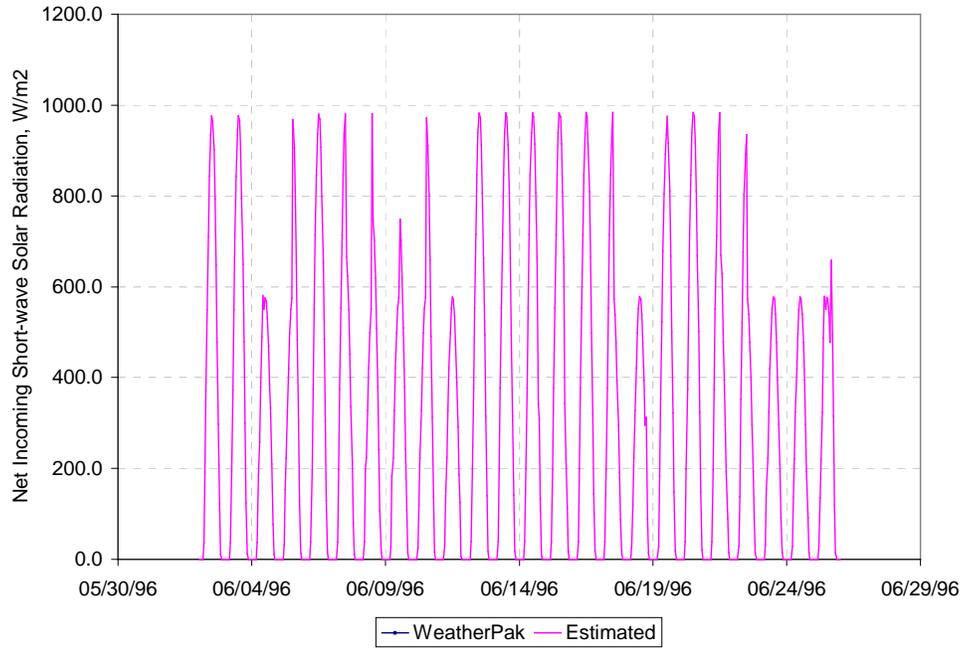


Figure 194. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Spring 1996 study period.

Appendix C. Summer 1996 Tidal Reach Study

C.1 Dissolved Gas Data

The Summer 1996 Tidal Reach dissolved gas study started on July 24 and ended on August 2. A total of 27 water quality monitors were used. These stations, and their records, are listed in Table 120. Stations locations are shown in Figure 195.

Table 120. Dissolved gas monitor stations, and their records, used during the Summer 1996 study period.

Station	Start Date	End Date	Temperature Records	Pressure Records
BON14603P	7/24/96 10:32:00 AM	8/1/96 2:54:00 PM	777	777
BONDTD1P	7/24/96 10:05:00 AM	8/1/96 2:42:00 PM	778	778
BONSWQ5P	7/24/96 10:30:00 AM	7/25/96 12:30:00 AM	56	56
BONSWQ3P	7/24/96 10:45:00 AM	8/1/96 6:00:00 PM	797	797
BONDTD2P	7/24/96 11:07:00 AM	8/1/96 2:29:00 PM	773	773
TID14403P	7/24/96 11:15:00 AM	8/1/96 12:45:00 PM	774	774
TID14405P	7/24/96 11:30:00 AM	8/1/96 1:00:00 PM	775	775
TID14401P	7/24/96 11:45:00 AM	8/1/96 12:45:00 PM	765	765
TID14025P	7/24/96 12:15:00 PM	8/1/96 11:30:00 AM	766	0
TID14021P	7/24/96 12:30:00 PM	8/1/96 11:45:00 AM	766	765
TID14023P	7/24/96 12:30:00 PM	8/1/96 12:15:00 PM	768	768
TID13452P	7/24/96 1:15:00 PM	8/2/96 5:00:00 PM	880	880
TID12803P	7/24/96 1:30:00 PM	8/1/96 11:30:00 AM	761	761
TID12323P	7/24/96 1:45:00 PM	8/1/96 11:15:00 AM	757	757
TID12165P	7/24/96 2:00:00 PM	8/1/96 10:45:00 AM	756	0
TID04201P	7/25/96 1:48:00 PM	8/1/96 6:29:00 AM	636	636
TID04202P	7/25/96 2:31:00 PM	8/1/96 6:42:00 AM	634	634
TID07705P	7/25/96 4:30:00 PM	8/1/96 8:30:00 AM	641	641
TID07721P	7/25/96 5:11:00 PM	8/1/96 8:11:00 AM	637	637
TID08983P	7/25/96 5:44:00 PM	8/1/96 1:14:00 AM	607	607
TID09991P	7/25/96 6:23:00 PM	8/1/96 9:23:00 AM	637	637
TID10224P	7/25/96 6:39:00 PM	8/1/96 9:39:00 AM	637	637
TID10655P	7/25/96 7:01:00 PM	8/1/96 10:16:00 AM	638	638
TID06622P	7/25/96 7:08:00 PM	8/1/96 3:53:00 AM	612	171
TID11254P	7/25/96 7:24:00 PM	7/29/96 5:24:00 PM	377	377
BONSWQ4P	7/26/96 10:00:00 AM	7/31/96 11:45:00 PM	536	536
BONSWQ2P	7/26/96 10:38:00 AM	8/1/96 1:54:00 PM	583	583

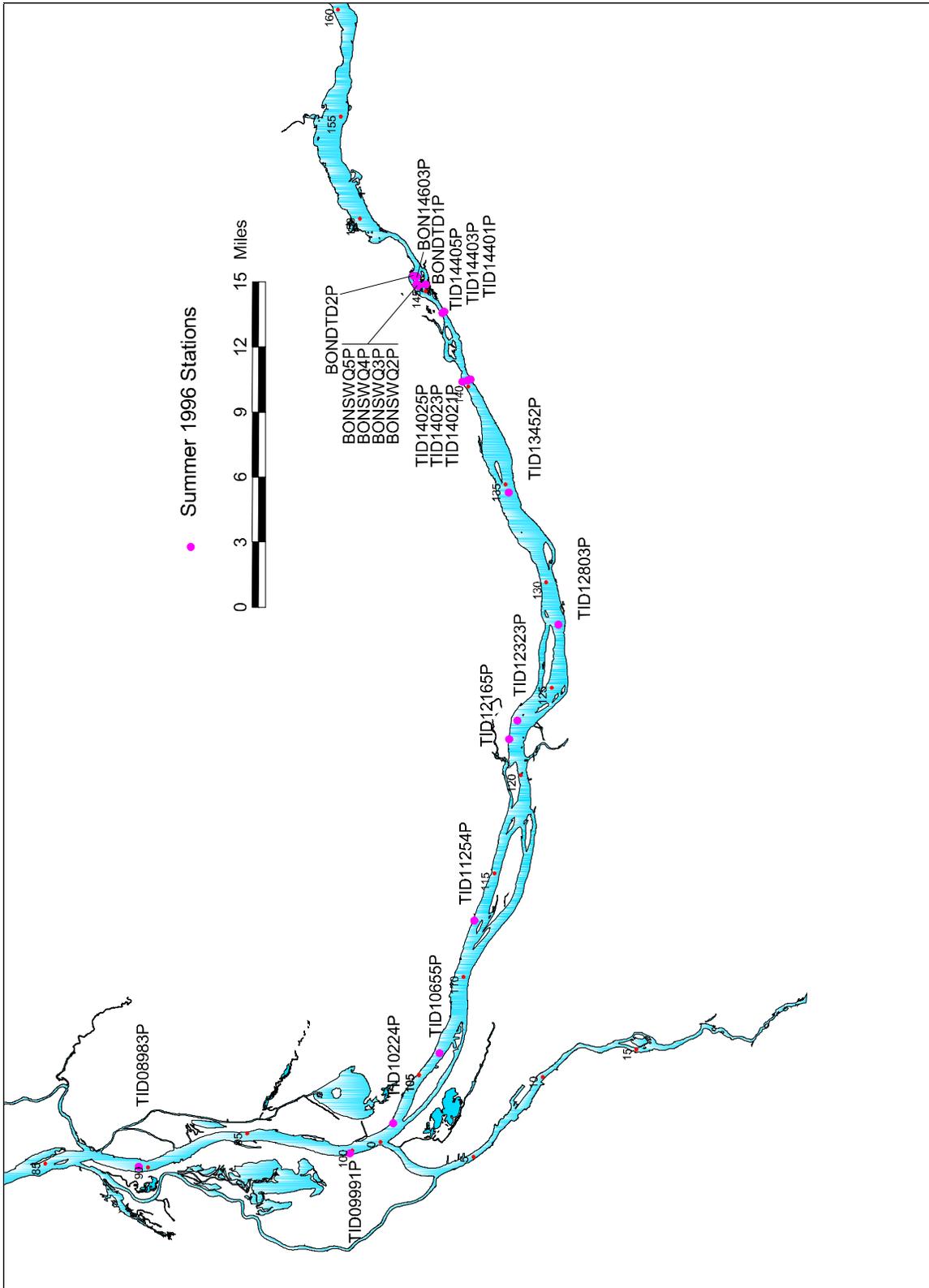


Figure 195. Temporary dissolved gas monitor locations during the Summer 1996 study period.

C.2 Velocity Data

No velocity measurements were made during the Summer 1996 study period

C.3 Bonneville Dam Model Boundary

C.3.1 Dam Operations

CHROMS operations data was used to establish the flow at the Bonneville dam model boundary. This data provided hourly spillway flows and powerhouse flow. Hourly total spill and powerhouse flows for the Summer 1996 study period are shown in Figure 196. The total powerhouse flow was split according to the powerhouse flow capacities. The north powerhouse has a hydraulic capacity of 136 kcfs; the south has a capacity of 152 kcfs. The north powerhouse flows were assumed to be 136/188 of the total powerhouse flow. Similarly, the south powerhouse flow was assumed to be 152/188 of the total powerhouse flow. The partitioned powerhouse and spillway flows were uniformly distributed across the corresponding part of the model grid.

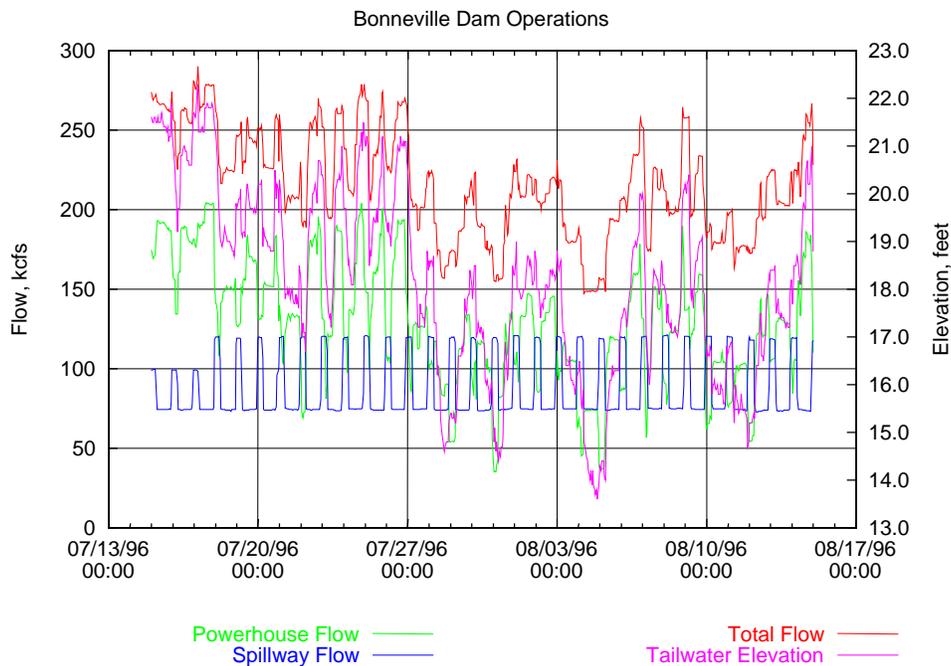


Figure 196. Bonneville dam operations during the Summer 1996 study.

C.3.2 Water Quality

Initially, data from the permanent fixed monitor located in the Bonneville dam forebay (station name "BON") was used to establish temperature at the Bonneville dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 197) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 198) was used to compute TDG concentrations (Figure 199) for the

powerhouse flow. Spillway TDG gas pressures and concentrations (also shown in Figure 198 and Figure 199, respectively) were estimated using the TDG sourcing function from Bonneville dam.

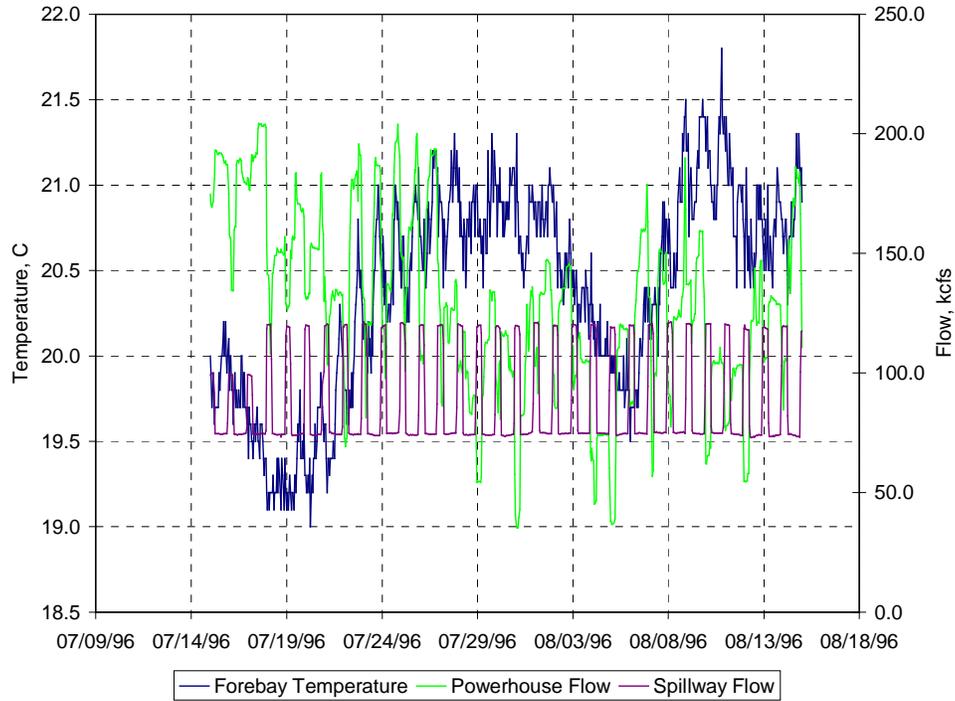


Figure 197. Bonneville forebay water temperature during the Summer 1996 study.

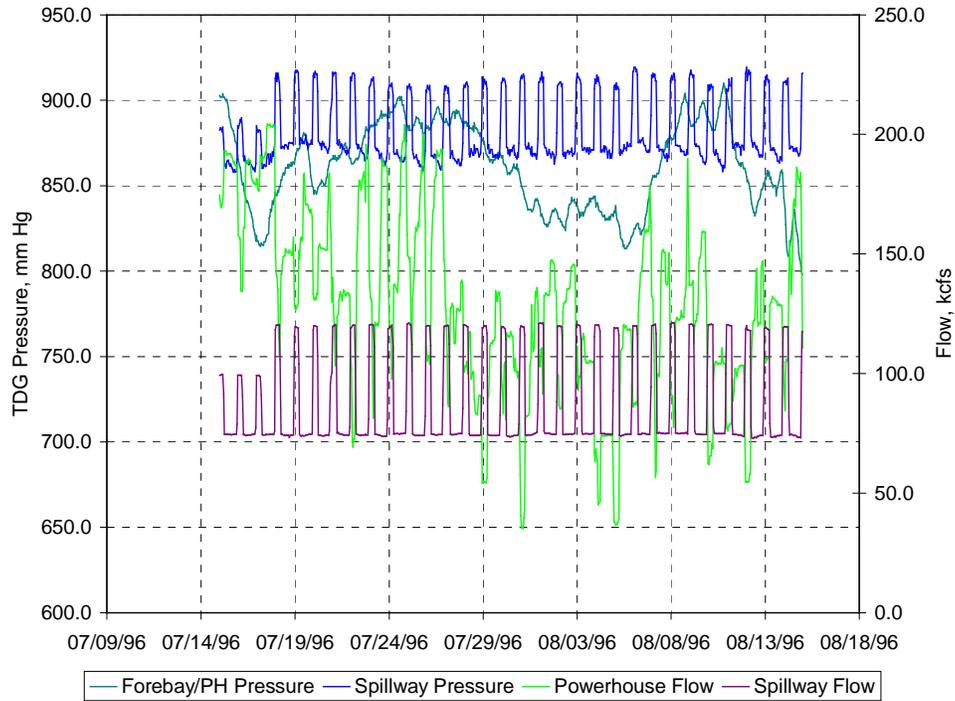


Figure 198. Bonneville forebay TDG pressure during the Summer 1996 study.

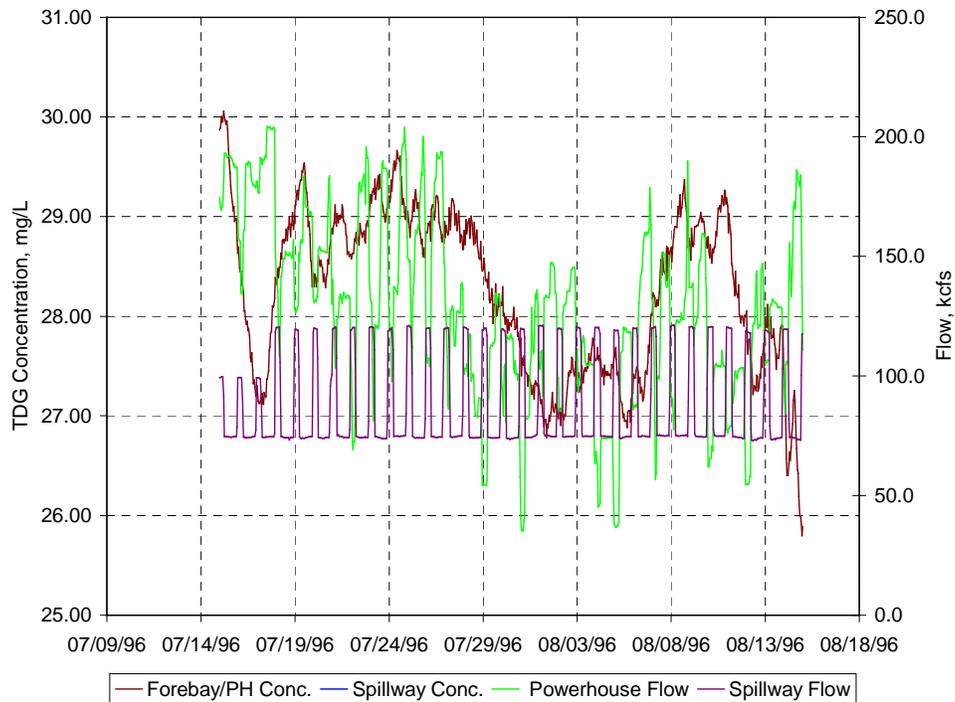


Figure 199. Computed TDG concentration in the Bonneville forebay during the Summer 1996 study period.

Model boundary temperature and dissolved gas concentrations were also established at the Bonneville dam boundary using the temporary pool study monitors. Six temporary monitors were located in the Bonneville tailrace during Summer 1996 study period, as shown in Figure 200. The temperatures and TDG pressures recorded by these monitors are shown in Figure 201 and Figure 202, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 203. The transport simulation boundary was established at grid row 1 of block 1 (below north powerhouse, shown in red in Figure 200), row 17 of block 2 (below spillway, green), and row 1 of block 4 (below south powerhouse cyan). In block 2, temporary monitor TDG concentrations and temperatures as follows along the model grid:

- BONSWQ4P: columns 1 to 3;
- BONSWQ3P: columns 4 to 5; and
- BONSWQ2P: columns 6 to 8.

Station BONSWQ5P was not used because of its short record.

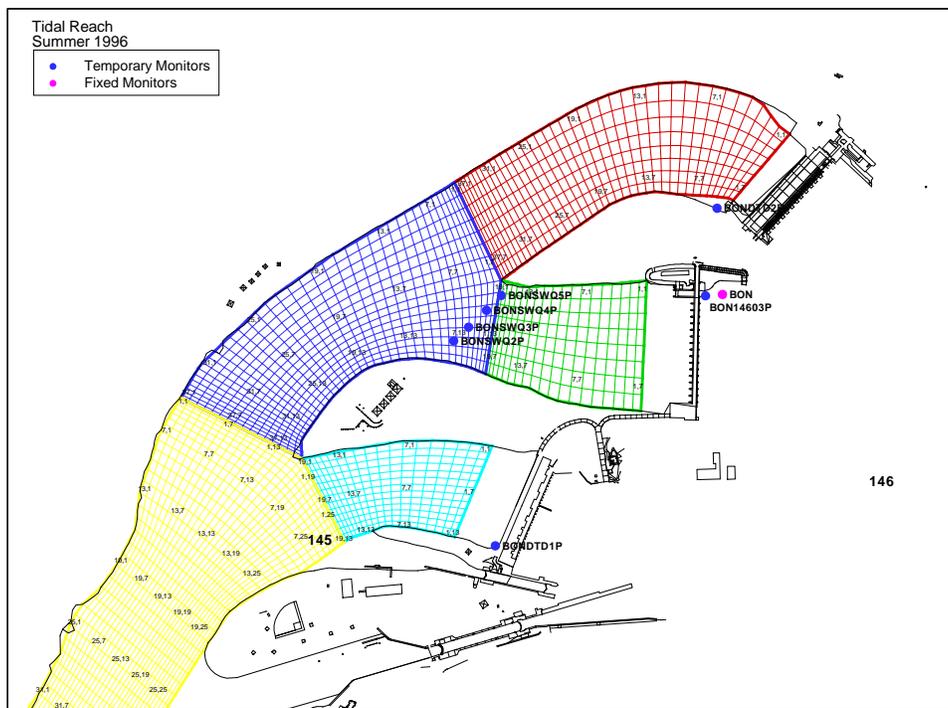


Figure 200. Locations, relative to the model grid, of temporary monitors during the Summer 1996 study period.

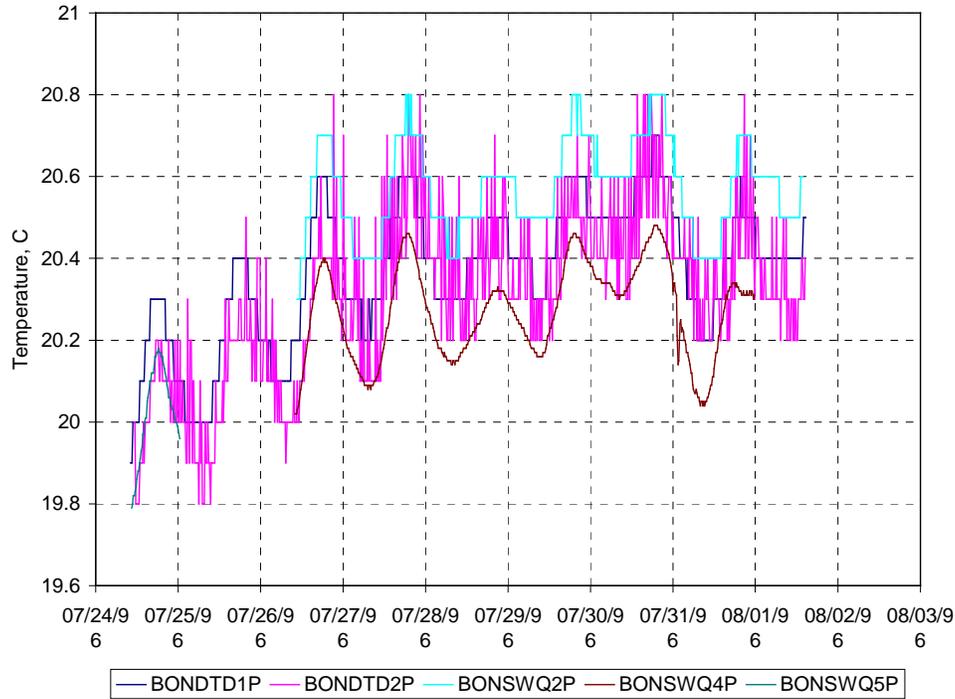


Figure 201. Temperatures measured by temporary monitors near Bonneville dam during the Summer 1996 study period.

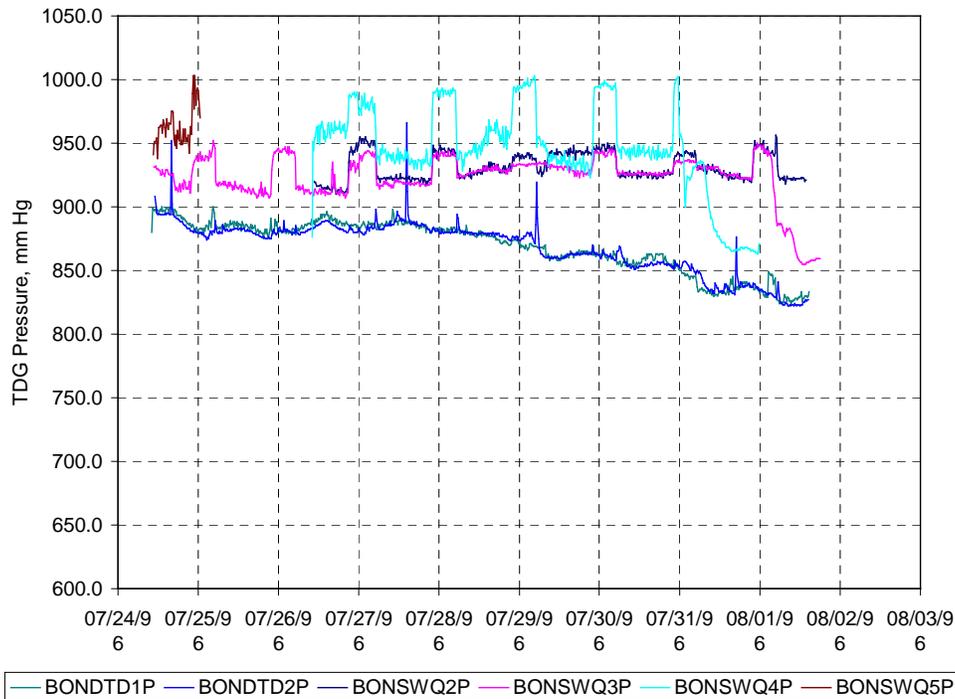


Figure 202. TDG pressures measured by temporary monitors near Bonneville dam during the Summer 1996 study period.

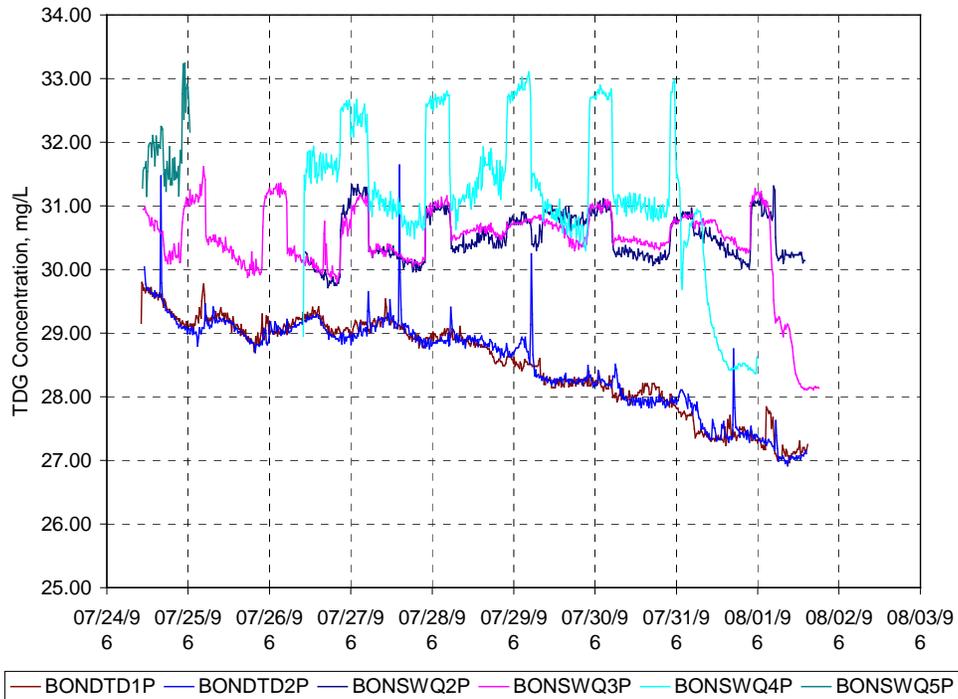


Figure 203. TDG concentrations computed from temporary monitor data near Bonneville dam during the Summer 1996 study period.

C.4 Downstream Boundary

Stage at the downstream model boundary was estimated using a one-dimensional hydrodynamic model as described in Section A.2.4. Results of the one-dimensional simulation are shown in Figure 204. Predicted stages at Columbia River model 110.0 were used for the downstream boundary of the two-dimensional model.

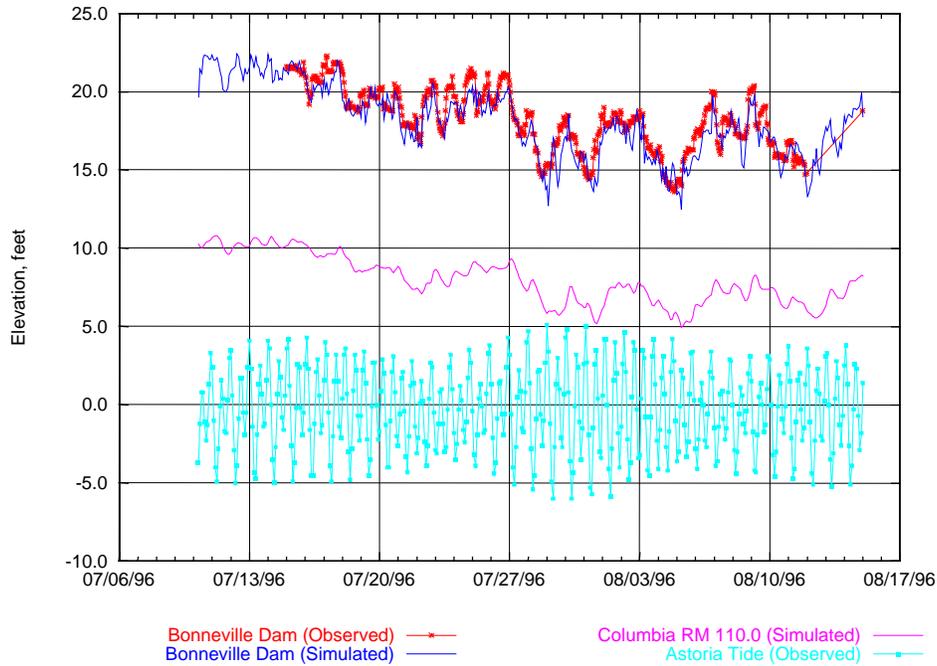


Figure 204. Predicted stage at Columbia River mile 110.0 during the Summer 1996 study period.

C.5 Weather

Atmospheric conditions were considered constant over the entire study area. Portland, Oregon, air and dew point temperature (Figure 205) and wind speed (Figure 206) were used from the NWS weather database. Barometric pressure measured by the WRNO FMS (also shown in Figure 205) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for part of the Summer 1996 study. The available radiation data was extended using NWS Portland dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 207.

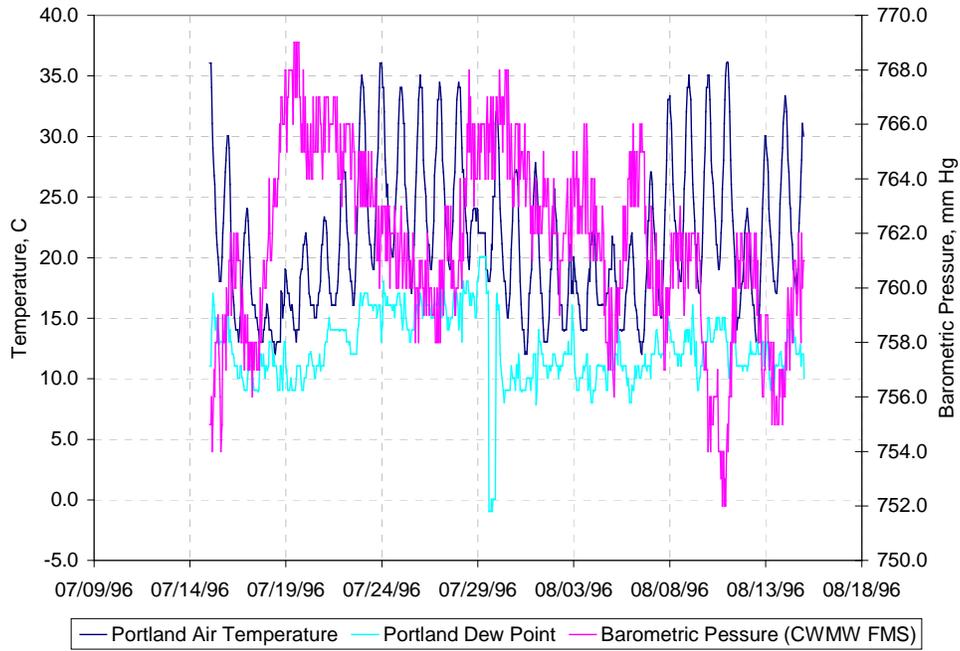


Figure 205. Air temperature, dew point, and barometric pressure used during the Summer 1996 study period.

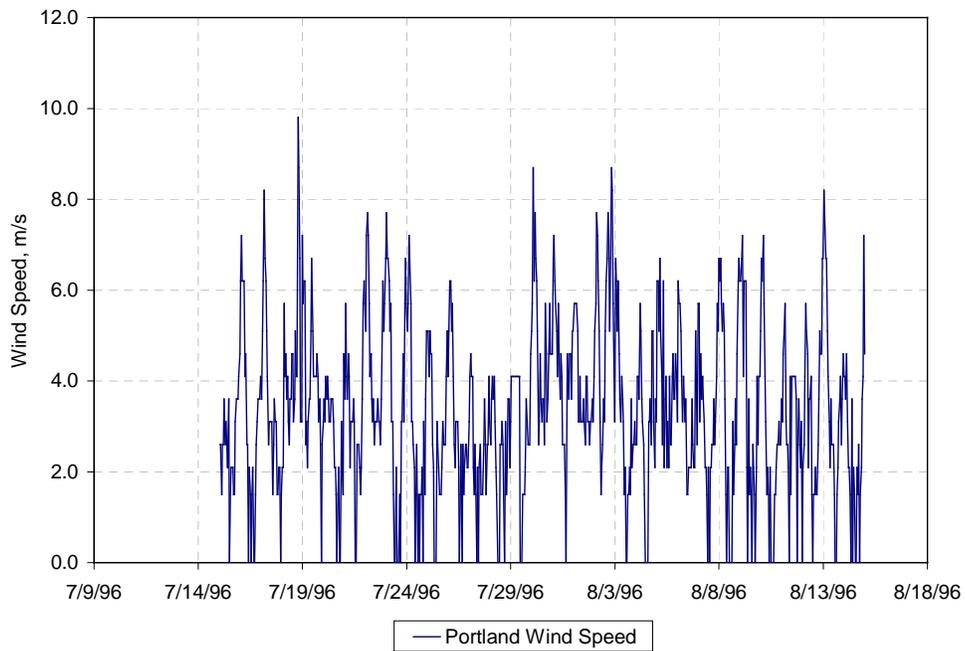


Figure 206. Wind speed used during the Summer 1996 study period.

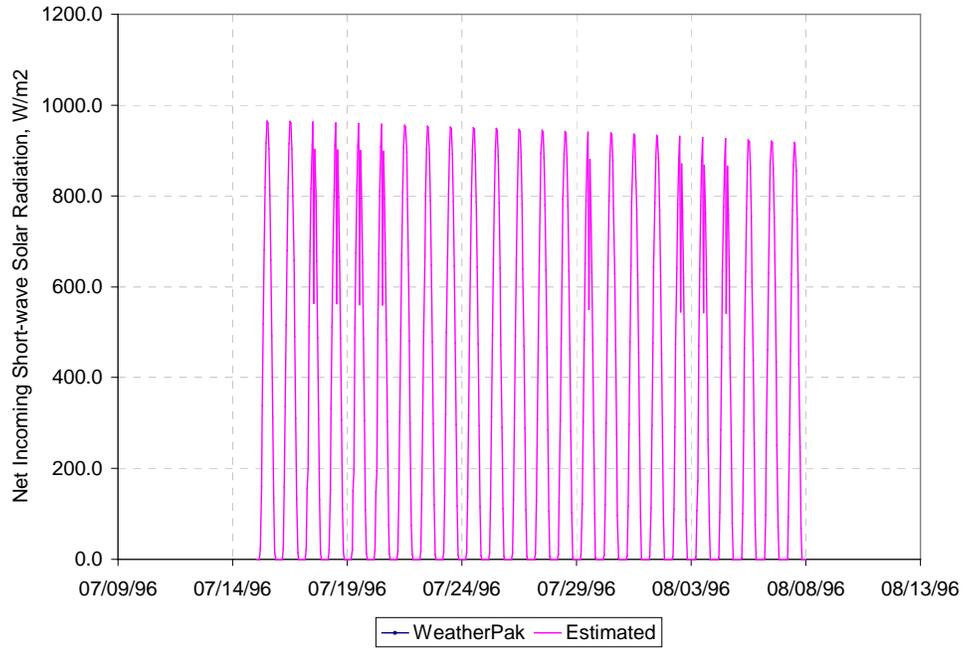


Figure 207. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Summer 1996 study period.

Appendix D. Summer 1997 Tidal Reach Study

D.1 Dissolved Gas Data

The Summer 1997 Tidal Reach dissolved gas study started on July 15 and ended on July 30. A total of 29 water quality monitors were used. These stations, and their records, are listed in Table 121. Stations locations are shown in Figure 208.

Table 121. Dissolved gas monitor stations, and their records, used during the Summer 1997 study period.

Station	Start Date	End Date	Temperature Records	Pressure Records
TID11035P	7/15/97 3:00:00 PM	7/26/97 1:00:00 PM	1049	1049
BONDTD2P	7/15/97 3:00:00 PM	7/29/97 10:45:00 AM	1328	1328
TID04201P	7/15/97 3:00:00 PM	7/30/97 11:15:00 AM	1426	1426
TID04203P	7/15/97 3:00:00 PM	7/19/97 12:15:00 AM	326	326
TID04205P	7/15/97 3:00:00 PM	7/30/97 11:30:00 AM	1427	1427
TID05921P	7/15/97 3:00:00 PM	7/30/97 10:45:00 AM	1424	1424
TID05923P	7/15/97 3:00:00 PM	7/30/97 7:00:00 AM	1409	1409
TID05925P	7/15/97 3:00:00 PM	7/30/97 10:15:00 AM	1422	1422
TID07701P	7/15/97 3:00:00 PM	7/30/97 9:30:00 AM	1419	1419
TID07703P	7/15/97 3:00:00 PM	7/28/97 5:30:00 PM	1257	1257
TID07705P	7/15/97 3:00:00 PM	7/30/97 9:30:00 AM	1419	1419
TID09503P	7/15/97 3:00:00 PM	7/29/97 2:00:00 PM	1341	1341
TID09505P	7/15/97 3:00:00 PM	7/29/97 1:45:00 PM	1340	1340
BONDTD1P	7/15/97 3:00:00 PM	7/28/97 4:00:00 PM	1253	1253
TID11033P	7/15/97 3:00:00 PM	7/27/97 12:30:00 PM	1143	1143
TID14404P	7/15/97 3:00:00 PM	7/29/97 7:30:00 AM	1312	1312
TID12165P	7/15/97 3:00:00 PM	7/29/97 9:15:00 AM	1322	1322
TID12252P	7/15/97 3:00:00 PM	7/29/97 9:00:00 AM	1321	1321
TID12254P	7/15/97 3:00:00 PM	7/29/97 9:00:00 AM	1321	1321
TID12801P	7/15/97 3:00:00 PM	7/29/97 9:45:00 AM	1324	1324
TID12803P	7/15/97 3:00:00 PM	7/29/97 8:15:00 AM	1318	1318
TID12805P	7/15/97 3:00:00 PM	7/29/97 9:30:00 AM	1323	1323
TID14021P	7/15/97 3:00:00 PM	7/29/97 10:15:00 AM	1326	1326
TID14022P	7/15/97 3:00:00 PM	7/29/97 10:45:00 AM	1328	0
TID14024P	7/15/97 3:00:00 PM	7/29/97 1:00:00 PM	1337	1337
TID14025P	7/15/97 3:00:00 PM	7/29/97 10:30:00 AM	1327	1327
TID14401P	7/15/97 3:00:00 PM	7/29/97 11:30:00 AM	1331	1331
TID14402P	7/15/97 3:00:00 PM	7/29/97 7:30:00 AM	1315	1315
TID11031P	7/15/97 3:00:00 PM	7/29/97 1:00:00 PM	1337	1337

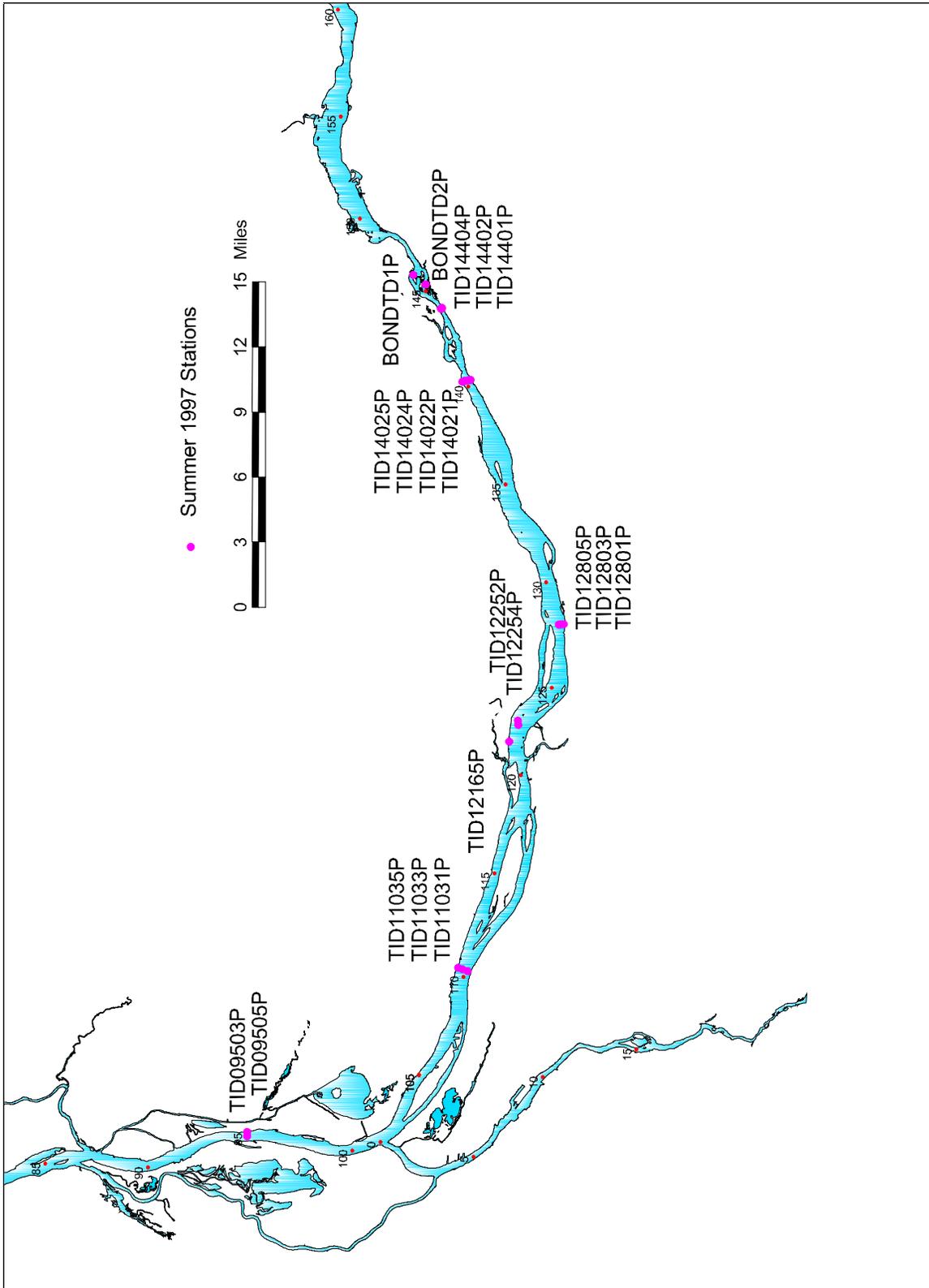


Figure 208. Temporary dissolved gas monitor locations during the Summer 1997 study period.

D.2 Velocity Data

Velocity measurements were made along a total of ?? transects during the Summer 1997 study period. The transects are summarized in Table 122. Supplied measurement locations are shown in Figure 209.

Table 122. Summary of ADCP transects made during the Summer 1997 study period.

Date Label	Average		Number of Measurements
	Velocity	Depth	
07-17-1997 07:44:00	4.8	49.5	30
07-17-1997 07:49:00	5.0	53.7	31
07-17-1997 07:54:00	5.3	54.3	32
07-17-1997 07:58:00	5.3	57.3	29
07-17-1997 08:10:00	7.0	45.1	29
07-17-1997 08:34:00	8.5	30.1	30
07-17-1997 08:44:00	6.6	29.8	37
07-17-1997 08:54:00	7.0	27.2	32
07-17-1997 09:06:00	4.0	35.8	39
07-17-1997 09:20:00	2.5	62.1	63
07-17-1997 09:29:00	2.5	64.1	59
07-17-1997 09:37:00	2.6	62.7	64
07-17-1997 09:53:00	2.5	57.8	59
07-17-1997 10:09:00	2.0	43.7	76
07-17-1997 10:29:00	2.2	23.1	150
07-17-1997 10:51:00	2.0	25.3	159
07-17-1997 11:15:00	2.0	31.7	125
07-17-1997 11:40:00	2.3	29.6	128
07-17-1997 12:08:00	2.6	47.8	63
07-17-1997 12:30:00	2.1	26.0	143
07-17-1997 12:50:00	2.2	25.7	132
07-17-1997 12:59:00	2.0	25.5	140
07-17-1997 13:27:00	2.6	24.8	115
07-18-1997 09:21:00	3.5	24.6	85
07-18-1997 09:46:00	3.5	24.6	85
07-18-1997 10:12:00	3.3	28.7	85
07-18-1997 10:34:00	3.2	30.5	86
07-18-1997 11:10:00	2.7	24.1	192
07-18-1997 11:50:00	2.9	30.1	75
07-18-1997 12:26:00	3.2	31.0	106
07-18-1997 12:42:00	3.2	29.6	98
07-18-1997 13:00:00	3.2	32.1	103
07-18-1997 13:54:00	3.1	39.4	78
07-22-1997 09:01:00	2.0	46.3	87
07-22-1997 09:27:00	2.5	40.5	82
07-22-1997 09:43:00	2.5	39.8	85
07-22-1997 09:53:00	2.7	40.4	81

Date Label	Average		Number of Measurements
	Velocity	Depth	
07-22-1997 10:28:00	2.7	46.2	70
07-22-1997 10:51:00	2.8	45.4	72
07-22-1997 11:11:00	2.9	39.2	78
07-22-1997 11:32:00	2.9	48.1	74
07-22-1997 11:44:00	2.9	49.6	73
07-22-1997 11:56:00	2.9	49.7	74
07-22-1997 12:18:00	3.3	51.2	66
07-22-1997 12:38:00	3.2	47.4	65
07-22-1997 13:01:00	2.9	43.8	112
07-22-1997 13:27:00	3.2	46.7	75
07-22-1997 13:44:00	3.0	47.1	74
07-22-1997 13:55:00	3.0	46.8	74
07-22-1997 14:16:00	3.3	69.9	53
07-22-1997 14:34:00	2.8	60.9	66
07-22-1997 14:55:00	1.6	33.8	111
07-22-1997 15:17:00	0.8	51.7	75
07-22-1997 15:26:00	0.7	47.0	59
07-22-1997 15:36:00	0.6	48.8	74

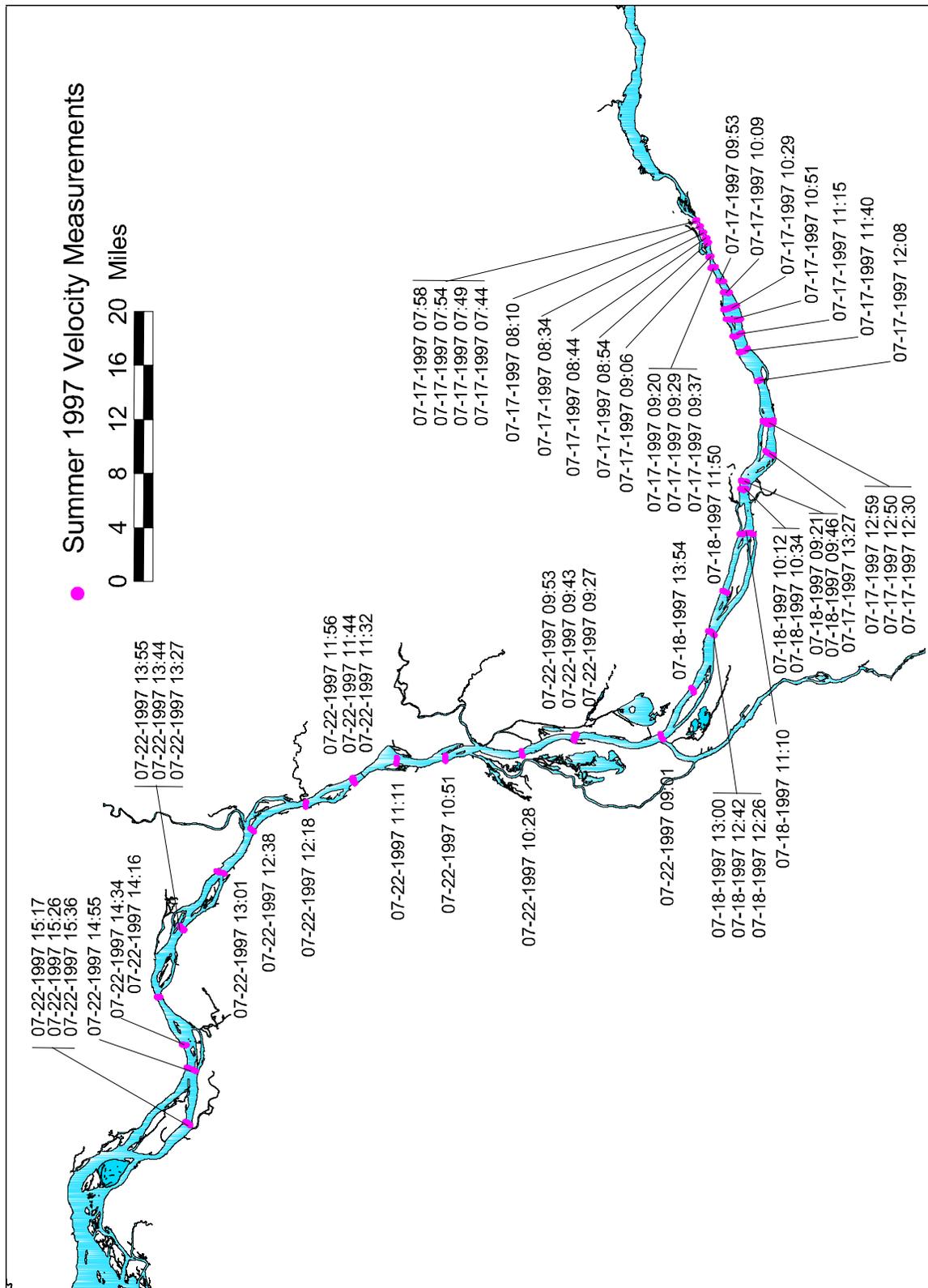


Figure 209. Locations of ADCP velocity measurements during the Summer 1997 study period.

D.3 Bonneville Dam Model Boundary

D.3.1 Dam Operations

CHROMS operations data was used to establish the flow at the Bonneville dam model boundary. This data provided hourly spillway flows and powerhouse flow. Hourly total spill and powerhouse flows for the Summer 1997 study period are shown in Figure 210. These flows were uniformly distributed across the corresponding part of the model grid.

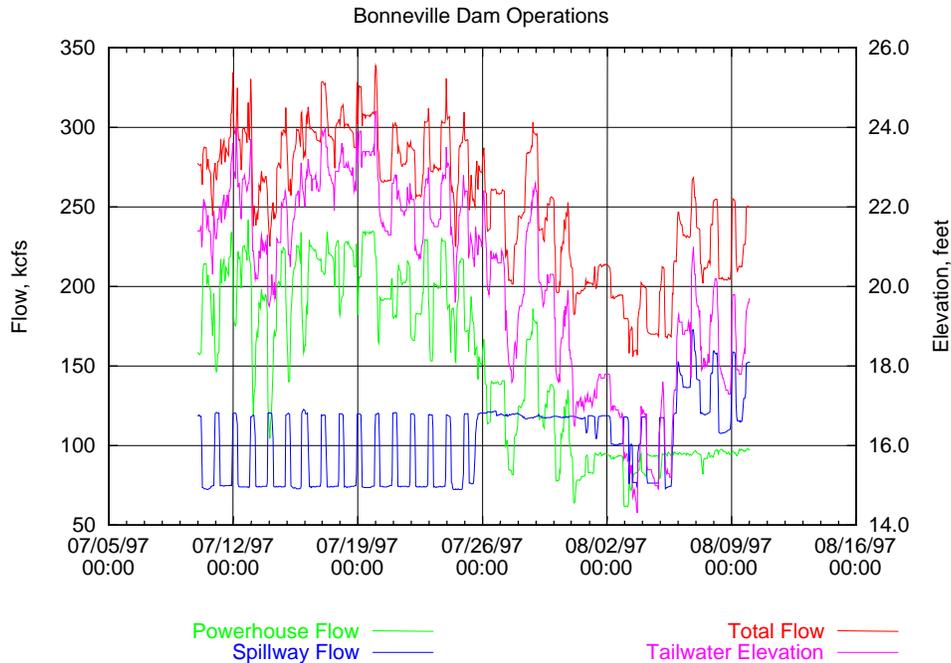


Figure 210. Bonneville dam operations during the Summer 1997 study.

D.3.2 Water Quality

Initially, data from the permanent fixed monitor located in the Bonneville dam forebay (station name "BON") was used to establish temperature at the Bonneville dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 211) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 212) was used to compute TDG concentrations (Figure 213) for the powerhouse flow. Spillway TDG gas pressures and concentrations (also shown in Figure 212 and Figure 213, respectively) were estimated using the TDG sourcing function from Bonneville dam.

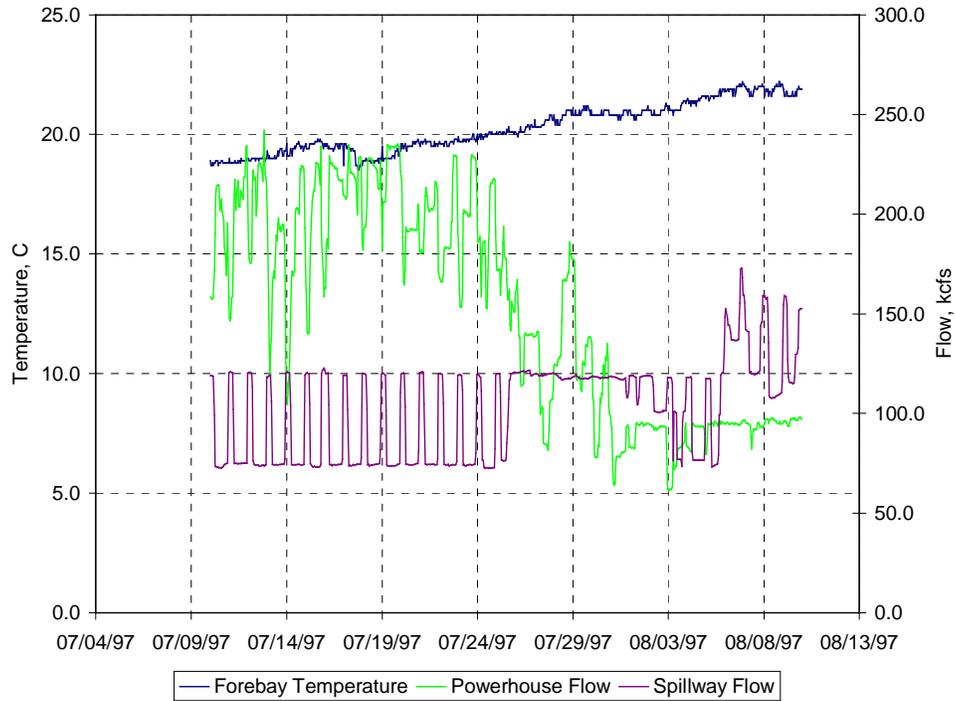


Figure 211. Bonneville forebay water temperature during the Summer 1997 study.

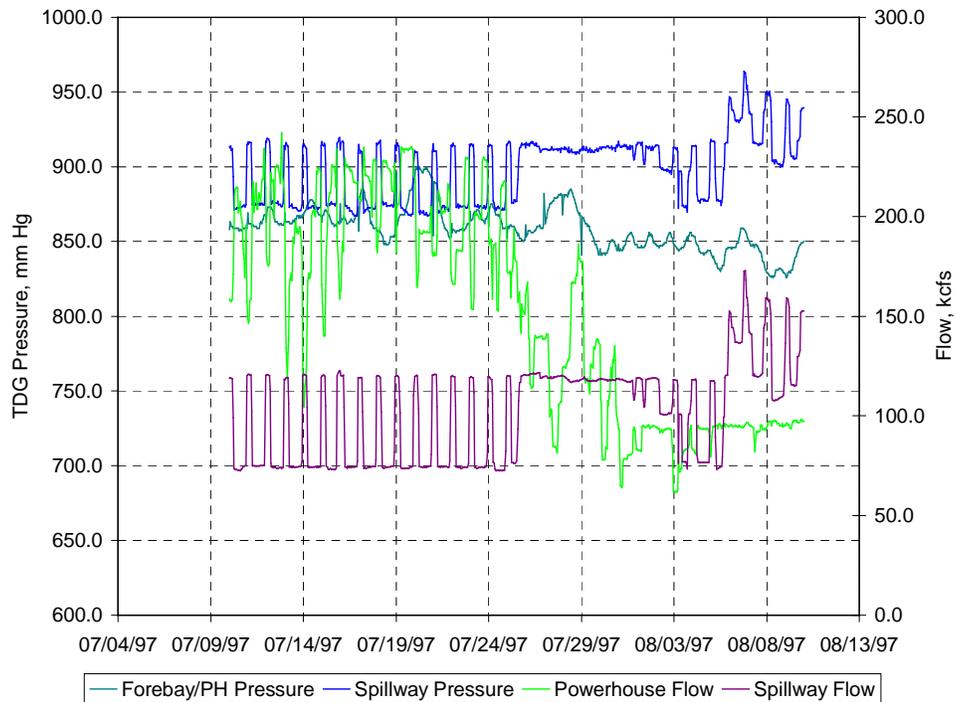


Figure 212. Bonneville forebay TDG pressure during the Summer 1997 study.

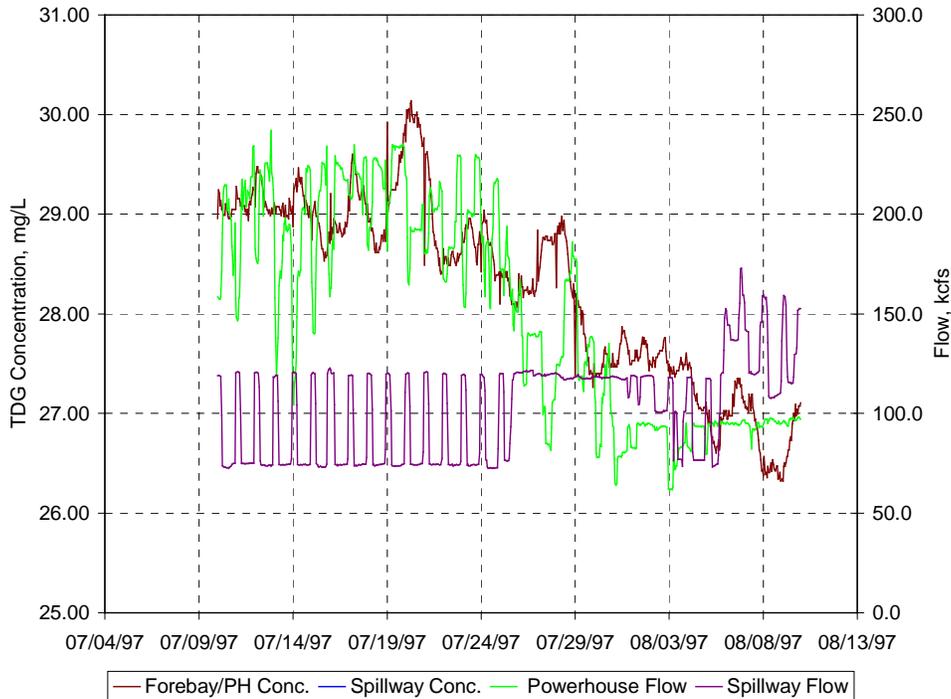


Figure 213. Computed TDG concentration in the Bonneville forebay during the Summer 1997 study period.

Model boundary temperature and dissolved gas concentrations were also established at the Bonneville dam boundary using the temporary pool study monitors. Five temporary monitors were located in the Bonneville tailrace during Summer 1997 study period, as shown in Figure 214. The temperatures and TDG pressures recorded by these monitors are shown in Figure 215 and Figure 216, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 217. The transport simulation boundary was established at grid row 56 of block 5 (shown in yellow in Figure 214), row 56 of block 17 (below spillway, green). Temporary monitor TDG concentrations and temperatures as follows along the model grid:

- TID14404P: columns 1 to 18;
- TID14402P: columns 19 to 25; and
- TID14401P: columns 26 to 29.

Stations BONDTD2P, and BONDTD1P were not used since they would have provided an incomplete description of gas levels at the dam (there was no monitor at the spillway).

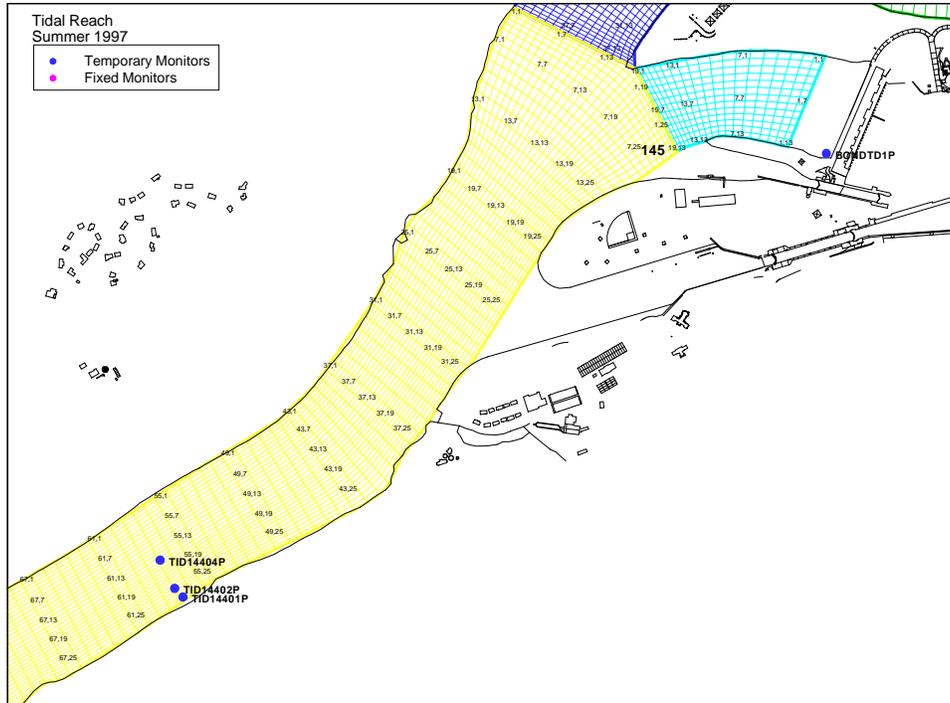


Figure 214. Locations, relative to the model grid, of temporary monitors during the Summer 1997 study period.

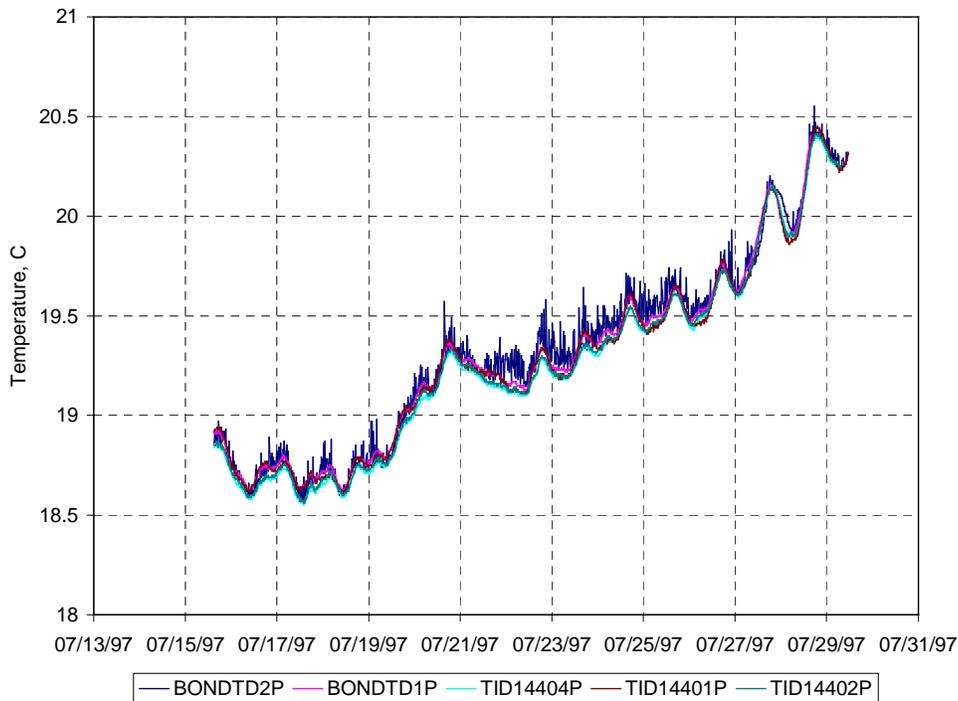


Figure 215. Temperatures measured by temporary monitors near Bonneville dam during the Summer 1997 study period.

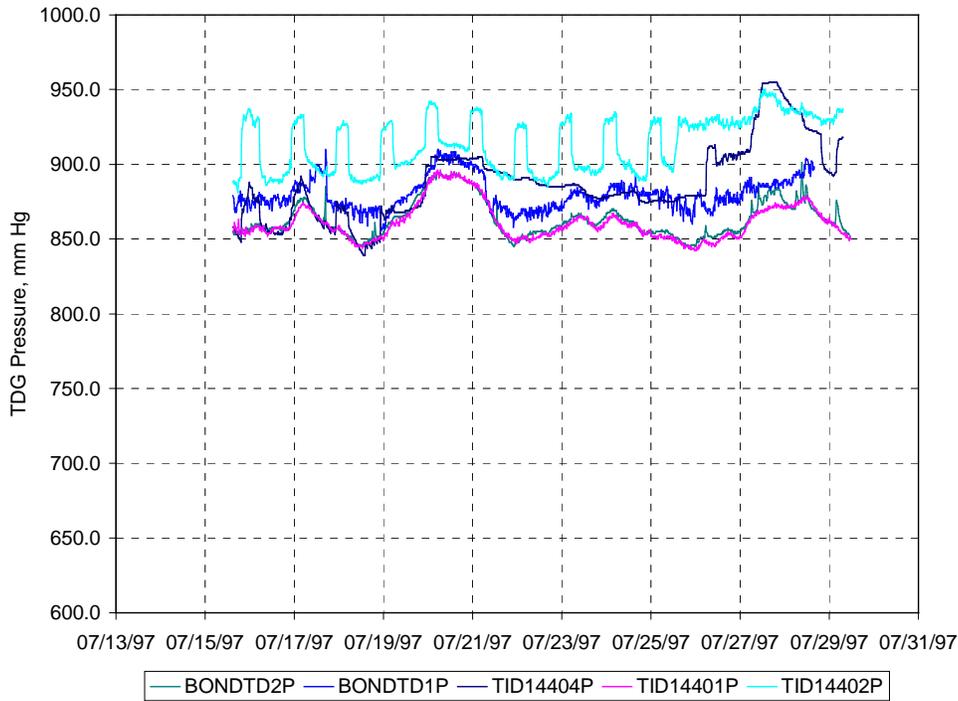


Figure 216. TDG pressures measured by temporary monitors near Bonneville dam during the Summer 1997 study period.

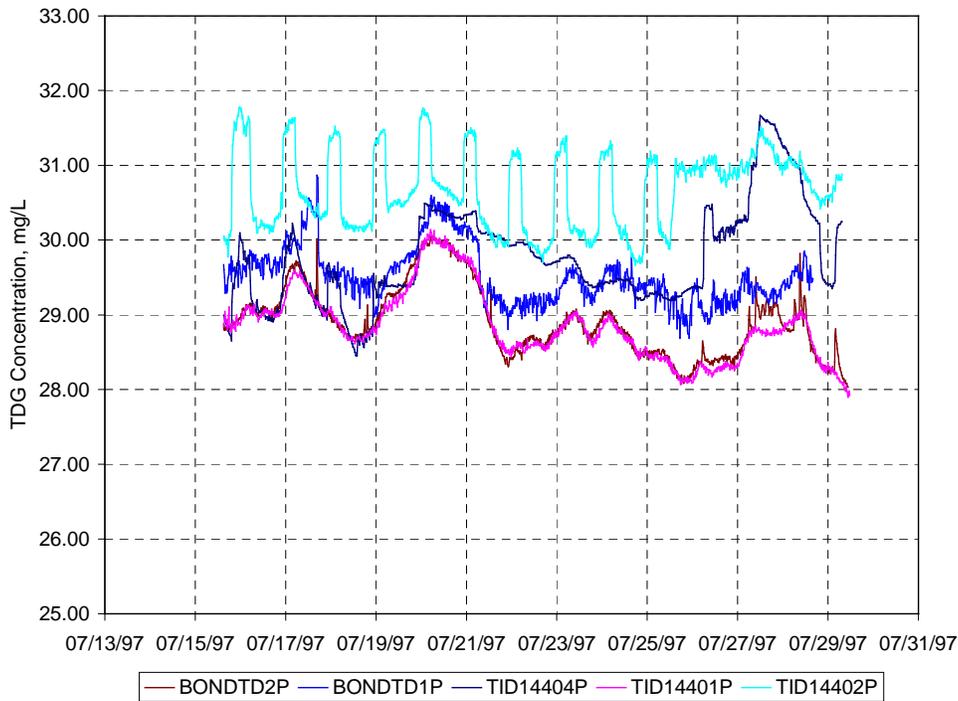


Figure 217. TDG concentrations computed from temporary monitor data near Bonneville dam during the Summer 1997 study period.

D.4 Downstream Boundary

Stage at the downstream model boundary was estimated using a one-dimensional hydrodynamic model as described in Section A.2.4. Results of the one-dimensional simulation are shown in Figure 218. Predicted stages at Columbia River model 110.0 were used for the downstream boundary of the two-dimensional model.

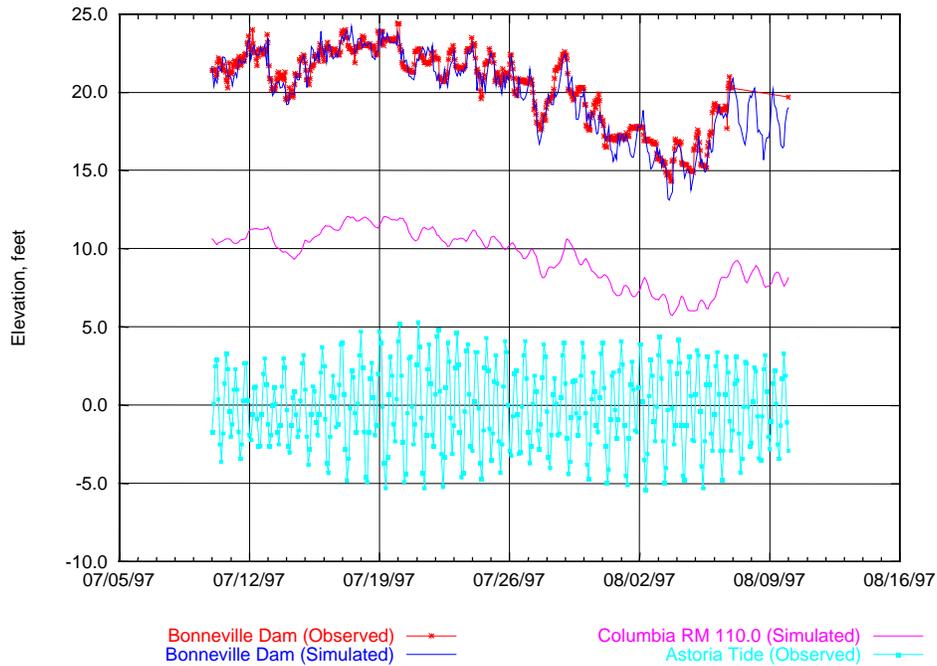


Figure 218. Predicted stage at Columbia River mile 110.0 during the Summer 1997 study period.

D.5 Weather

Atmospheric conditions were considered constant over the entire study area. Portland, Oregon, air and dew point temperature (Figure 219) and wind speed (Figure 220) were used from the NWS weather database. Barometric pressure measured by the WRNO FMS (also shown in) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for part of the Summer 1997 study. The available radiation data was extended using NWS Portland dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 221.

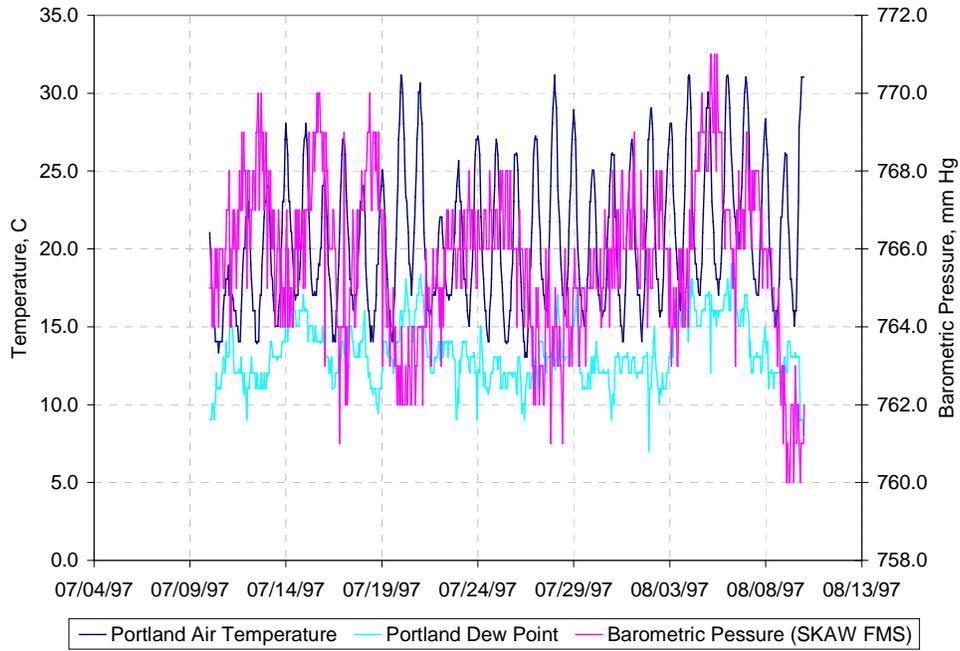


Figure 219. Air temperature, dew point and barometric pressure used during the Summer 1997 study period.

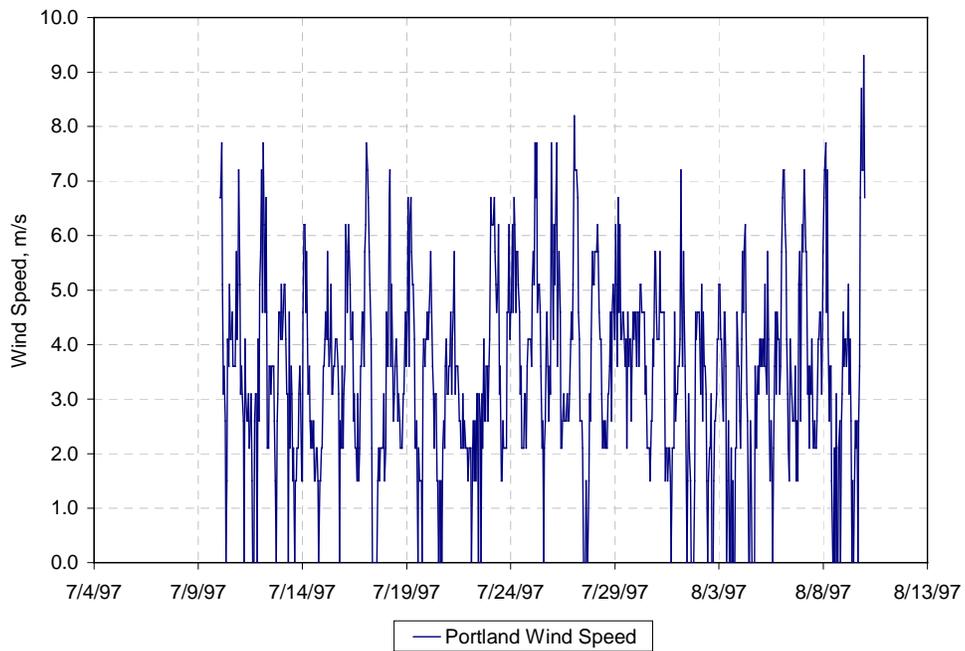


Figure 220. Wind speed used during the Summer 1997 study period.

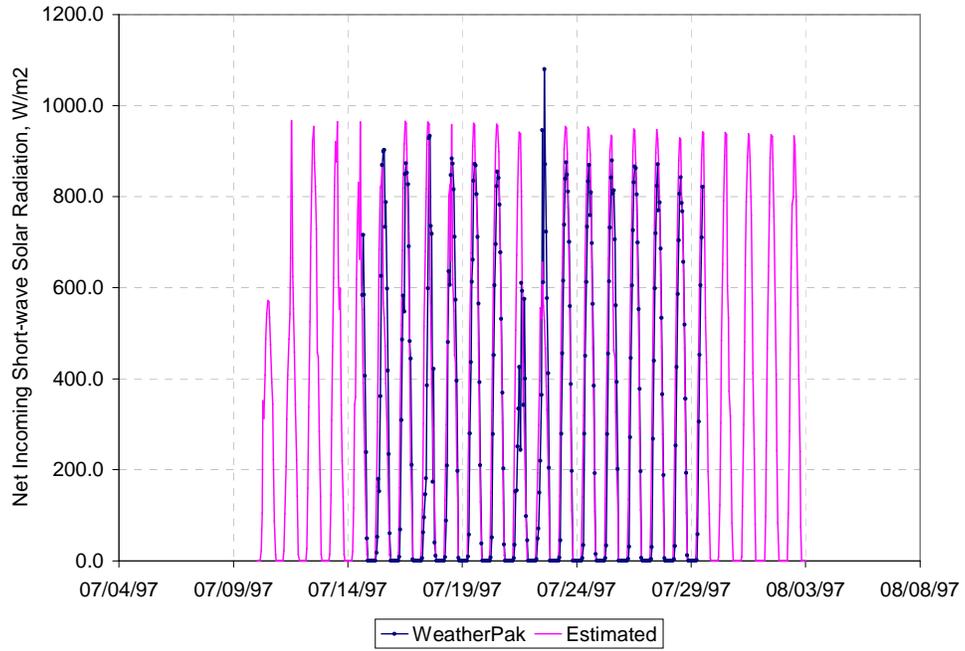


Figure 221. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Summer 1997 study period.