



**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 9: Bonneville Reservoir

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 9 of the report series summarizes the development and application of a two-dimensional depth-averaged hydrodynamic and water quality model (MASS2) to the Bonneville Reservoir of the Lower Columbia River system.

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Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers. Part 9: Bonneville Reservoir

Under Biological Services Contract DACW68-96-D-0002, Delivery Order No. 8, Battelle's 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 The Dalles Pool of the Columbia River. The modeled domain encompasses the following region:

- The Dalles Dam, at Columbia rivermile (RM) 192
- Bonneville Dam, at Columbia RM 145

1 Application of the Hydrodynamics and Water Quality Models to Bonneville Pool

A two-dimensional-depth averaged hydrodynamics and transport model has been developed and applied to the part of the Columbia River that forms the Bonneville Dam pool. 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 Bonneville Pool. 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 Bonneville pool is shown in Figure 1. Larger scale maps of the model grid near The Dalles dam and Bonneville dam 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).

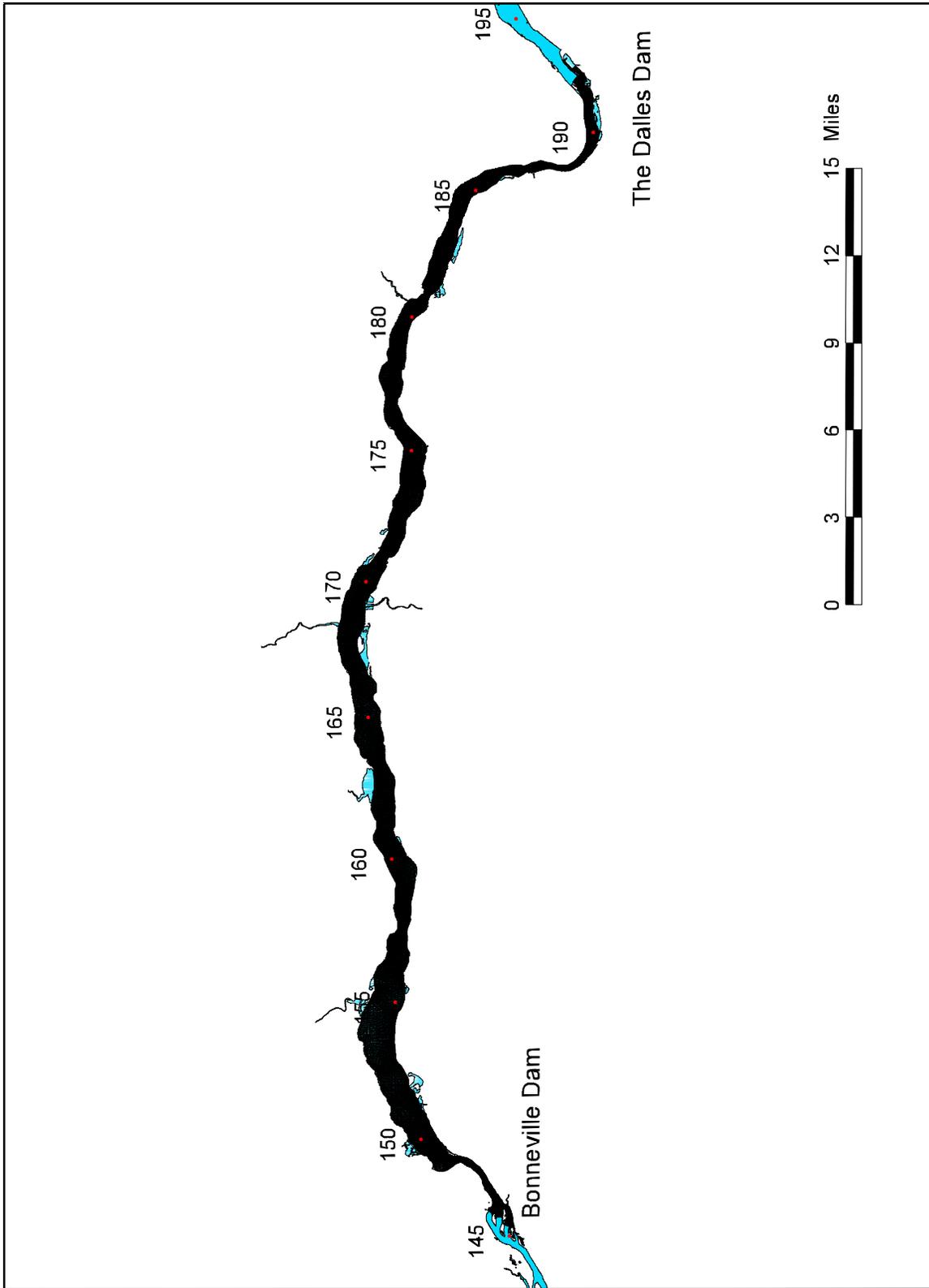


Figure 1. Model grid for Bonneville pool.

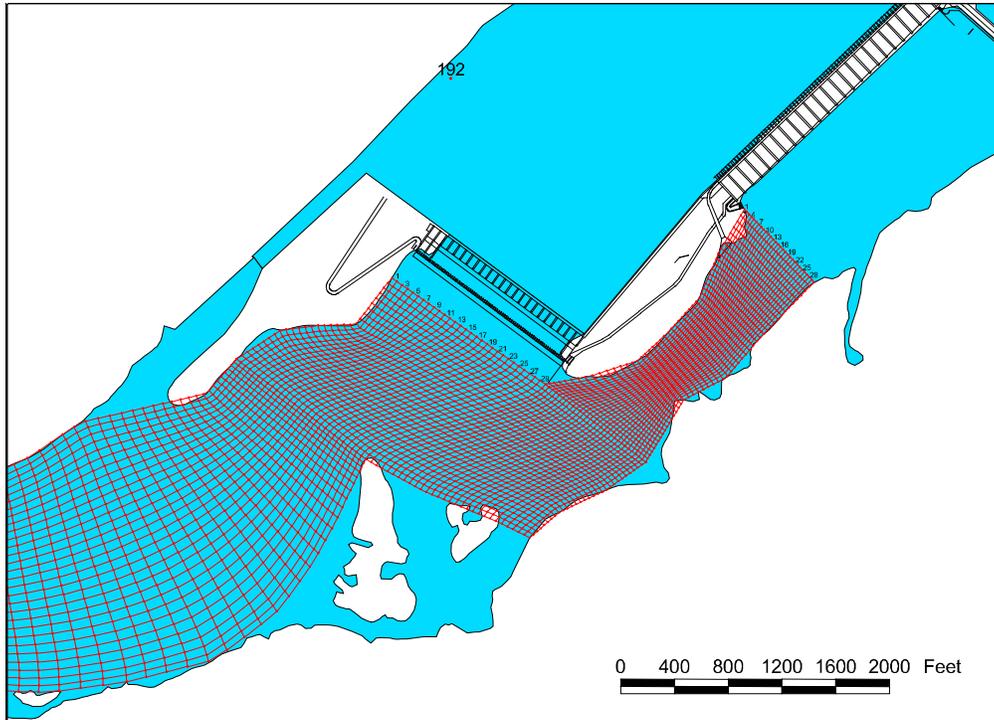


Figure 2. Model grid near The Dalles Dam.

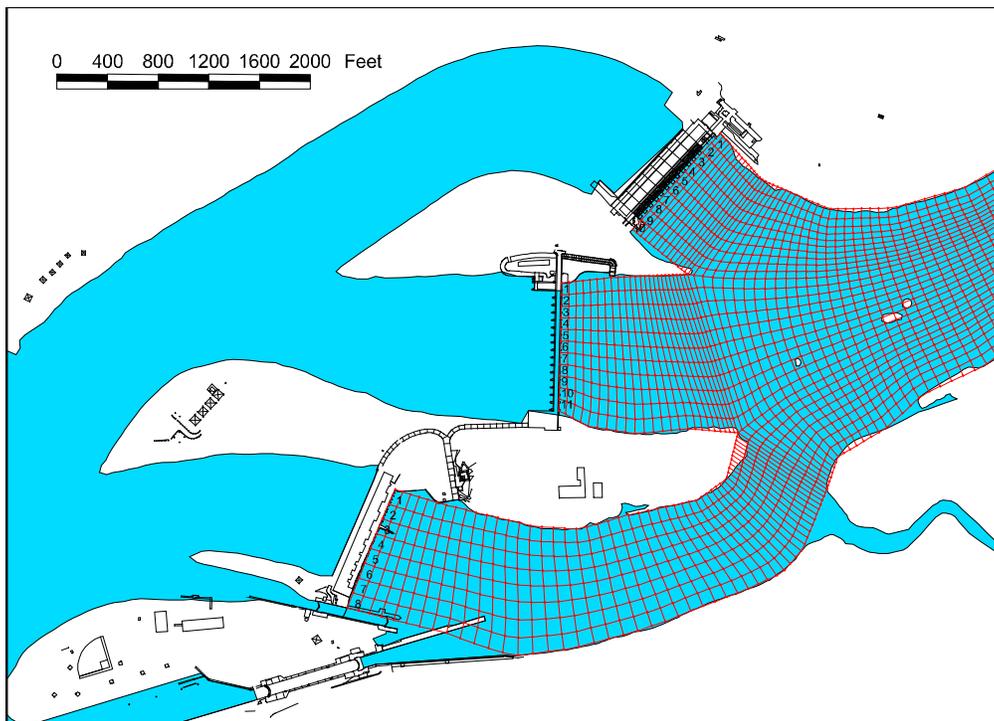


Figure 3. Model grid near Bonneville Dam.

1.2 Boundary Conditions

1.2.1 The Dalles Dam Sourcing Function

Spillway TDG concentrations were estimated using The Dalles dam TDG sourcing function presented by Schnieder and Wilhelms (1997):

$$S_s = 124.3 + 9.0 \exp(-2.73 \times 10^{-4} q_s) \quad (1)$$

where

S_s = TDG saturation of spillway flow, percent; and

q_s = spillway flow per spill bay, cfs.

The Dalles dam has 23 spill bays. When model boundary conditions were prepared, it was assumed that all spill bays were in operation. 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 Dalles dam tailwater elevation gage. ADCP velocity measurements were available for the Spring 1996 and Summer 1997 Bonneville pool 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 all simulations in this report a time step of 25 seconds was used. The simulations also used constant longitudinal and lateral turbulent eddy viscosities of 0.2 ft²/s.

1.3.1 The Dalles 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 Dalles Dam tailwater gage. The Summer 1997 pool study period was selected for calibration. Figure 4 compares the model simulation and measured tailwater elevation for a n-value of 0.029 which was chosen as the final parameter value to be used in the remainder of the Bonneville Pool simulations.

The selected n-value was verified for the Spring 1996 and Summer 1996 study periods. The verification results are shown in Figure 5 and Figure 6.

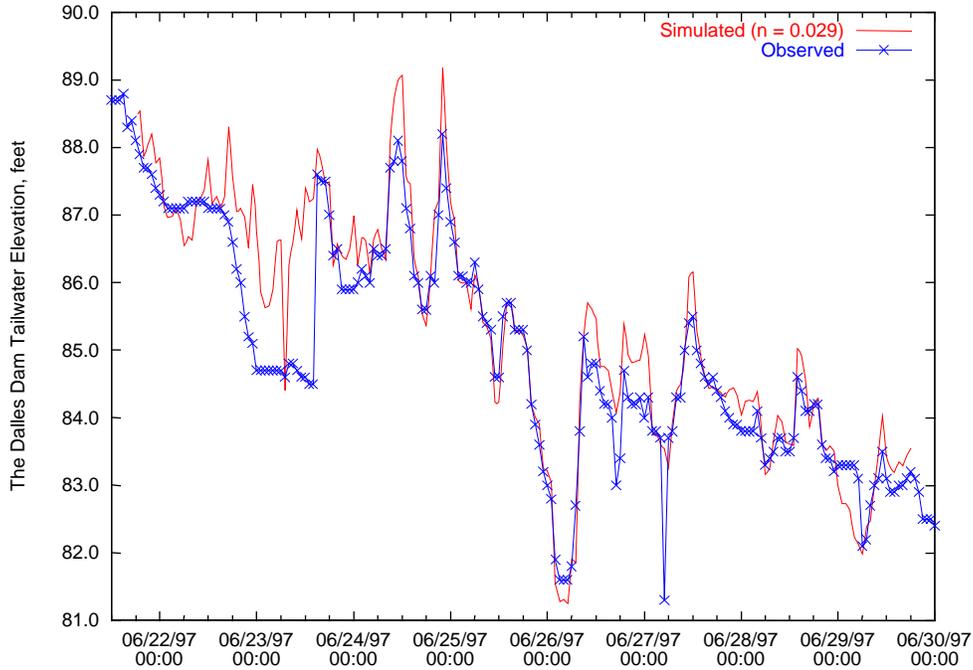


Figure 4. Comparison of simulated (Manning’s $n = 0.029$) and measured water surface elevation at The Dalles Dam tailwater gage during the Summer 1997 study period

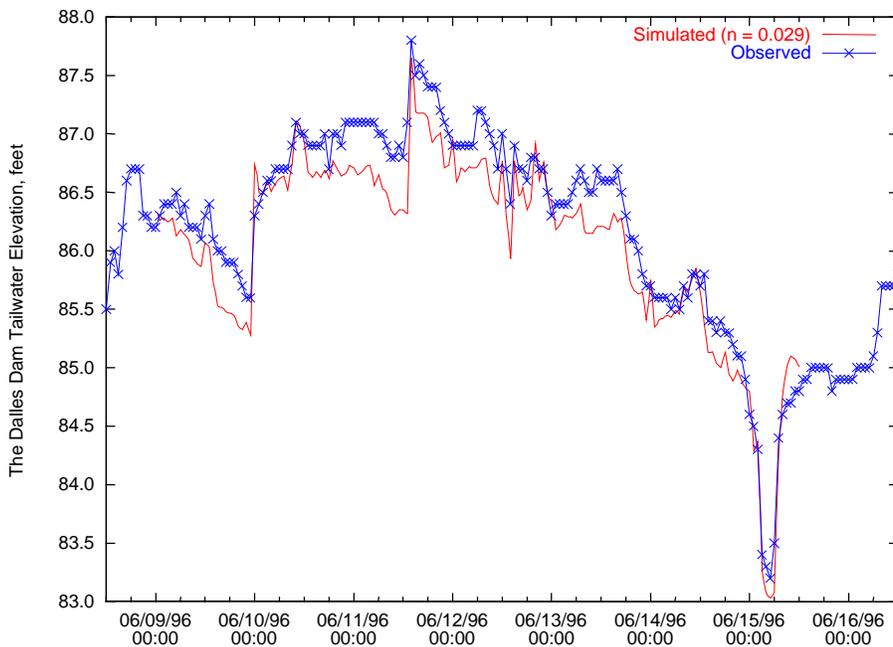


Figure 5. Comparison of simulated (Manning’s $n = 0.029$) and measured water surface elevation at The Dalles Dam tailwater gage during the Spring 1996 study period

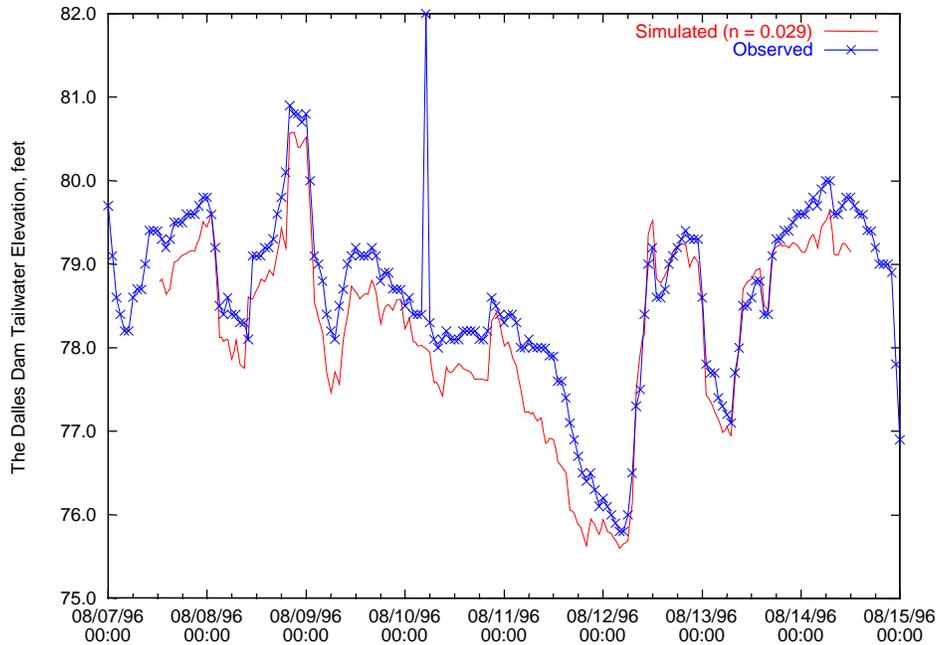


Figure 6. Comparison of simulated (Manning’s $n = 0.029$) and measured water surface elevation at The Dalles Dam tailwater gage during the Summer 1996 study period

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 1996 ADCP measurements were performed. The Manning n value was not altered from the value of 0.029 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged ADCP data in Figure 7 through Figure 18.

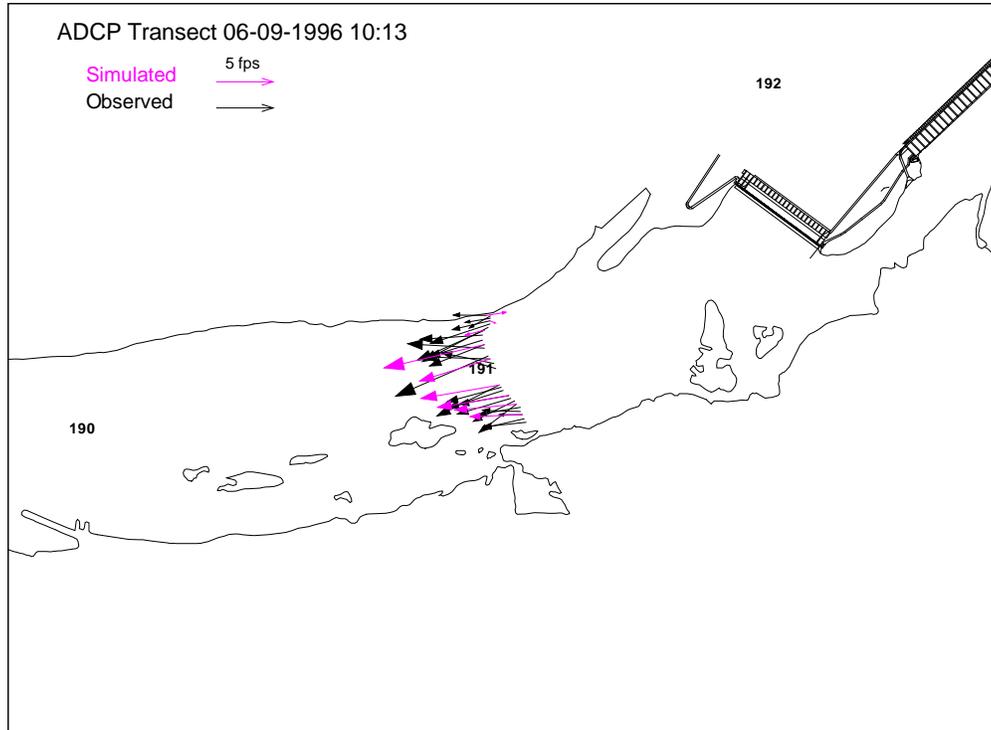


Figure 7. Simulated and observed depth-averaged velocities near Columbia River Mile 191 on 6-9-1996.

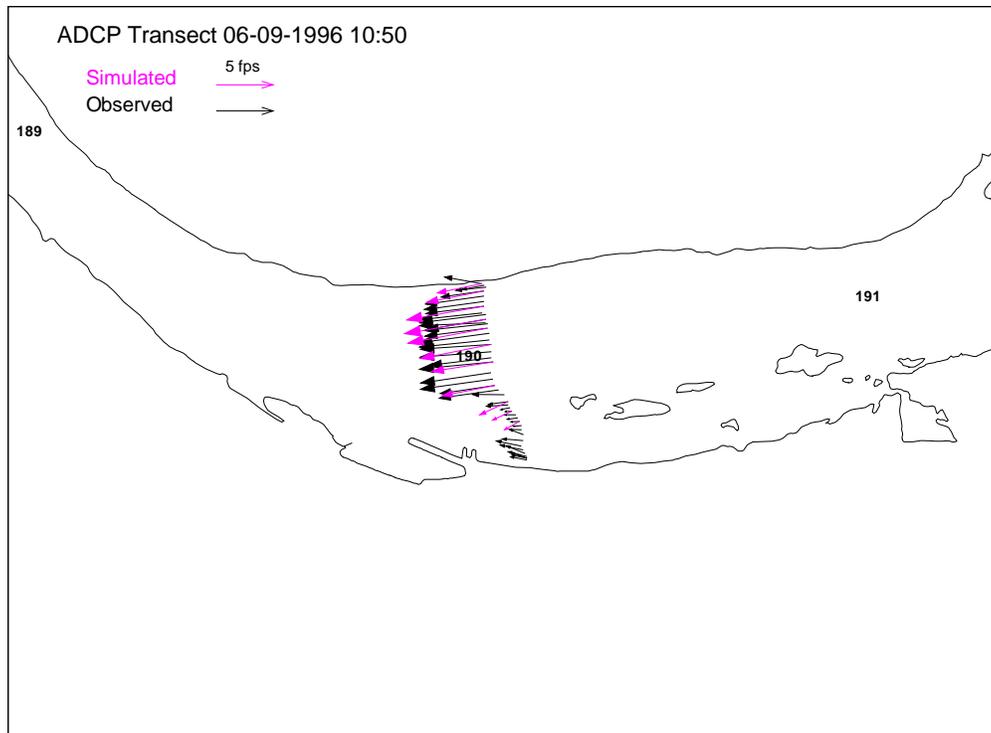


Figure 8. Simulated and observed depth-averaged velocities near Columbia River Mile 190 on 6-9-1996.

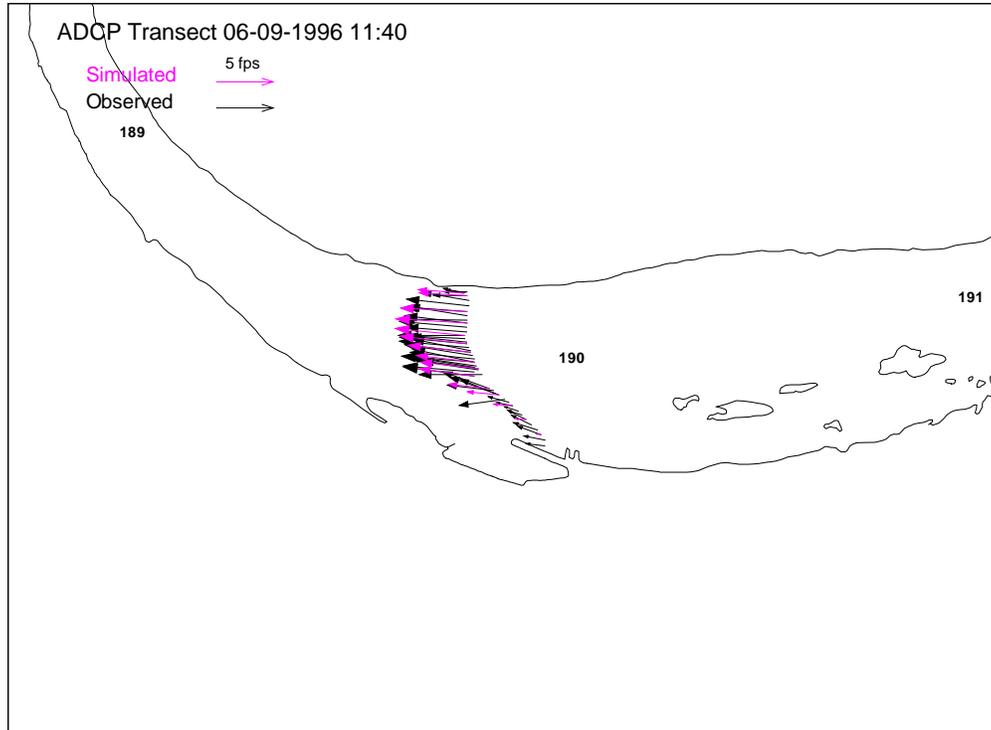


Figure 9. Simulated and observed depth-averaged velocities near Columbia River Mile 190 on 6-9-1996.

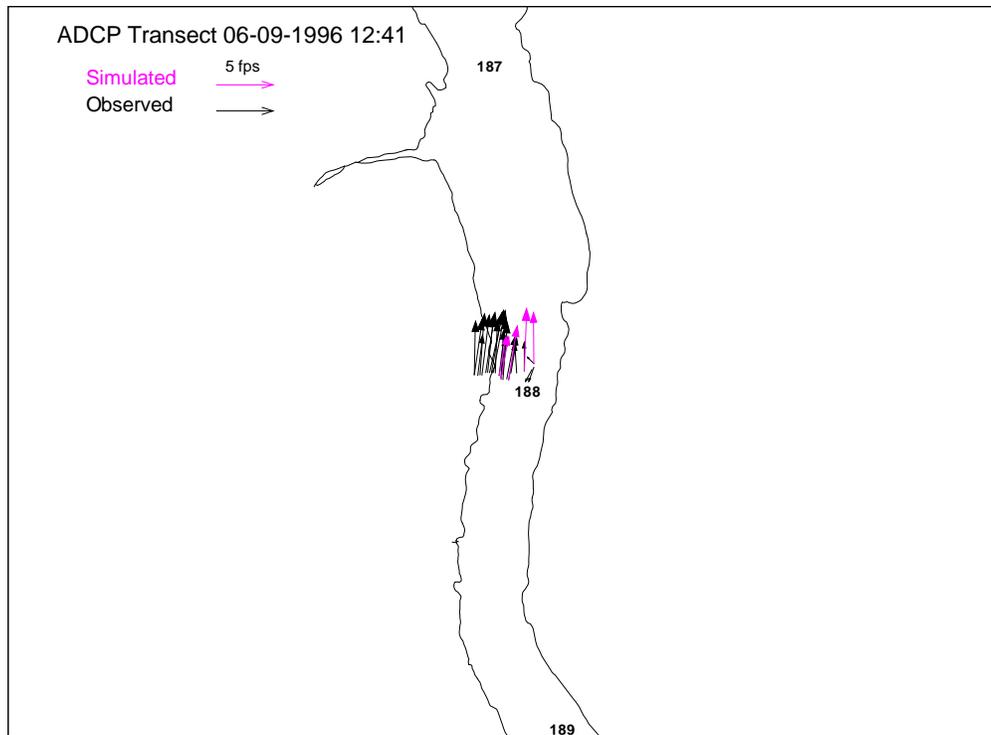


Figure 10. Simulated and observed depth-averaged velocities near Columbia River Mile 188 on 6-9-1996.

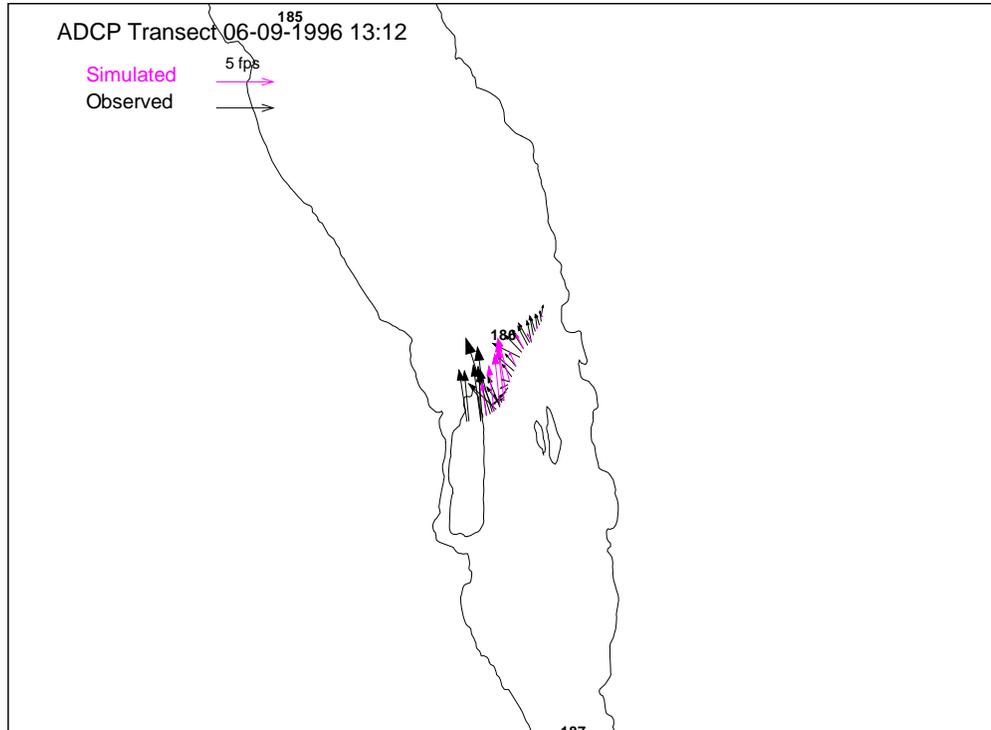


Figure 11. Simulated and observed depth-averaged velocities near Columbia River Mile 186 on 6-9-1996.

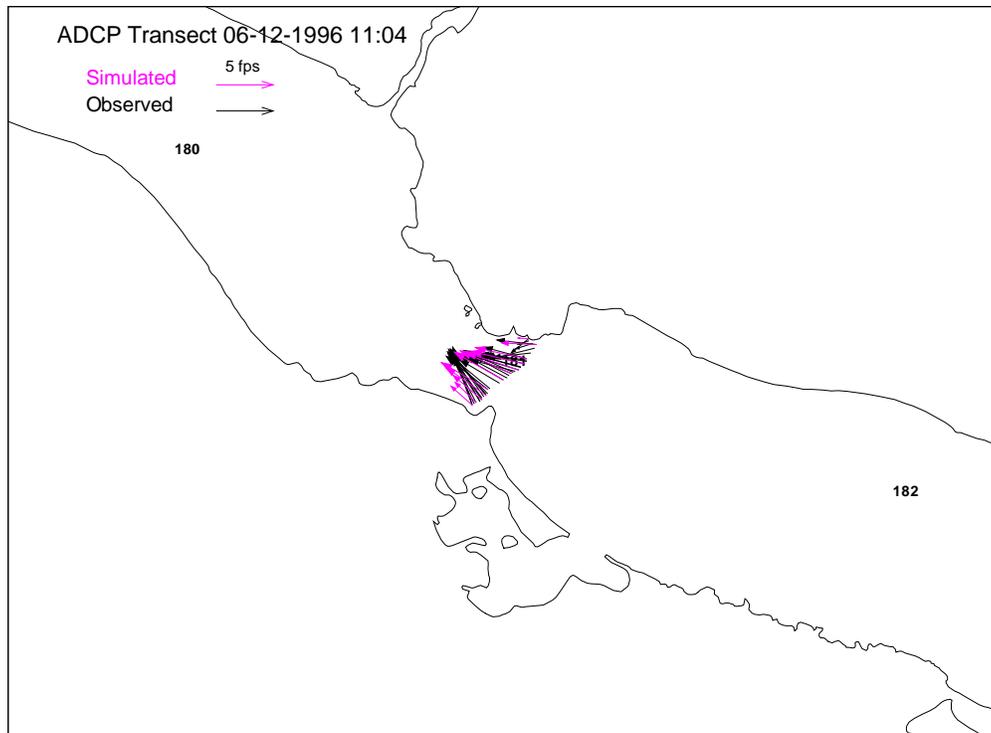


Figure 12. Simulated and observed depth-averaged velocities near Columbia River Mile 181 on 6-9-1996.

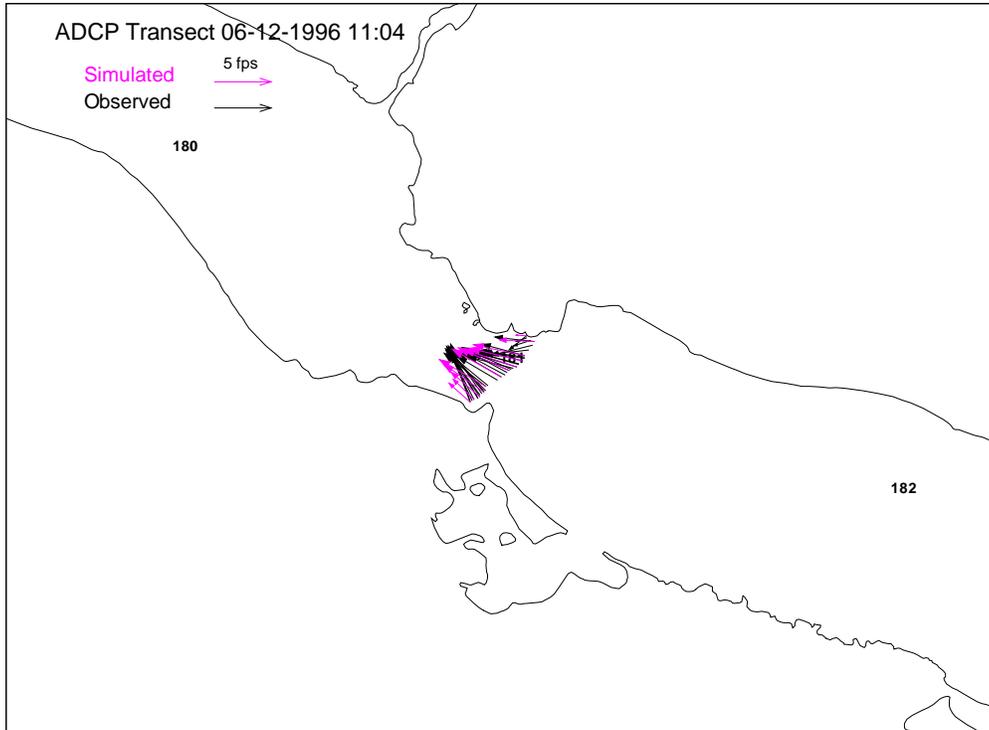


Figure 13. Simulated and observed depth-averaged velocities near Columbia River Mile 181 on 6-12-1996.

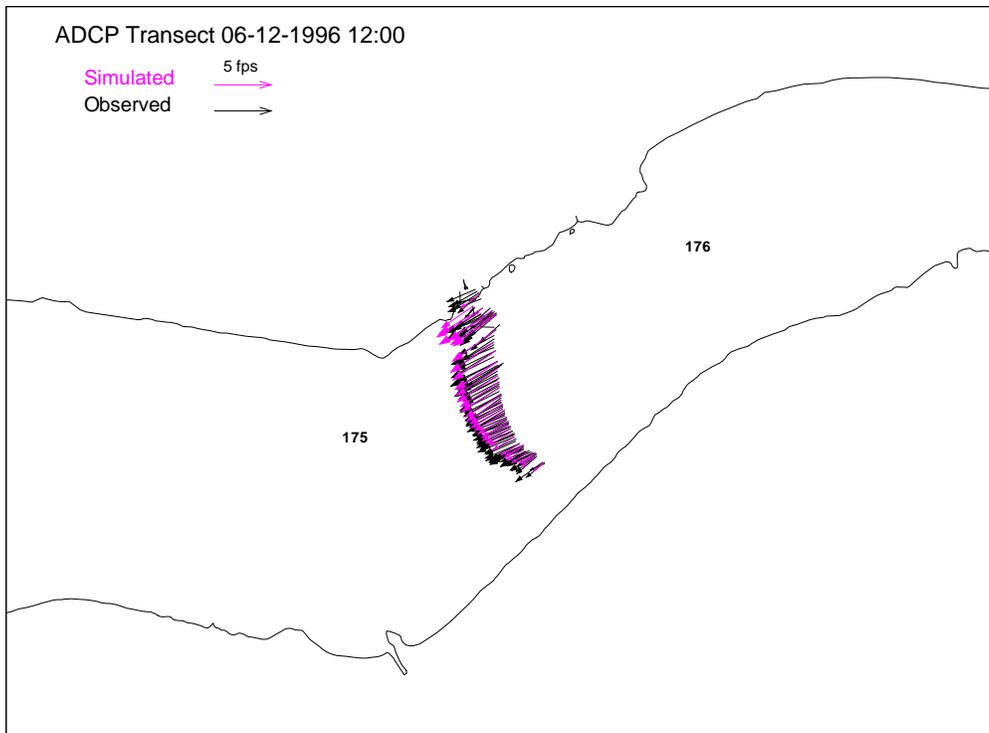


Figure 14. Simulated and observed depth-averaged velocities near Columbia River Mile 175 on 6-12-1996.

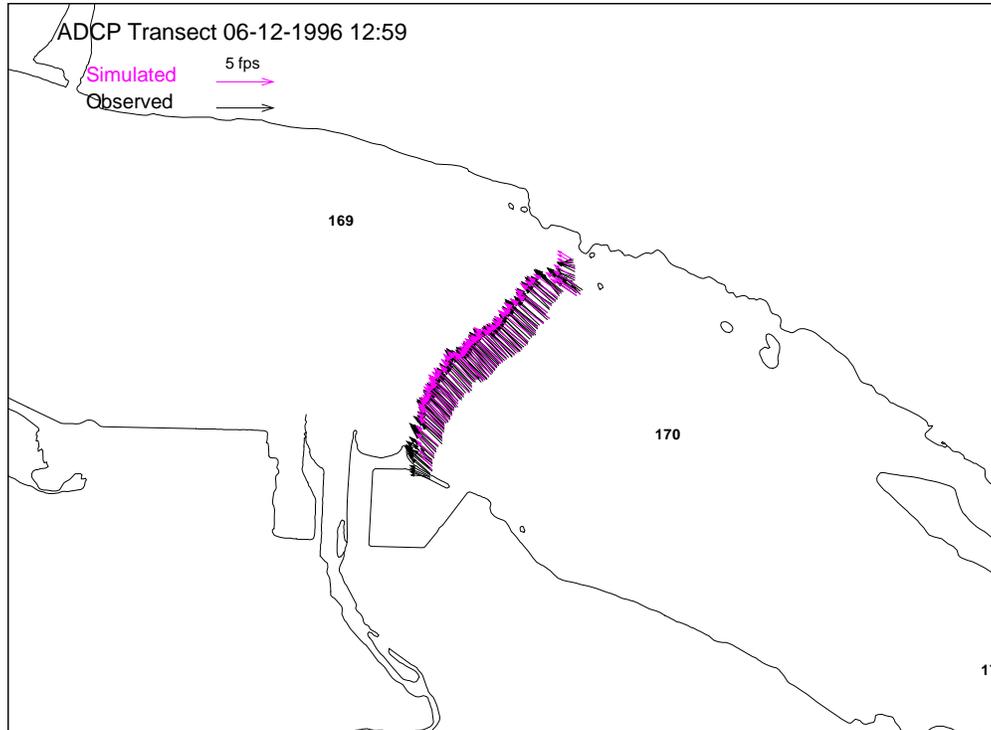


Figure 15. Simulated and observed depth-averaged velocities near Columbia River Mile 169.5 on 6-12-1996.

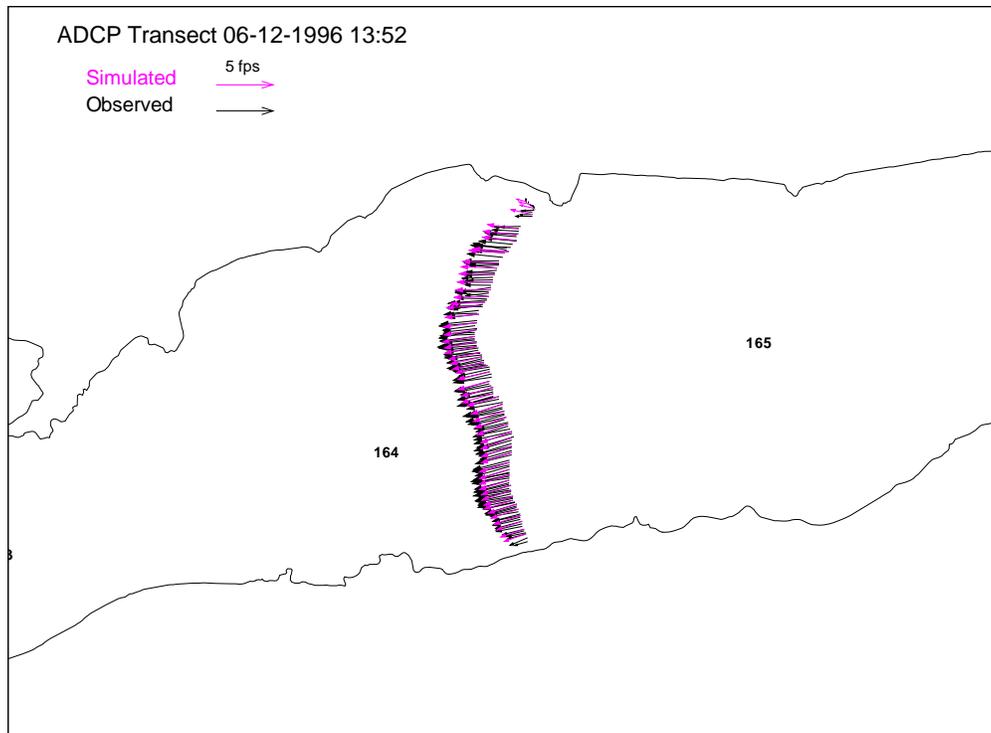


Figure 16. Simulated and observed depth-averaged velocities near Columbia River Mile 164 on 6-12-1996.

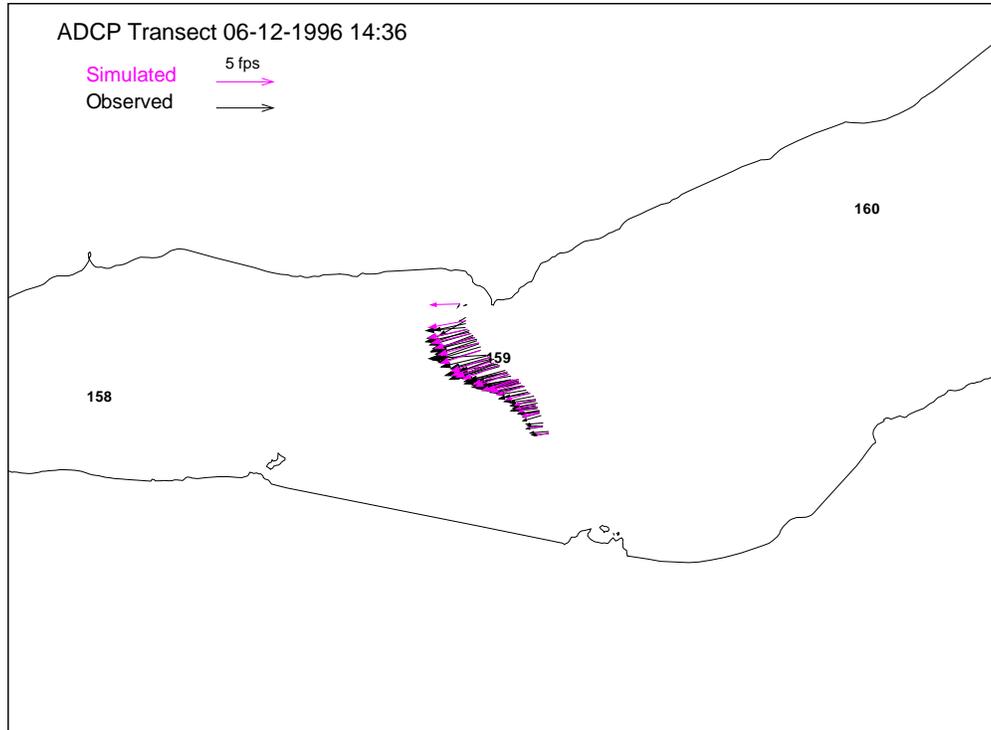


Figure 17. Simulated and observed depth-averaged velocities near Columbia River Mile 159 on 6-12-1996.

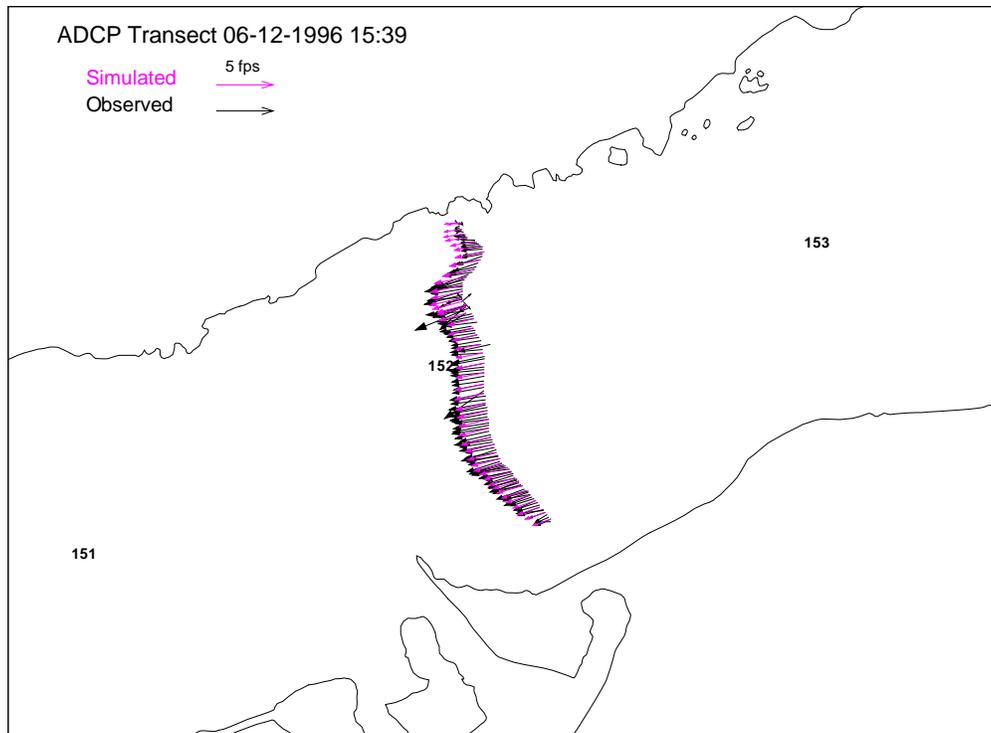


Figure 18. Simulated and observed depth-averaged velocities near Columbia River Mile 152 on 6-12-1996.

1.3.3 Summer 1997 ADCP Data

The model was also run for the operational conditions that existed when the Summer 1997 ADCP measurements were performed, using the same Manning’s n value of 0.029 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged ADCP data in Figure 19 through Figure 49.

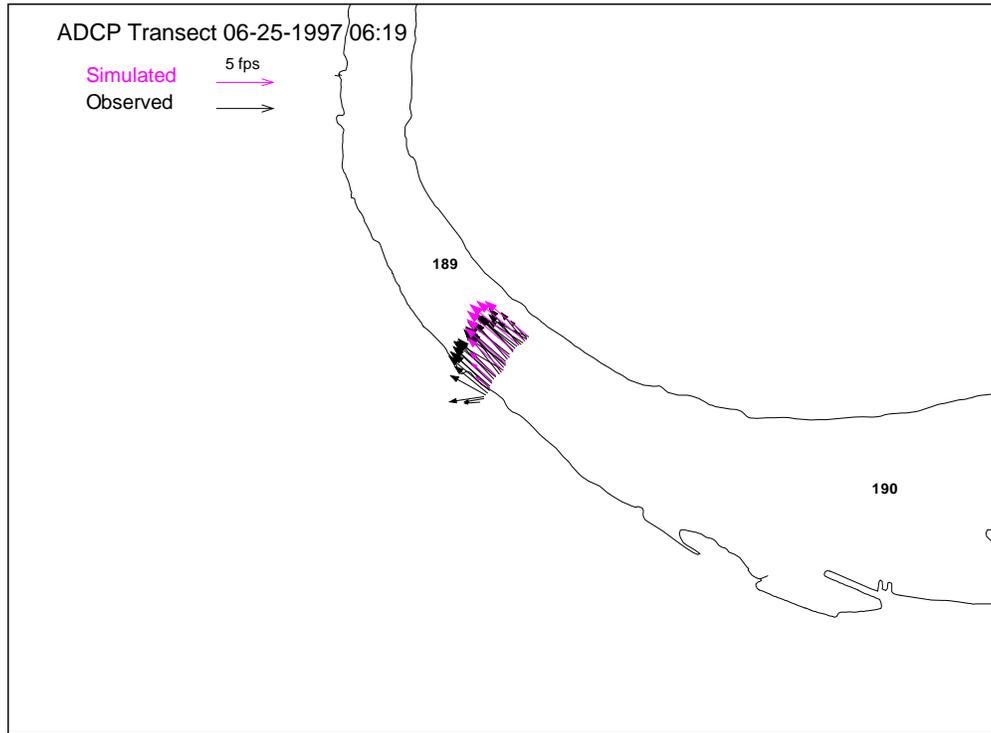


Figure 19. Simulated and observed depth-averaged velocities near Columbia River Mile 189 on 6-25-1997.

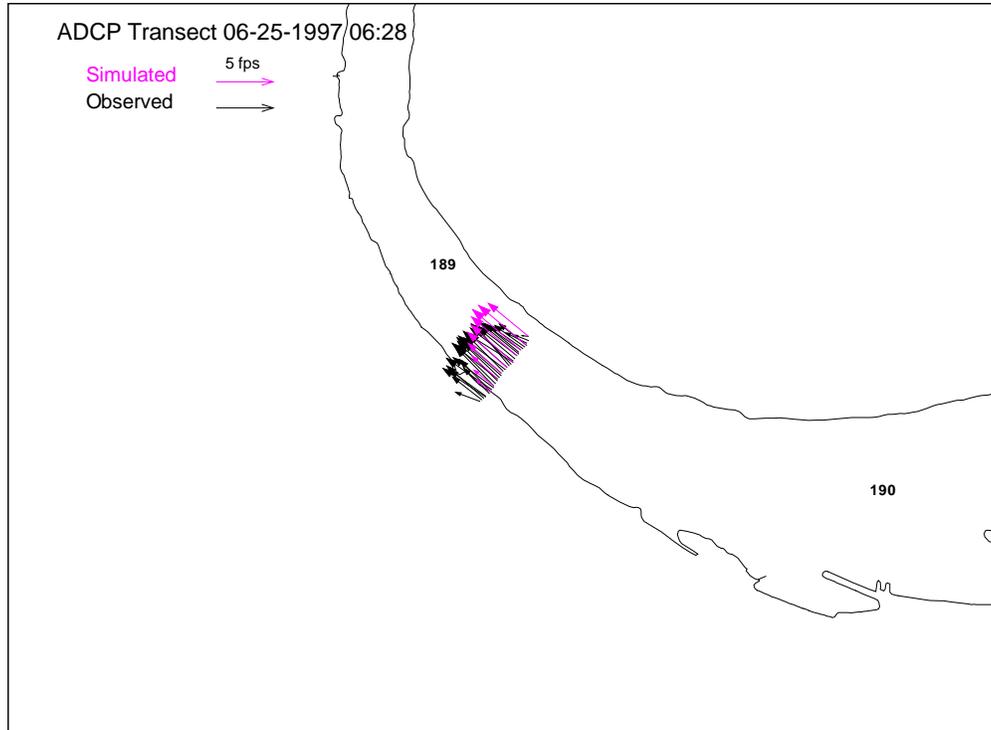


Figure 20. Simulated and observed depth-averaged velocities near Columbia River Mile 189 on 6-25-1997.

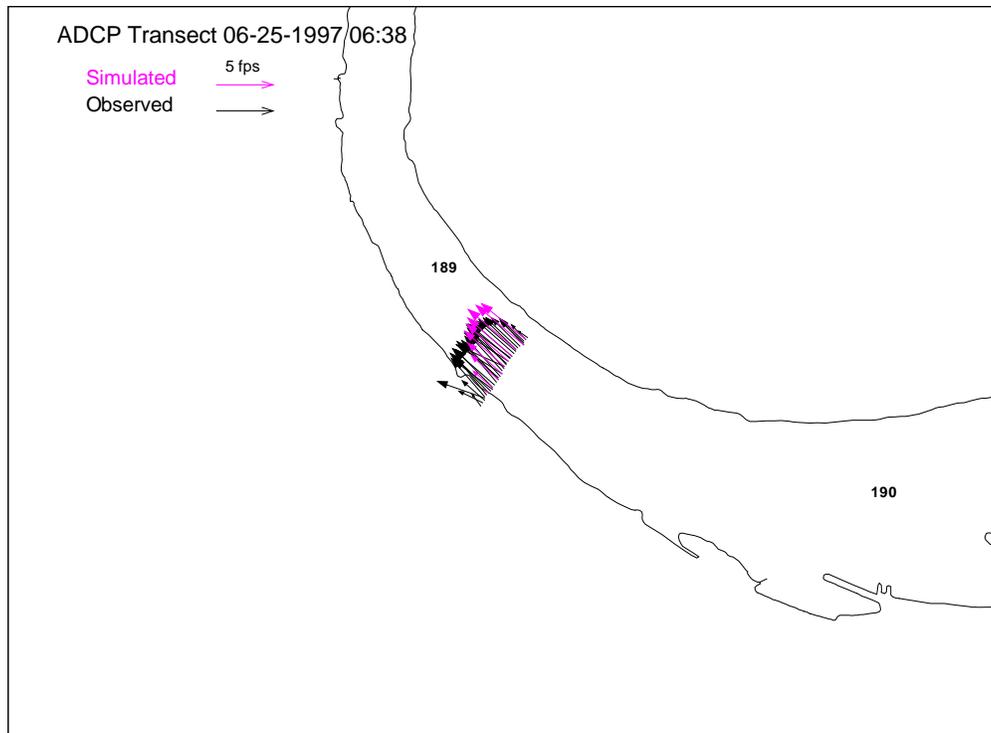


Figure 21. Simulated and observed depth-averaged velocities near Columbia River Mile 189 on 6-25-1997.

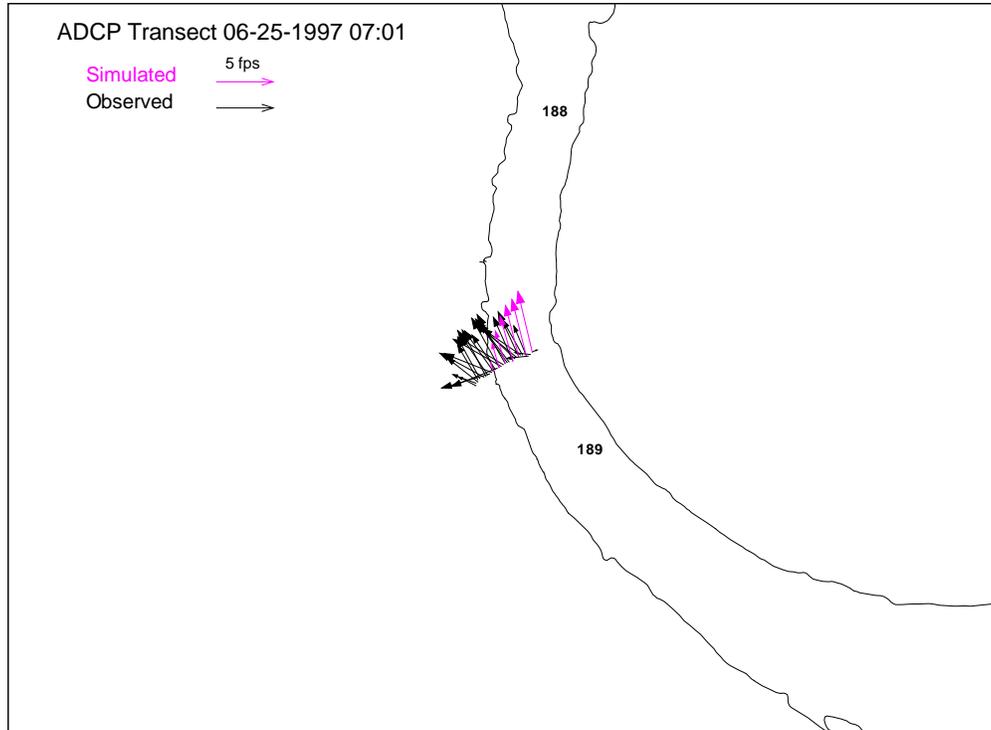


Figure 22. Simulated and observed depth-averaged velocities near Columbia River Mile 189.5 on 6-25-1997.

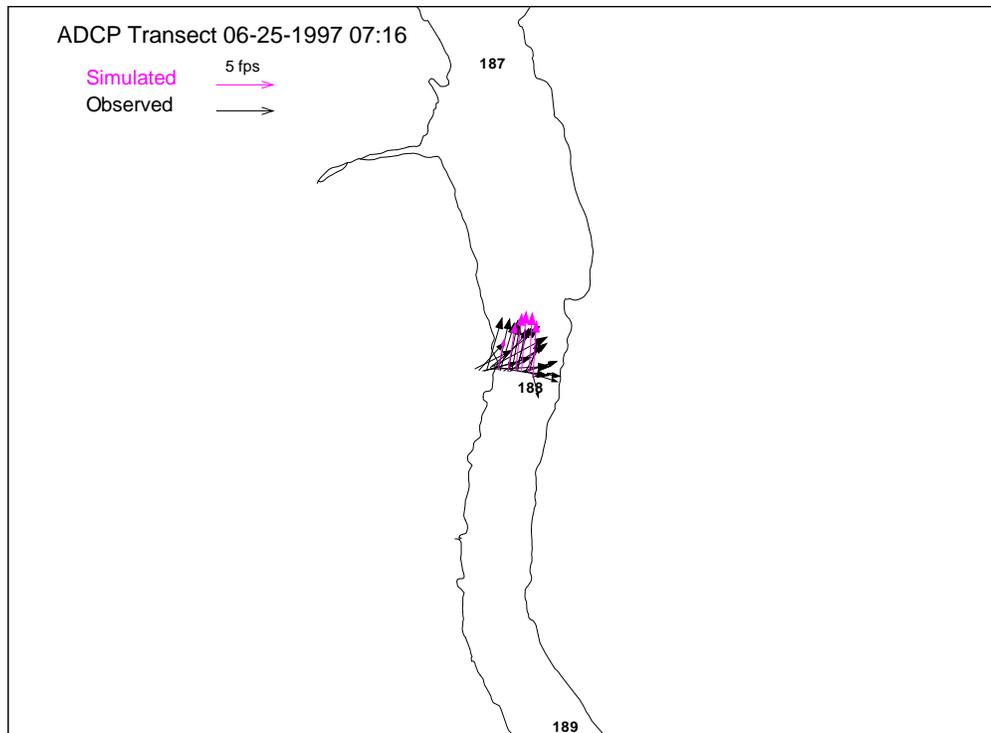


Figure 23. Simulated and observed depth-averaged velocities near Columbia River Mile 188 on 6-25-1997.

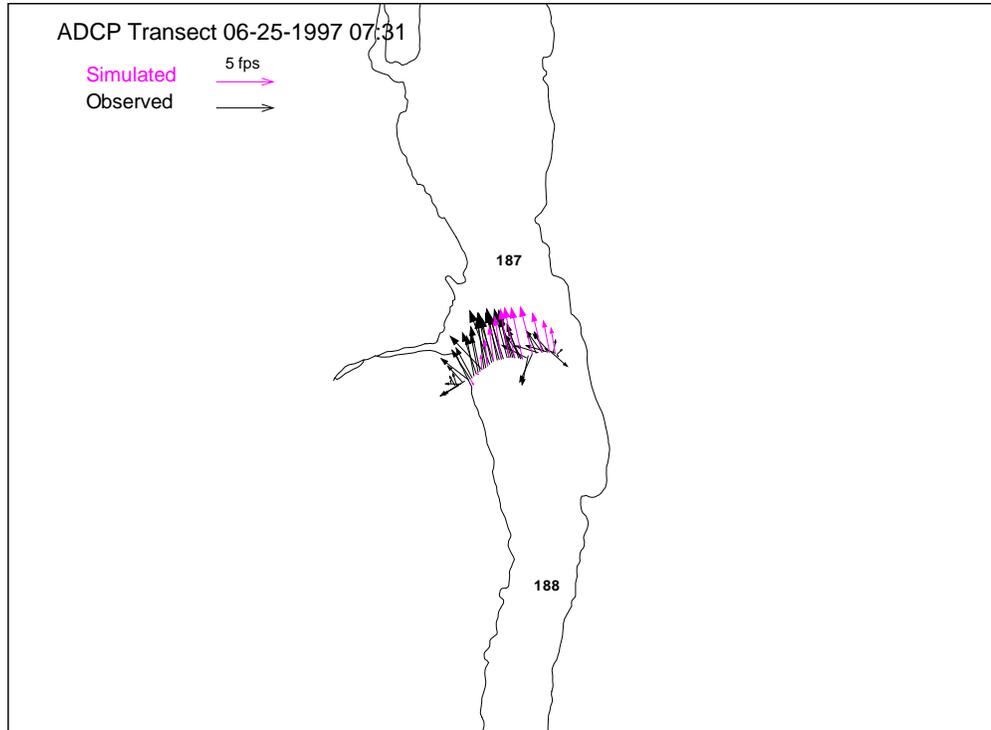


Figure 24. Simulated and observed depth-averaged velocities near Columbia River Mile 187 on 6-25-1997.

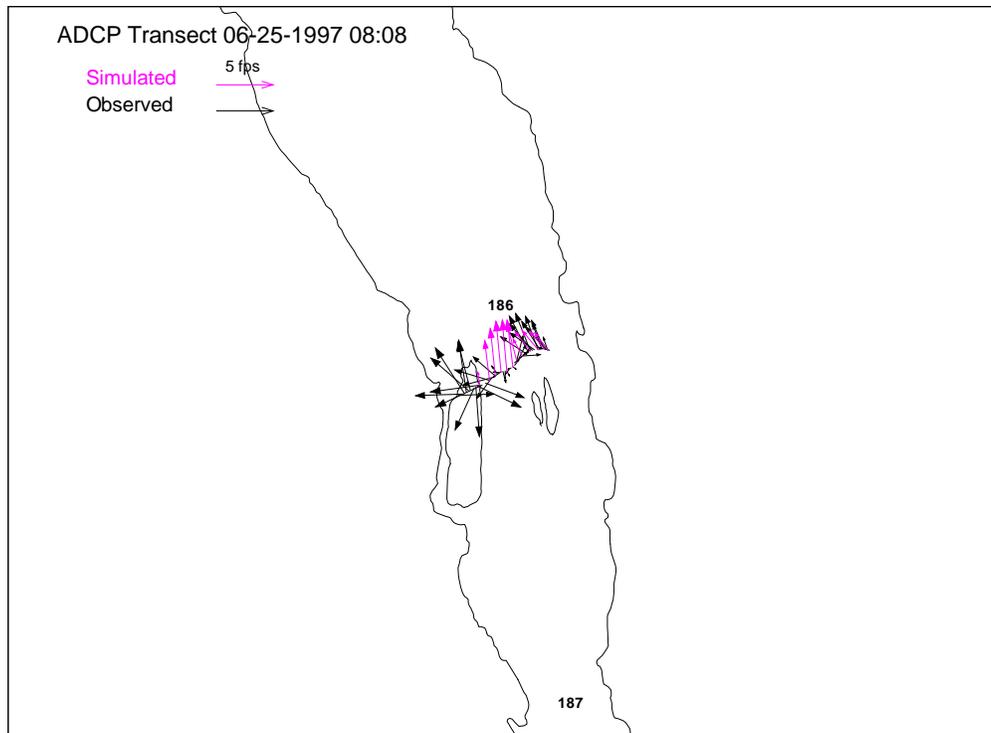


Figure 25. Simulated and observed depth-averaged velocities near Columbia River Mile 186 on 6-25-1997.

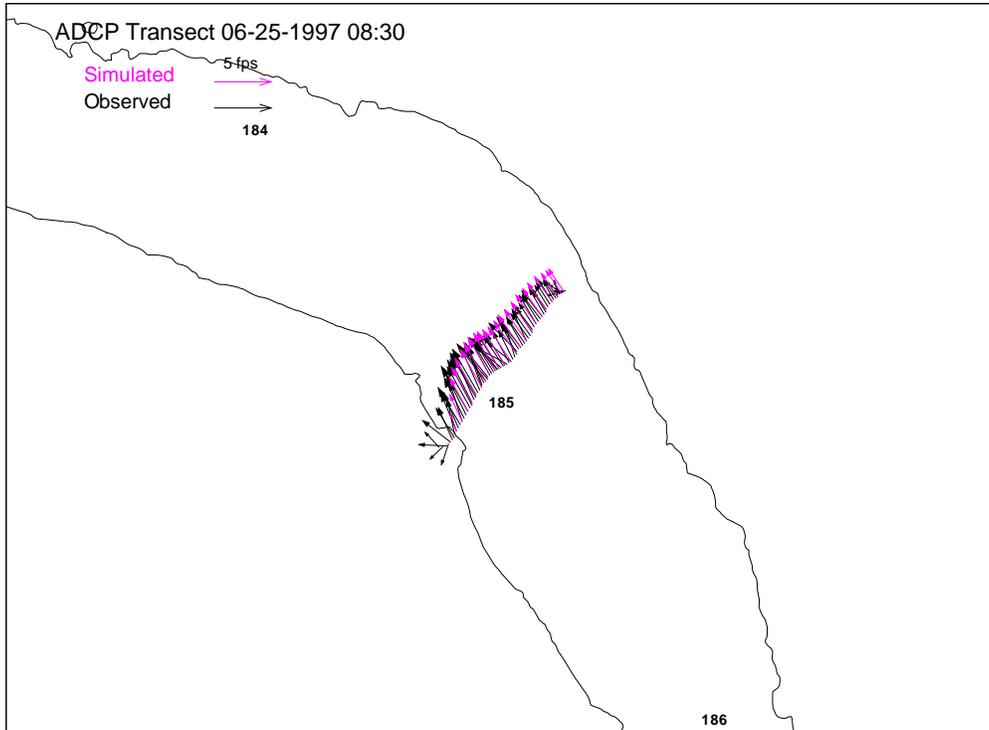


Figure 26. Simulated and observed depth-averaged velocities near Columbia River Mile 185 on 6-25-1997.

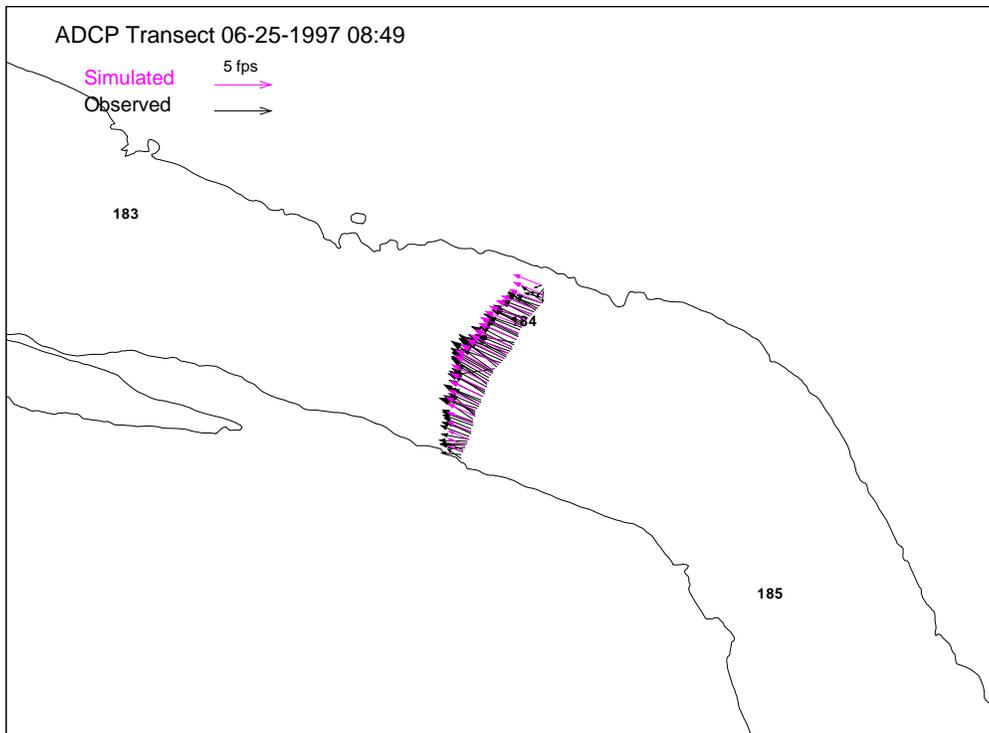


Figure 27. Simulated and observed depth-averaged velocities near Columbia River Mile 184 on 6-25-1997.

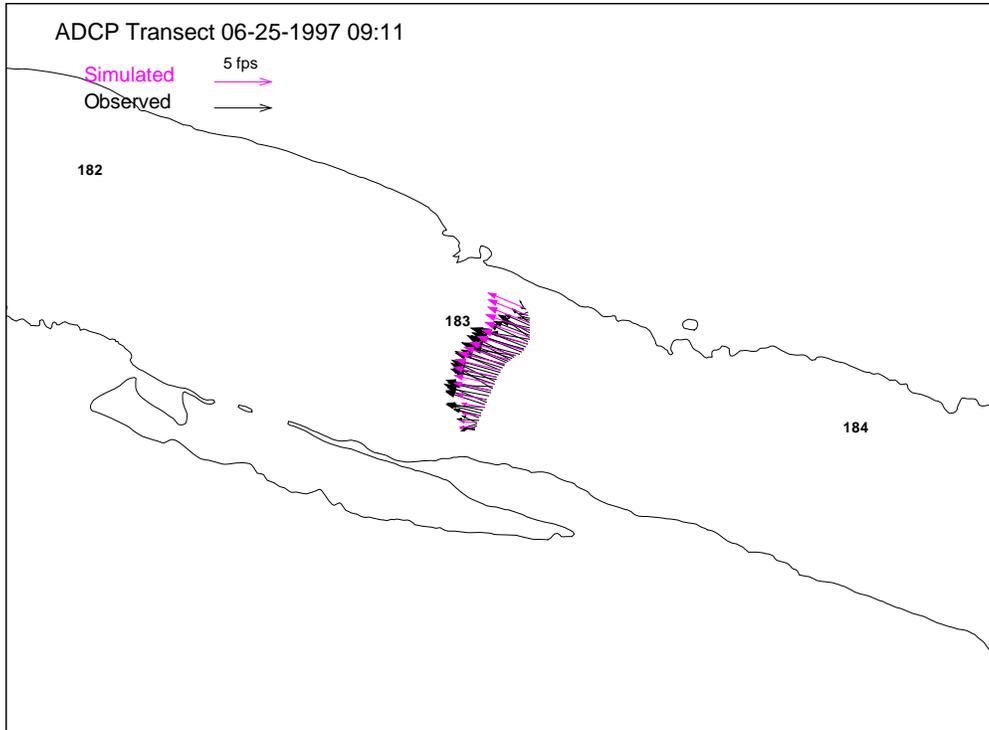


Figure 28. Simulated and observed depth-averaged velocities near Columbia River Mile 18 on 6-25-1997.

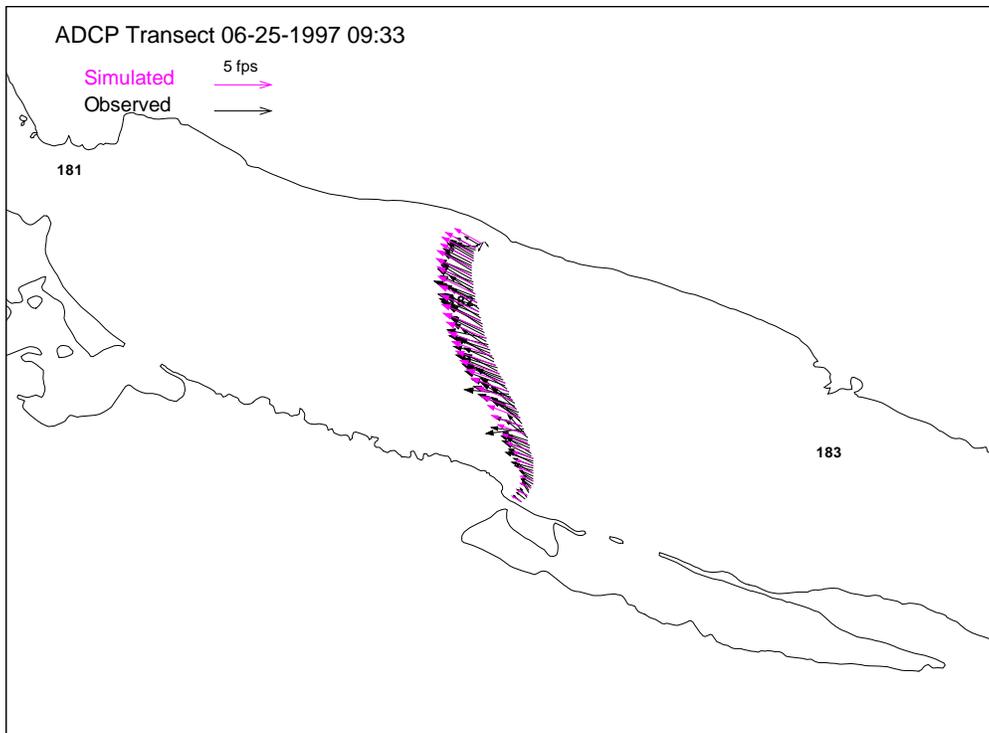


Figure 29. Simulated and observed depth-averaged velocities near Columbia River Mile 182 on 6-25-1997.

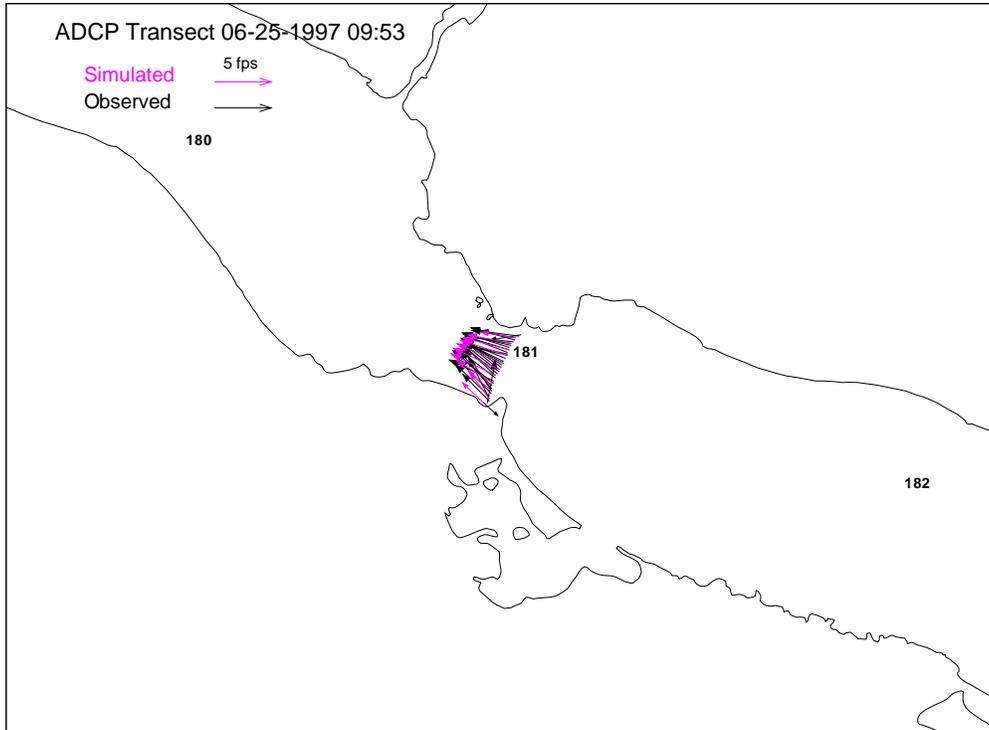


Figure 30. Simulated and observed depth-averaged velocities near Columbia River Mile 181 on 6-25-1997.

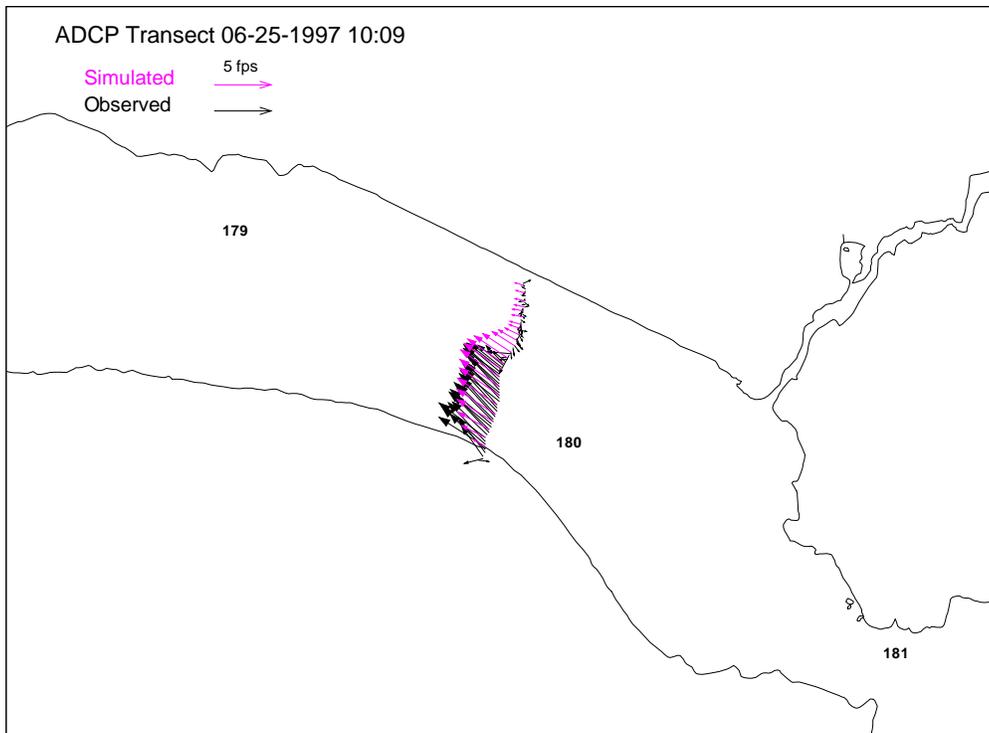


Figure 31. Simulated and observed depth-averaged velocities near Columbia River Mile 180 on 6-25-1997.

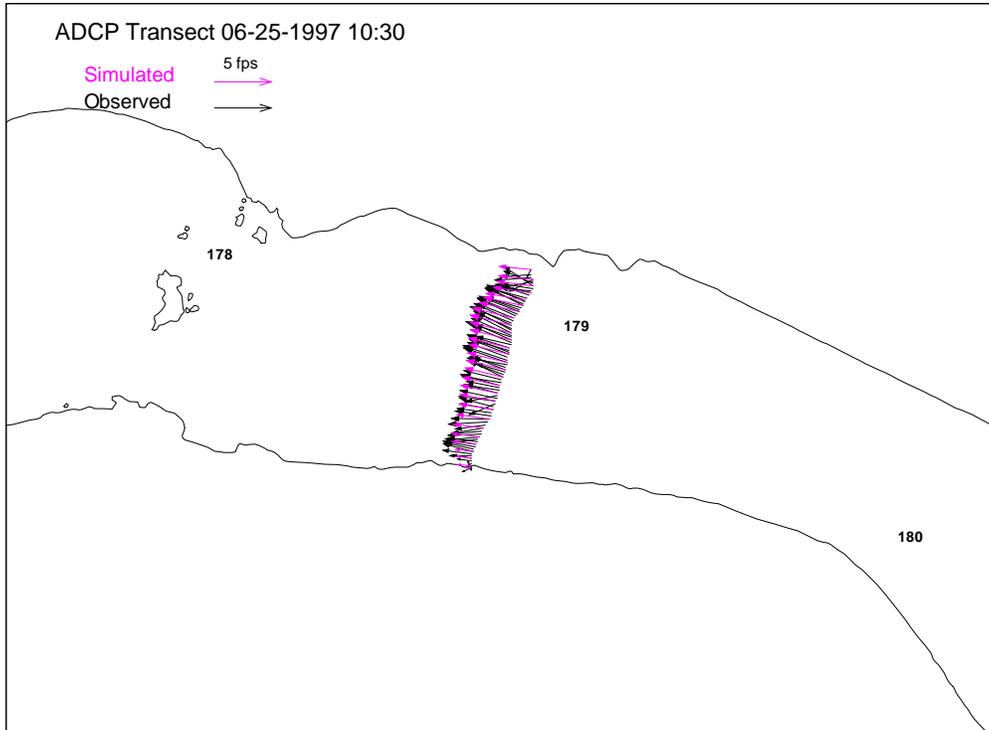


Figure 32. Simulated and observed depth-averaged velocities near Columbia River Mile 179 on 6-25-1997.

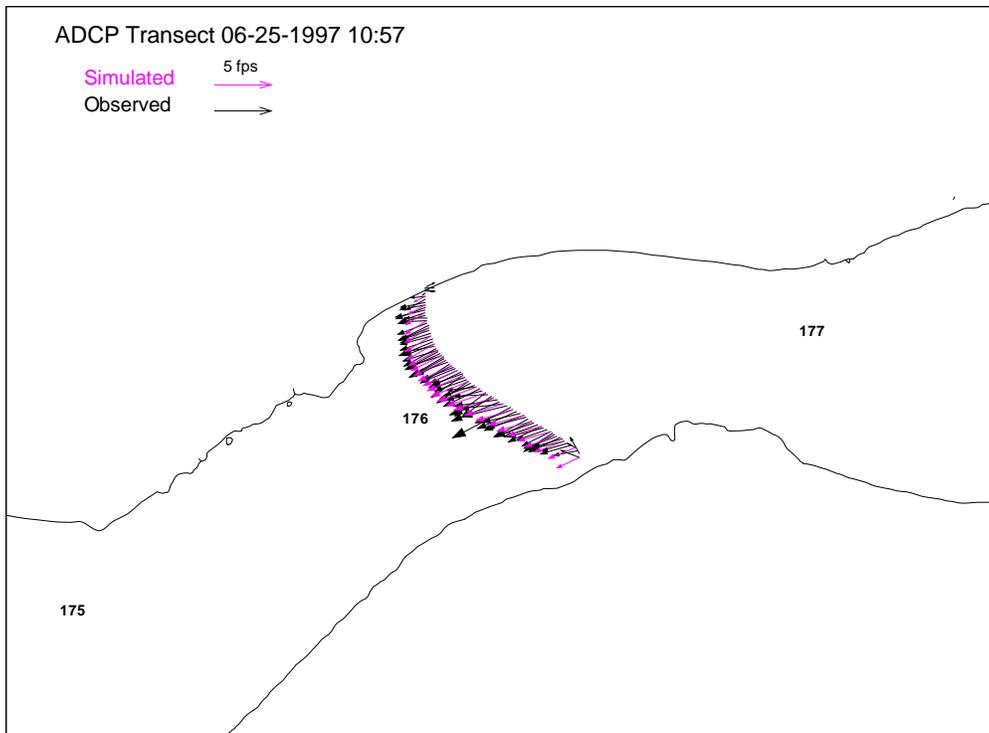


Figure 33. Simulated and observed depth-averaged velocities near Columbia River Mile 176 on 6-25-1997.

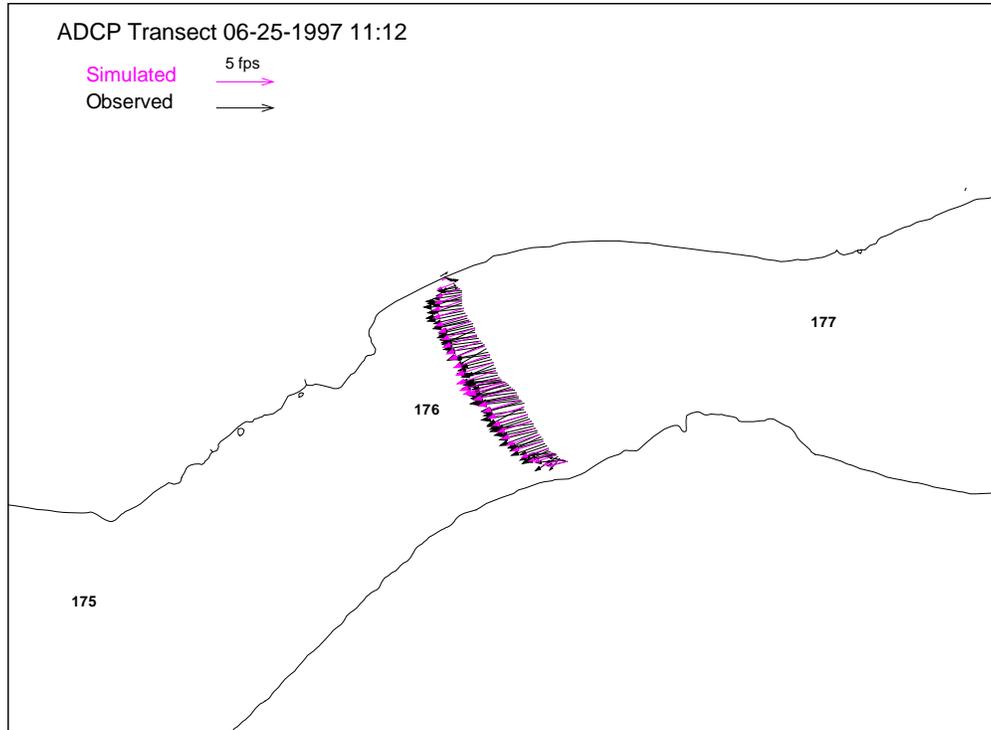


Figure 34. Simulated and observed depth-averaged velocities near Columbia River Mile 176 on 6-25-1997.

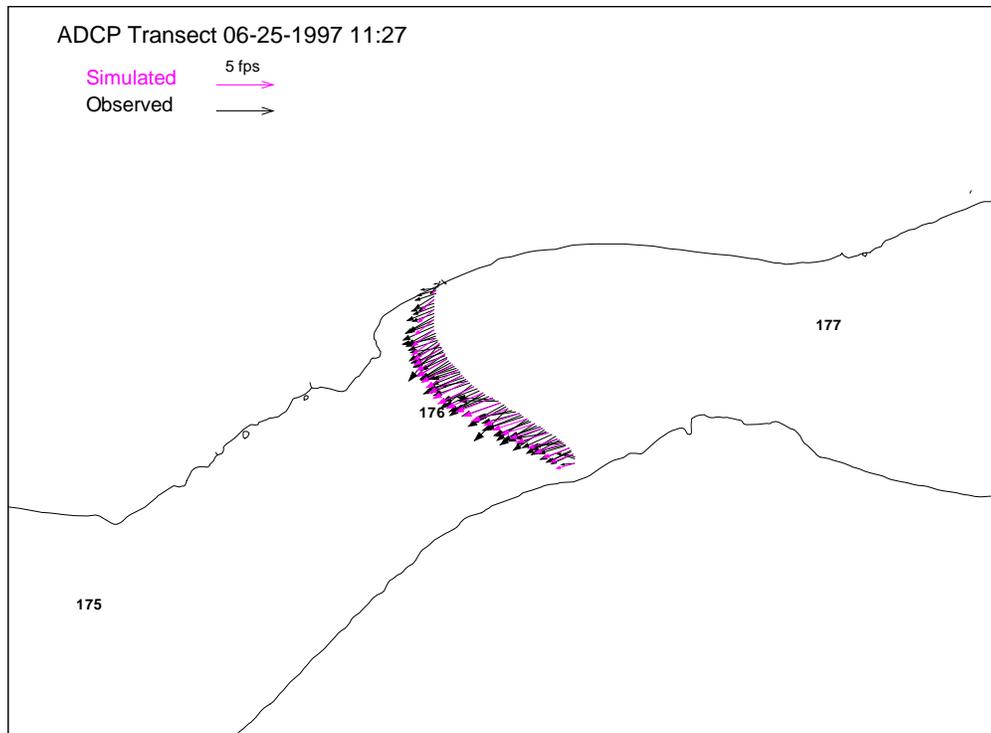


Figure 35. Simulated and observed depth-averaged velocities near Columbia River Mile 176 on 6-25-1997.

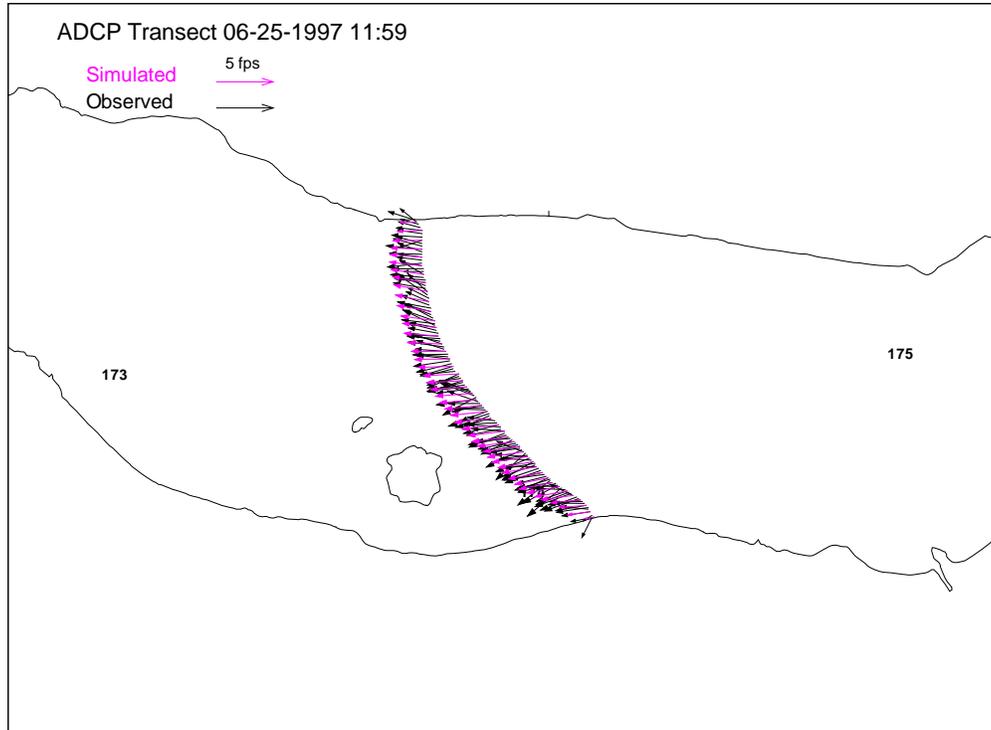


Figure 36. Simulated and observed depth-averaged velocities near Columbia River Mile 174 on 6-25-1997.

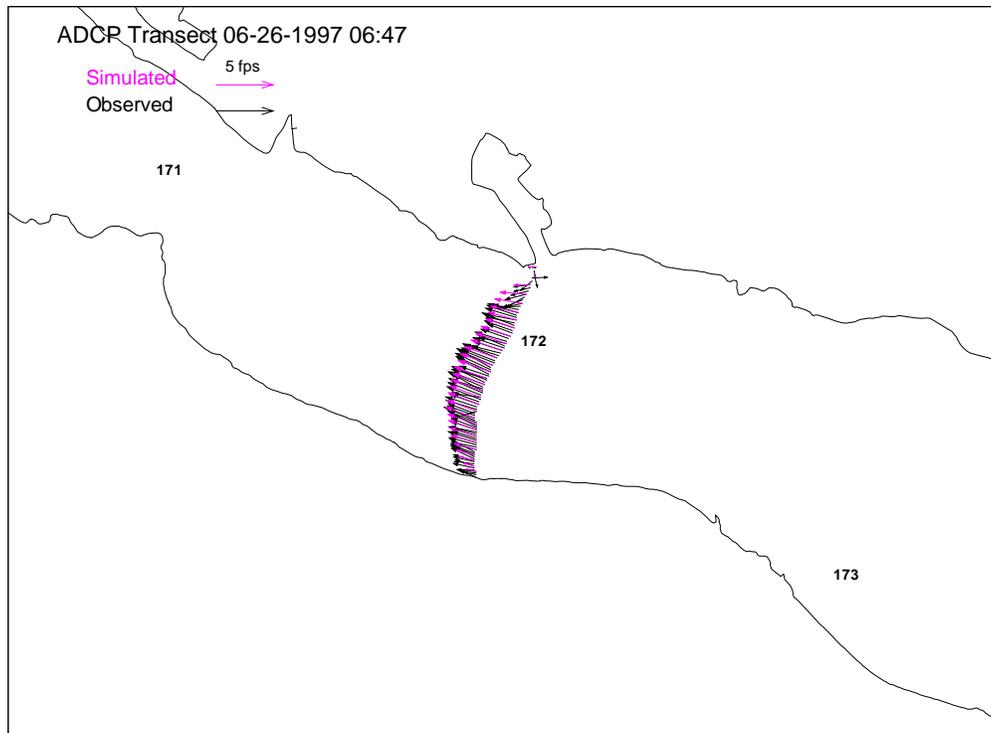


Figure 37. Simulated and observed depth-averaged velocities near Columbia River Mile 172 on 6-26-1997.

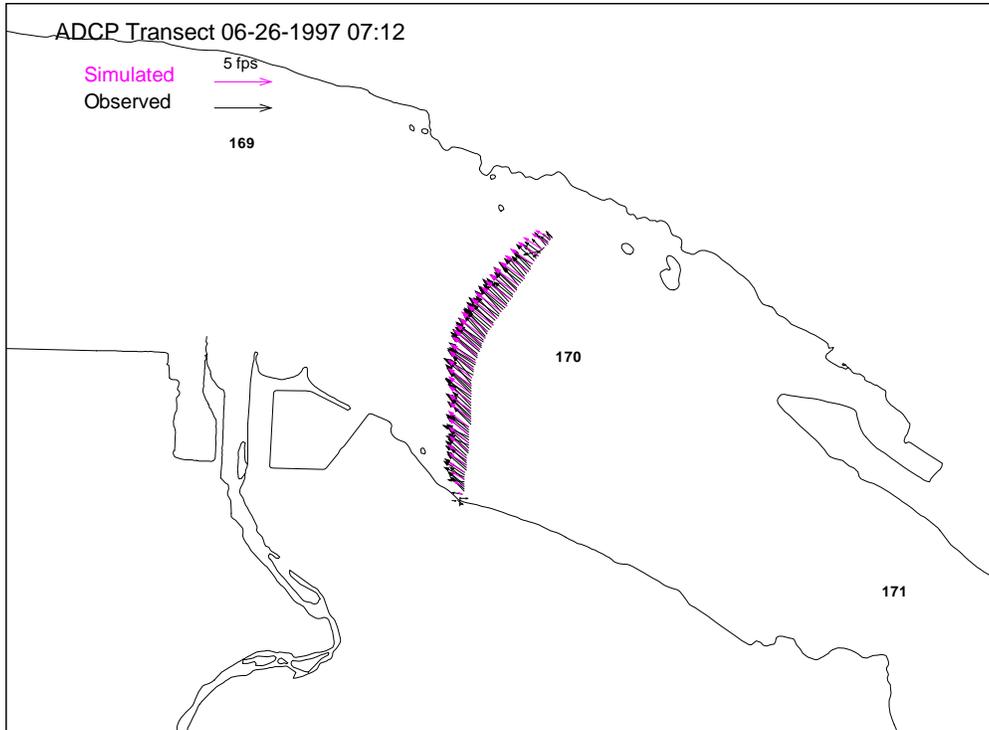


Figure 38. Simulated and observed depth-averaged velocities near Columbia River Mile 170 on 6-26-1997.

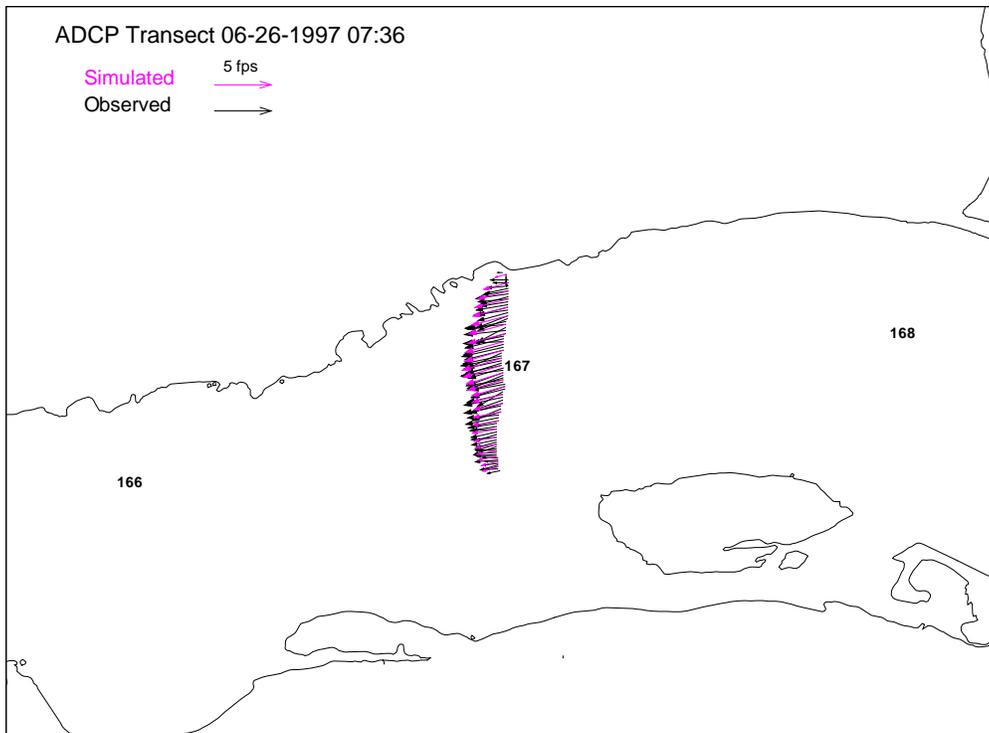


Figure 39. Simulated and observed depth-averaged velocities near Columbia River Mile 167 on 6-26-1997.

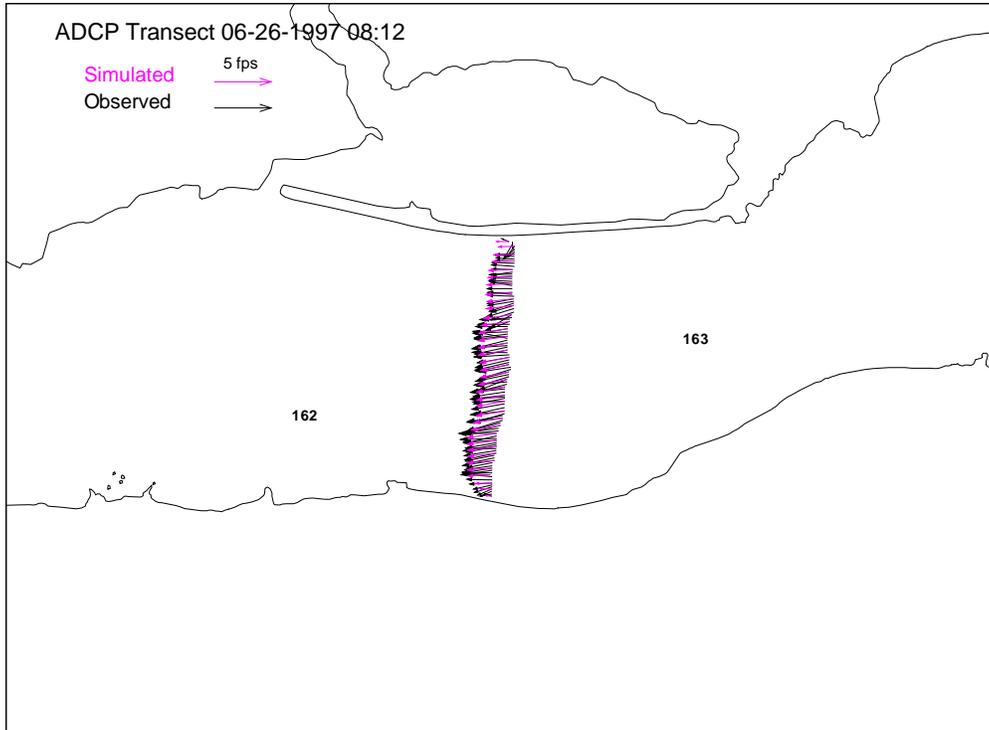


Figure 40. Simulated and observed depth-averaged velocities near Columbia River Mile 162.5 on 6-26-1997.

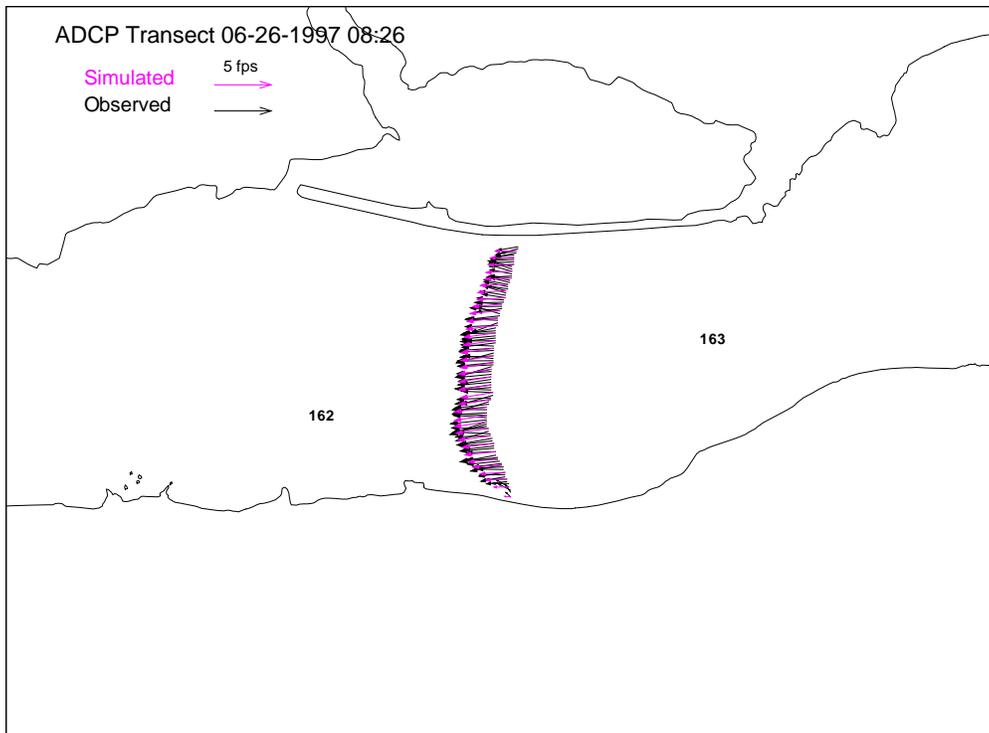


Figure 41. Simulated and observed depth-averaged velocities near Columbia River Mile 162.5 on 6-26-1997.

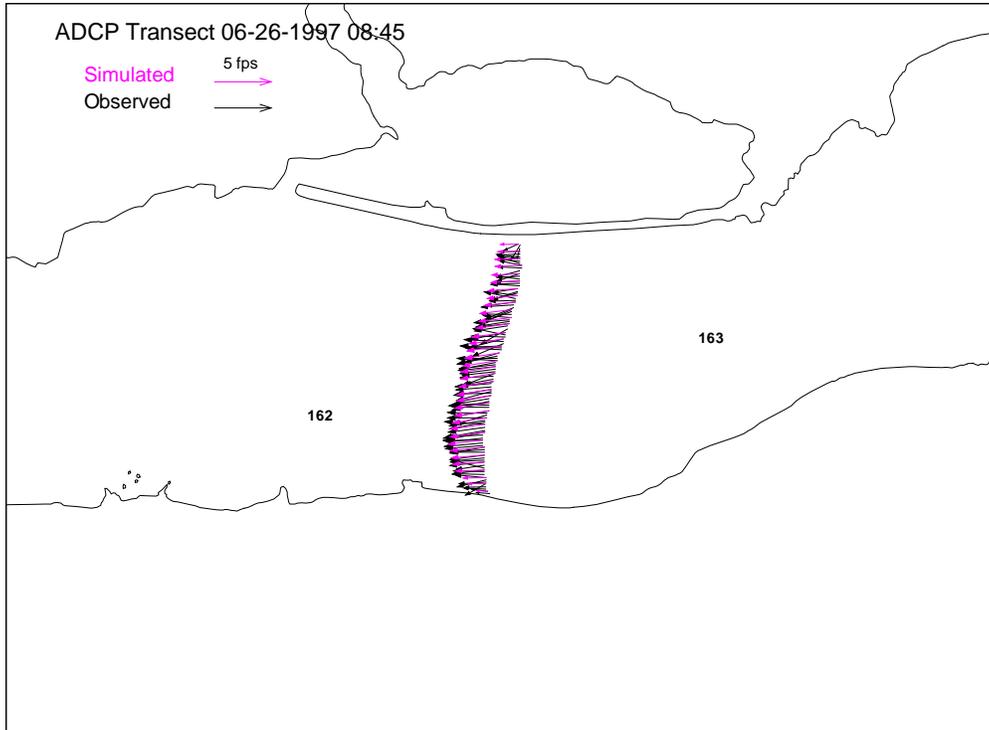


Figure 42. Simulated and observed depth-averaged velocities near Columbia River Mile 162.5 on 6-26-1997.

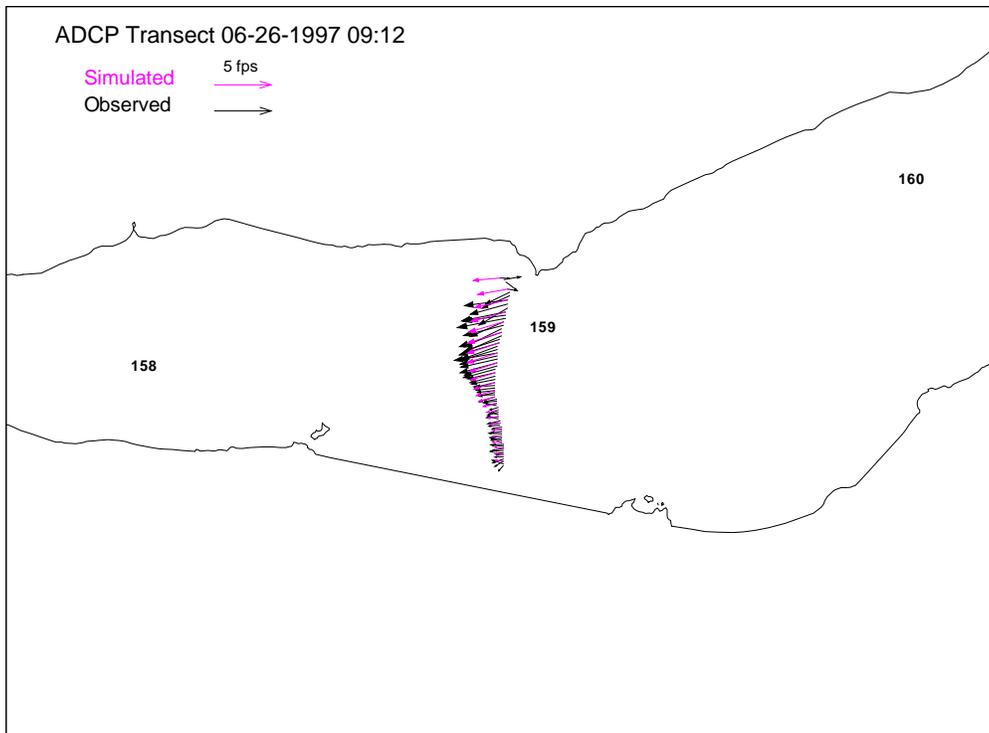


Figure 43. Simulated and observed depth-averaged velocities near Columbia River Mile 159 on 6-26-1997.

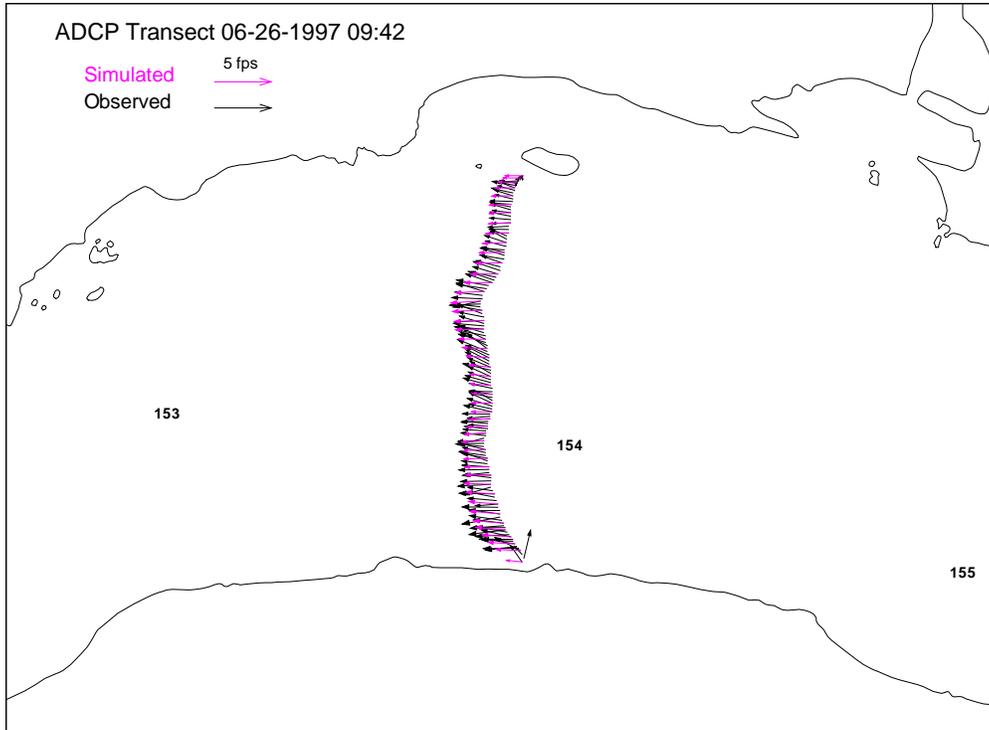


Figure 44. Simulated and observed depth-averaged velocities near Columbia River Mile 154 on 6-26-1997.

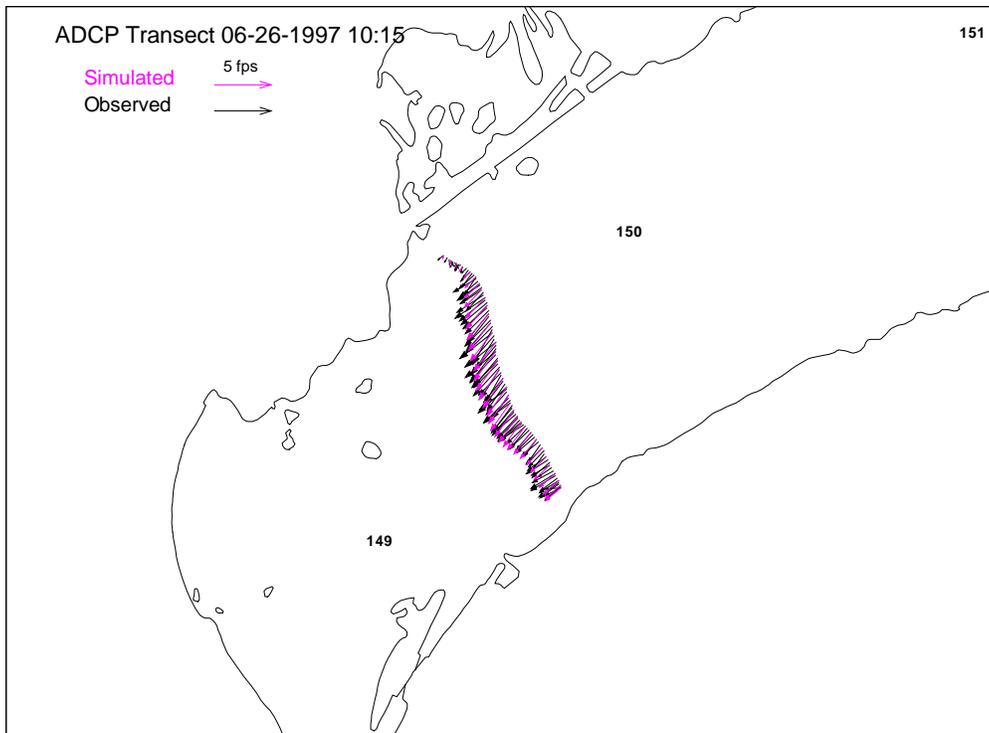


Figure 45. Simulated and observed depth-averaged velocities near Columbia River Mile 149.5 on 6-26-1997.

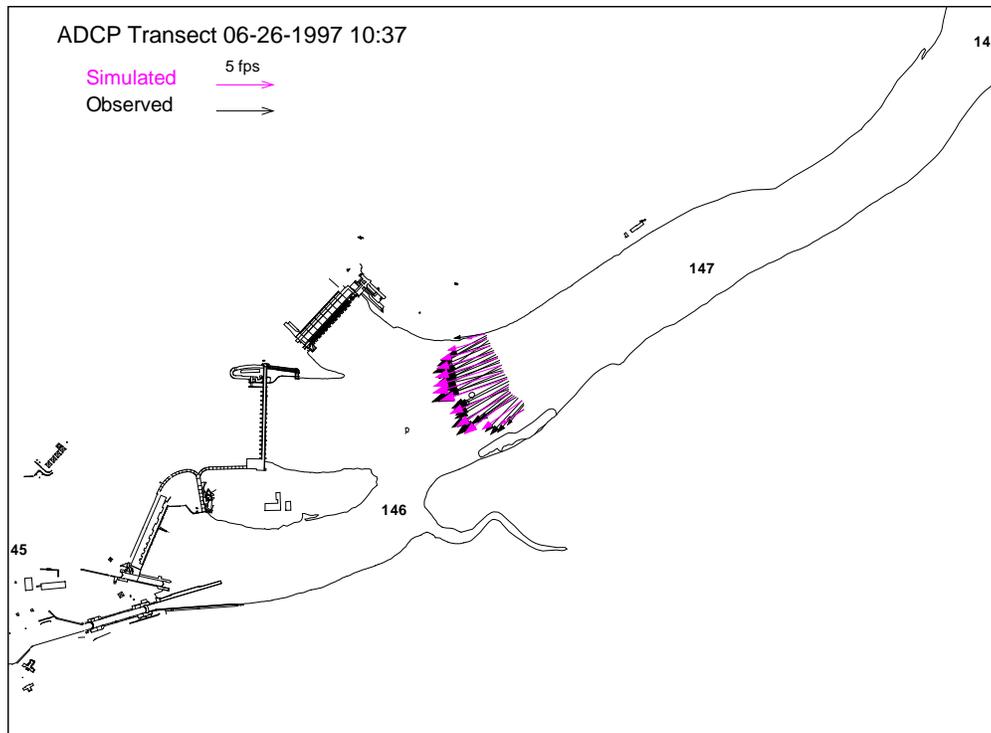


Figure 46. Simulated and observed depth-averaged velocities near Columbia River Mile 146.5 on 6-26-1997.

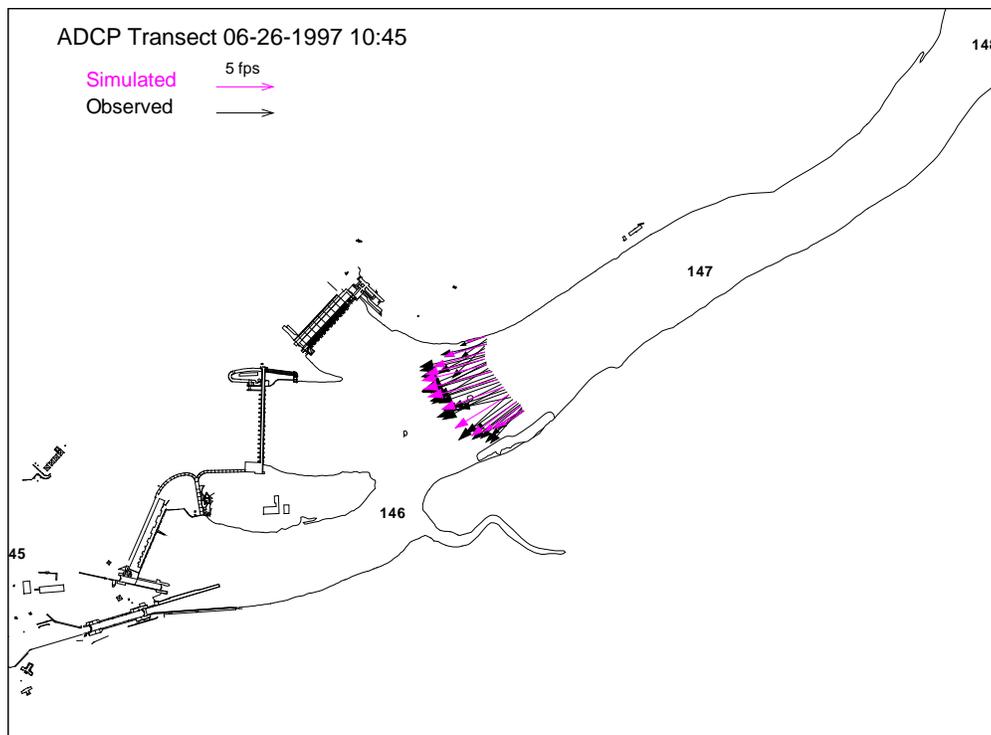


Figure 47. Simulated and observed depth-averaged velocities near Columbia River Mile 146.5 on 6-26-1997.

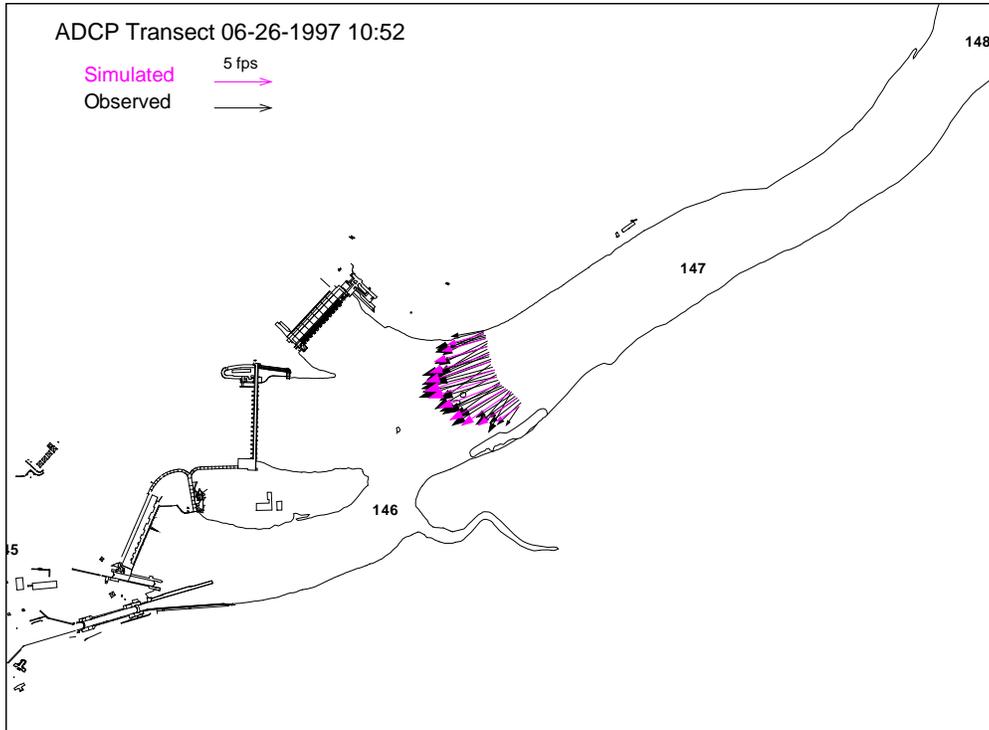


Figure 48. Simulated and observed depth-averaged velocities near Columbia River Mile 146.5 on 6-26-1997.

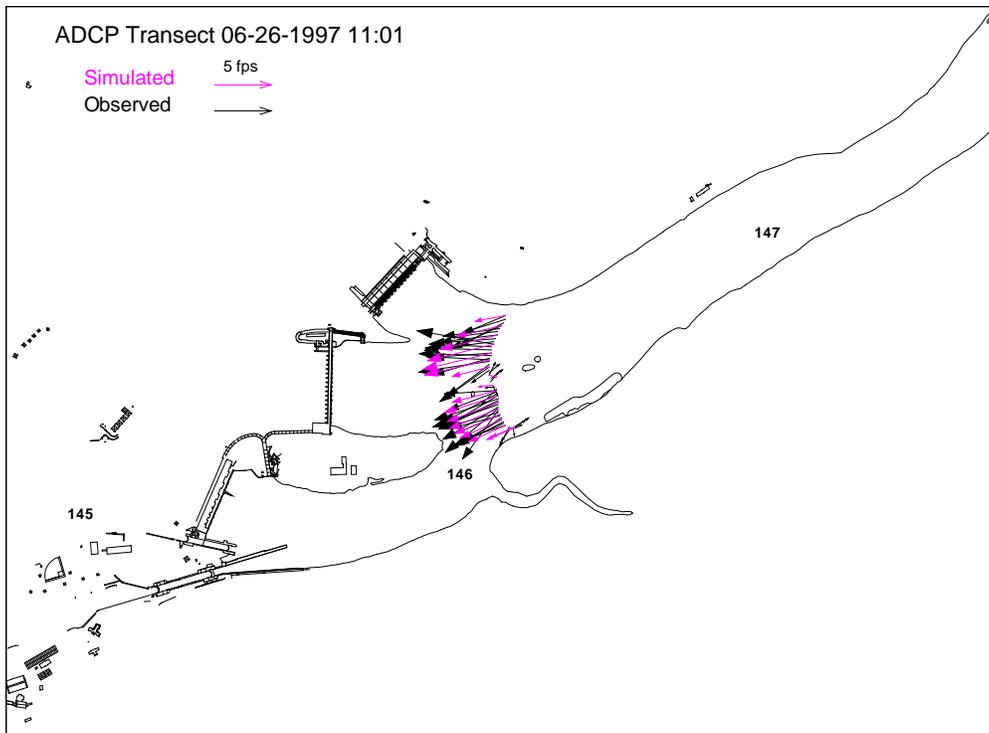


Figure 49. Simulated and observed depth-averaged velocities near Columbia River Mile 146 on 6-26-1997.

1.3.4 Simulated Spatial Velocity Distribution during the Spring 1996 study period.

Figure 50 through Figure 58 show the spatial variation of velocity, relative to bathymetry, simulated for the Spring 1996 study period.

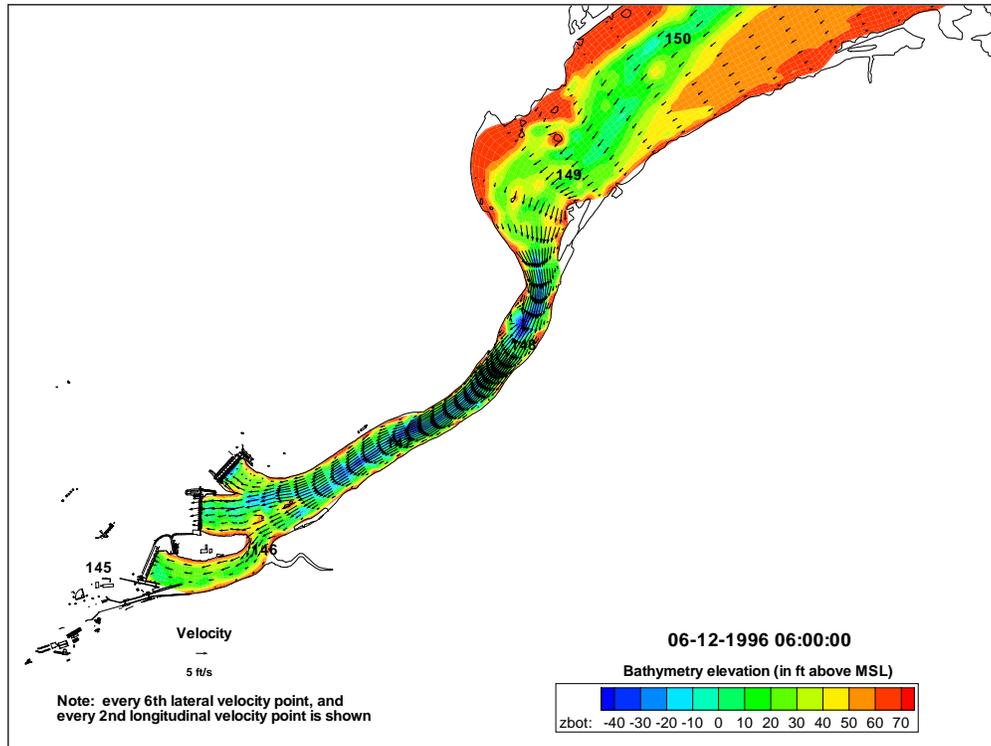


Figure 50. Spatial velocity distribution during the Spring 1996 study period.

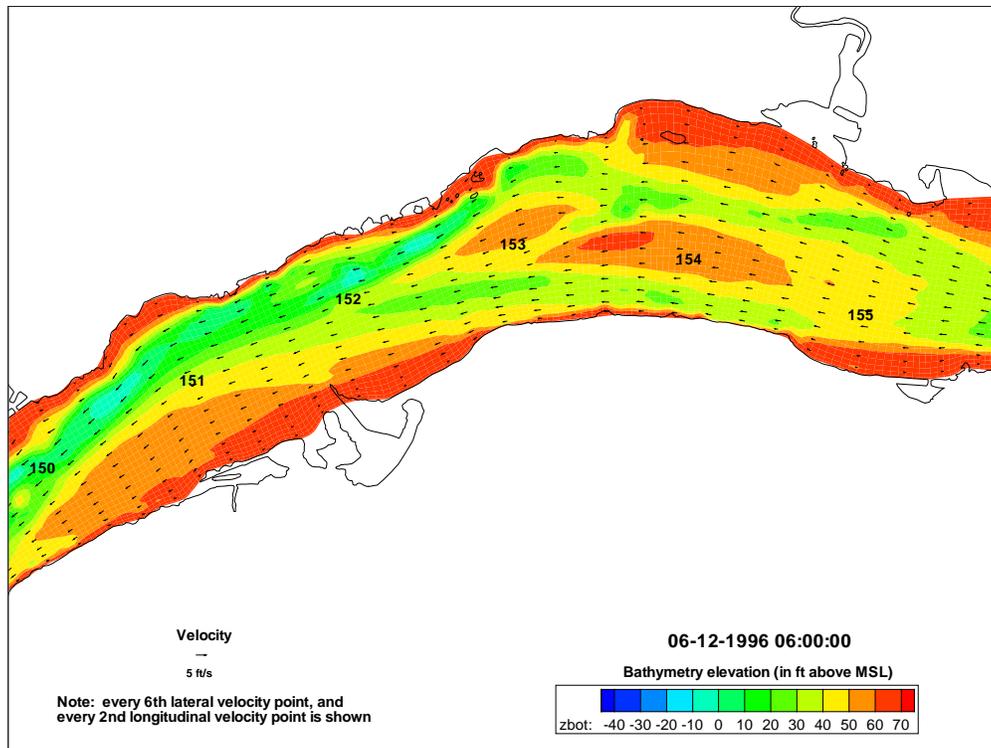


Figure 51. Spatial velocity distribution during the Spring 1996 study period.

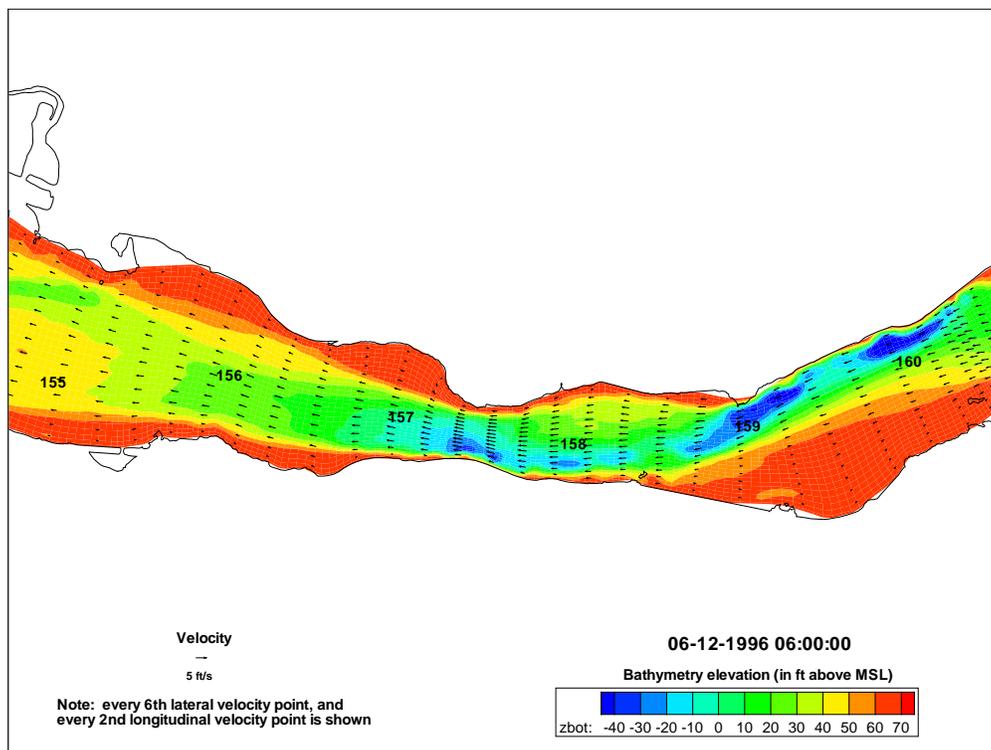


Figure 52. Spatial velocity distribution during the Spring 1996 study period.

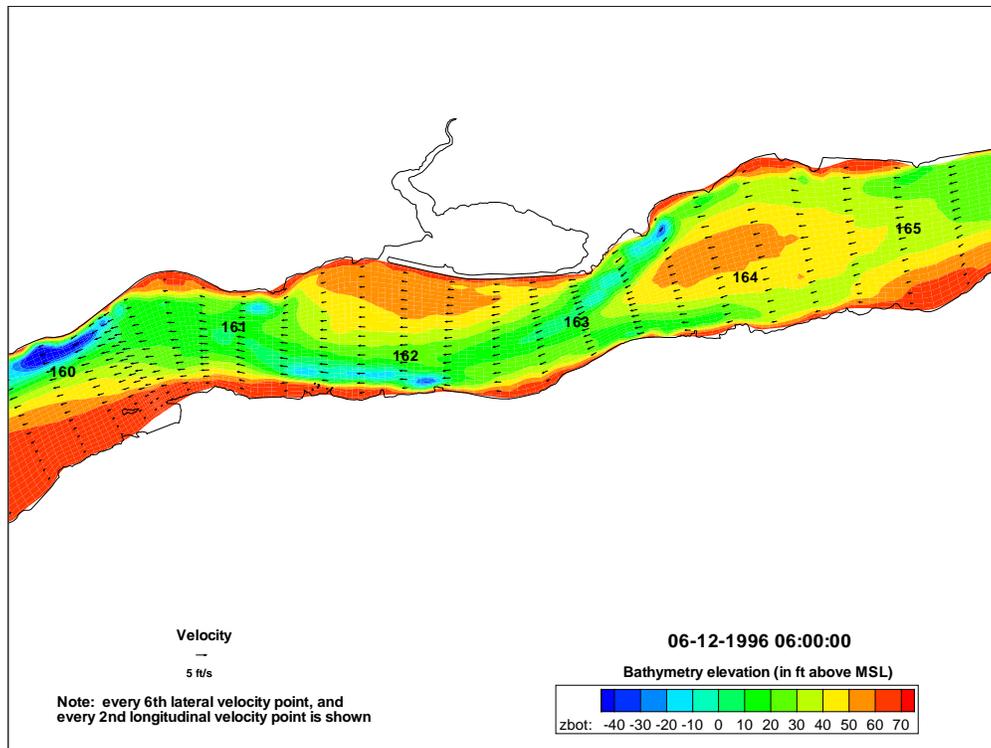


Figure 53. Spatial velocity distribution during the Spring 1996 study period.

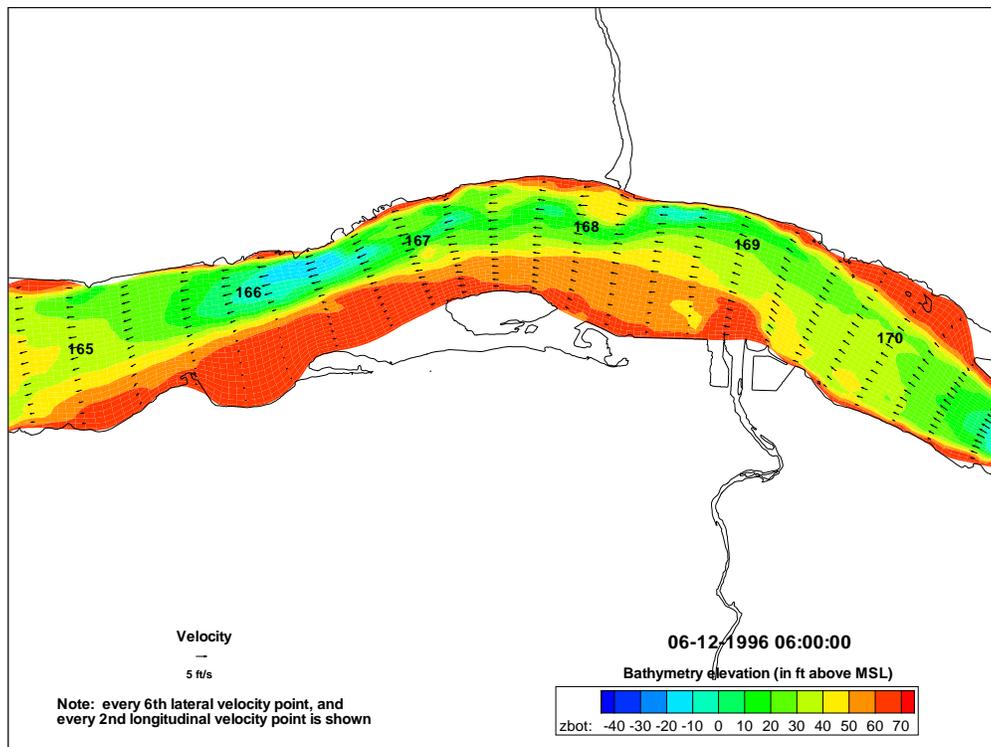


Figure 54. Spatial velocity distribution during the Spring 1996 study period.

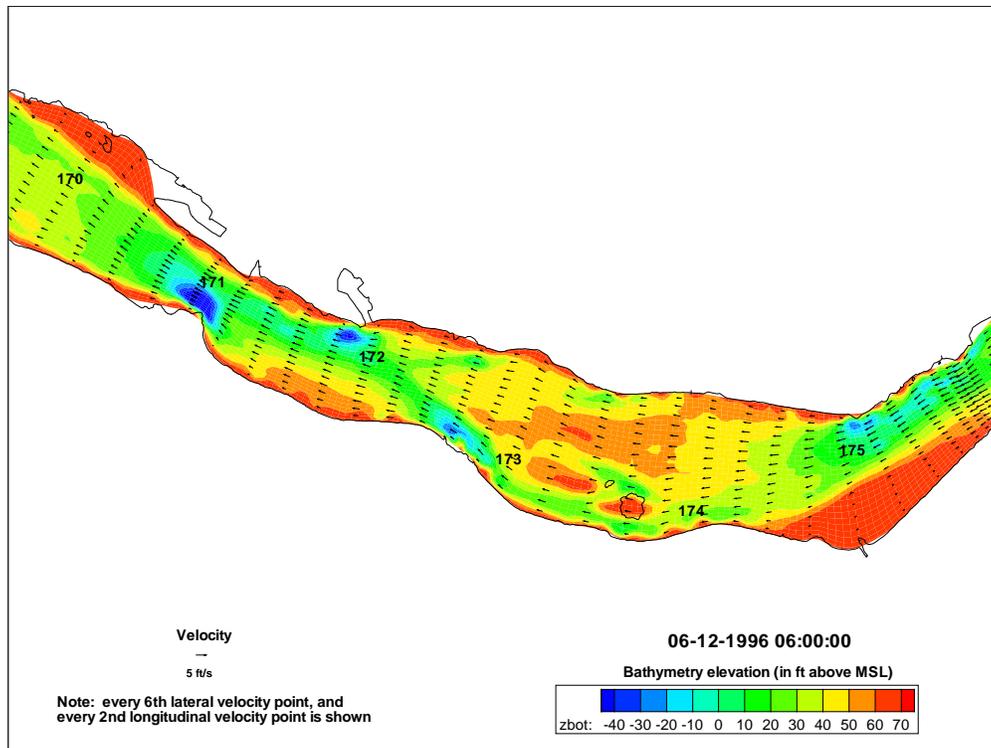


Figure 55. Spatial velocity distribution during the Spring 1996 study period.

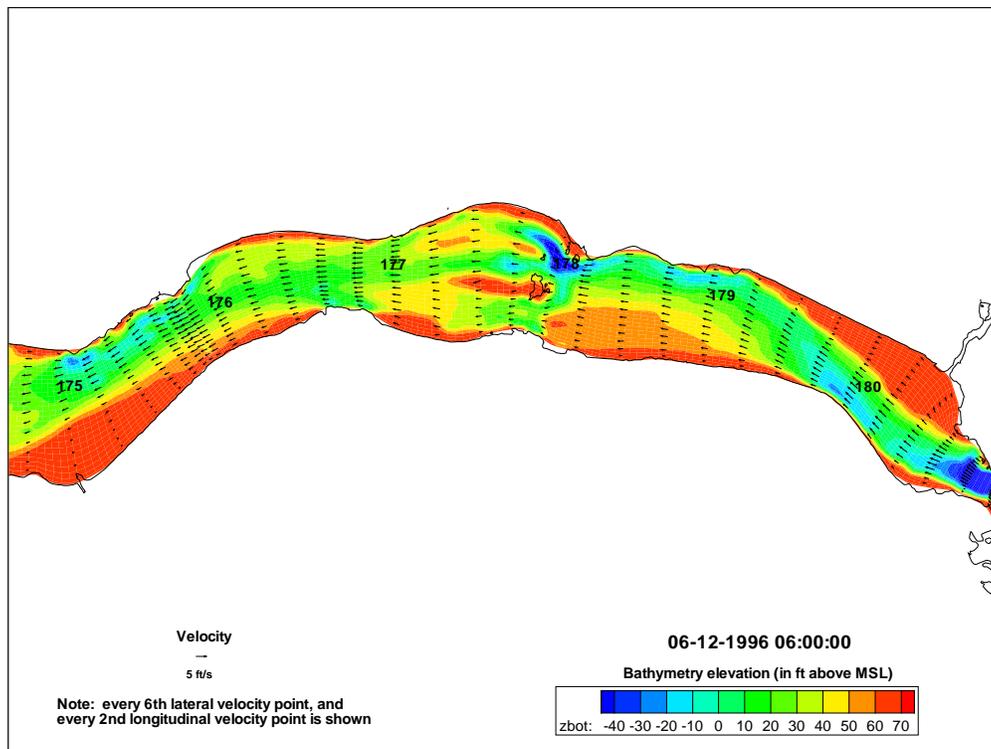


Figure 56. Spatial velocity distribution during the Spring 1996 study period.

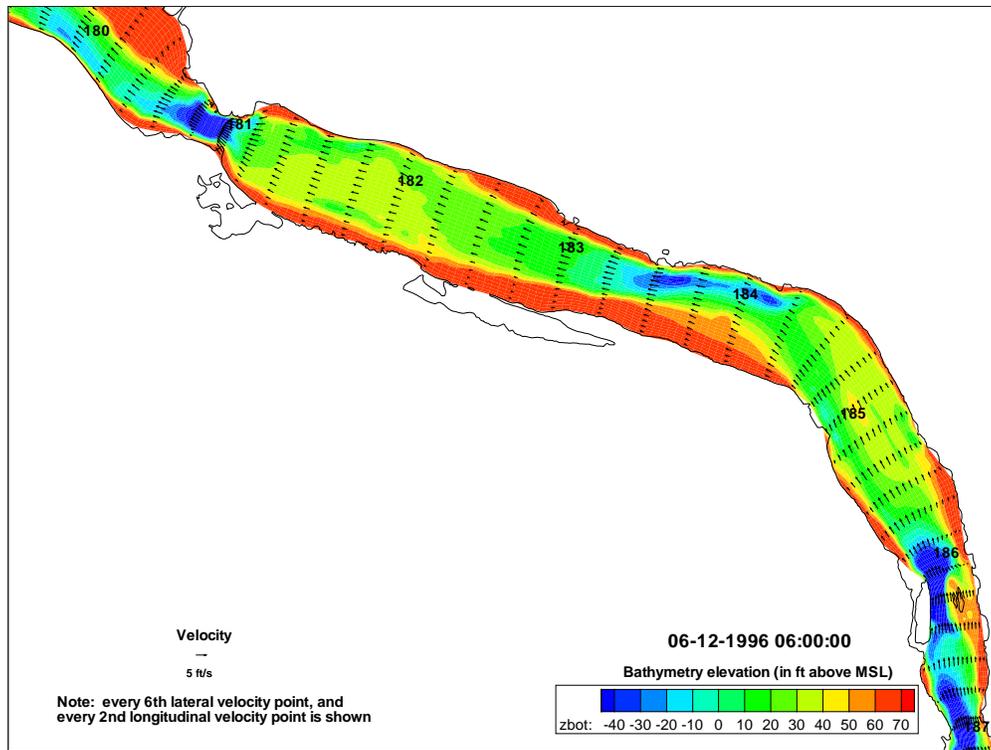


Figure 57. Spatial velocity distribution during the Spring 1996 study period.

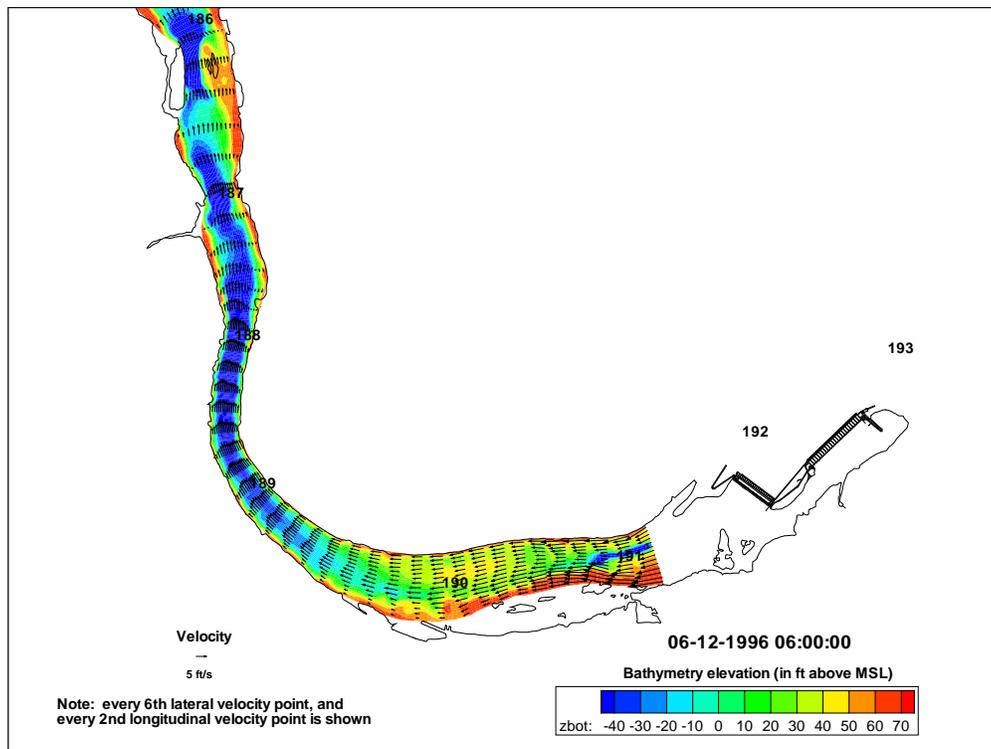


Figure 58. Spatial velocity distribution during the Spring 1996 study period.

1.4 Water Quality Calibration and Verification

1.4.1 *Spring 1996 Simulation*

Boundary Conditions using The Dalles 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.

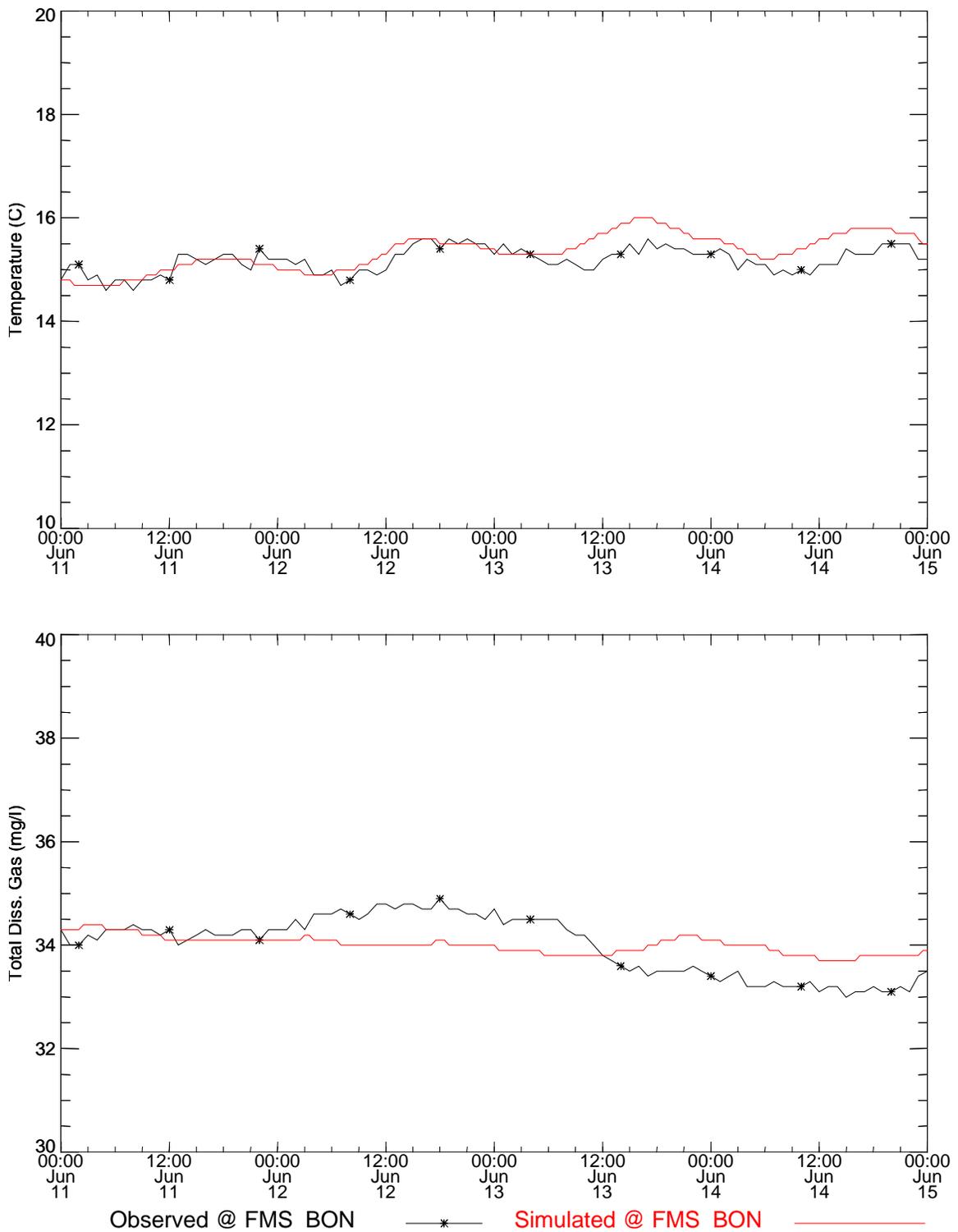


Figure 59. Temperature and total dissolved gas time series comparisons near fixed monitor BON for the Spring 1996 study period. (FMS-BC).

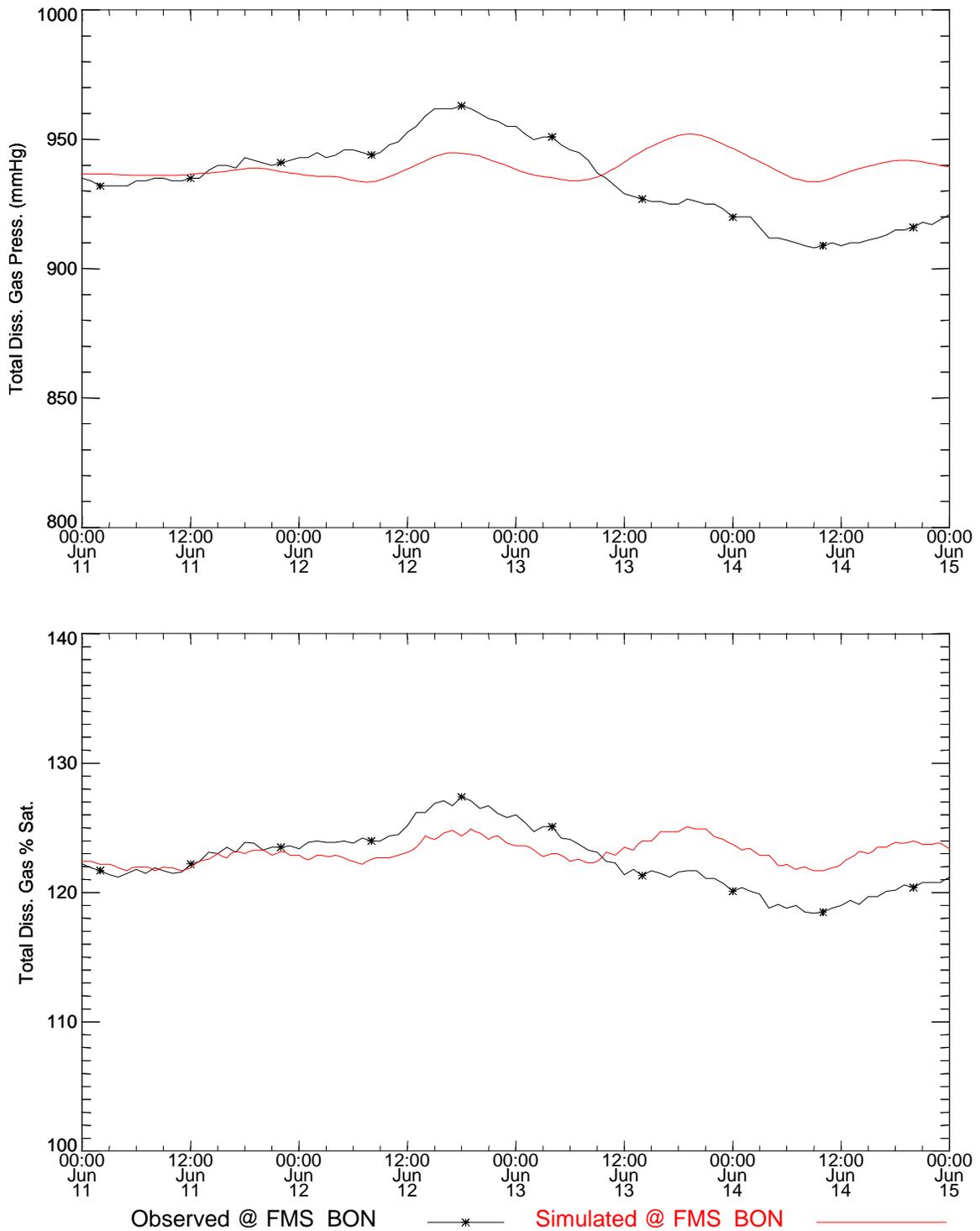


Figure 60. Total dissolved gas pressure and saturation time series comparisons near fixed monitor BON for Spring 1996 study period (FMS-BC).

Table 1. Statistical summary of measurements and simulations fixed monitor BON for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_BON	15.18	15.34	0.24	0.34	0.29
Concentration FMS_BON	34	34	0.57	0.17	0.52
Gas Pressure FMS_BON	934.33	939.36	15.49	4.65	17.36
% Saturation FMS_BON	122.51	123.12	2.32	0.89	2.27

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

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

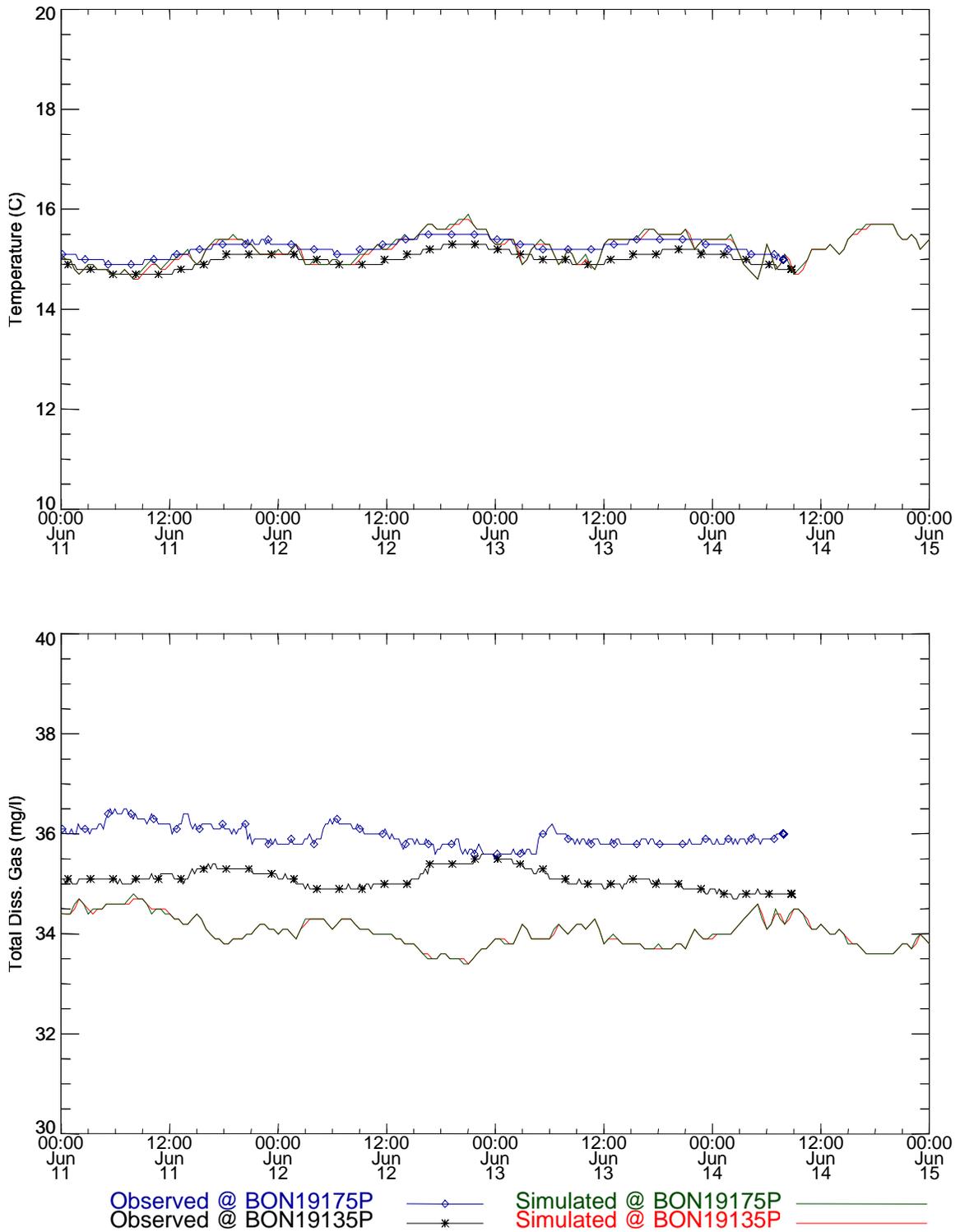


Figure 61. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 191.3 for the Spring 1996 study period (FMS-BC).

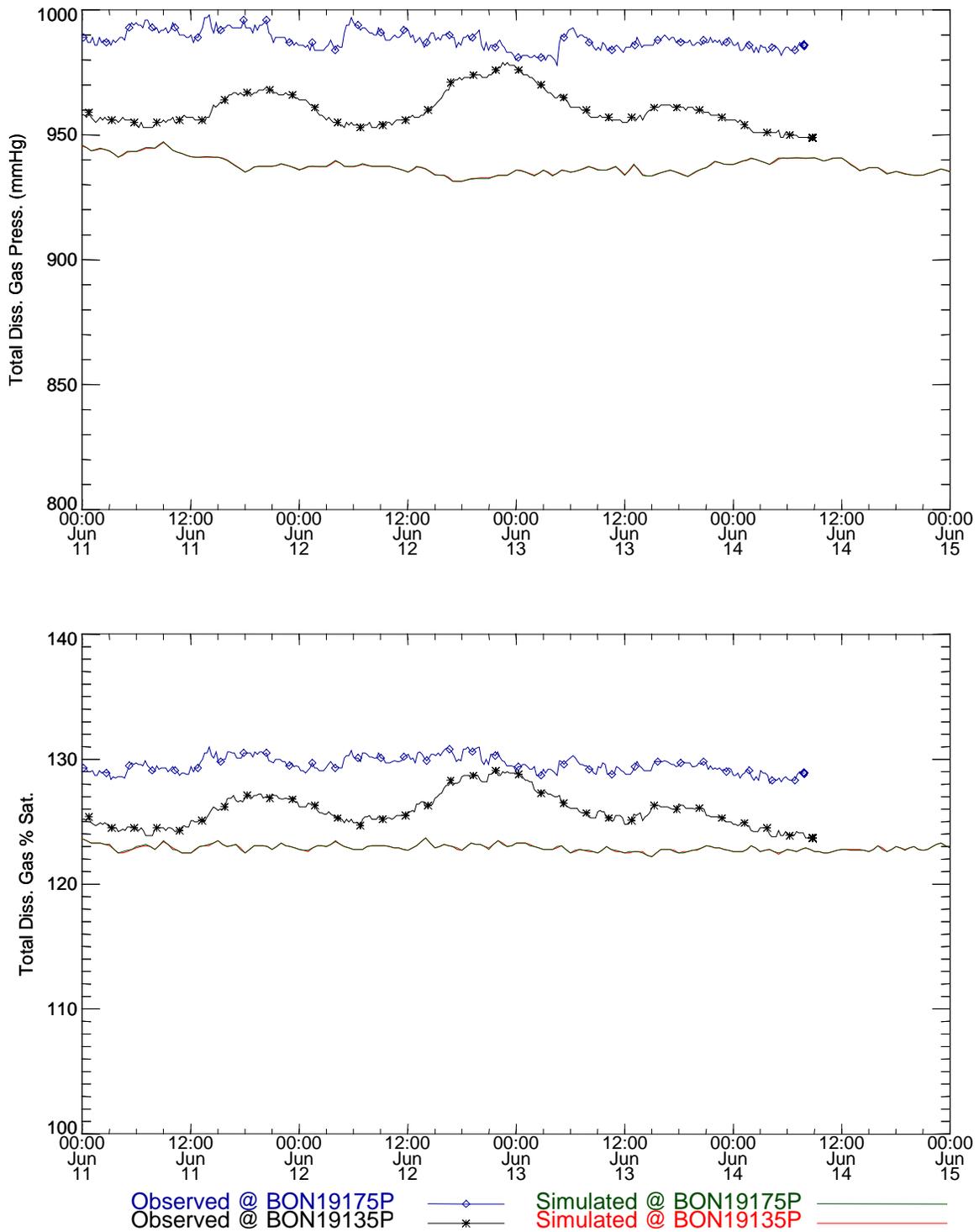


Figure 62. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 191.3 for the Spring 1996 study period (FMS-BC).

Table 3. Statistical summary of measurements and simulations near the Columbia River Mile 191.3 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON19135P	15	15.18	0.16	0.29	0.25
BON19175P	15.24	15.19	0.16	0.29	0.17
Concentration					
BON19135P	35.1	34.07	0.2	0.3	1.11
BON19175P	35.95	34.07	0.21	0.31	1.89
Gas Pressure					
BON19135P	960.23	937.82	7.09	3.38	24.36
BON19175P	988.1	937.84	3.65	3.48	50.43
% Saturation					
BON19135P	125.89	122.91	1.35	0.27	3.25
BON19175P	129.55	122.91	0.63	0.27	6.66

Table 4. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 191.3 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON19135P	100	52.47	88.27	89.2
BON19175P	100	0	0	0

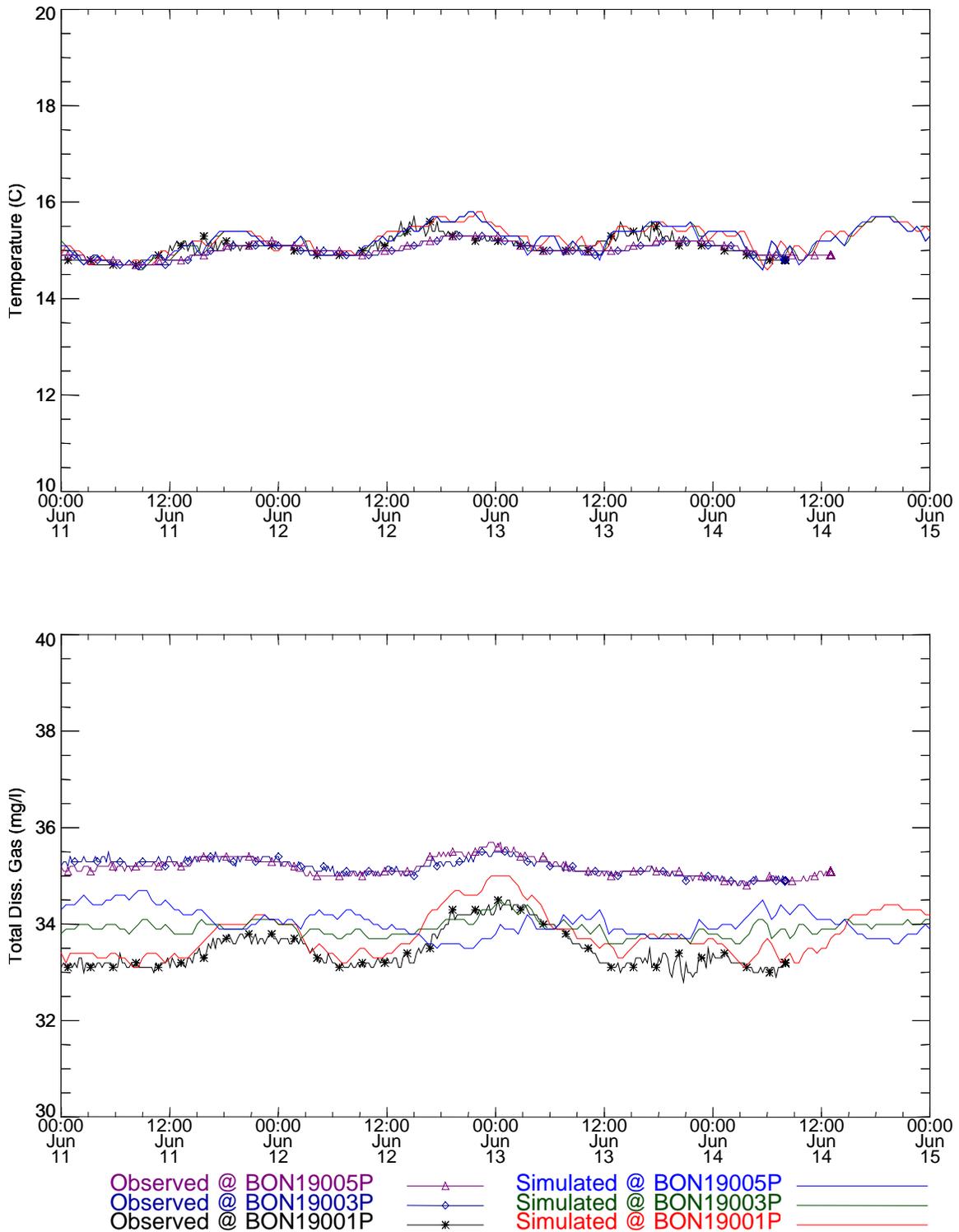


Figure 63. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 190.0 for the Spring 1996 study period (FMS-BC).

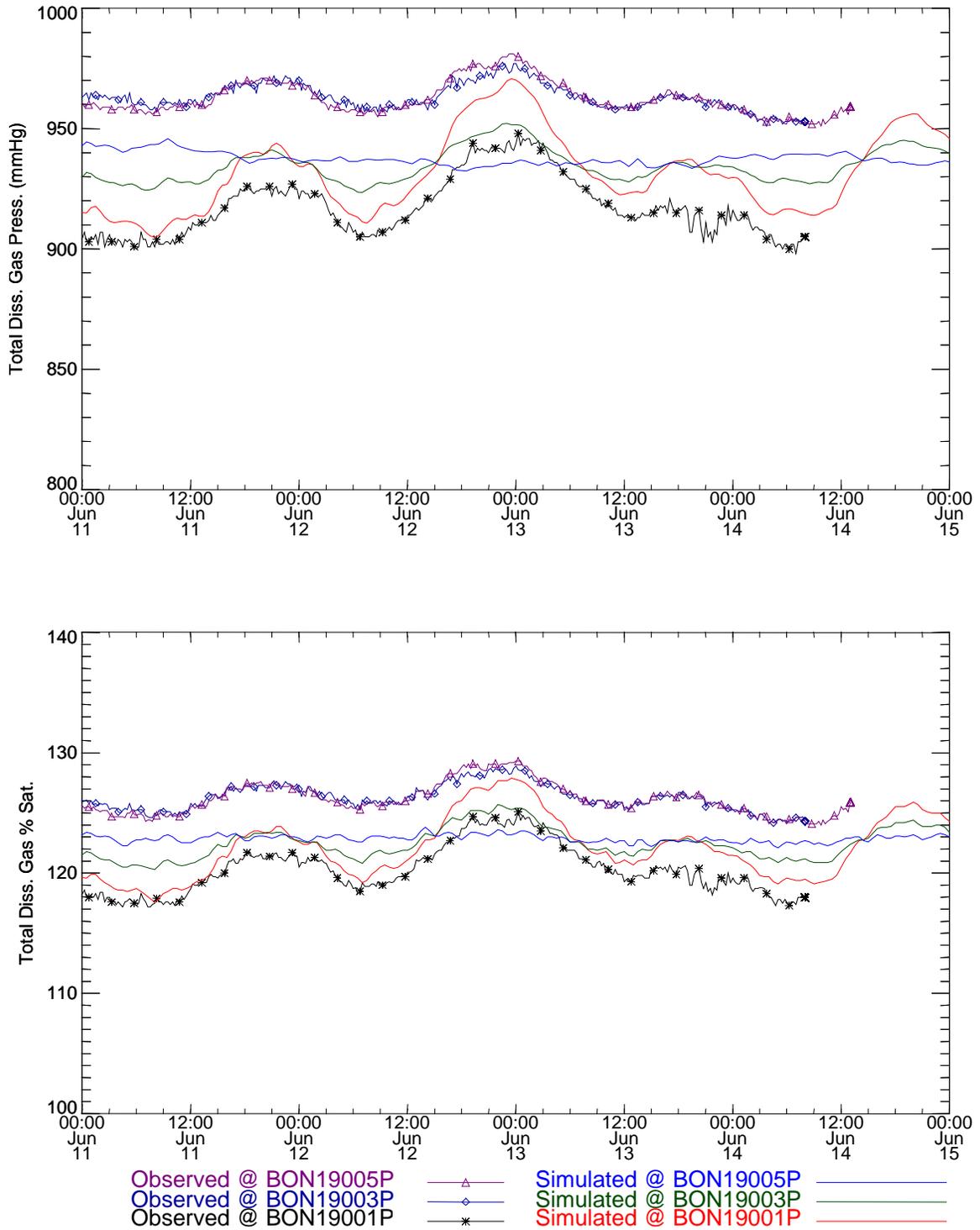


Figure 64. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 190.0 for the Spring 1996 study period (FMS-BC).

Table 5. Statistical summary of measurements and simulations near the Columbia River Mile 190.0 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON19001P	15.08	15.21	0.21	0.28	0.2
BON19003P	15.01	15.19	0.16	0.28	0.24
BON19005P	15.03	15.19	0.16	0.28	0.23
Concentration					
BON19001P	33.46	33.76	0.4	0.48	0.35
BON19003P	35.19	33.91	0.17	0.18	1.29
BON19005P	35.19	34.05	0.19	0.28	1.2
Gas Pressure					
BON19001P	917.42	930.13	12.51	16.45	14.07
BON19003P	963.15	933.8	5.44	6.98	29.59
BON19005P	963.21	937.61	6.79	2.82	26.98
% Saturation					
BON19001P	120.28	121.91	2.03	2.57	1.84
BON19003P	126.28	122.39	1.09	1.32	3.92
BON19005P	126.28	122.88	1.3	0.31	3.59

Table 6. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 190.0 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
BON19001P	100	100	100	100
BON19003P	100	4.67	100	99.38
BON19005P	100	42.06	87.85	88.47

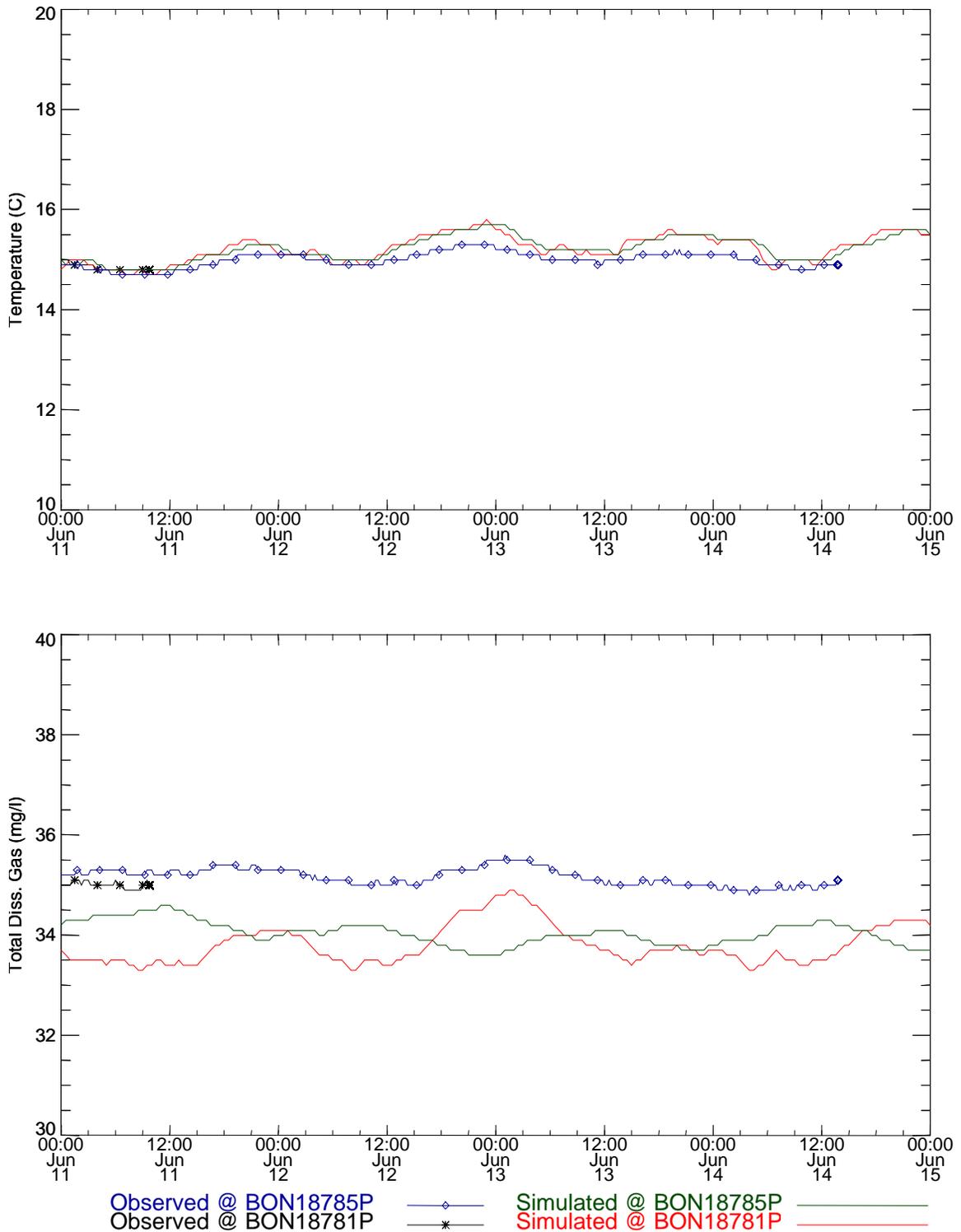


Figure 65. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 187.8 for the Spring 1996 study period (FMS-BC).

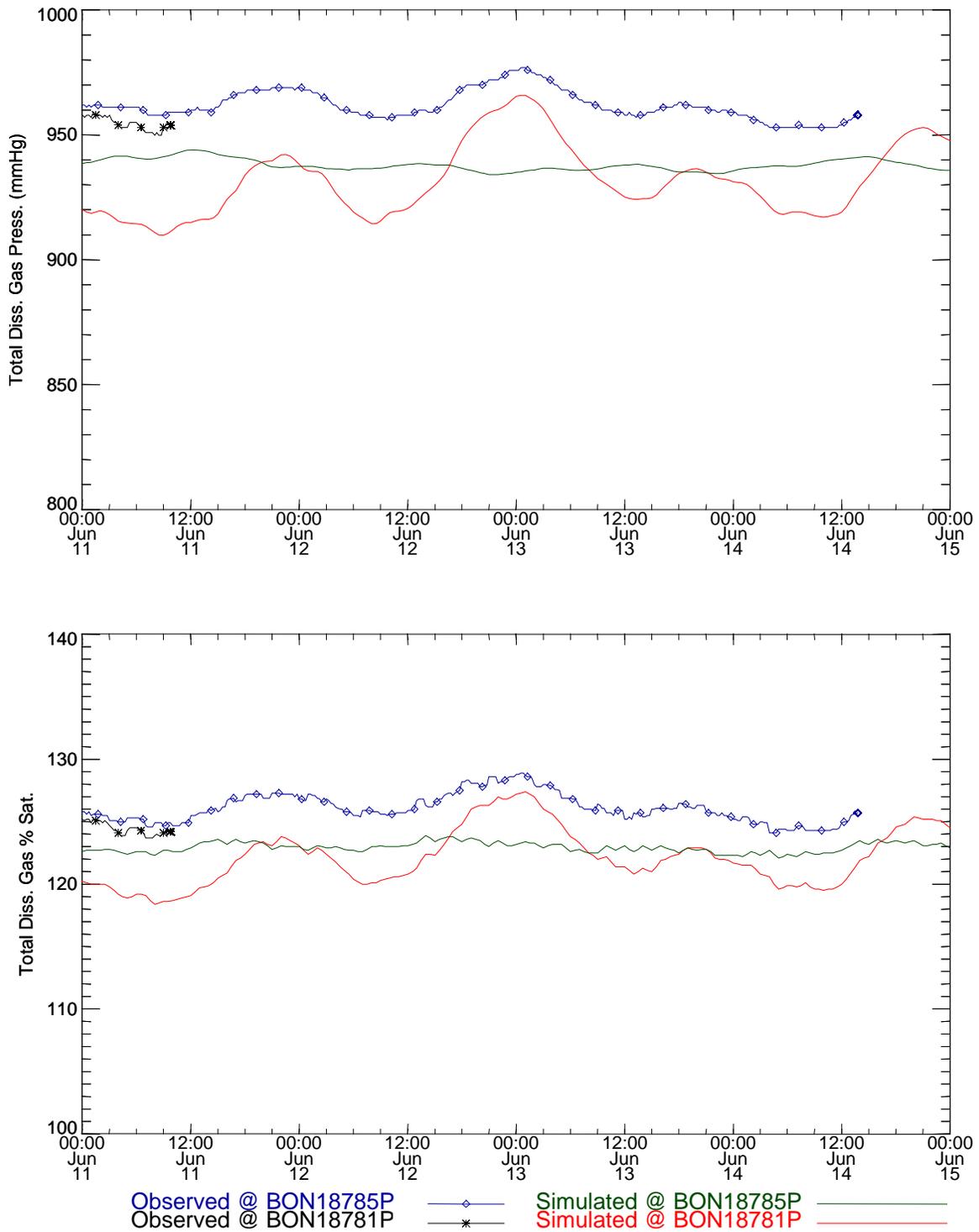


Figure 66. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 187.8 for the Spring 1996 study period (FMS-BC).

Table 7. Statistical summary of measurements and simulations near the Columbia River Mile 187.8 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON18781P	14.85	14.83	0.07	0.1	0.08
BON18785P	14.78	14.87	0.08	0.08	0.11
Concentration					
BON18781P	35	33.47	0.07	0.08	1.53
BON18785P	35.25	34.38	0.05	0.07	0.87
Gas Pressure					
BON18781P	954.58	915.22	2.69	3.29	39.39
BON18785P	960.3	940.63	1.44	0.87	19.77
% Saturation					
BON18781P	124.42	119.28	0.5	0.58	5.15
BON18785P	125.18	122.6	0.35	0.13	2.6

Table 8. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 187.8 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON18781P	100	0	15	40
BON18785P	100	100	100	100

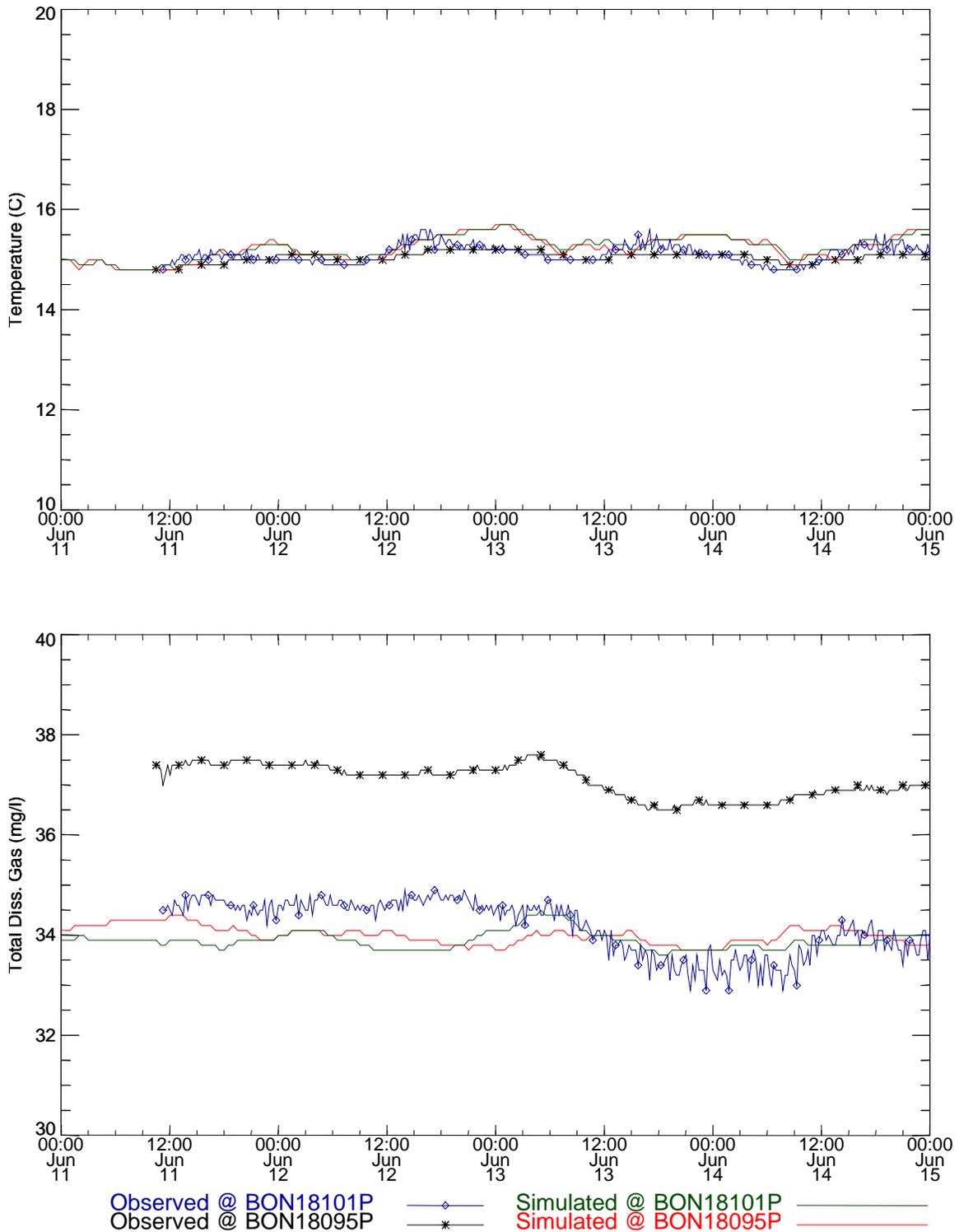


Figure 67. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 180.9 for the Spring 1996 study period (FMS-BC).

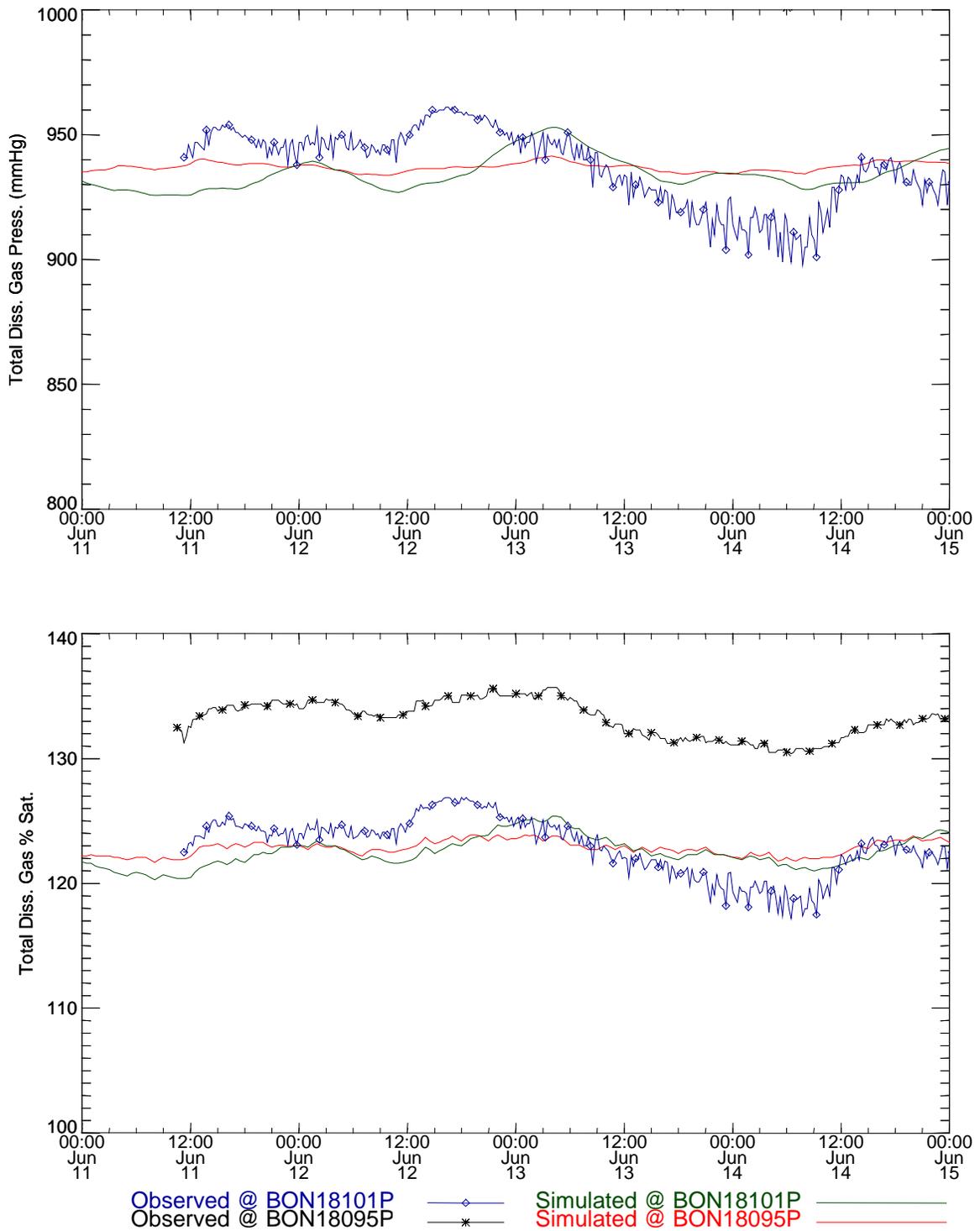


Figure 68. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 180.9 for the Spring 1996 study period (FMS-BC).

Table 9. Statistical summary of measurements and simulations near the Columbia River Mile 180.9 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON18095P	15.05	15.27	0.1	0.22	0.26
BON18101P	15.11	15.29	0.18	0.2	0.26
Concentration					
BON18095P	37.09	33.98	0.33	0.16	3.12
BON18101P	34.17	33.89	0.54	0.19	0.58
Gas Pressure					
BON18095P	1015.16	937.2	8.94	1.84	78.38
BON18101P	937.16	935.44	15.09	6.68	15.63
% Saturation					
BON18095P	133.2	122.92	1.47	0.54	10.34
BON18101P	122.97	122.69	2.27	1.12	2.09

Table 10. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 180.9 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON18095P	100	0	0	0
BON18101P	100	95.92	100	100

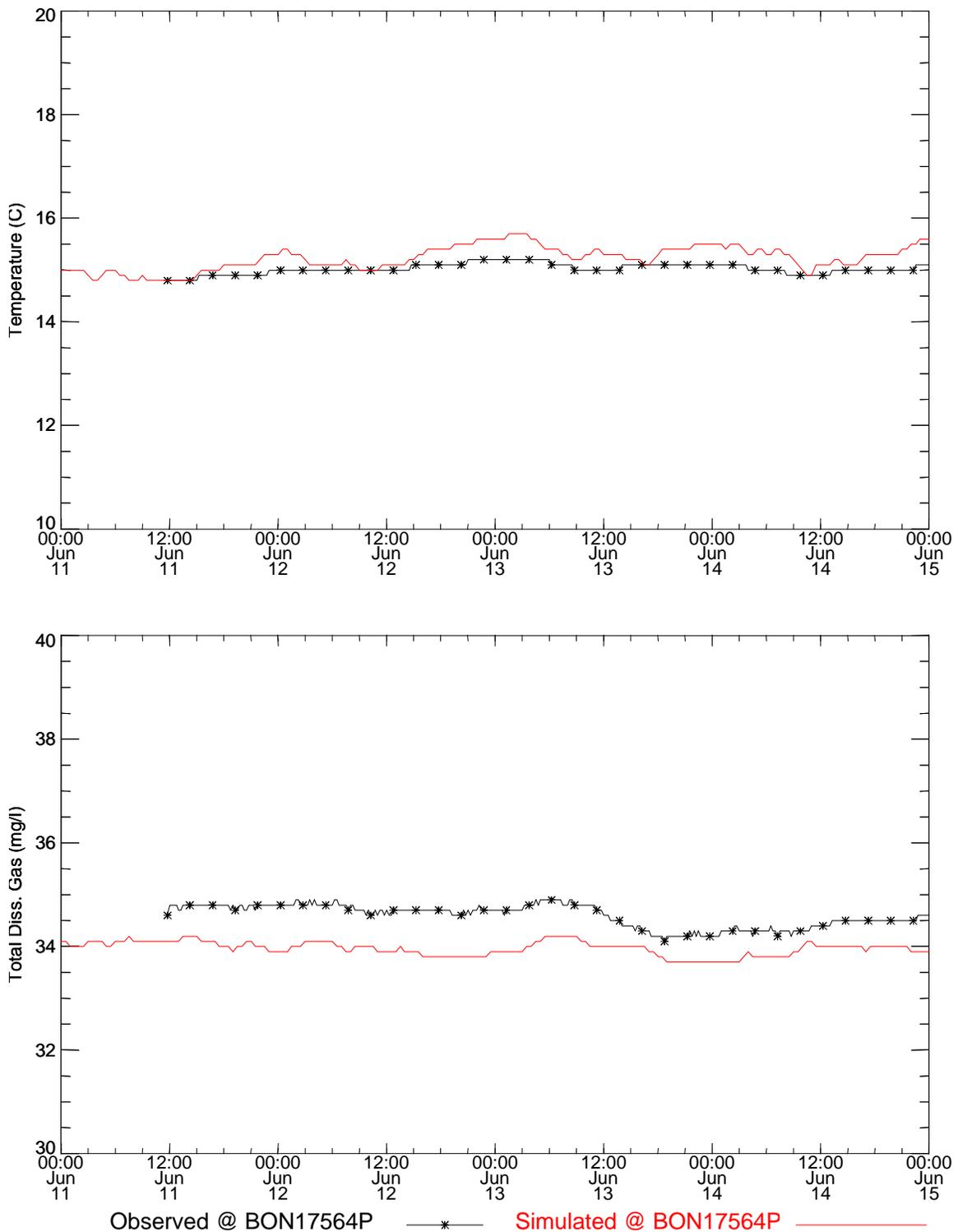


Figure 69. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 175.6 for the Spring 1996 study period (FMS-BC).

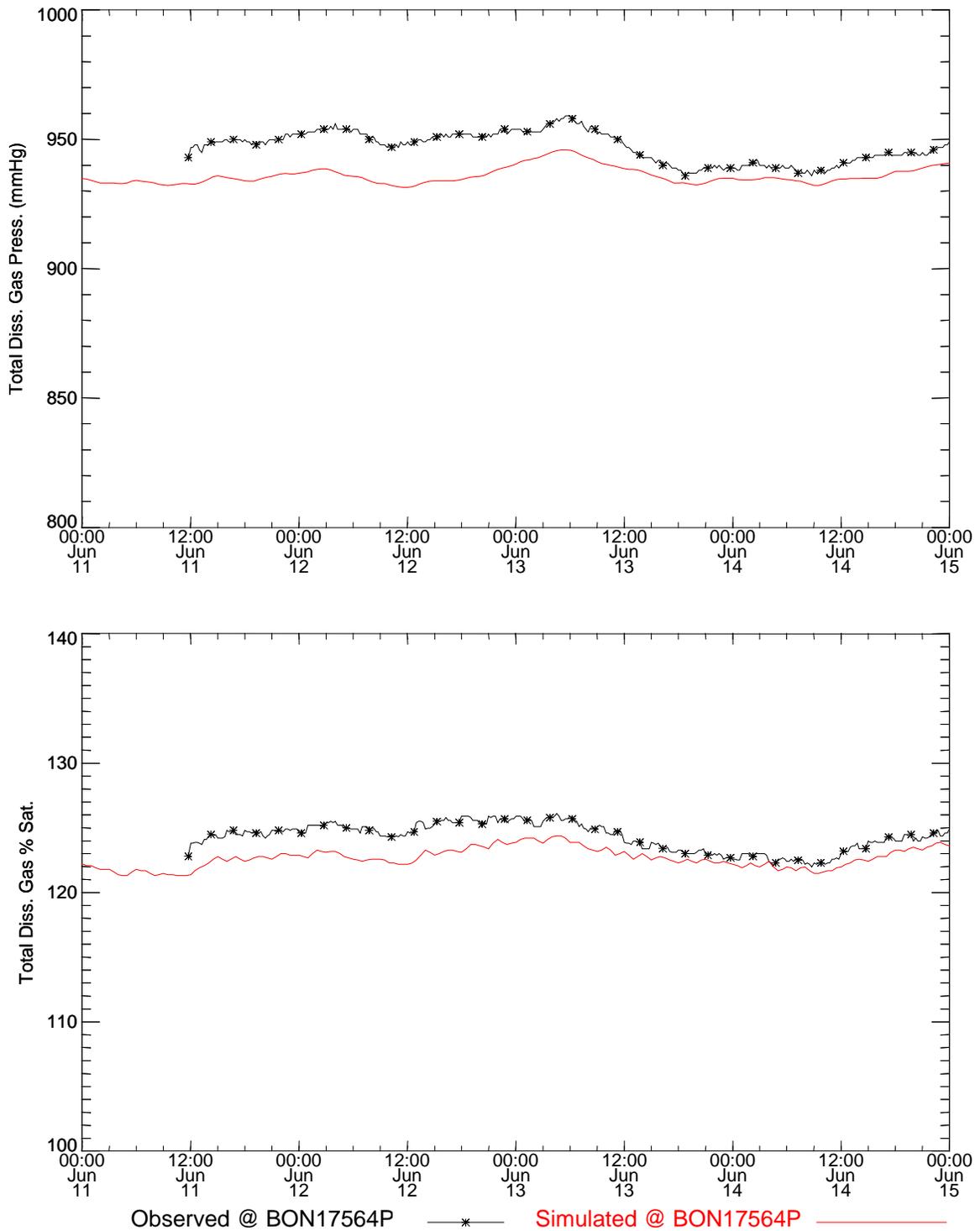


Figure 70. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 175.6 for the Spring 1996 study period (FMS-BC).

Table 11. Statistical summary of measurements and simulations near the Columbia River Mile 175.6 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON17564P	15.03	15.27	0.1	0.21	0.28
Concentration BON17564P	34.59	33.94	0.22	0.14	0.67
Gas Pressure BON17564P	947.12	936.42	5.9	3.37	11.69
% Saturation BON17564P	124.29	122.84	1.06	0.68	1.6

Table 12. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 175.6 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON17564P	100	100	100	100

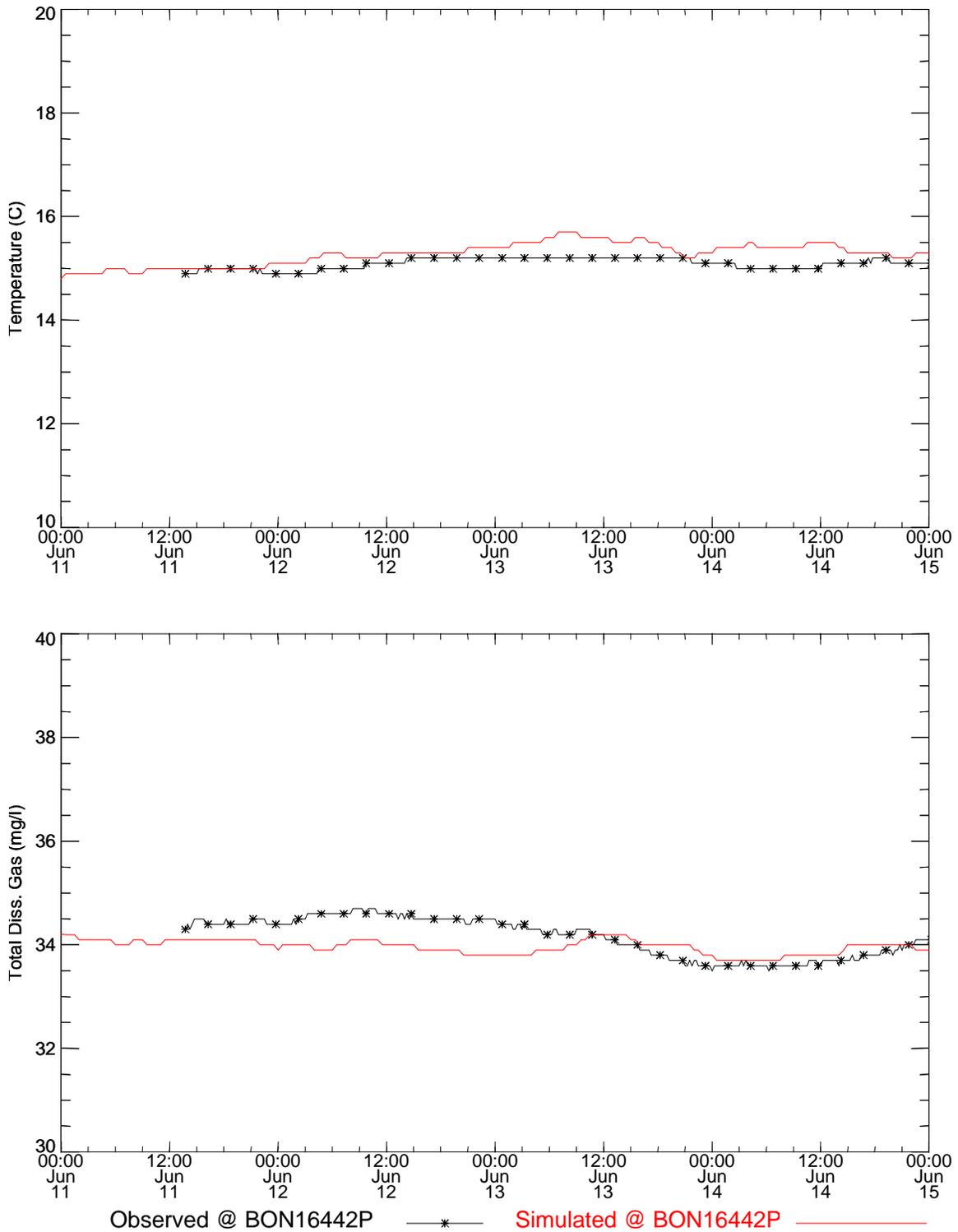


Figure 71. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 164.4 for the Spring 1996 study period (FMS-BC).

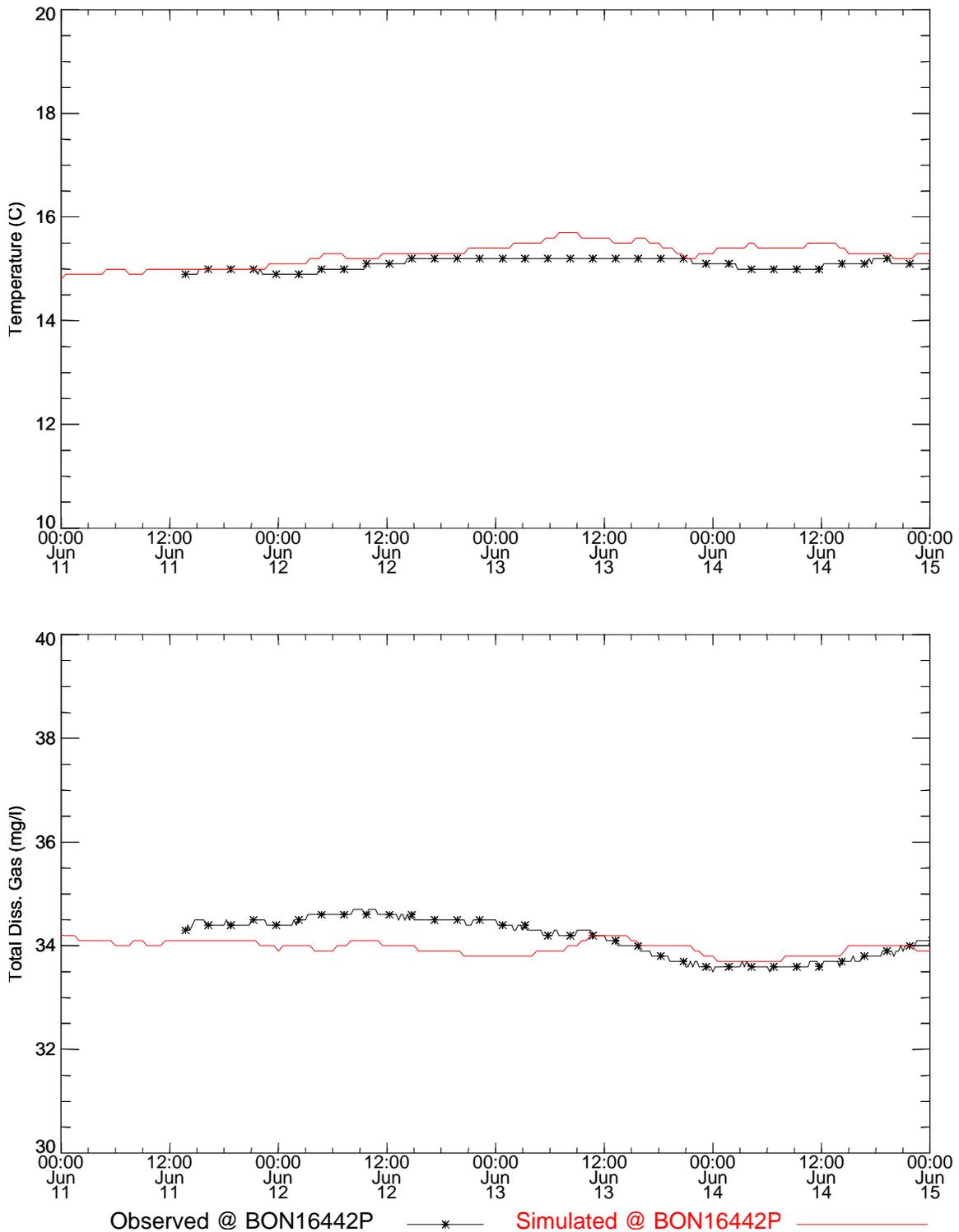


Figure 72. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 164.4 for the Spring 1996 study period (FMS-BC).

Table 13. Statistical summary of measurements and simulations near the Columbia River Mile 164.4 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON16442P	15.1	15.33	0.1	0.18	0.27
Concentration BON16442P	34.15	33.94	0.37	0.13	0.4
Gas Pressure BON16442P	936.28	937.46	10.01	4.09	10.47
% Saturation BON16442P	122.88	122.99	1.62	0.67	1.39

Table 14. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 164.4 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON16442P	100	100	100	100

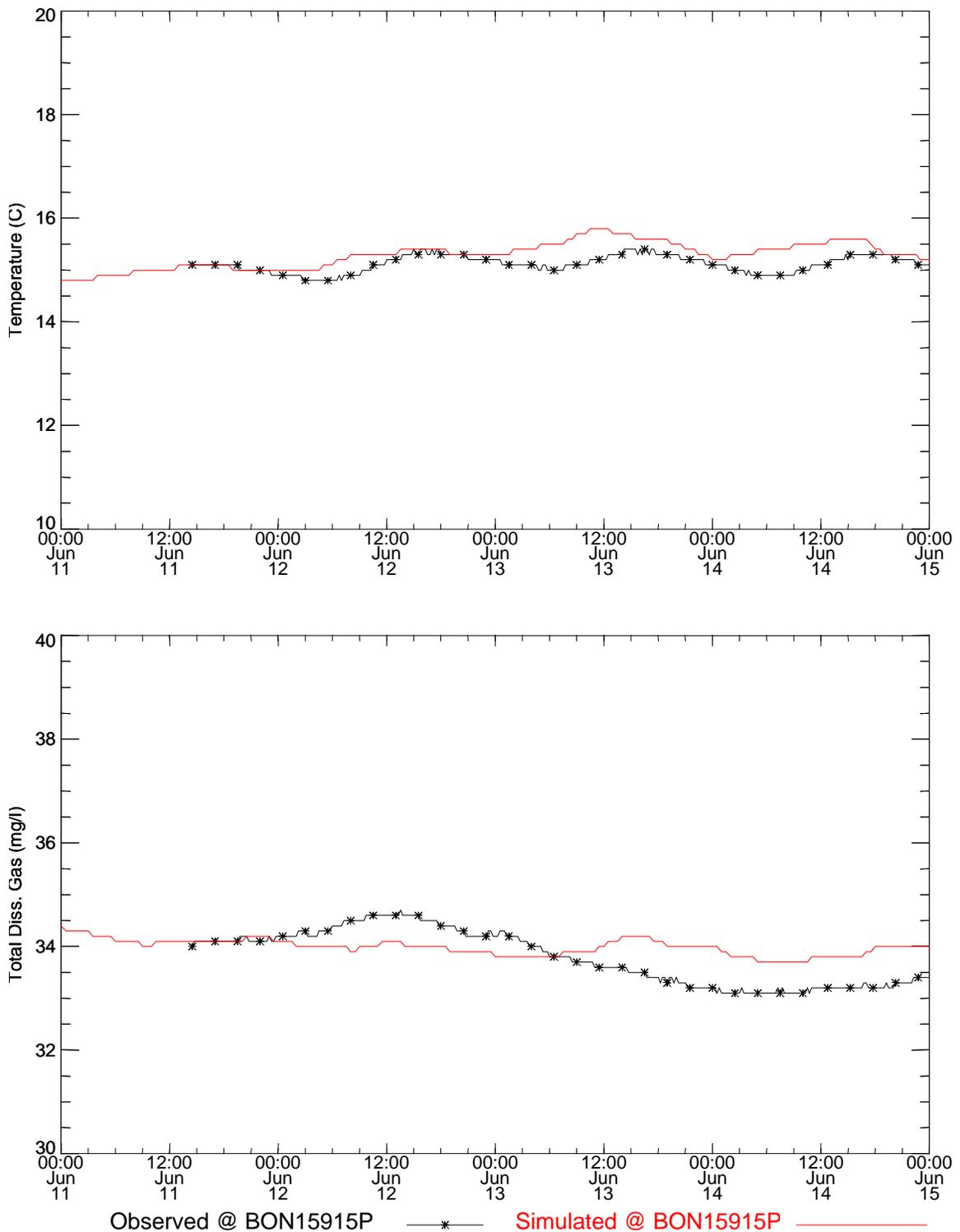


Figure 73. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 159.1 for the Spring 1996 study period (FMS-BC).

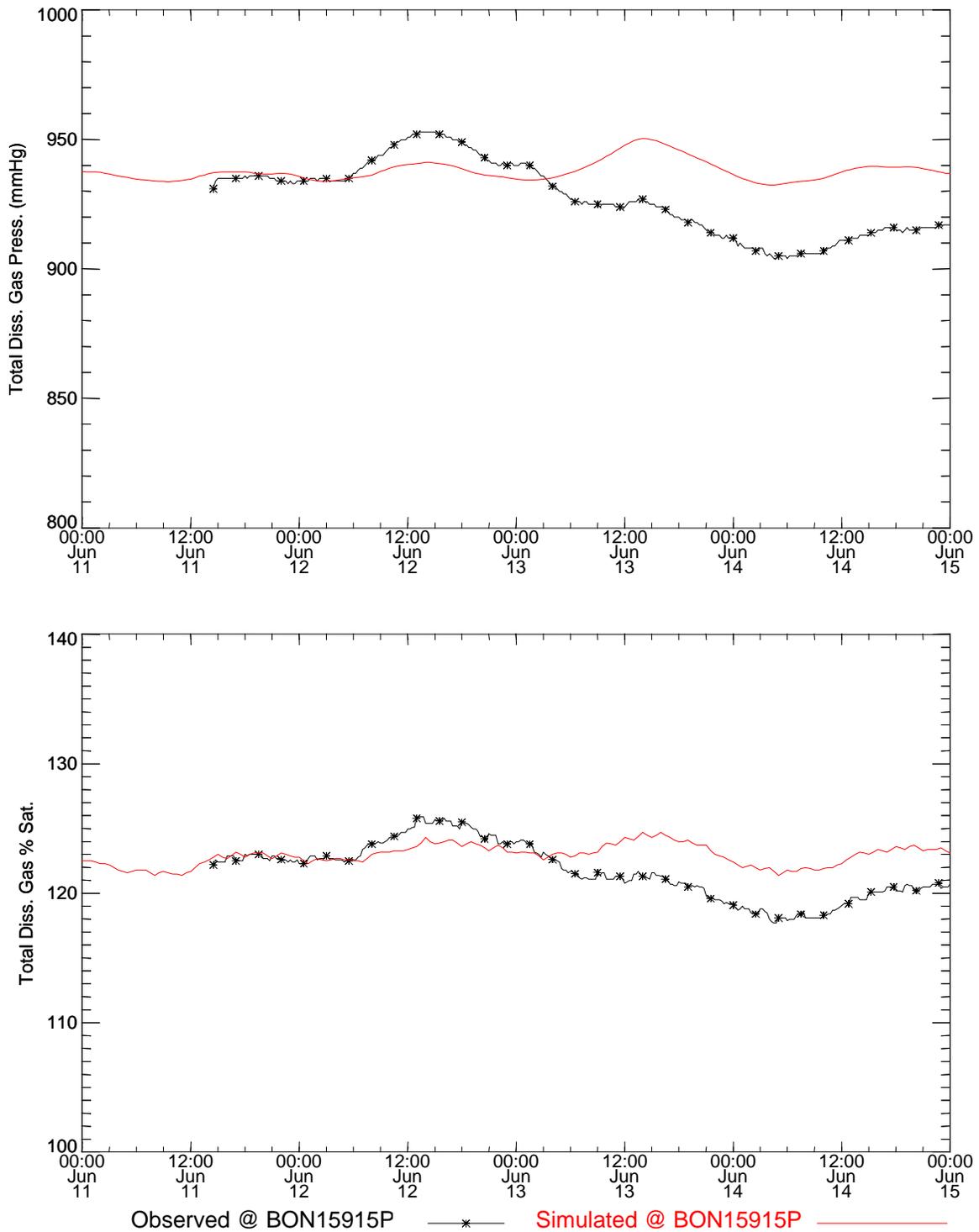


Figure 74. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 159.1 for the Spring 1996 study period (FMS-BC).

Table 15. Statistical summary of measurements and simulations near the Columbia River Mile 159.1 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON15915P	15.12	15.35	0.16	0.21	0.3
Concentration BON15915P	33.79	33.96	0.52	0.14	0.52
Gas Pressure BON15915P	927.4	938.37	14.11	4.16	18.19
% Saturation BON15915P	121.72	123.11	2.16	0.71	2.37

Table 16. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 159.1 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON15915P	100	100	100	100

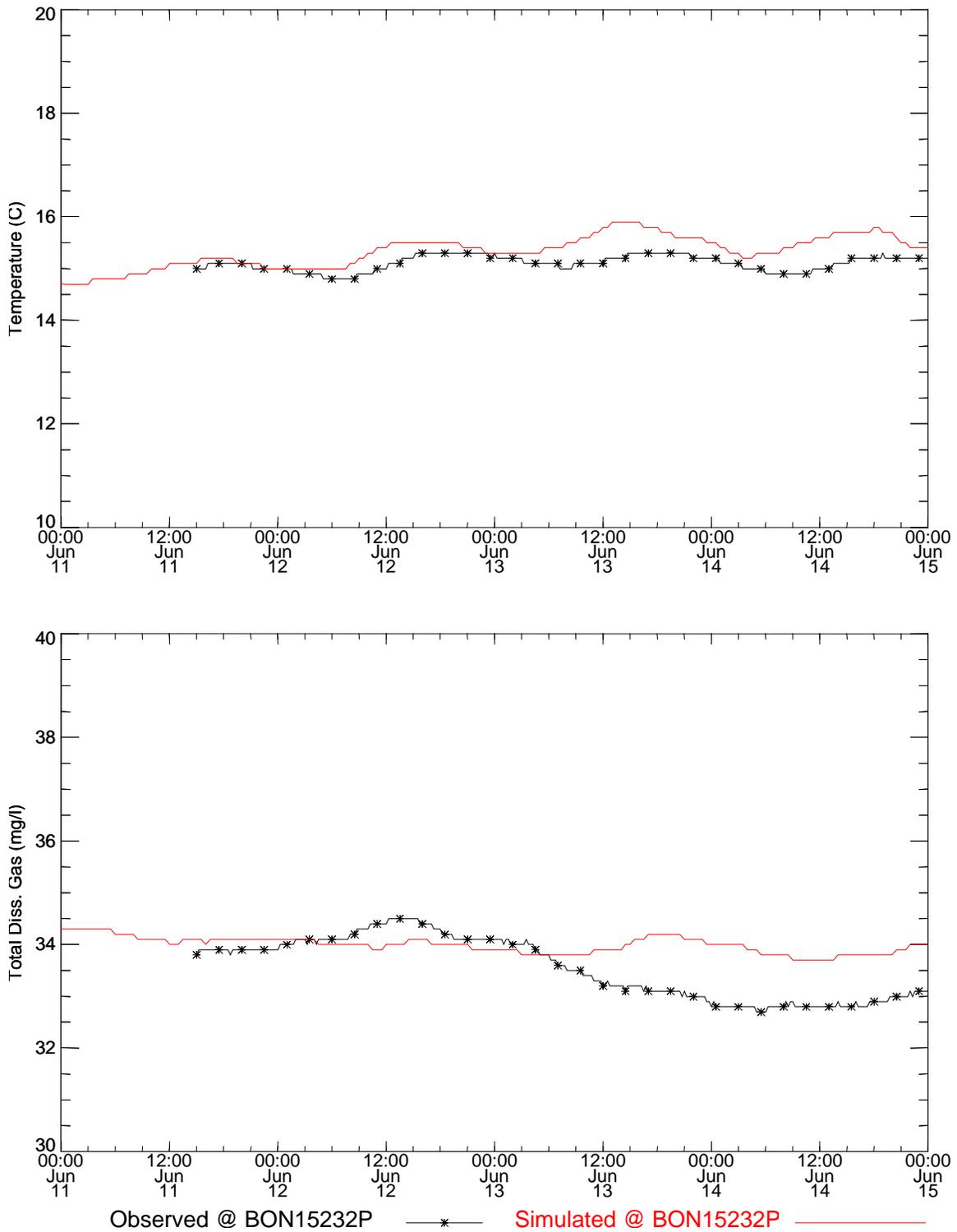


Figure 75. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 152.3 for the Spring 1996 study period (FMS-BC).

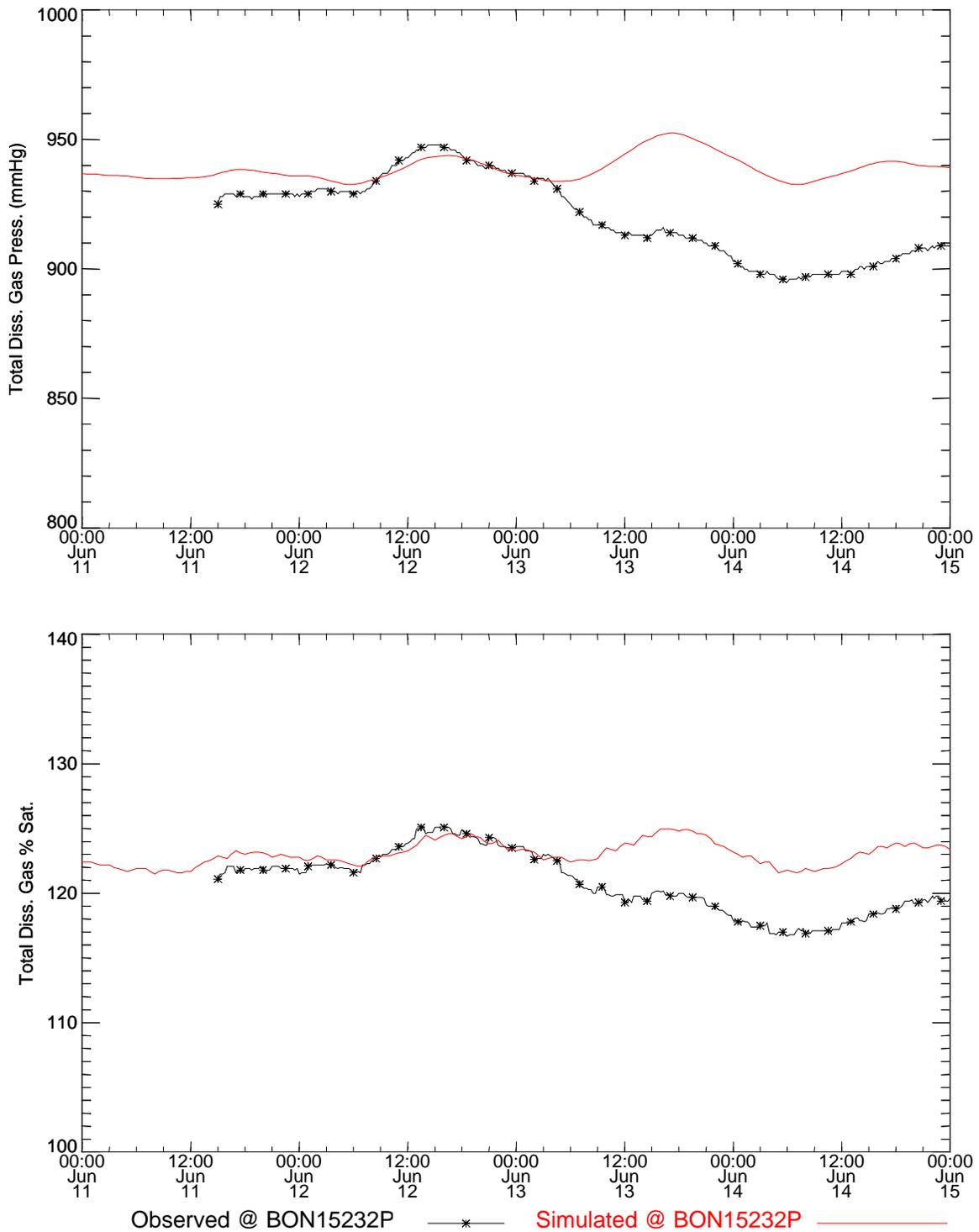


Figure 76. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 152.3 for the Spring 1996 study period (FMS-BC).

Table 17. Statistical summary of measurements and simulations near the Columbia River Mile 152.3 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON15232P	15.11	15.41	0.15	0.25	0.36
Concentration BON15232P	33.54	33.95	0.59	0.13	0.69
Gas Pressure BON15232P	920.23	939.35	15.88	5.03	25.63
% Saturation BON15232P	120.77	123.24	2.39	0.84	3.33

Table 18. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 152.3 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON15232P	100	83.69	79.08	86.77

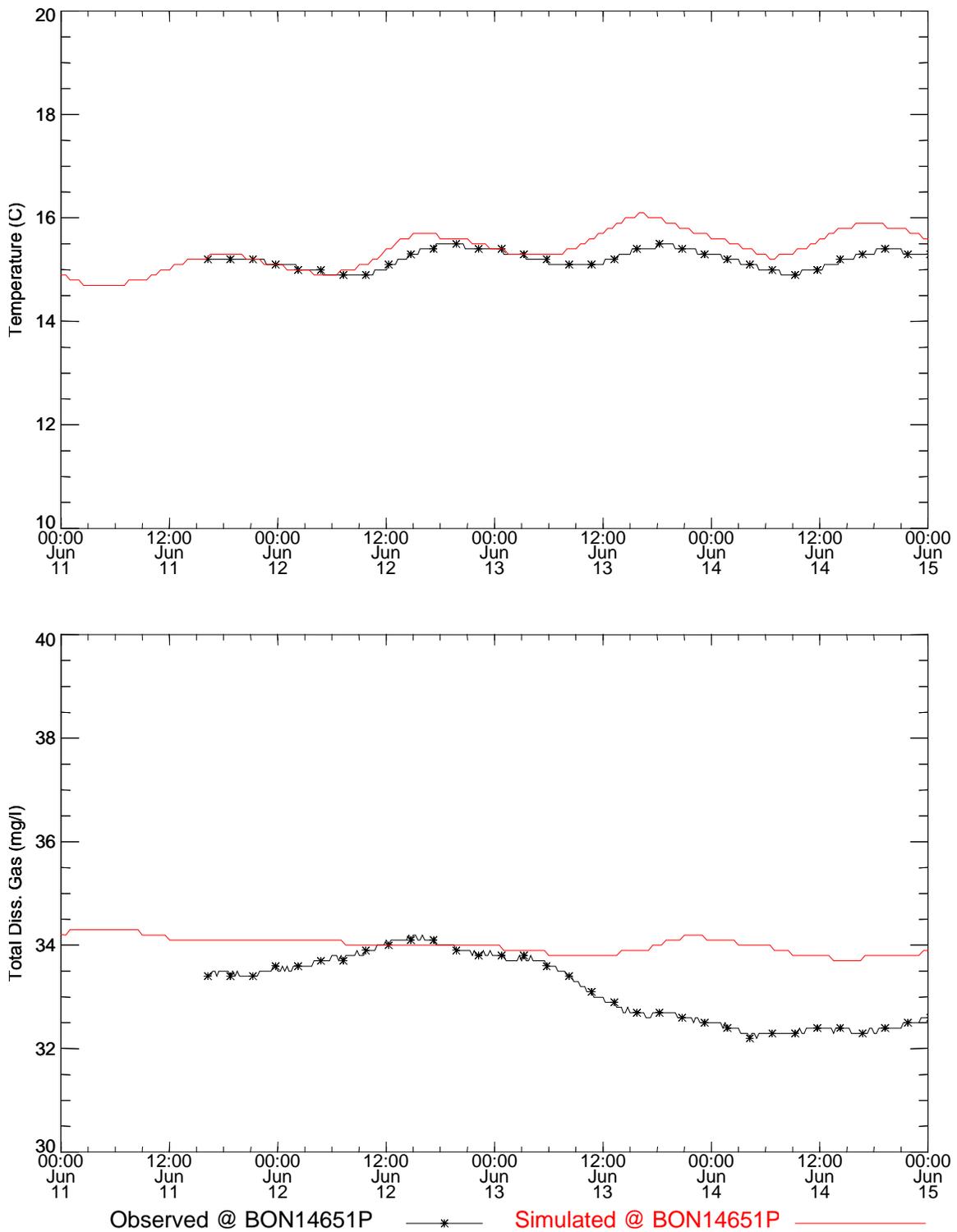


Figure 77. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 146.5 for the Spring 1996 study period (FMS-BC).

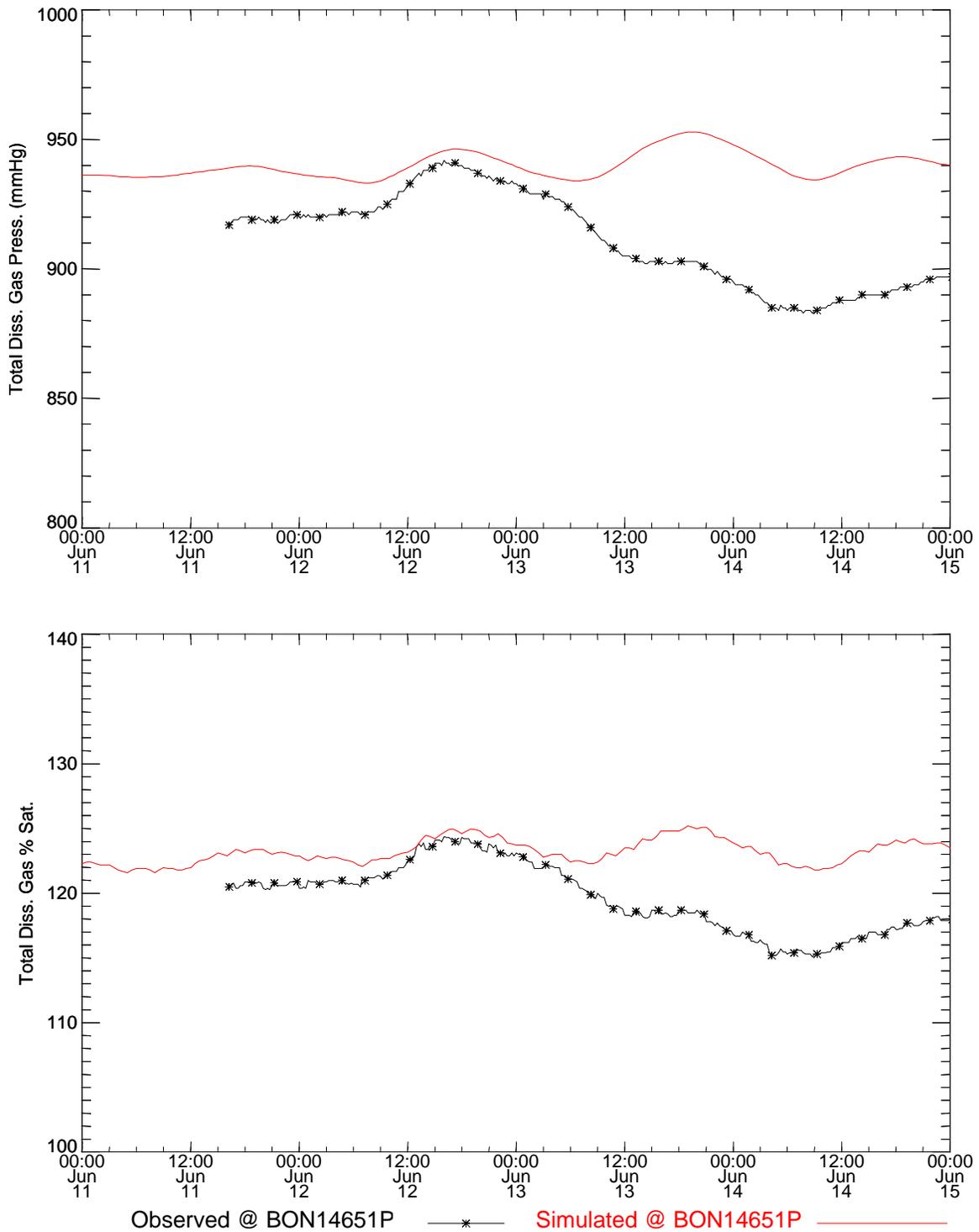


Figure 78. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 146.5 for the Spring 1996 study period (FMS-BC).

Table 19. Statistical summary of measurements and simulations near the Columbia River Mile 146.5 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON14651P	15.2	15.48	0.17	0.3	0.36
Concentration BON14651P	33.15	33.96	0.65	0.13	1.02
Gas Pressure BON14651P	911.17	940.7	17.76	5.26	35.23
% Saturation BON14651P	119.59	123.42	2.63	0.87	4.58

Table 20. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 146.5 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON14651P	100	56.88	55.31	55

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.

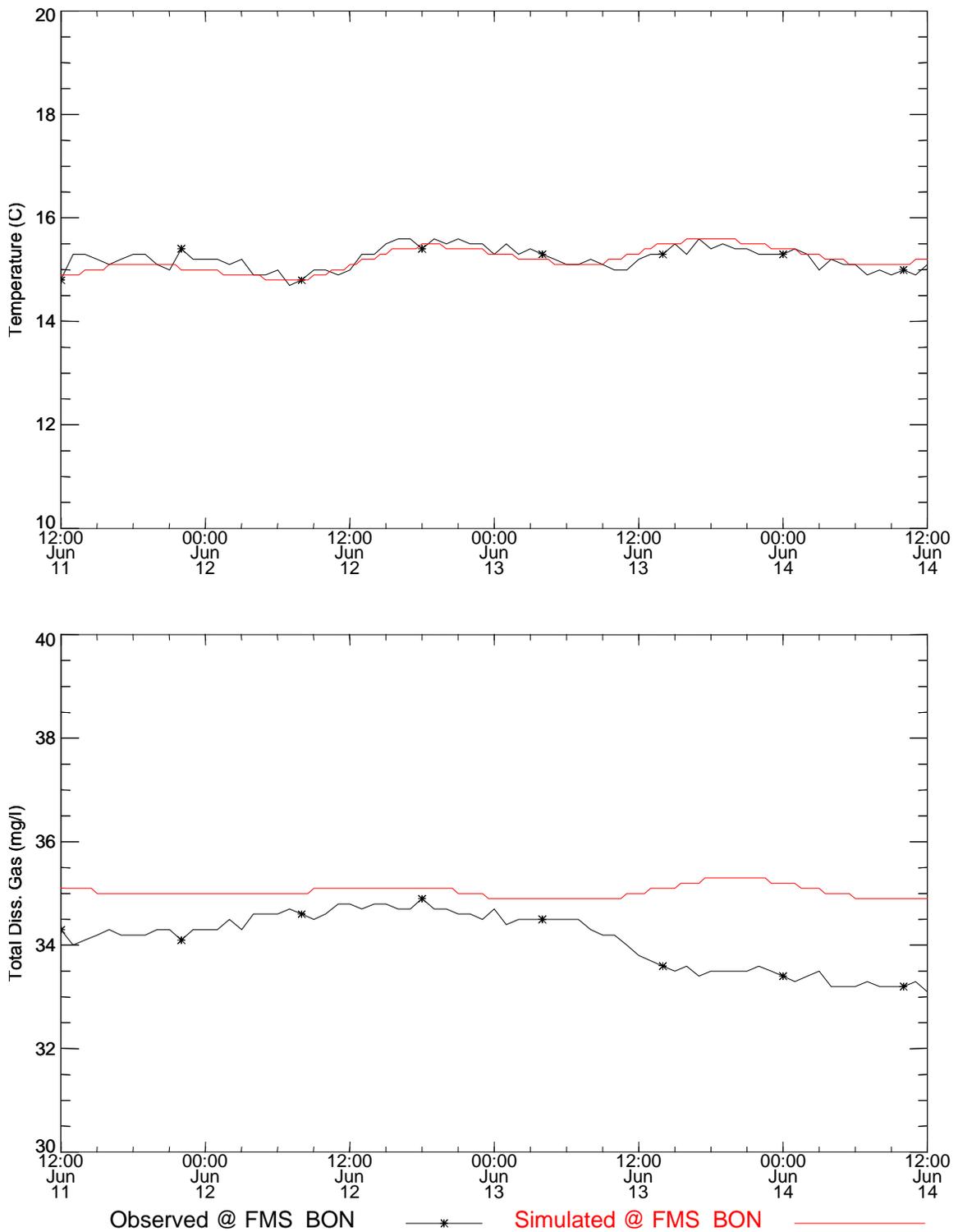


Figure 79. Temperature and total dissolved gas time series comparisons near the fixed monitor BON for the Spring 1996 study period (TM-BC).

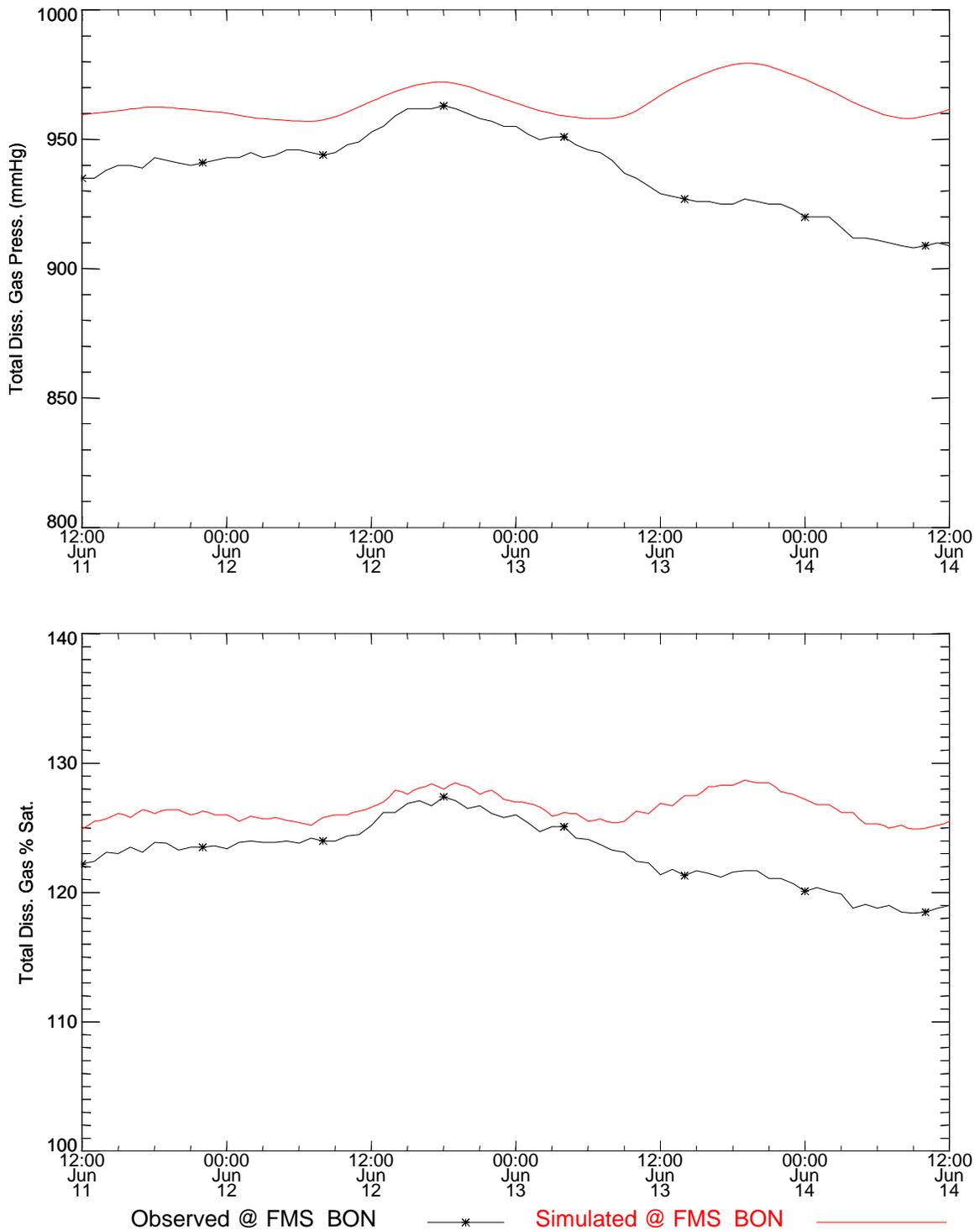


Figure 80. Total dissolved gas pressure and saturation time series comparisons near fixed monitor BON for the Spring 1996 study period (TM-BC).

Table 21. Statistical summary of measurements and simulations near the fixed monitor BON for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_BON	15.22	15.2	0.21	0.22	0.16
Concentration FMS_BON	34.1	35.04	0.54	0.11	1.1
Gas Pressure FMS_BON	937.74	964.7	15.51	6.5	32.04
% Saturation FMS_BON	123.04	126.53	2.4	1.06	4.17

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

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_BON	100	64.14	66.9	66.9

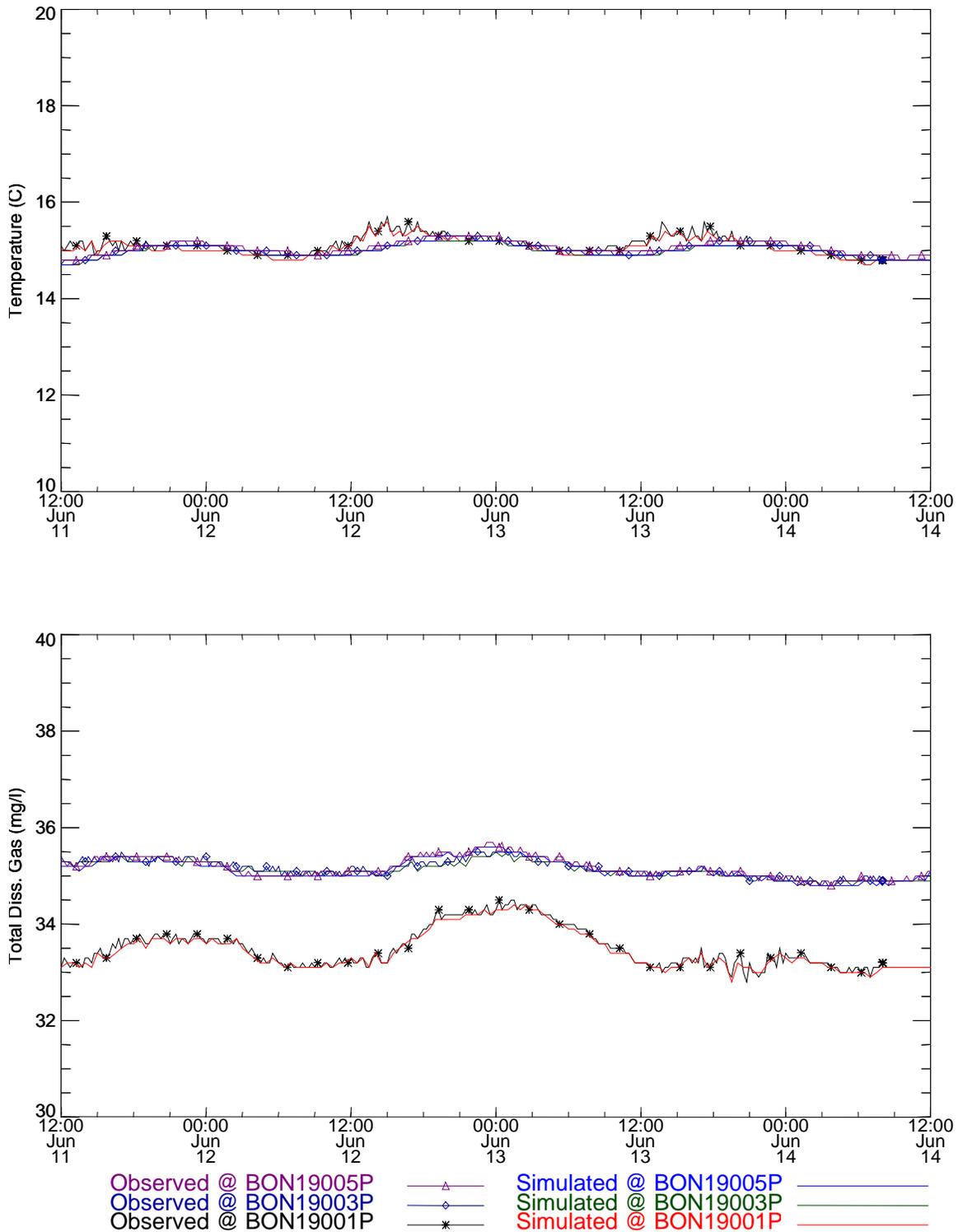


Figure 81. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 190.0 for the Spring 1996 study period (TM-BC).

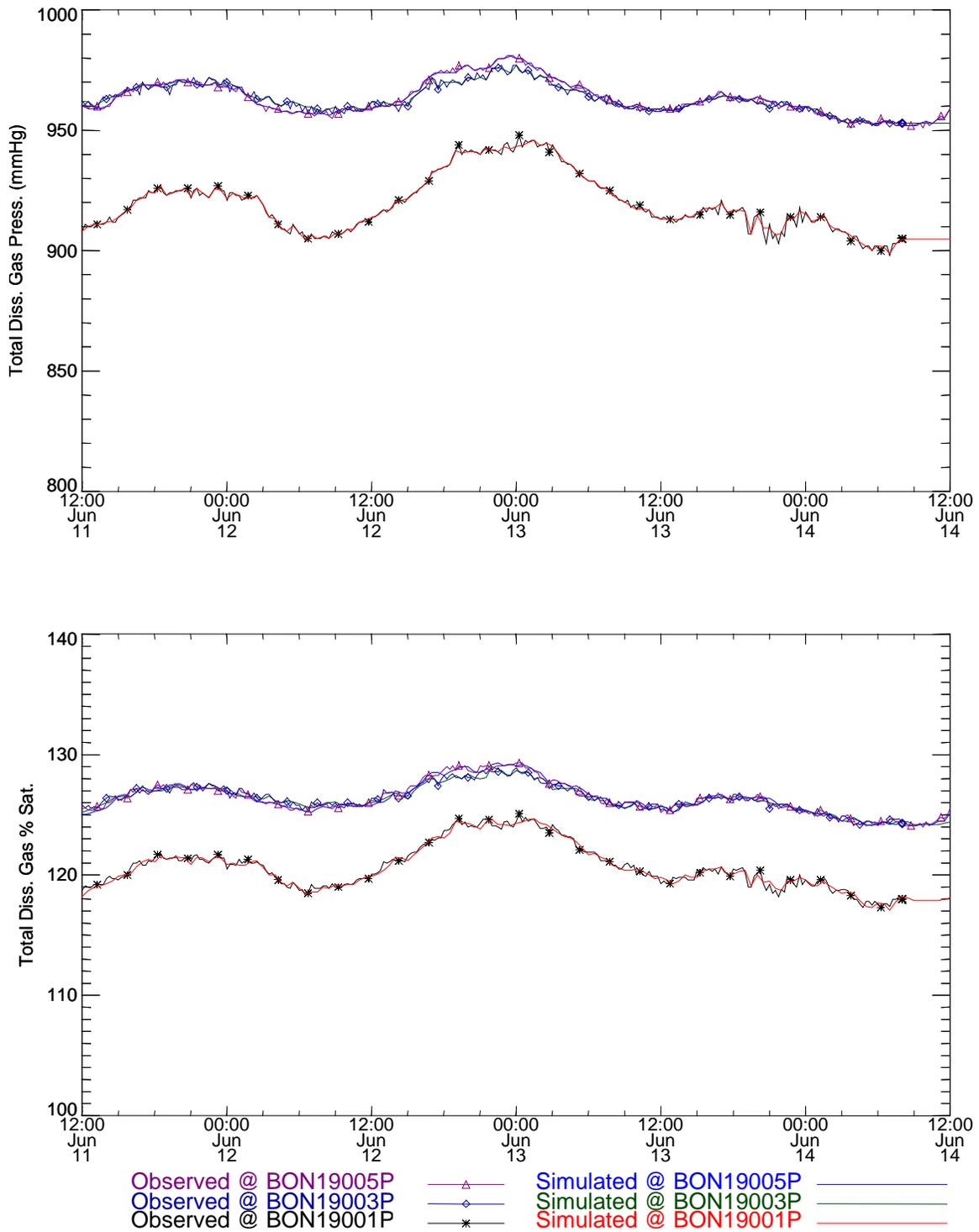


Figure 82. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 190.0 for the Spring 1996 study period (TM-BC).

Table 23. Statistical summary of measurements and simulations near the Columbia River Mile 190.0 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON19001P	15.11	15.06	0.19	0.19	0.07
BON19003P	15.04	14.99	0.14	0.13	0.07
BON19005P	15.06	15	0.13	0.14	0.08
Concentration					
BON19001P	33.5	33.45	0.4	0.4	0.07
BON19003P	35.16	35.12	0.18	0.17	0.06
BON19005P	35.17	35.13	0.21	0.21	0.07
Gas Pressure					
BON19001P	919.1	919.03	12.07	12.06	0.41
BON19003P	962.91	962.86	6.05	6.05	0.15
BON19005P	963.43	963.4	7.23	7.23	0.12
% Saturation					
BON19001P	120.58	120.54	1.92	1.93	0.26
BON19003P	126.33	126.29	1.16	1.17	0.26
BON19005P	126.41	126.36	1.31	1.33	0.26

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 190.0 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
BON19001P	100	100	100	100
BON19003P	100	100	100	100
BON19005P	100	100	100	100

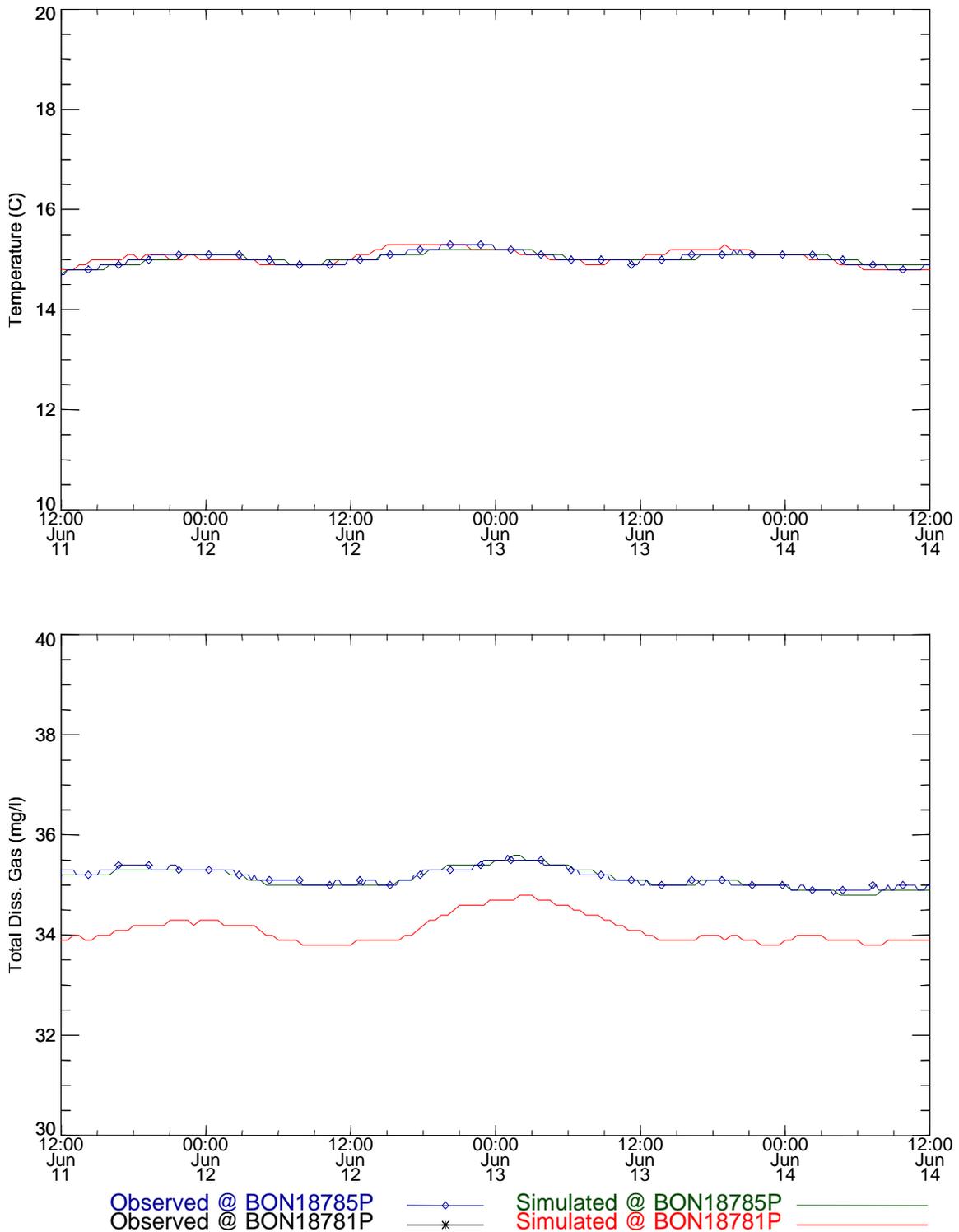


Figure 83. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 187.8 for the Spring 1996 study period (TM-BC).

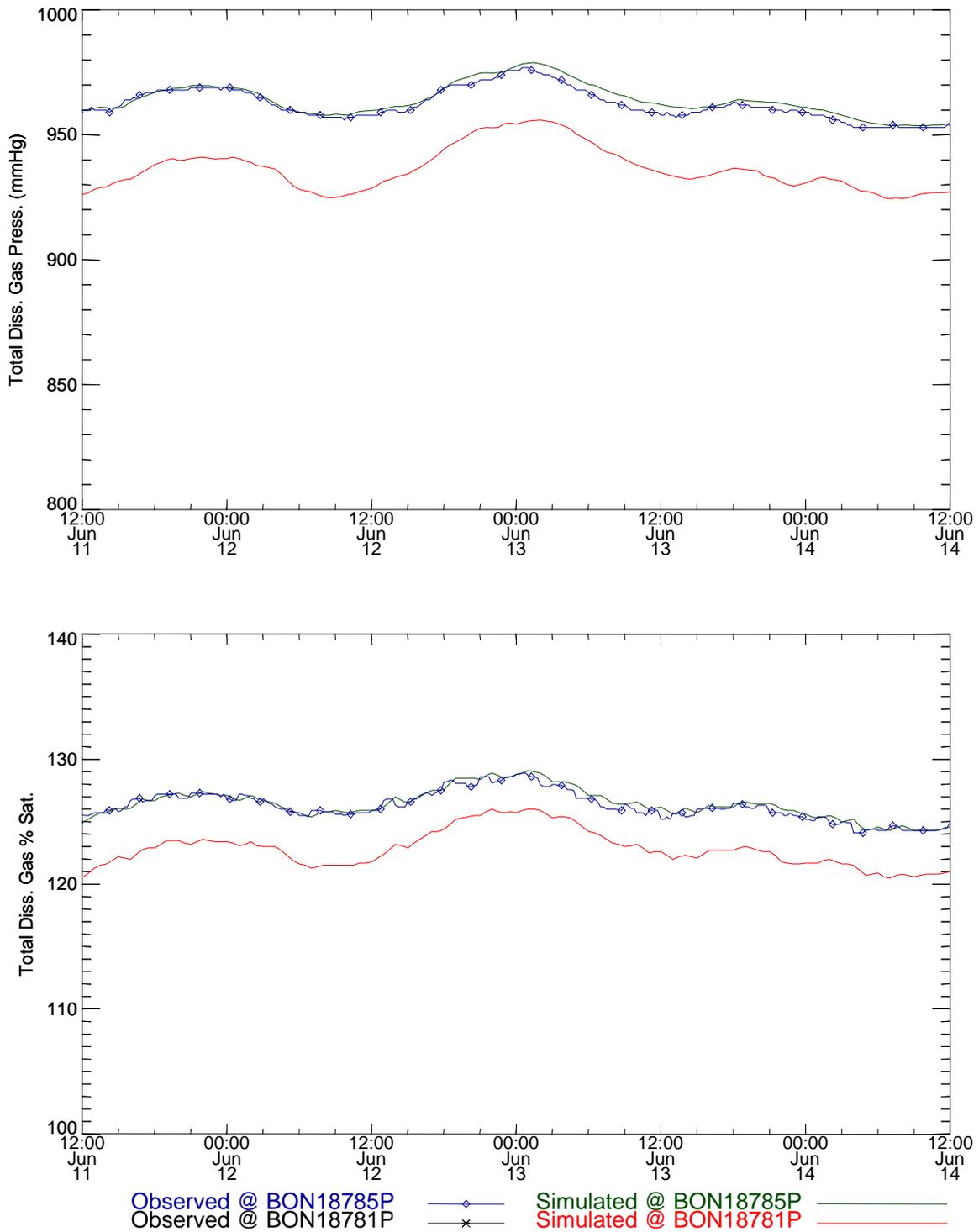


Figure 84. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 187.8 for the Spring 1996 study period (TM-BC).

Table 25. Statistical summary of measurements and simulations near the Columbia River Mile 187.8 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON18781P	14.8	15.05	0	0.15	0.29
BON18785P	15.03	15.03	0.13	0.11	0.06
Concentration					
BON18781P	35	34.11	0	0.28	0.93
BON18785P	35.15	35.13	0.18	0.19	0.07
Gas Pressure					
BON18781P	954	936.51	0	8.78	19.57
BON18785P	962.41	964.06	6.23	6.45	2.17
% Saturation					
BON18781P	124.2	122.83	0	1.48	2.02
BON18785P	126.27	126.44	1.16	1.2	0.38

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 187.8 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON18781P	100	58.62	100	100
BON18785P	100	100	100	100

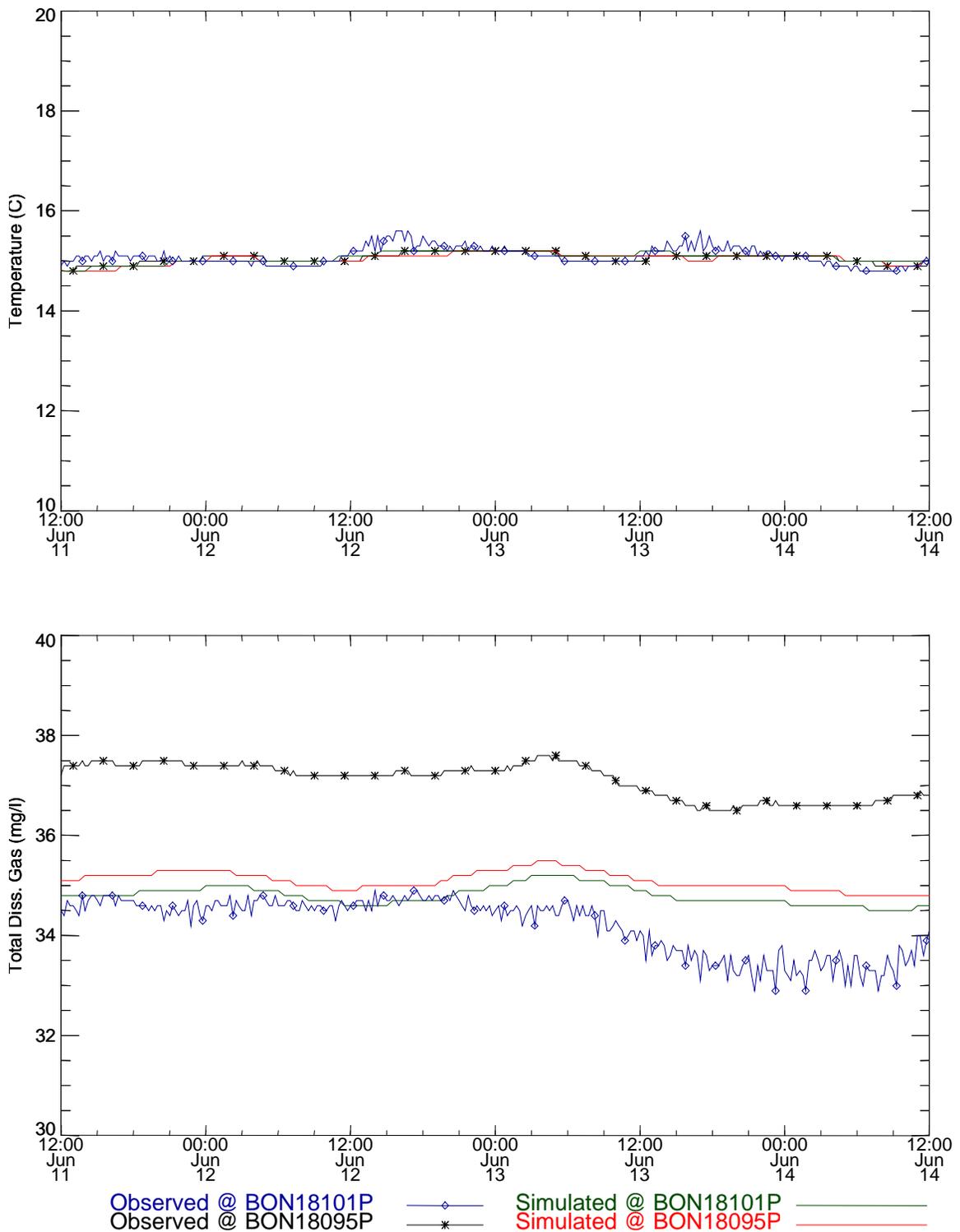


Figure 85. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 180.9 for the Spring 1996 study period (TM-BC).

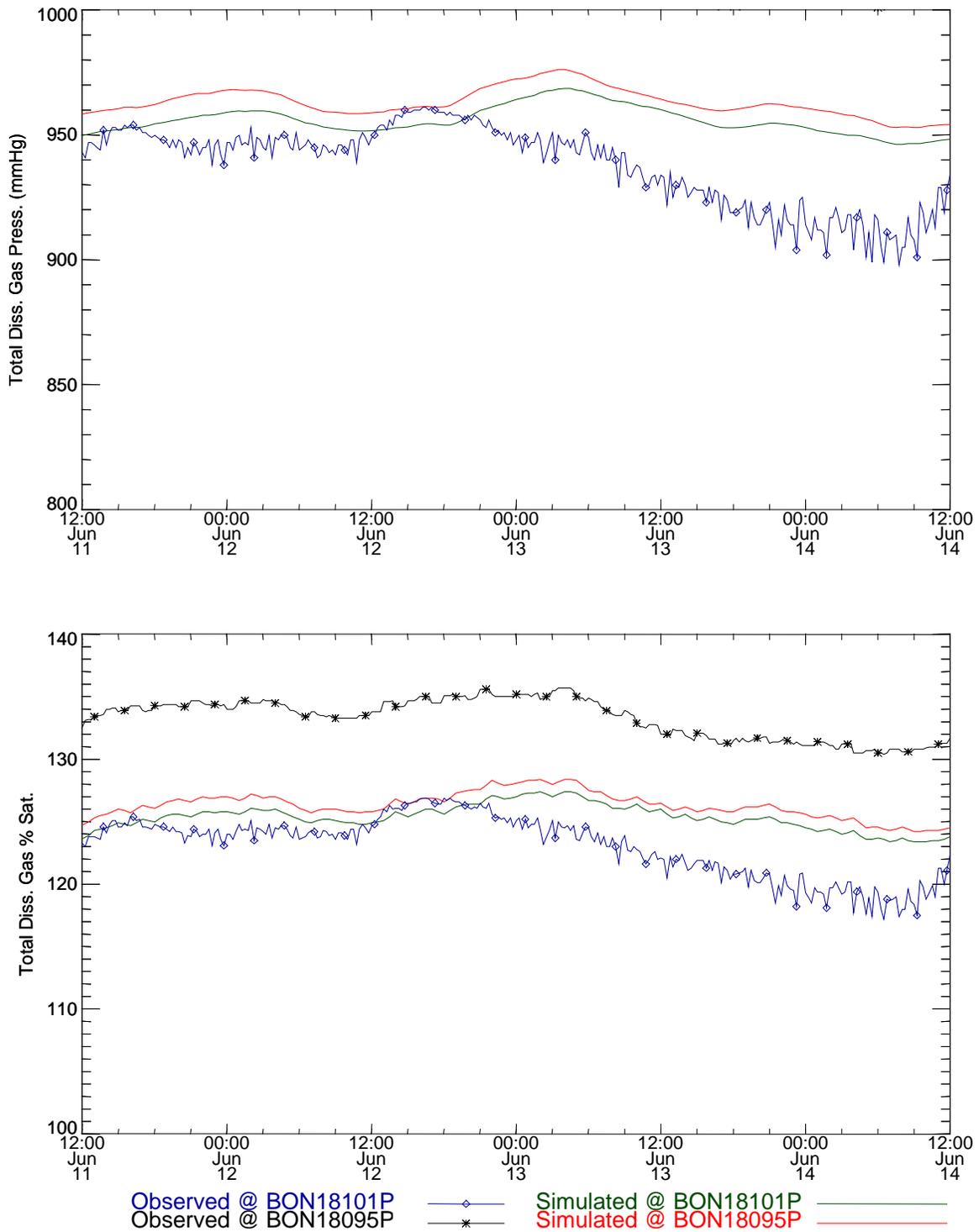


Figure 86. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 180.9 for the Spring 1996 study period (TM-BC).

Table 27. Statistical summary of measurements and simulations near the Columbia River Mile 180.9 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON18095P	15.06	15.05	0.1	0.1	0.05
BON18101P	15.1	15.07	0.18	0.1	0.15
Concentration					
BON18095P	37.11	35.1	0.35	0.18	2.02
BON18101P	34.2	34.8	0.57	0.18	0.79
Gas Pressure					
BON18095P	1015.9	963.14	9.49	5.62	53.16
BON18101P	937.76	955.87	16.2	5.56	23.31
% Saturation					
BON18095P	133.29	126.32	1.57	1.05	7.02
BON18101P	123.04	125.37	2.46	1.02	3.04

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 180.9 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON18095P	100	0	0	0.35
BON18101P	100	76.82	89.27	91.35

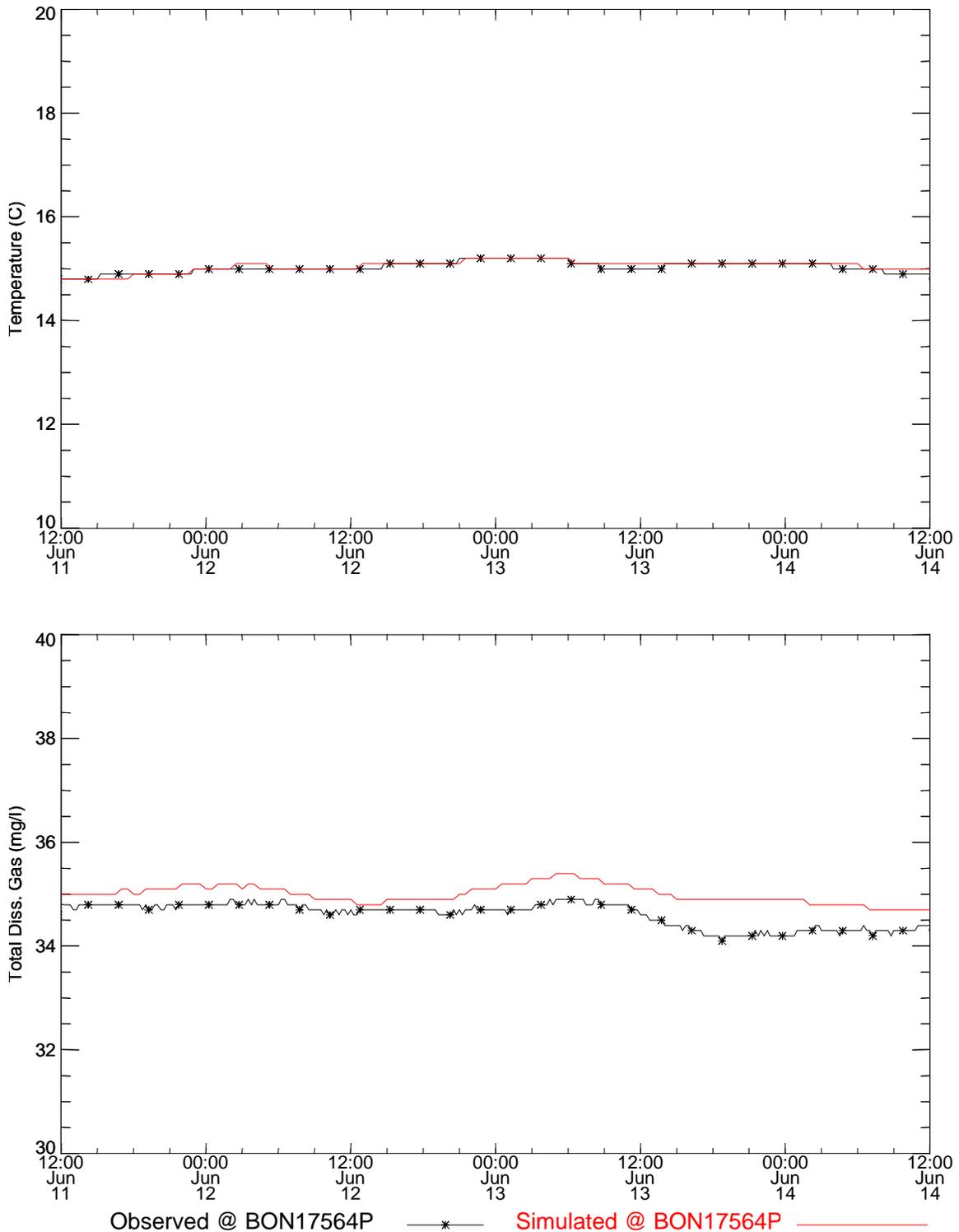


Figure 87. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 175.6 for the Spring 1996 study period (TM-BC).

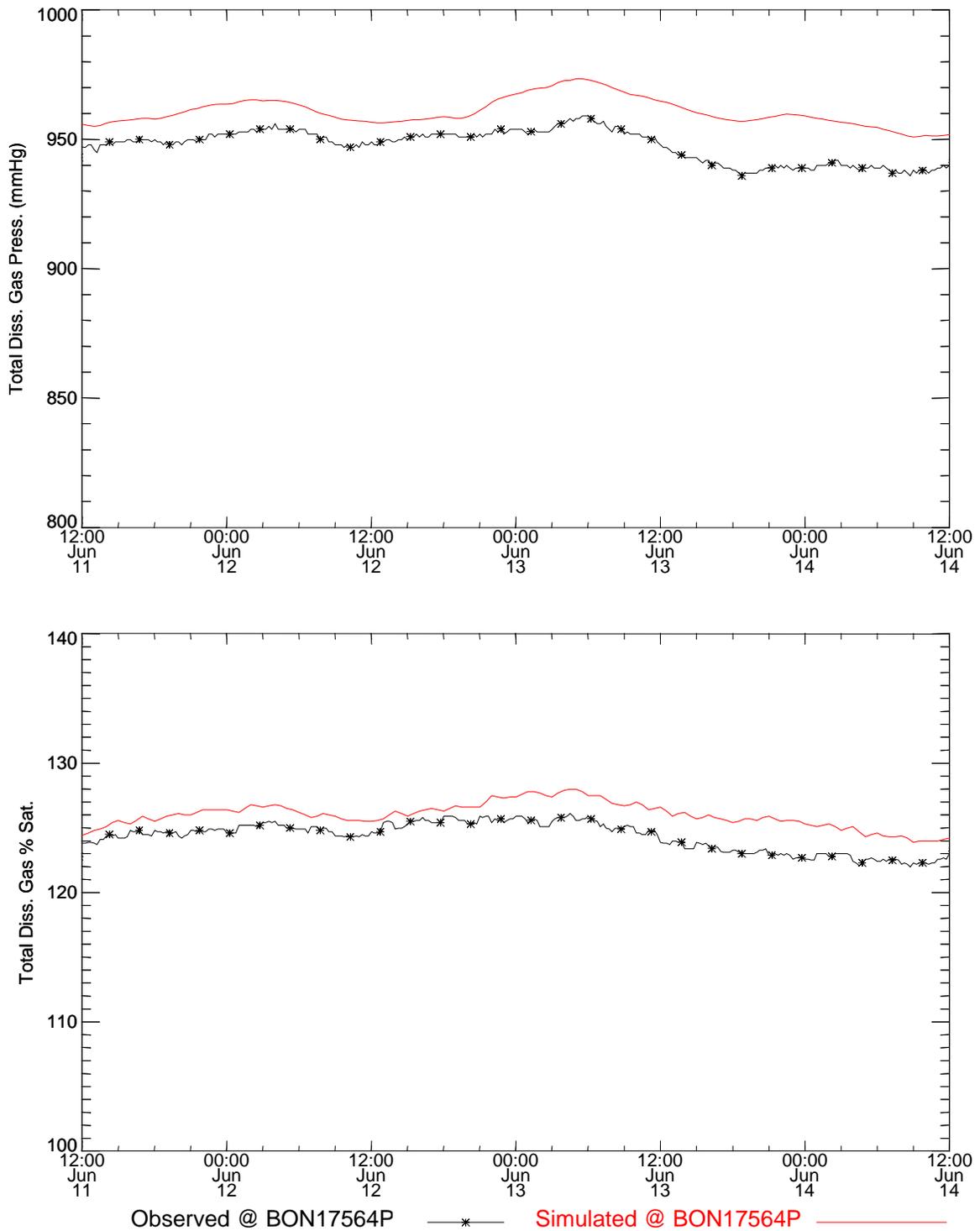


Figure 88. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 175.6 for the Spring 1996 study period (TM-BC).

Table 29. Statistical summary of measurements and simulations near the Columbia River Mile 175.6 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON17564P	15.03	15.05	0.1	0.11	0.05
Concentration BON17564P	34.6	35	0.23	0.17	0.43
Gas Pressure BON17564P	947.61	960.7	6.21	5.43	13.76
% Saturation BON17564P	124.33	126	1.13	0.97	1.78

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 175.6 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON17564P	100	100	100	100

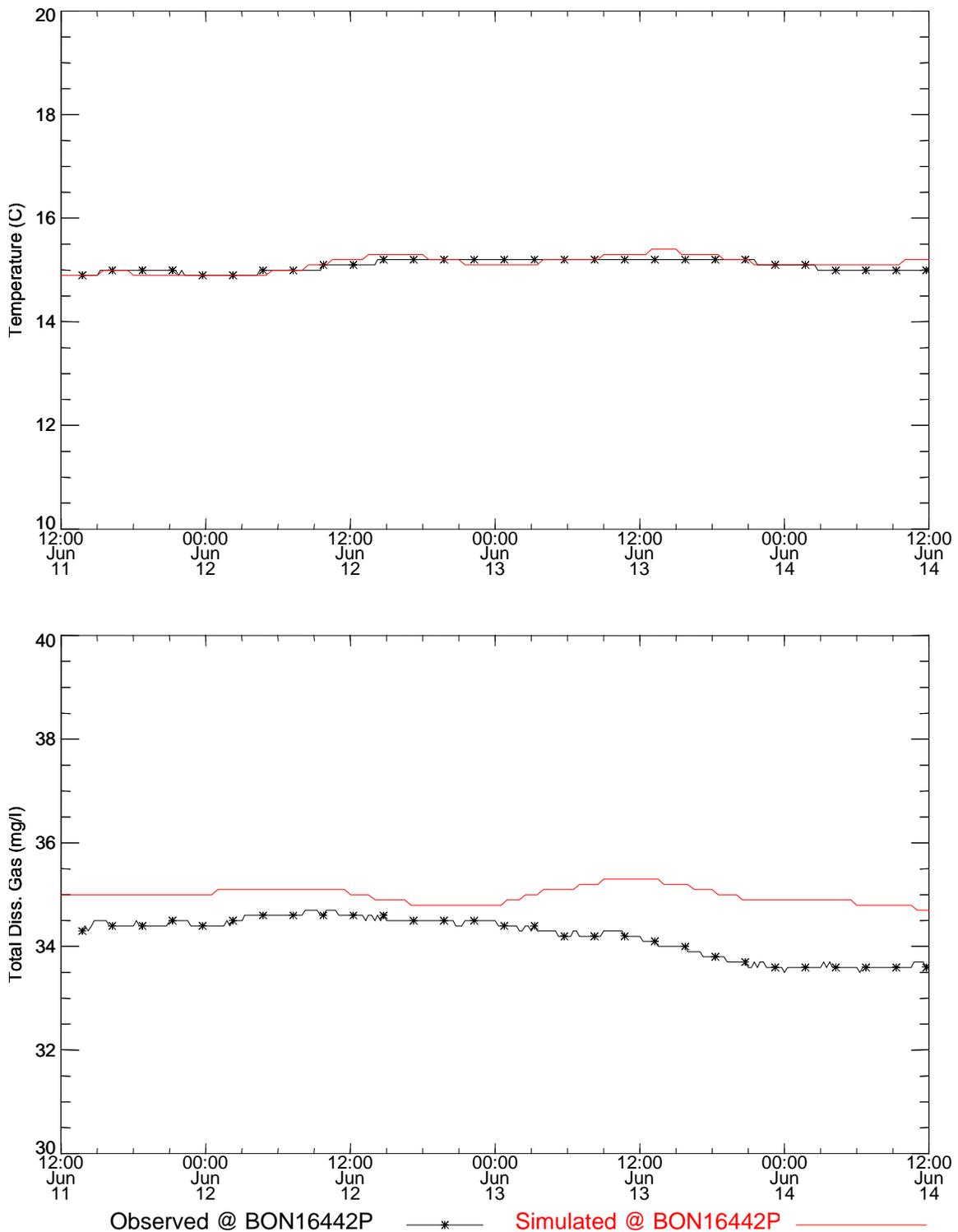


Figure 89. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 164.4 for the Spring 1996 study period (TM-BC).

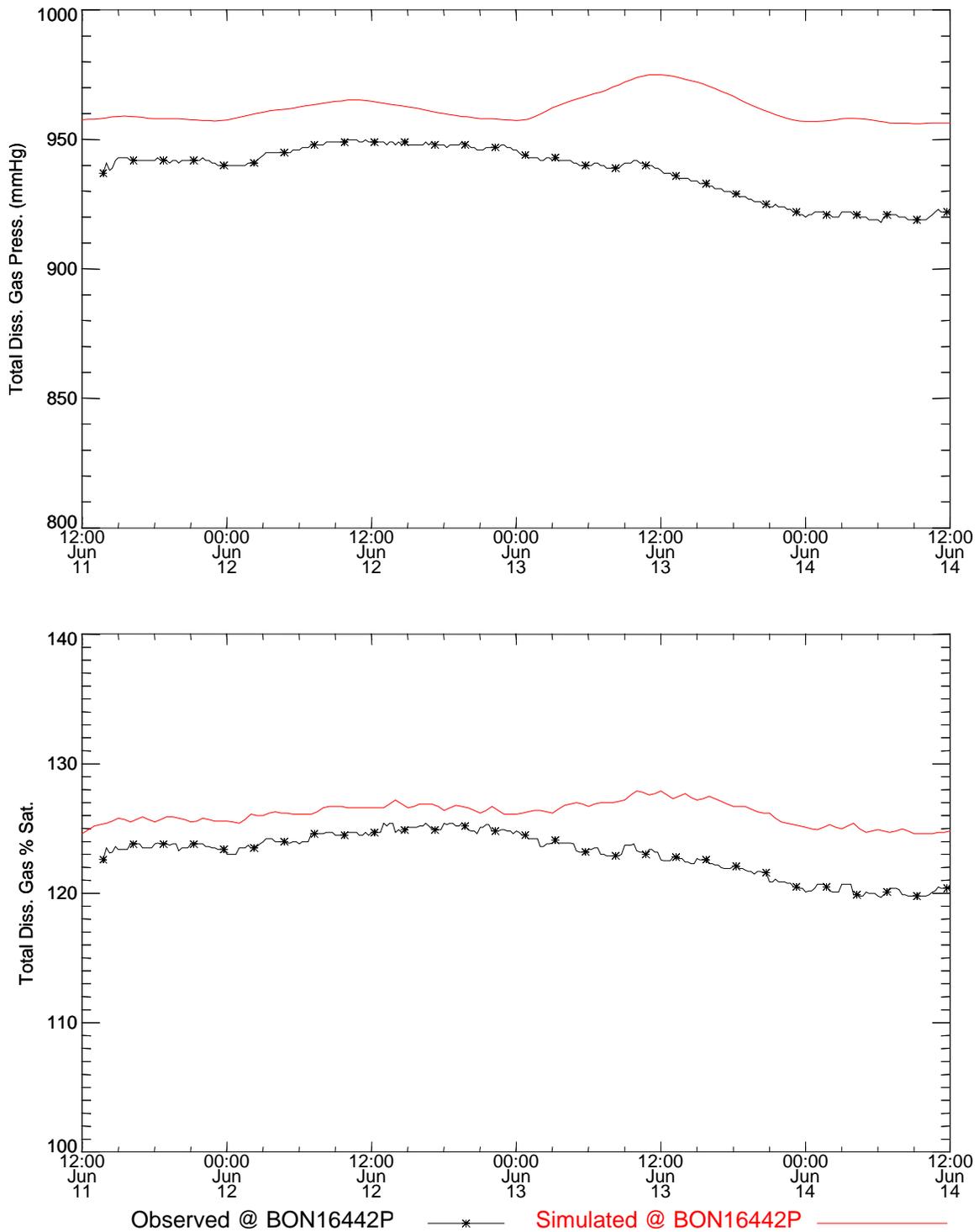


Figure 90. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 164.4 for the Spring 1996 study period (TM-BC).

Table 31. Statistical summary of measurements and simulations near the Columbia River Mile 164.4 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON16442P	15.09	15.12	0.11	0.14	0.09
Concentration BON16442P	34.2	34.99	0.38	0.15	0.87
Gas Pressure BON16442P	937.58	961.91	10.16	5.28	26.42
% Saturation BON16442P	123.03	126.17	1.69	0.84	3.44

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 164.4 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON16442P	100	64.18	92.55	91.49

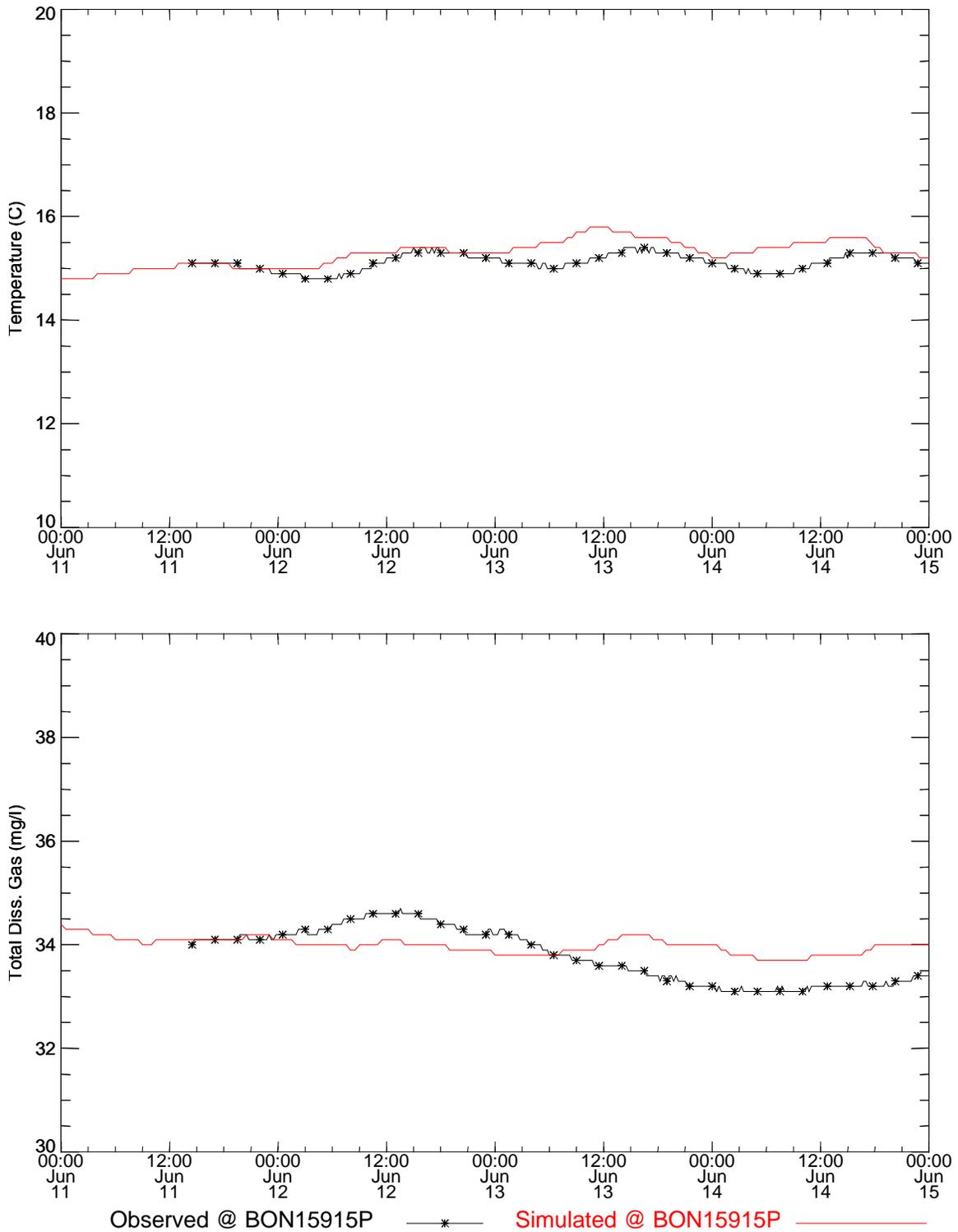


Figure 91. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 159.1 for the Spring 1996 study period (TM-BC).

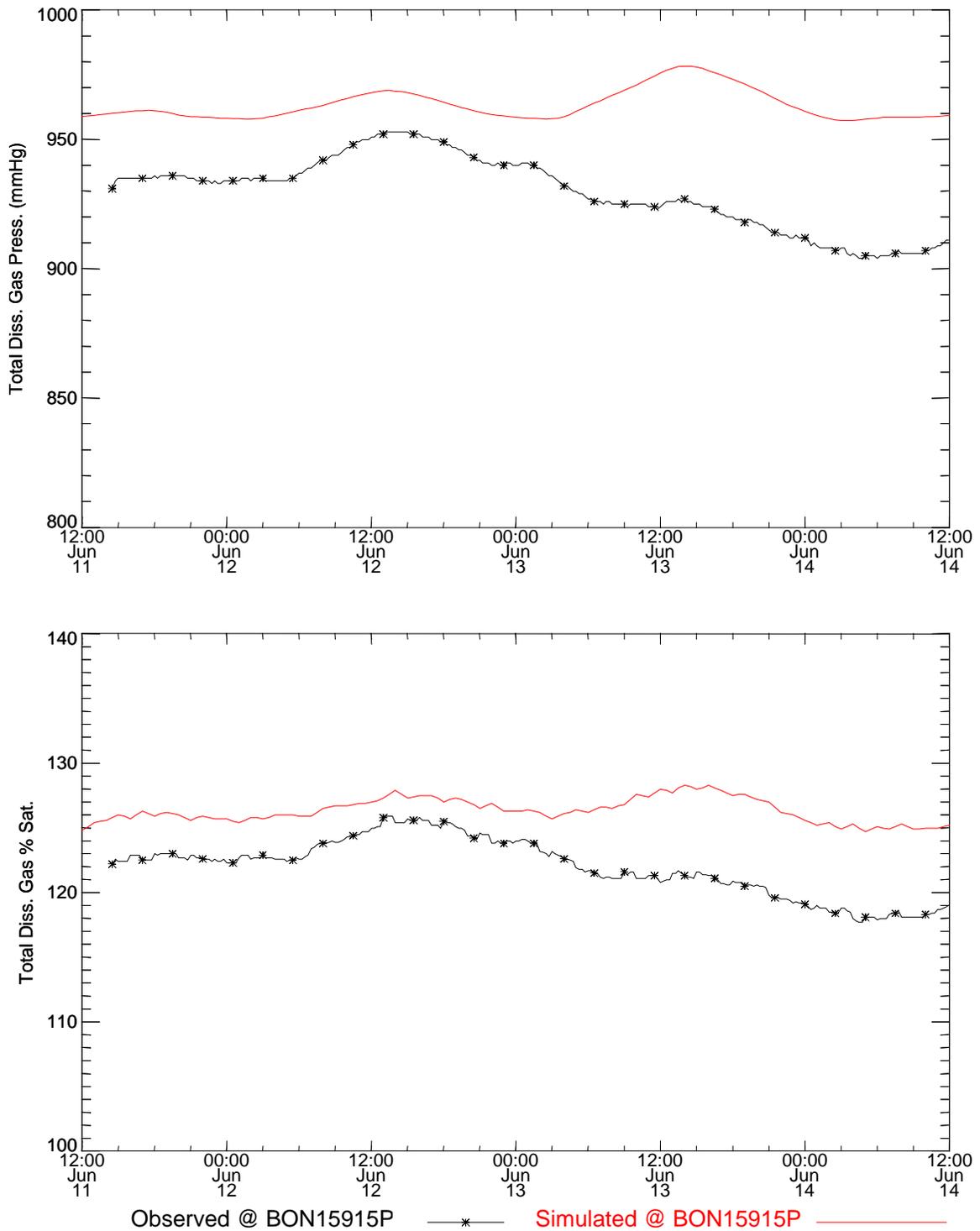


Figure 92. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 159.1 for the Spring 1996 study period (TM-BC).

Table 33. Statistical summary of measurements and simulations near the Columbia River Mile 159.1 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON15915P	15.1	15.13	0.16	0.18	0.09
Concentration BON15915P	33.88	35.04	0.51	0.14	1.26
Gas Pressure BON15915P	929.59	963.48	14.16	5.88	36.99
% Saturation BON15915P	121.98	126.39	2.23	0.92	4.82

Table 34. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 159.1 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON15915P	100	55.4	57.55	57.91

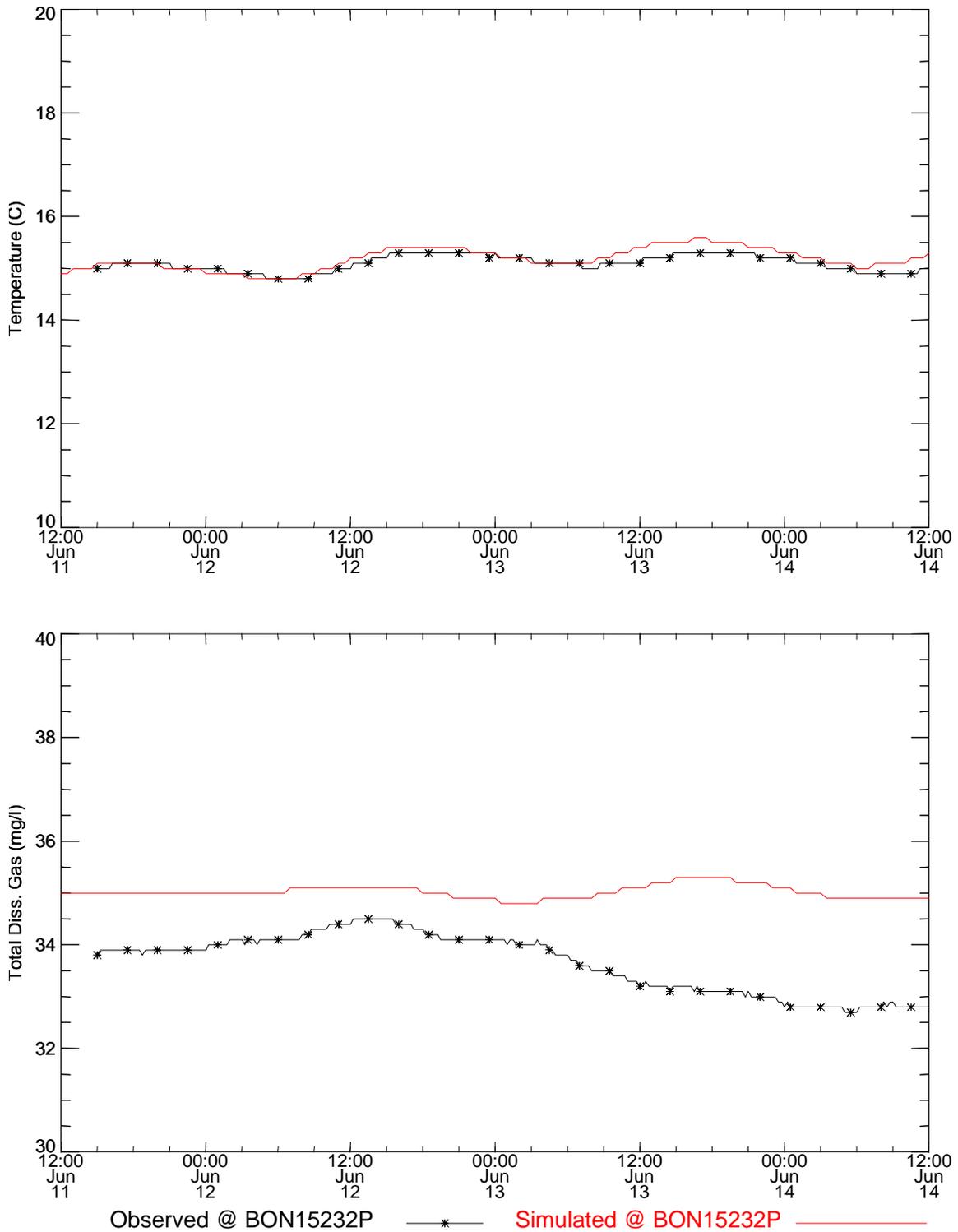


Figure 93. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 152.3 for the Spring 1996 study period (TM-BC).

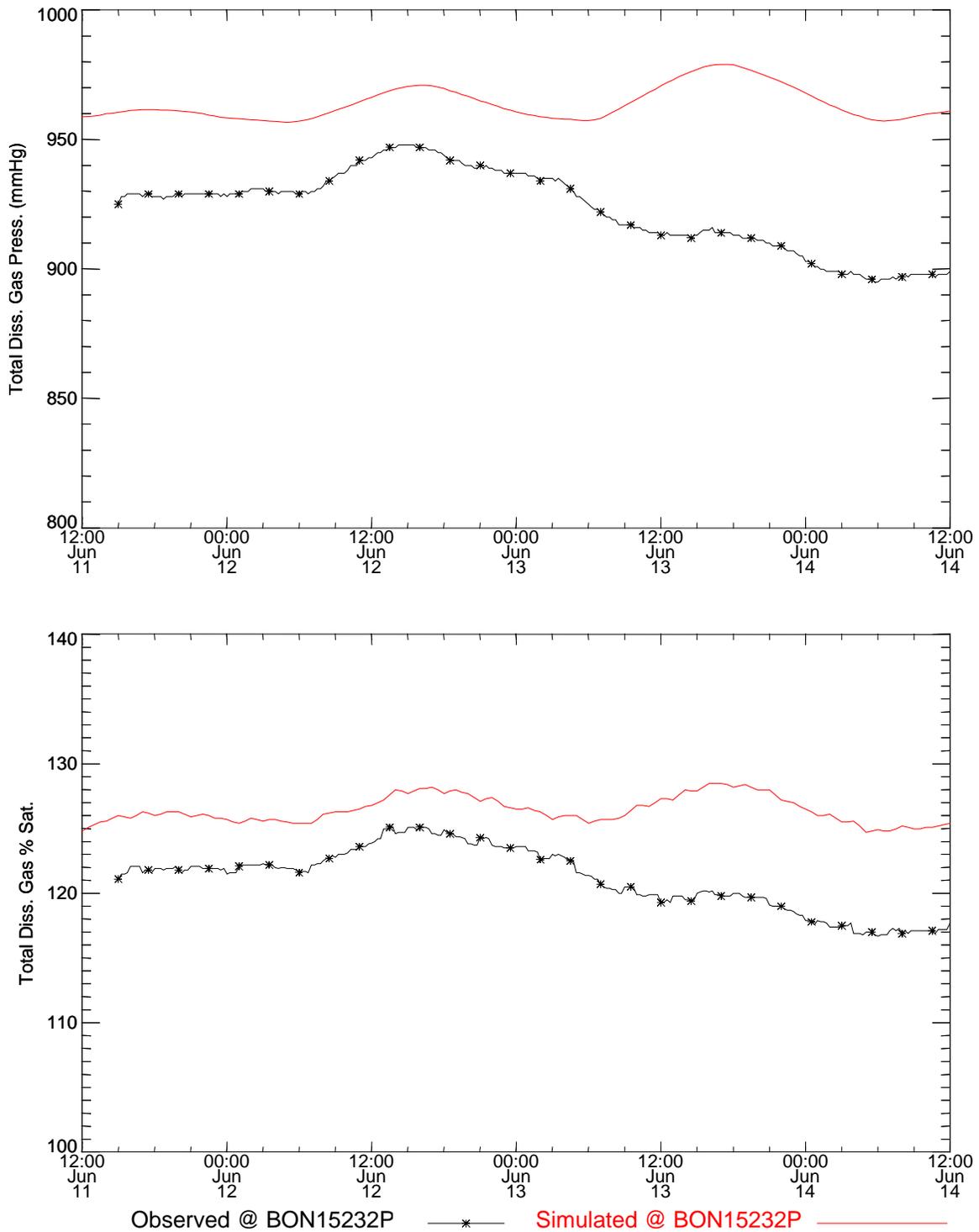


Figure 94. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 152.3 for the Spring 1996 study period (TM-BC).

Table 35. Statistical summary of measurements and simulations near the Columbia River Mile 152.3 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON15232P	15.1	15.19	0.15	0.21	0.14
Concentration BON15232P	33.65	35.02	0.57	0.12	1.5
Gas Pressure BON15232P	922.97	964.09	15.59	6.44	44.54
% Saturation BON15232P	121.11	126.47	2.42	1.02	5.81

Table 36. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 152.3 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON15232P	100	41.16	58.48	57.76

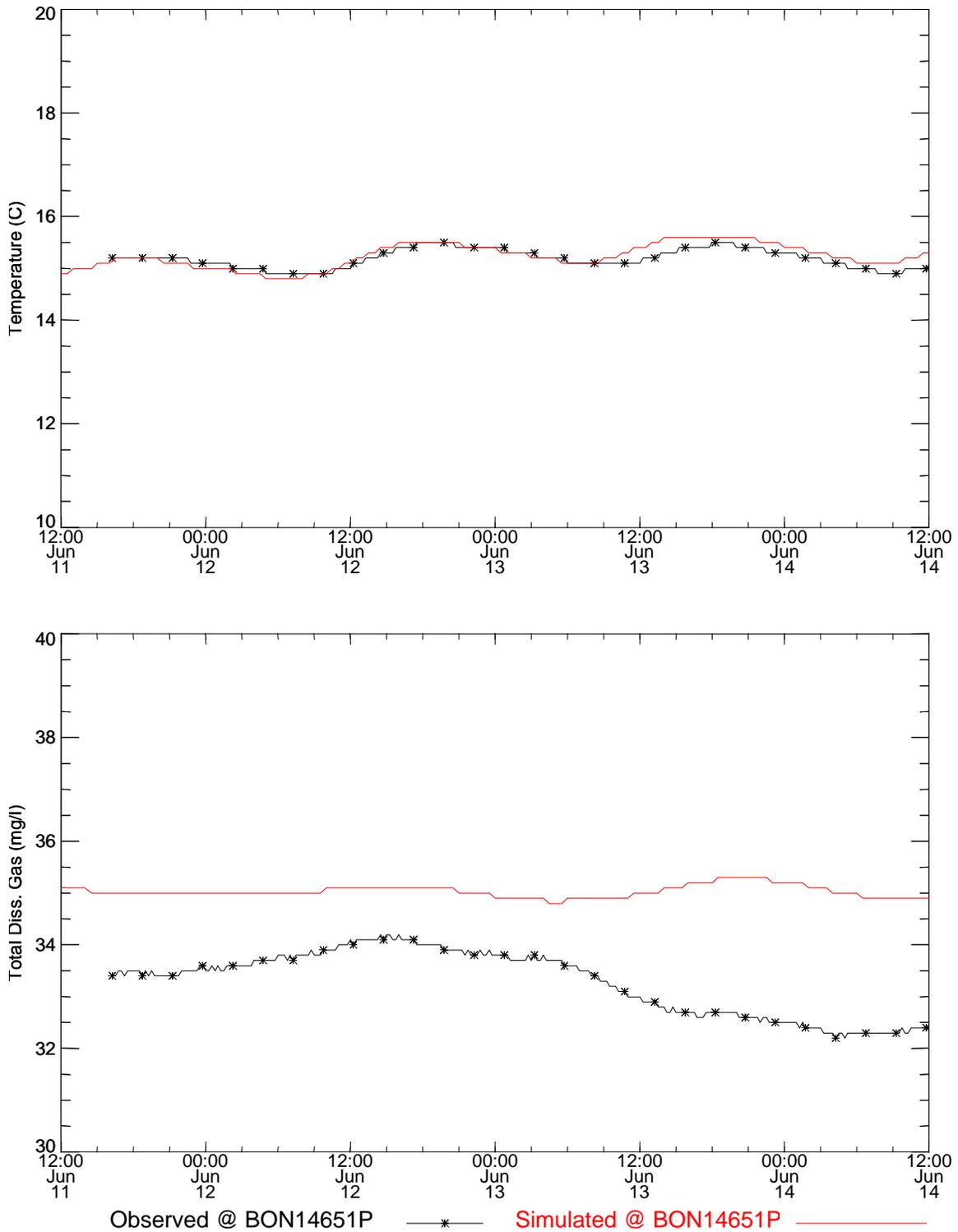


Figure 95. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 146.5 for the Spring 1996 study period (TM-BC).

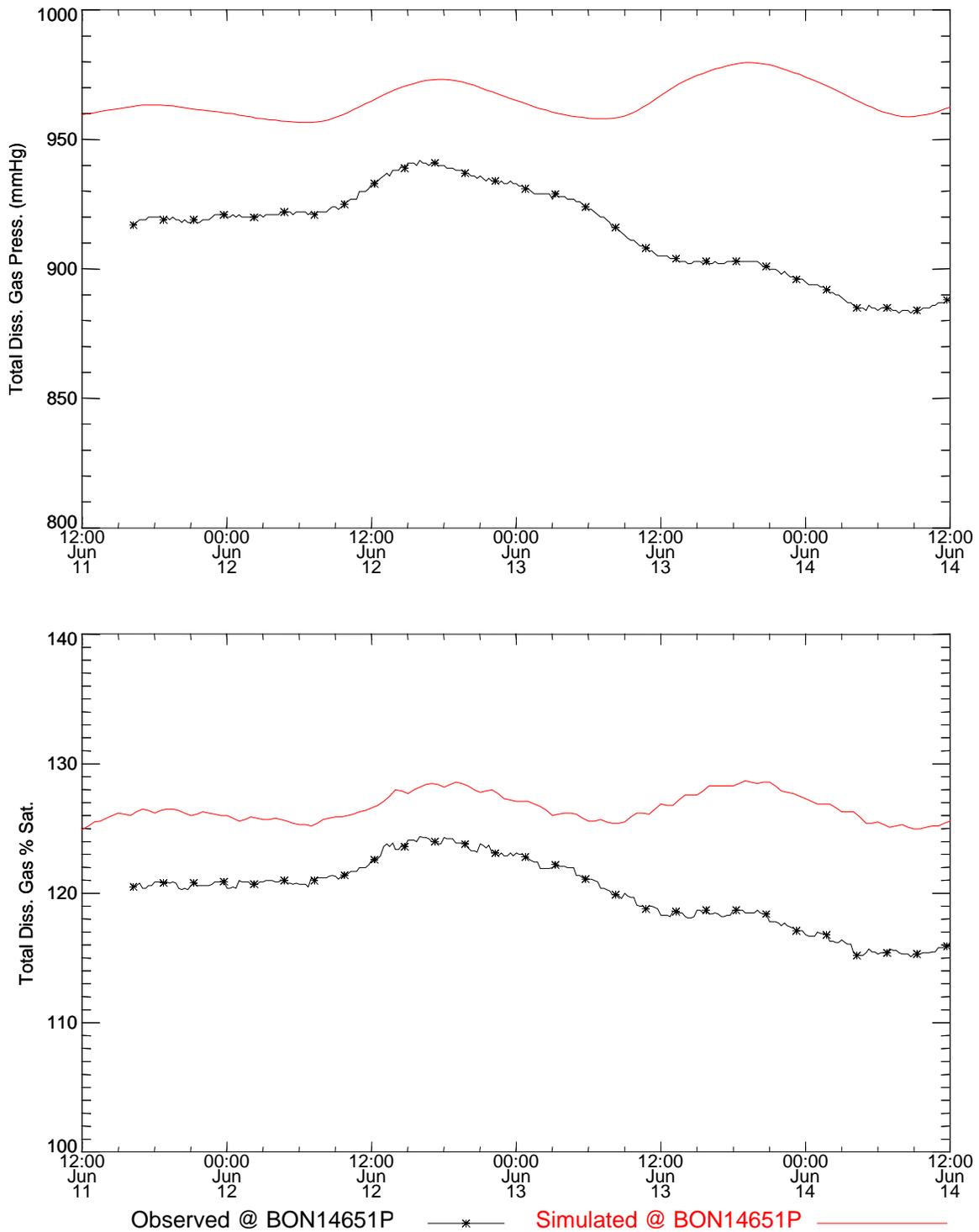


Figure 96. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 146.5 for the Spring 1996 study period (TM-BC).

Table 37. Statistical summary of measurements and simulations near the Columbia River Mile 146.5 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON14651P	15.19	15.25	0.18	0.23	0.13
Concentration					
BON14651P	33.28	35.03	0.62	0.12	1.87
Gas Pressure					
BON14651P	914.49	965.49	17.21	6.82	54.47
% Saturation					
BON14651P	120	126.65	2.63	1.08	7.1

Table 38. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 146.5 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON14651P	100	7.72	41.54	43.01

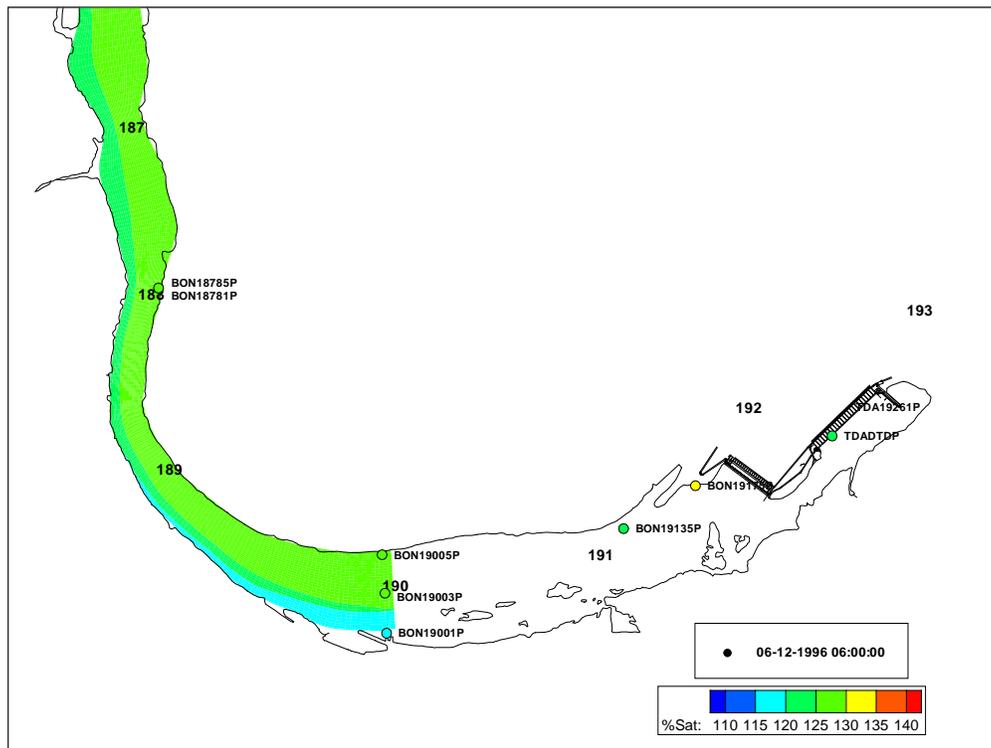


Figure 97. Spatial distribution of dissolved gas near Columbia river mile 190 during the Spring 1996 study period.

1.4.2 Summer 1996 Simulation

Boundary Conditions using The Dalles 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.

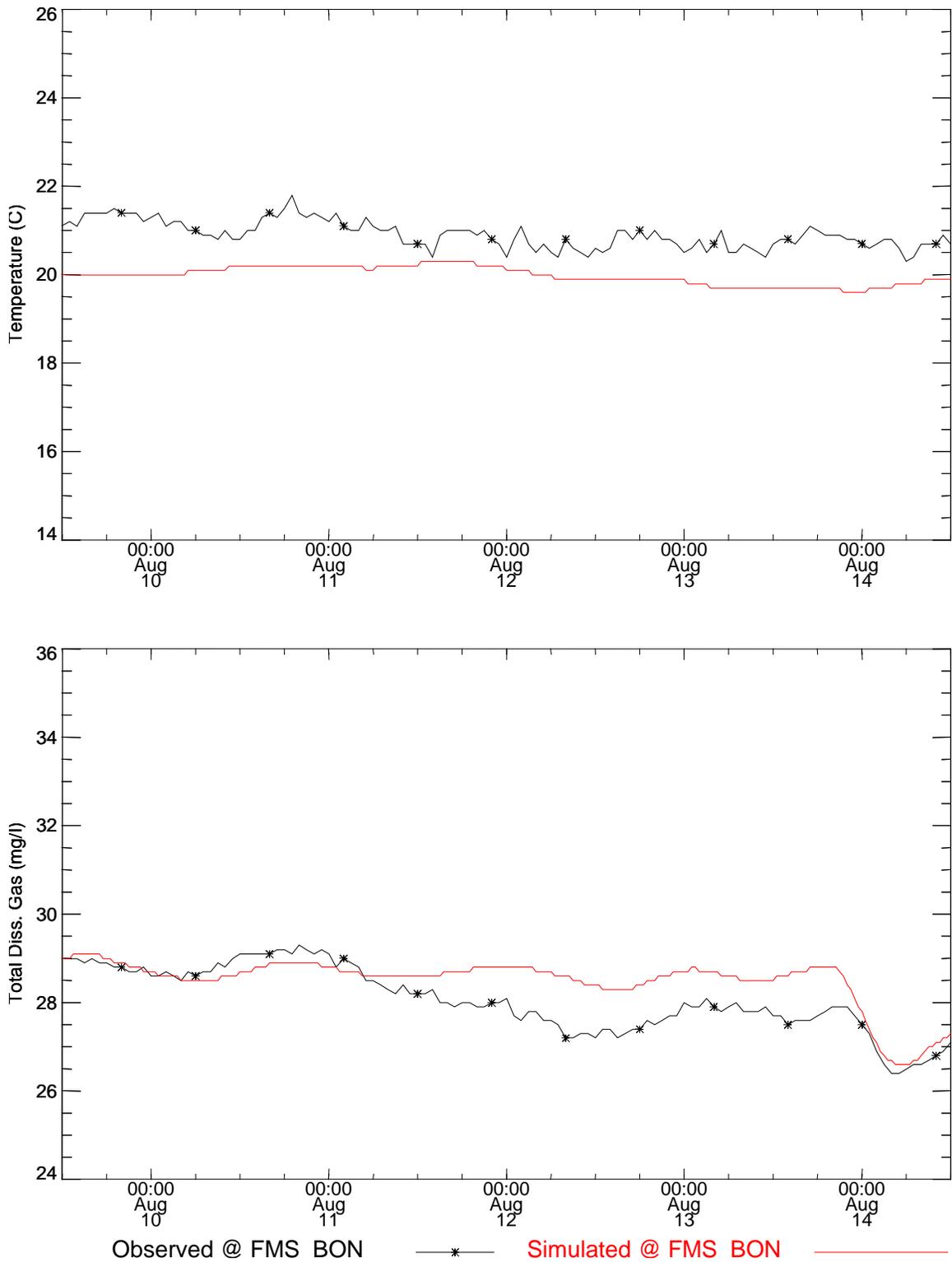


Figure 98. Temperature and total dissolved gas time series comparisons near the fixed monitor BON for the Summer 1996 study period (FMS-BC).

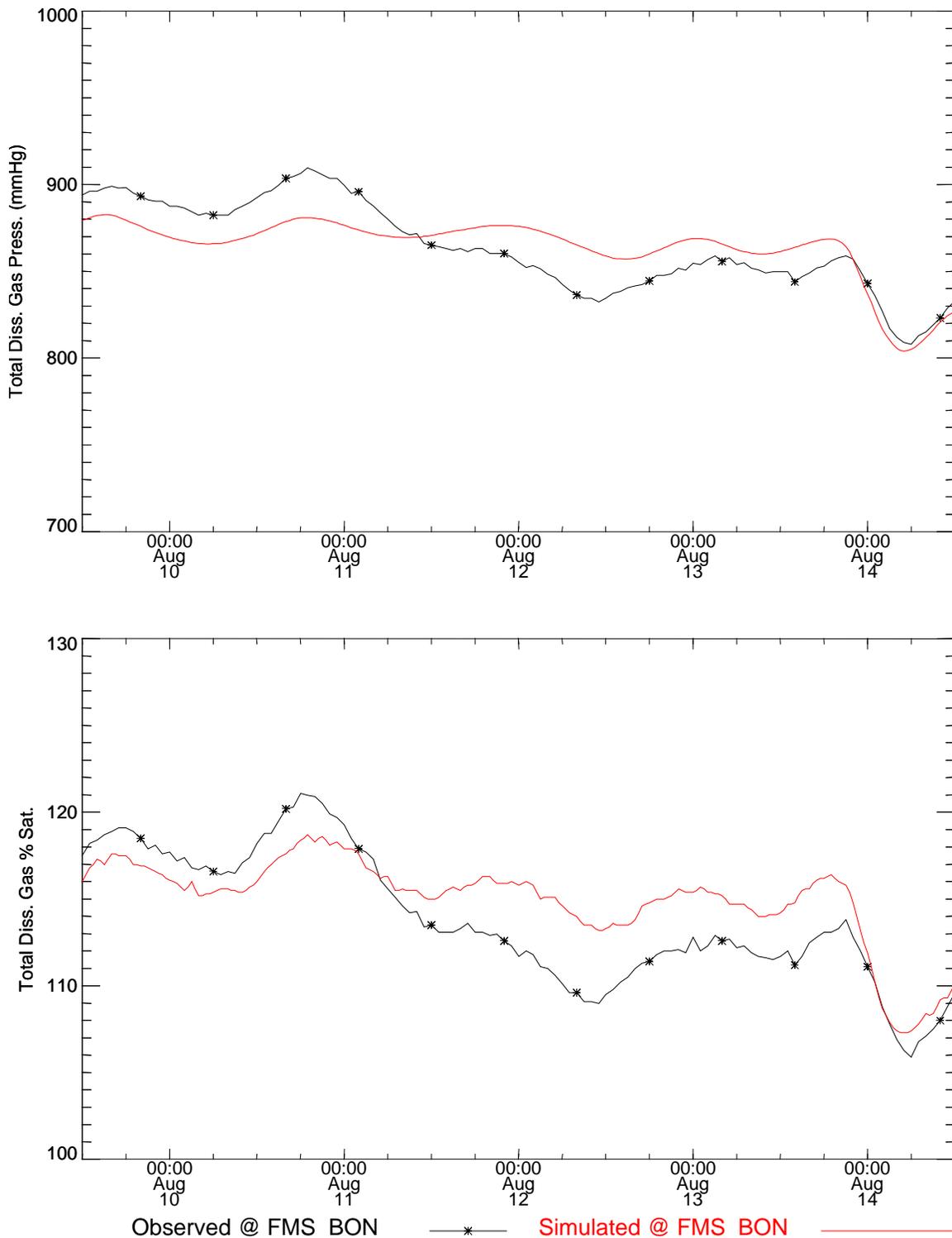


Figure 99. Total dissolved gas pressure and saturation time series comparisons near the fixed monitor BON for the Summer 1996 study period (FMS-BC).

Table 39. Statistical summary of measurements and simulations near the fixed monitor BON for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_BON	20.91	19.98	0.3	0.2	0.97
Concentration FMS_BON	28.07	28.5	0.73	0.56	0.66
Gas Pressure FMS_BON	863.98	864.04	25.57	18.01	16.74
% Saturation FMS_BON	113.83	114.99	3.76	2.5	2.49

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

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_BON	61.41	86.31	100	100

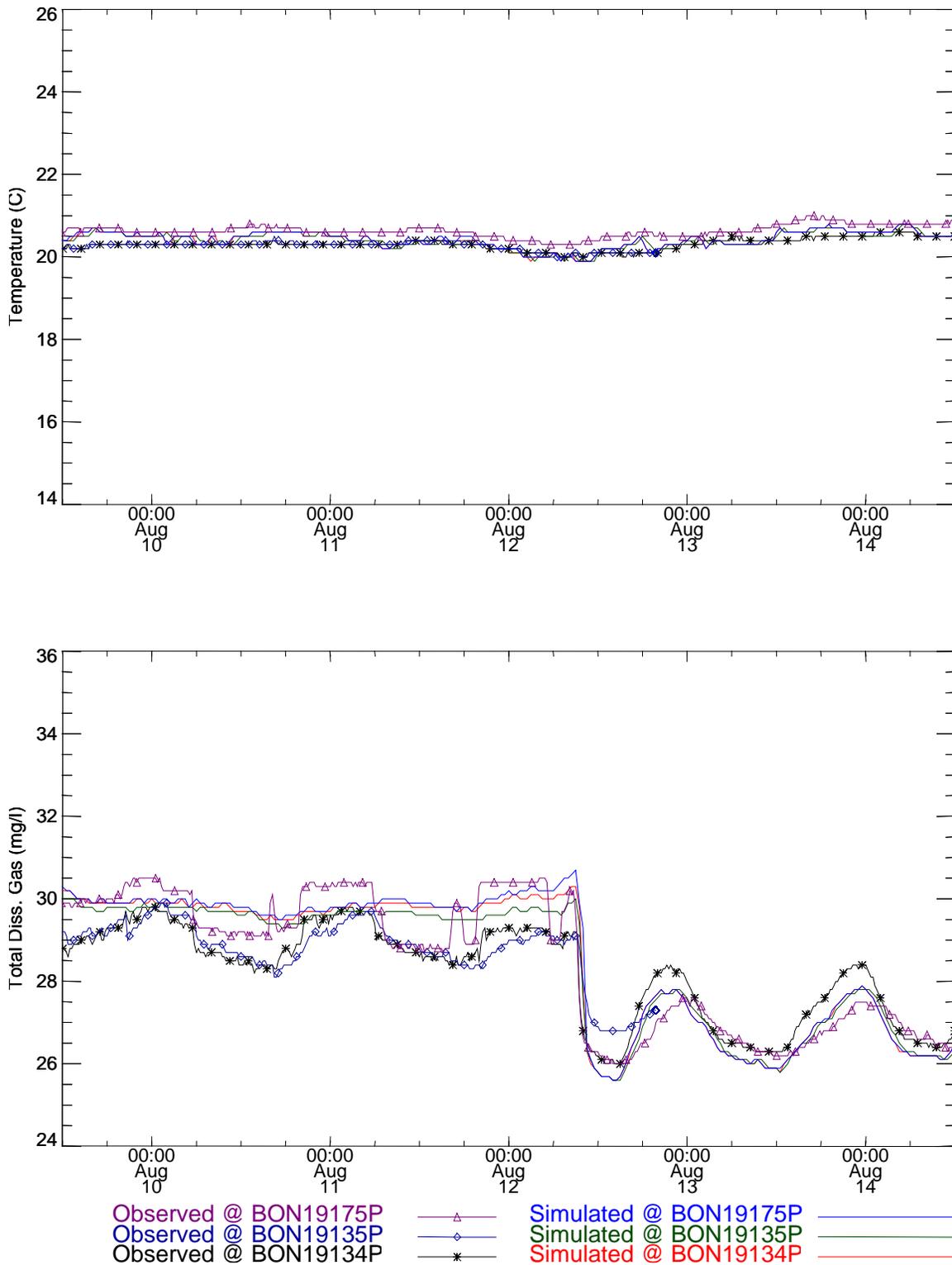


Figure 100. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 191.3 for the Summer 1996 study period (FMS-BC).

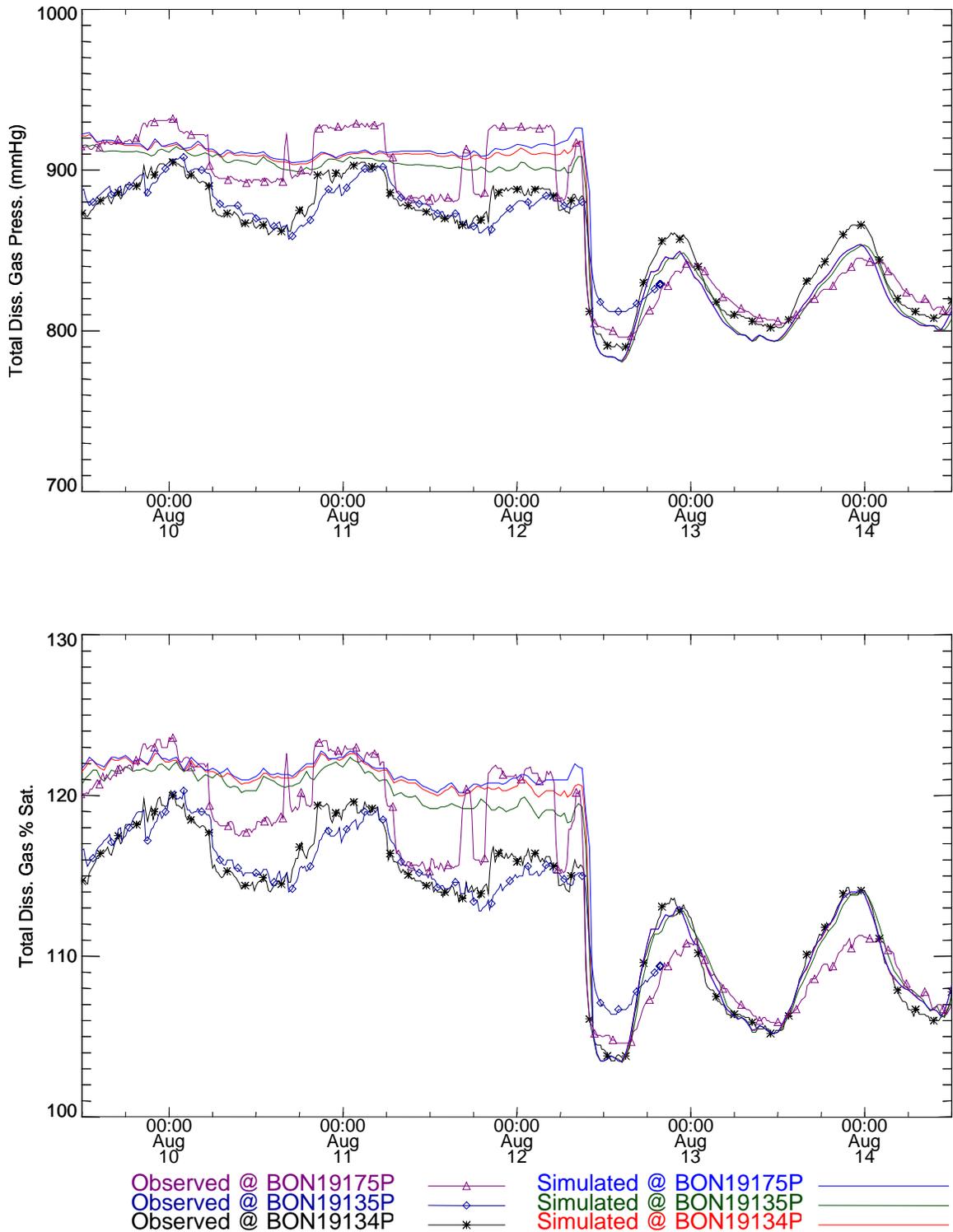


Figure 101. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 191.3 for the Summer 1996 study period (FMS-BC).

Table 41. Statistical summary of measurements and simulations near the Columbia River Mile 191.3 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON19134P	20.31	20.41	0.14	0.2	0.18
BON19135P	20.2	20.4	0.12	0.19	0.28
BON19175P	20.63	20.42	0.15	0.2	0.24
Concentration					
BON19134P	28.21	28.52	1.15	1.64	0.75
BON19135P	28.27	28.41	0.93	1.55	0.79
BON19175P	28.49	28.57	1.59	1.67	0.57
Gas Pressure					
BON19134P	858.53	871.38	33.65	48.64	24.3
BON19135P	858.91	868.09	28.72	46.19	24.04
BON19175P	872.26	872.78	46.85	49.5	16.32
% Saturation					
BON19134P	113.11	115.97	4.63	6.55	3.89
BON19135P	113.25	115.53	3.84	6.25	3.81
BON19175P	114.91	116.15	6.34	6.65	2.45

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 191.3 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON19134P	100	77.59	86.72	71.78
BON19135P	100	78.84	97.51	83.82
BON19175P	100	92.53	99.17	94.61

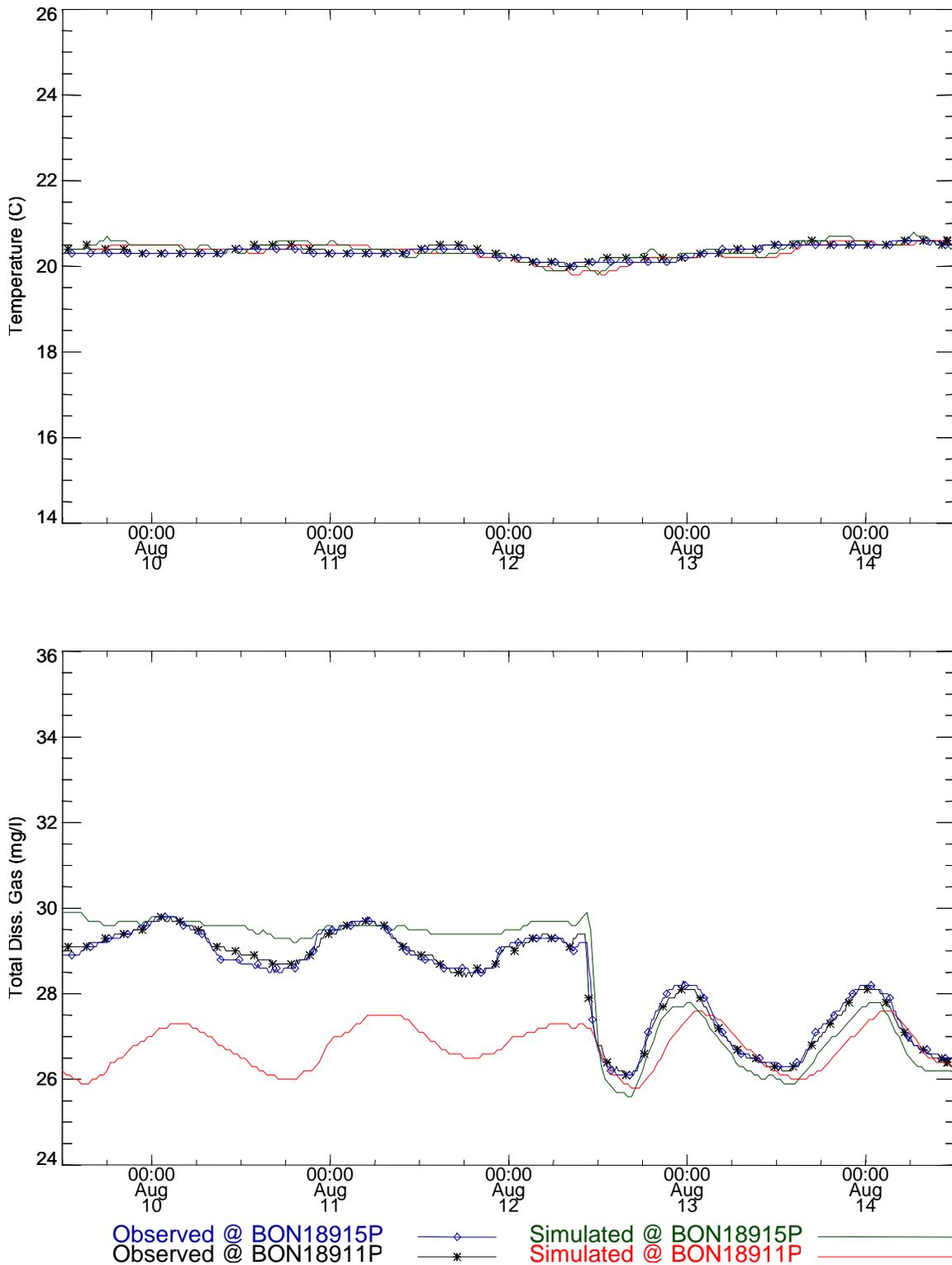


Figure 102. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 189.1 for the Summer 1996 study period (FMS-BC).

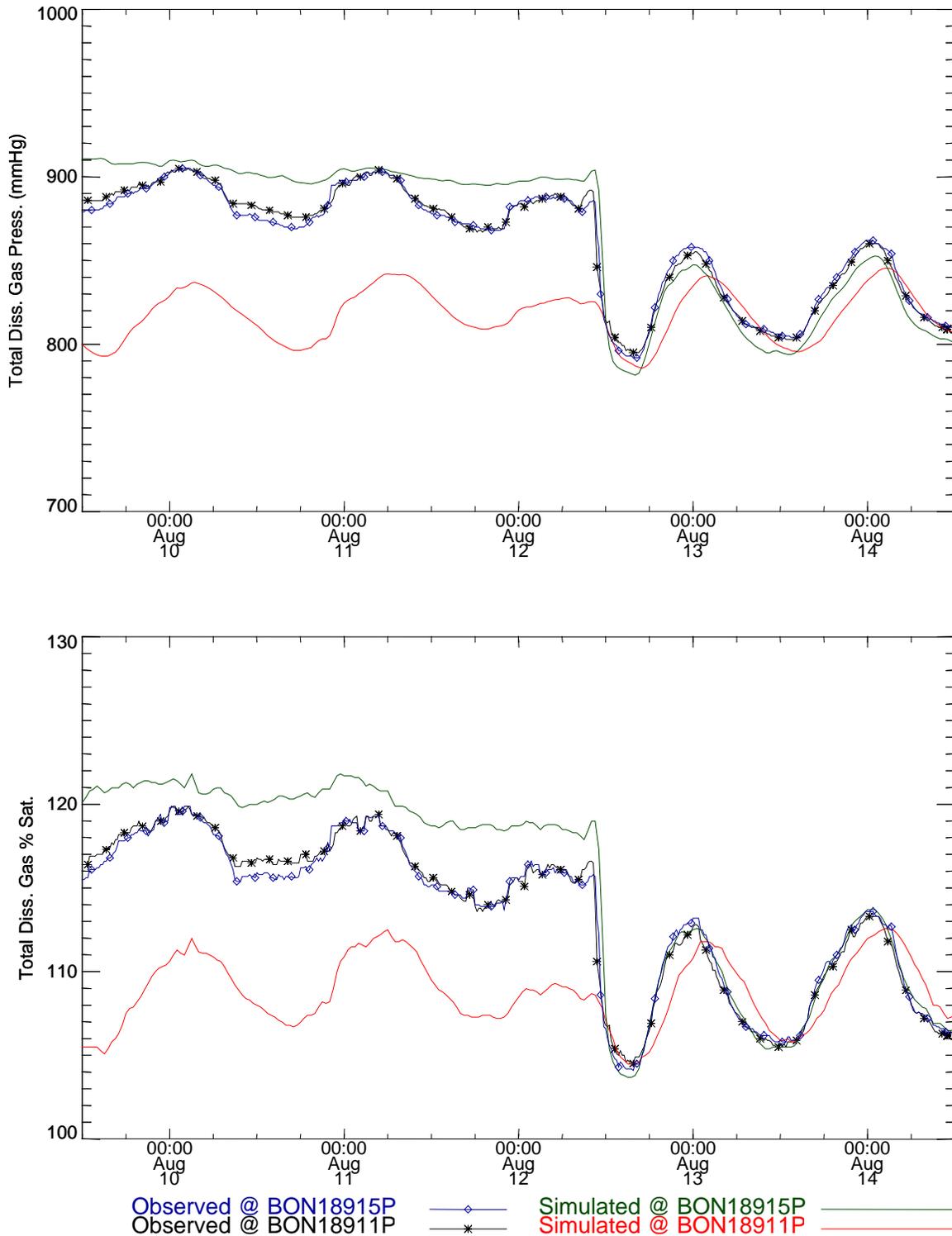


Figure 103. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 189.1 for the Summer 1996 study period (FMS-BC).

Table 43. Statistical summary of measurements and simulations near the Columbia River Mile 189.1 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON18911P	20.36	20.33	0.14	0.2	0.14
BON18915P	20.33	20.38	0.14	0.2	0.15
Concentration					
BON18911P	28.29	26.76	1.16	0.51	1.87
BON18915P	28.3	28.41	1.13	1.48	0.52
Gas Pressure					
BON18911P	861.76	817.78	33.81	15.51	54.07
BON18915P	861.4	867.59	32.91	43.94	16.08
% Saturation					
BON18911P	113.53	108.83	4.6	2.12	6.36
BON18915P	113.49	115.46	4.47	5.9	2.72

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 189.1 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON18911P	100	39.42	41.08	41.91
BON18915P	100	99.59	100	100

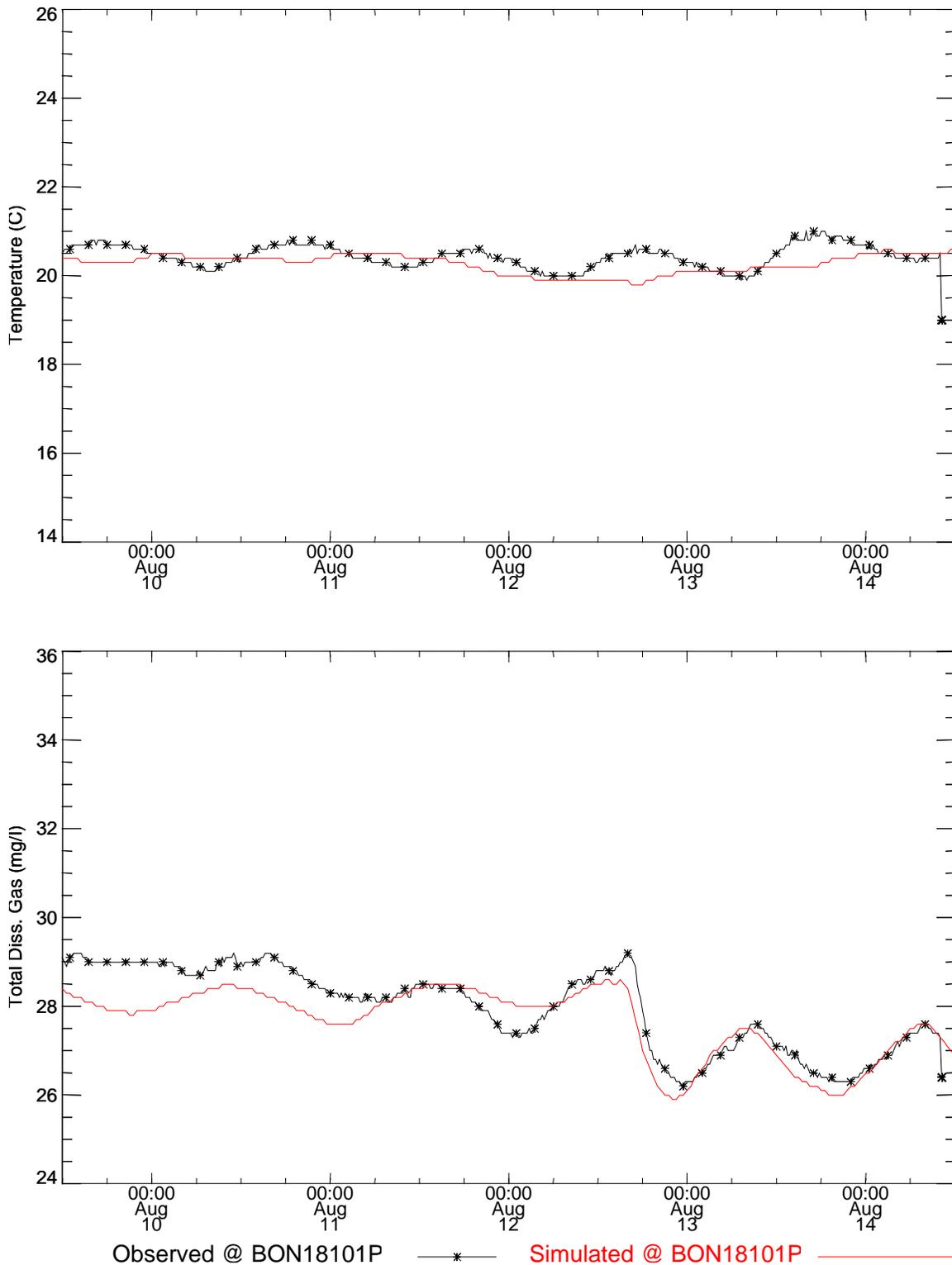


Figure 104. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 181.0 for the Summer 1996 study period (FMS-BC).

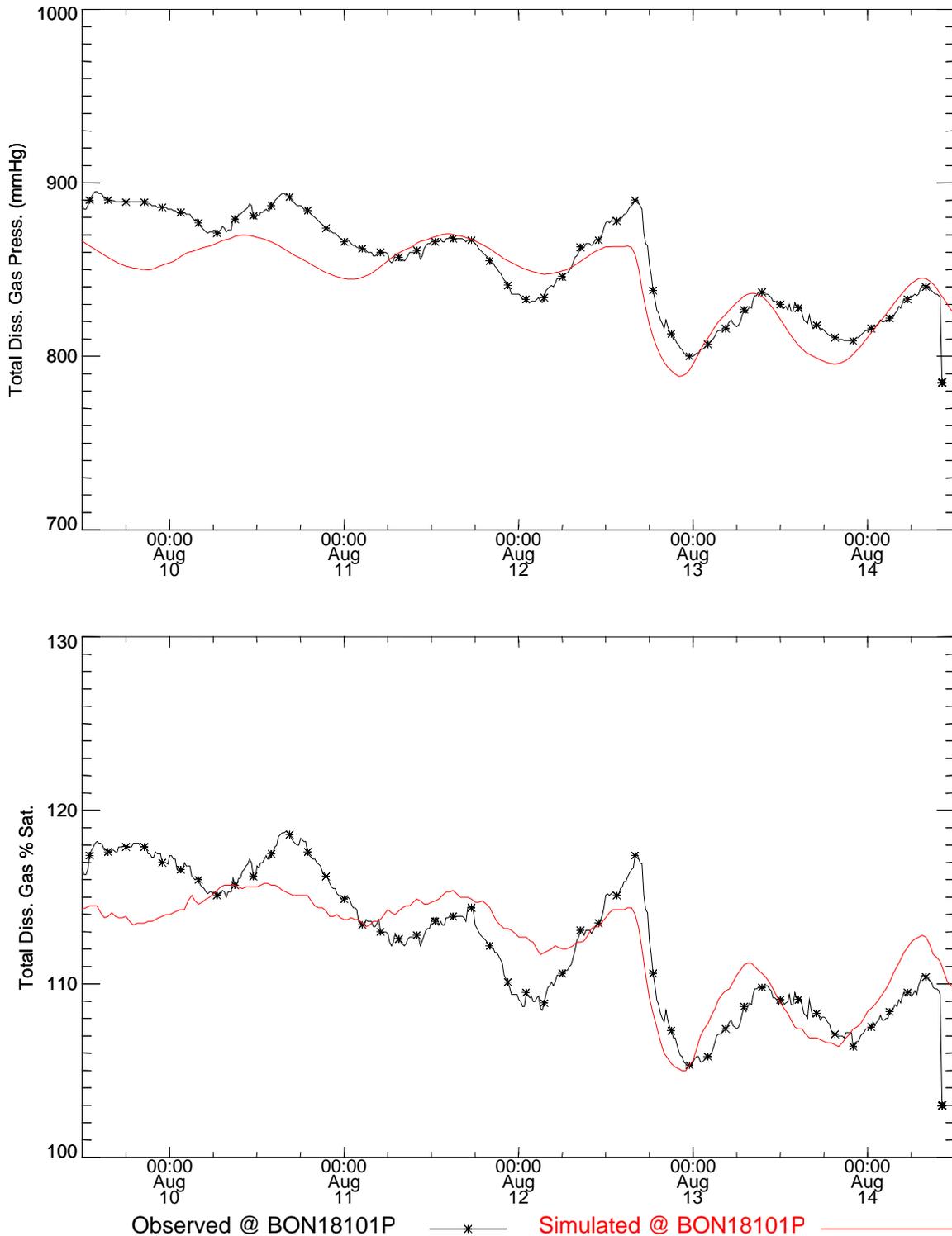


Figure 105. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 181.0 for the Summer 1996 study period (FMS-BC).

Table 45. Statistical summary of measurements and simulations near the Columbia River Mile 181.0 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON18101P	20.42	20.27	0.31	0.21	0.38
Concentration BON18101P	27.95	27.65	0.94	0.77	0.56
Gas Pressure BON18101P	852.51	843.33	28.88	23.05	19.01
% Saturation BON18101P	112.32	112.23	4.05	2.98	2.33

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 181.0 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON18101P	98.34	93.78	96.27	98.34

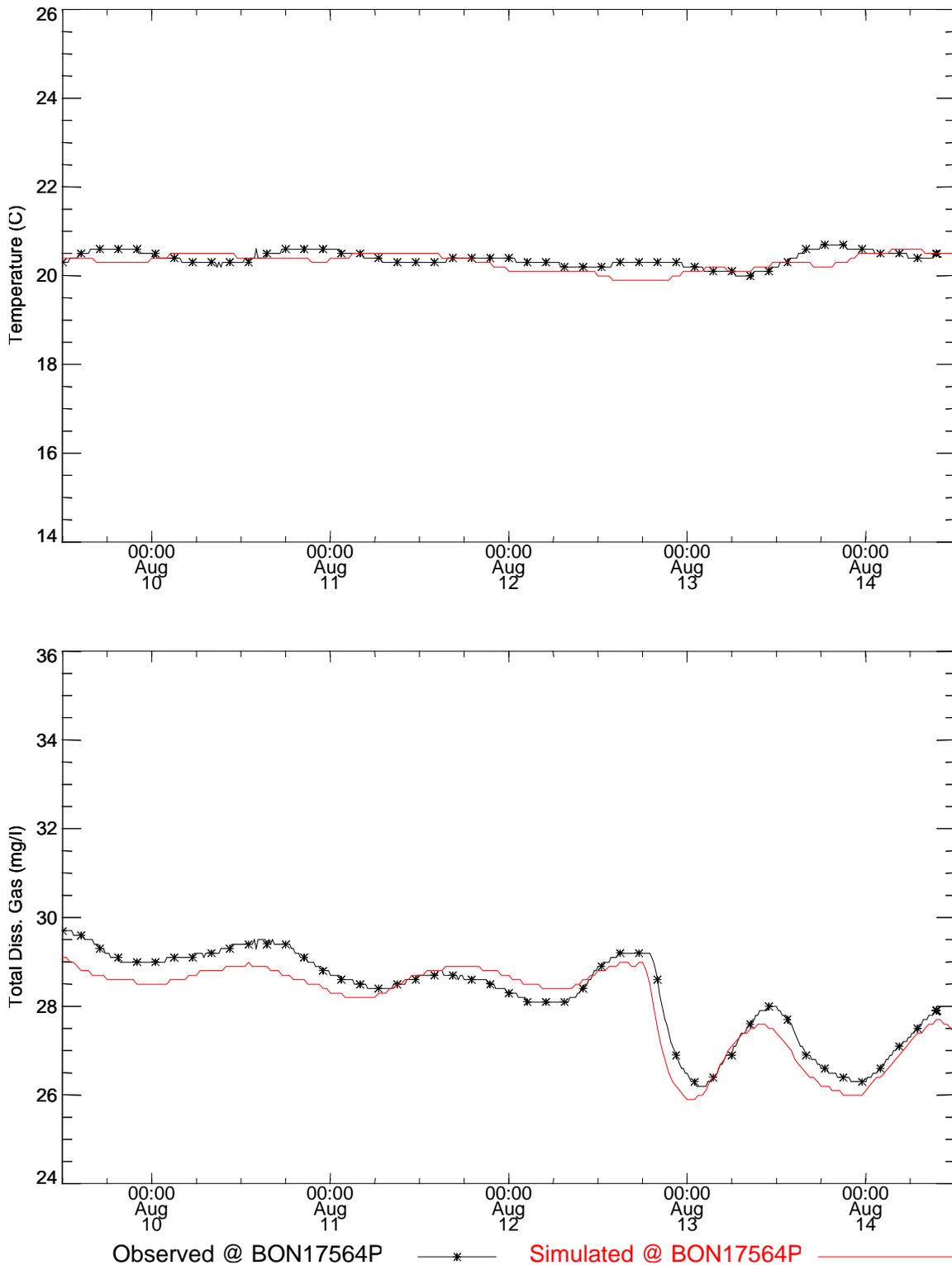


Figure 106. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 175.6 for the Summer 1996 study period (FMS-BC).

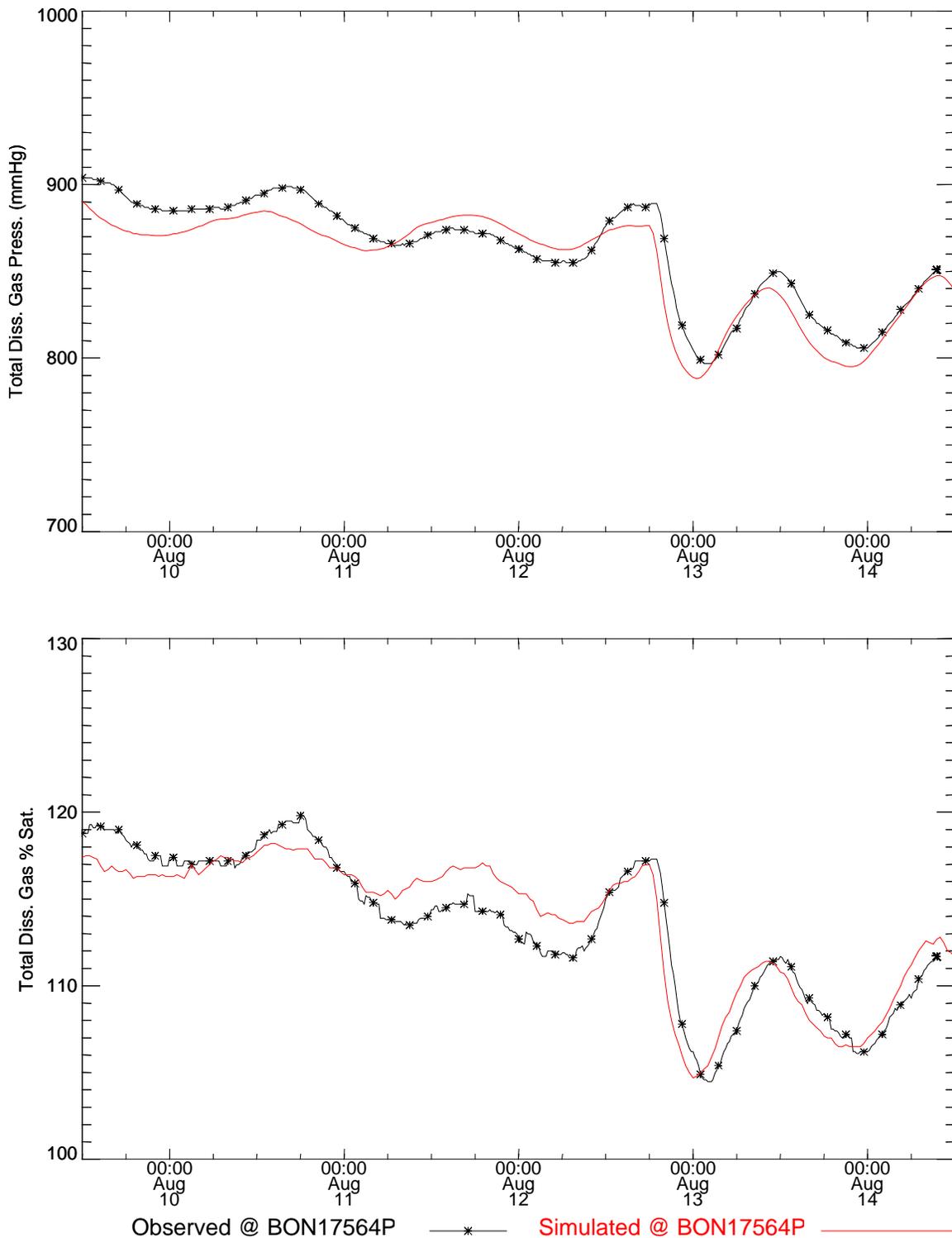


Figure 107. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 175.6 for the Summer 1996 study period (FMS-BC).

Table 47. Statistical summary of measurements and simulations near the Columbia River Mile 175.6 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON17564P	20.39	20.31	0.16	0.19	0.21
Concentration BON17564P	28.27	28.02	0.98	0.97	0.41
Gas Pressure BON17564P	861.66	854.87	29.48	29.36	12.58
% Saturation BON17564P	113.52	113.76	4.11	3.86	1.51

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 175.6 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON17564P	100	99.59	100	100

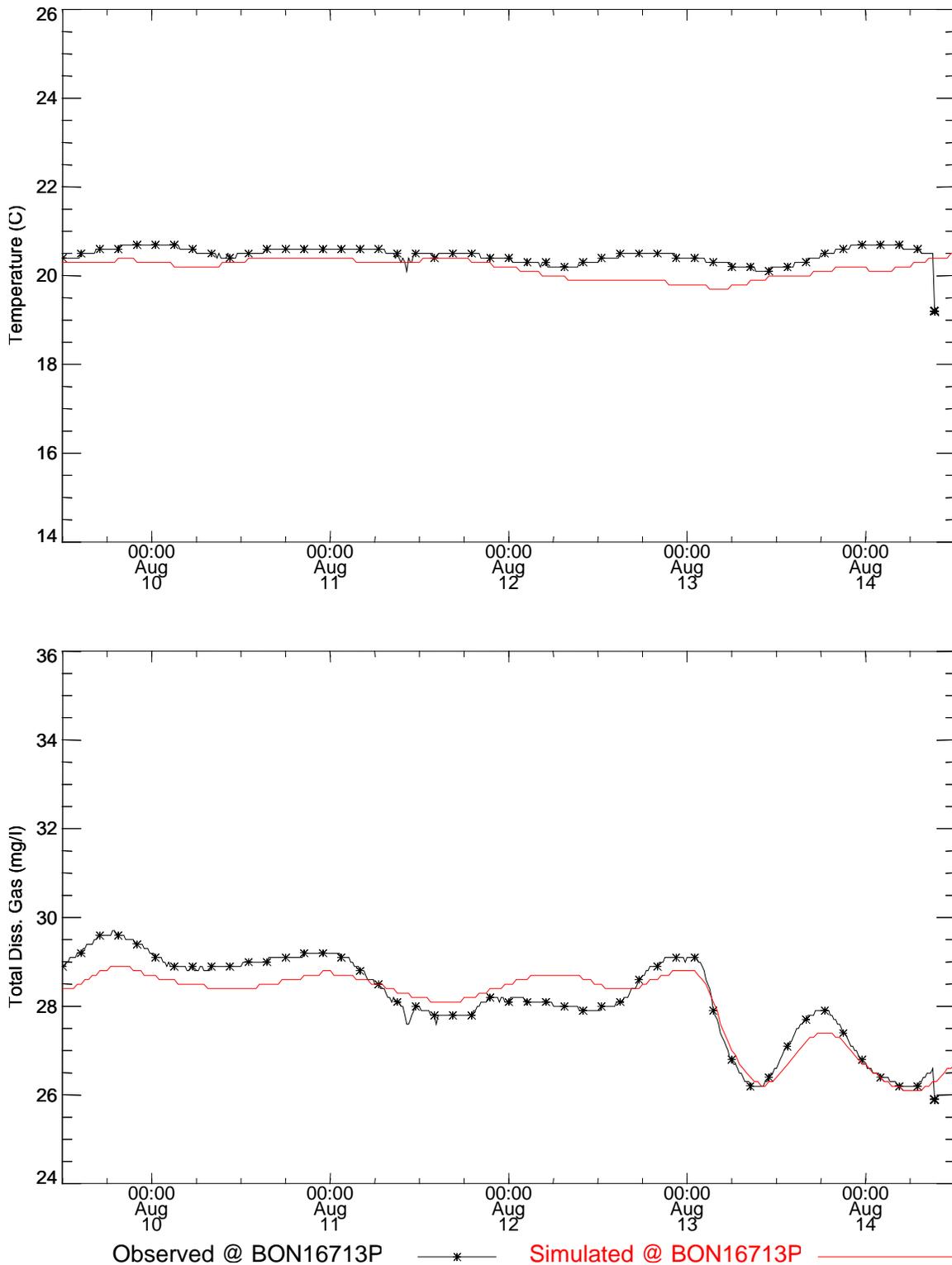


Figure 108. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 167.1 for the Summer 1996 study period (FMS-BC).

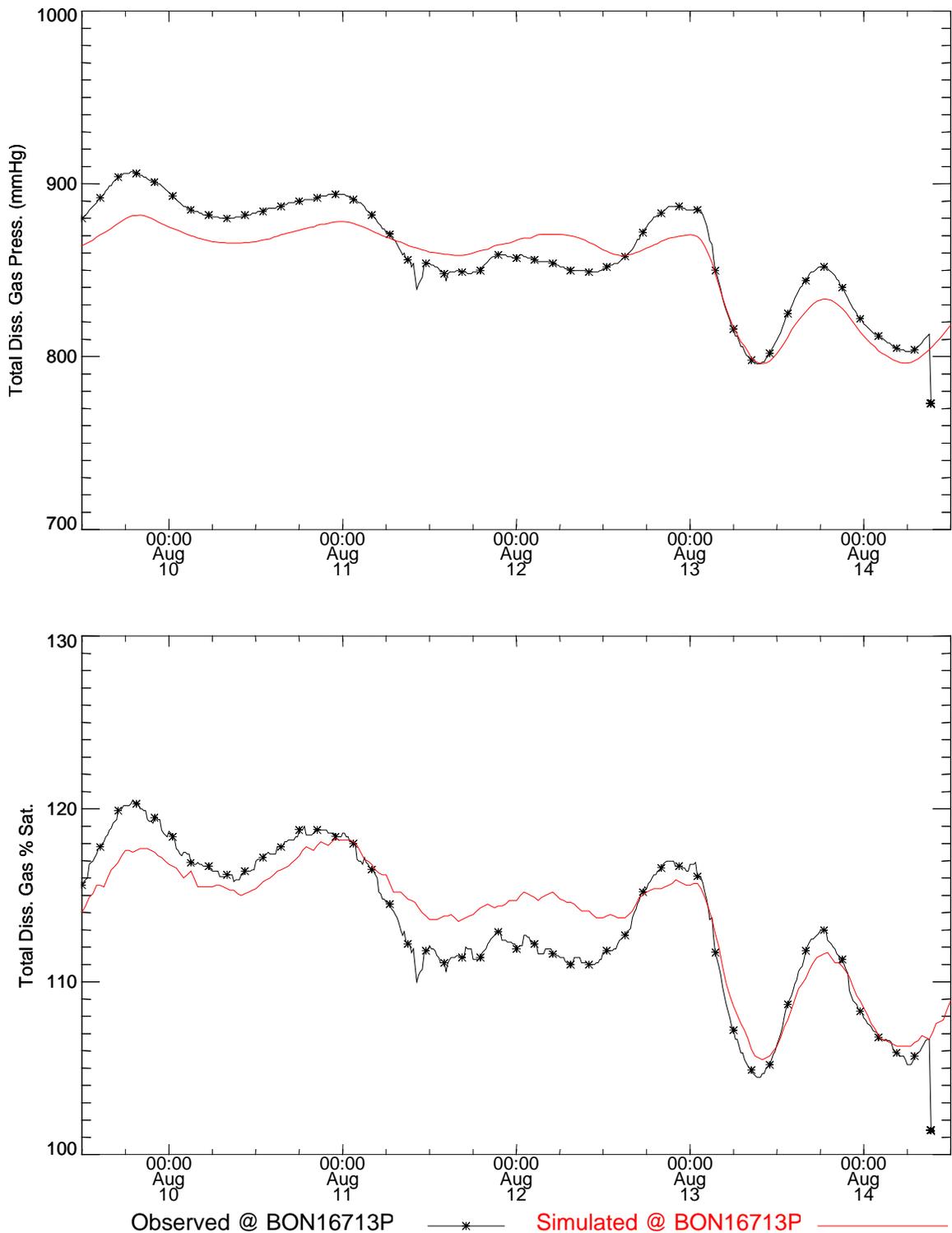


Figure 109. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 167.1 for the Summer 1996 study period (FMS-BC).

Table 49. Statistical summary of measurements and simulations near the Columbia River Mile 167.1 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON16713P	20.44	20.17	0.25	0.21	0.4
Concentration BON16713P	28.14	28.03	1.01	0.87	0.44
Gas Pressure BON16713P	858.63	853.25	32.18	26.34	15.32
% Saturation BON16713P	113.13	113.56	4.57	3.59	1.99

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 167.1 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON16713P	97.51	100	98.76	97.51

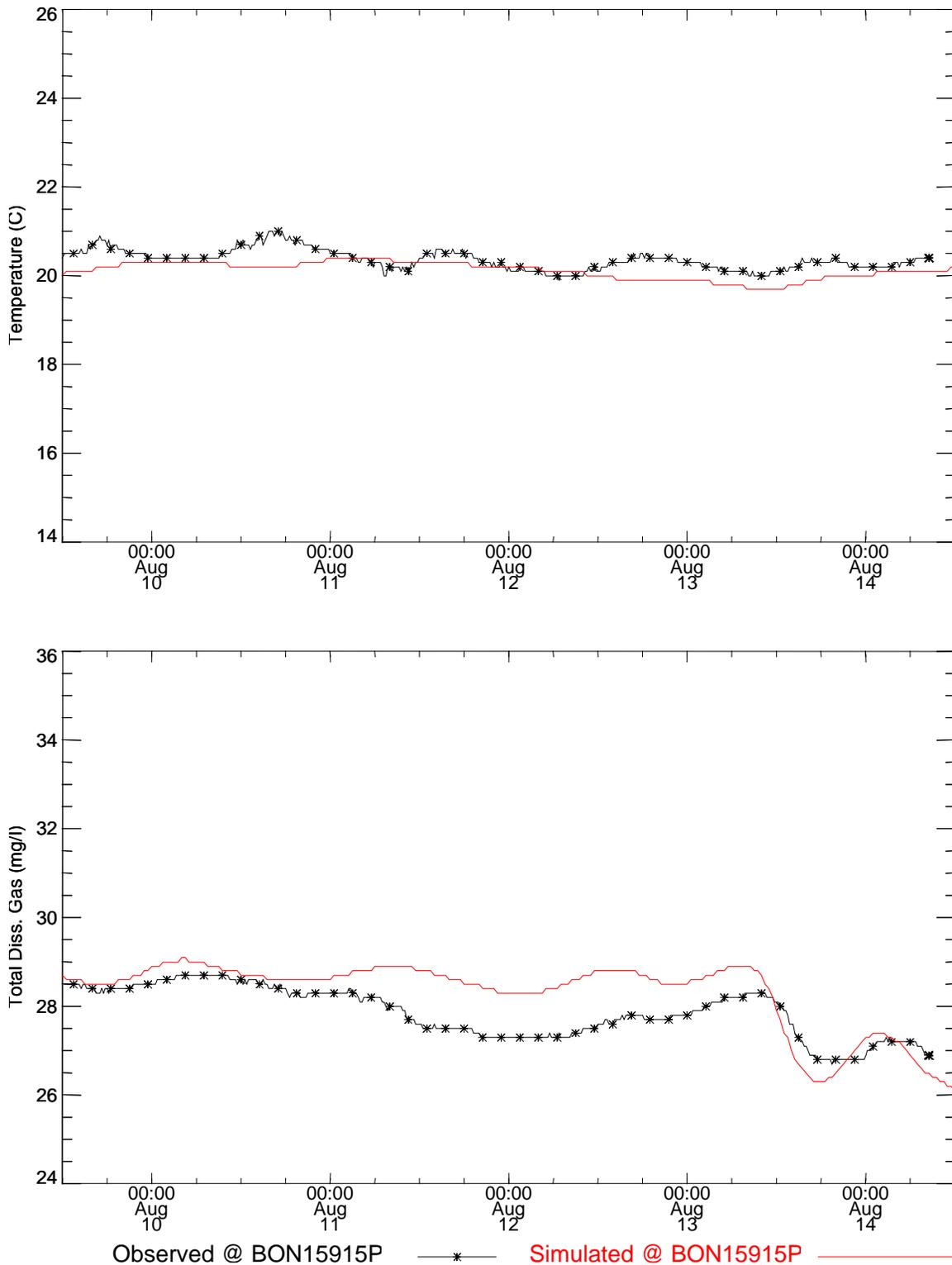


Figure 110. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 159.1 for the Summer 1996 study period (FMS-BC).

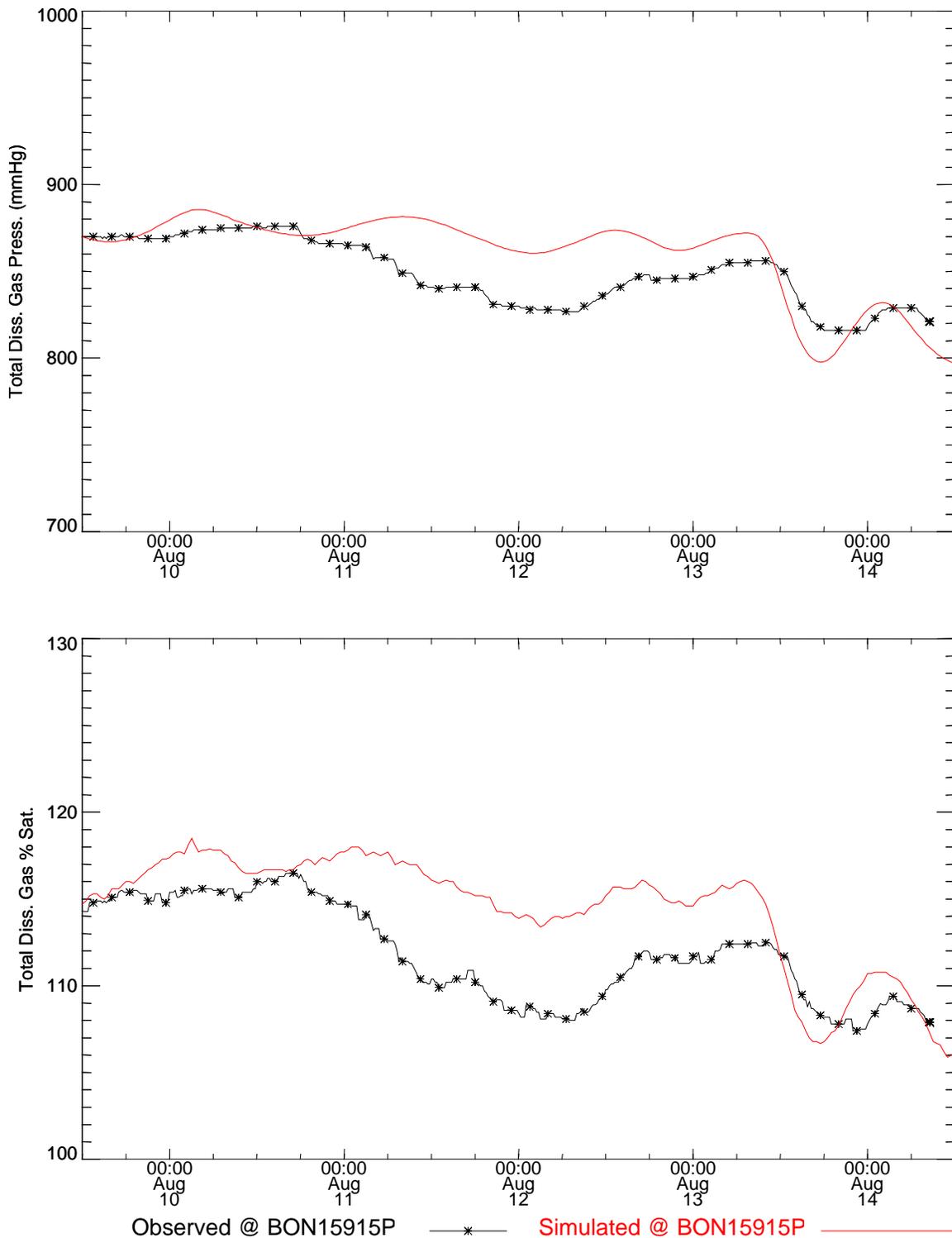


Figure 111. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 159.1 for the Summer 1996 study period (FMS-BC).

Table 51. Statistical summary of measurements and simulations near the Columbia River Mile 159.1 for the Summer 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON15915P	20.36	20.12	0.22	0.19	0.33
Concentration BON15915P	27.84	28.3	0.58	0.79	0.7
Gas Pressure BON15915P	848.29	860.15	19.09	24.51	21.05
% Saturation BON15915P	111.76	114.47	2.86	3.24	3.55

Table 52. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 159.1 for the Summer 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON15915P	100	82.57	94.19	75.52

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.

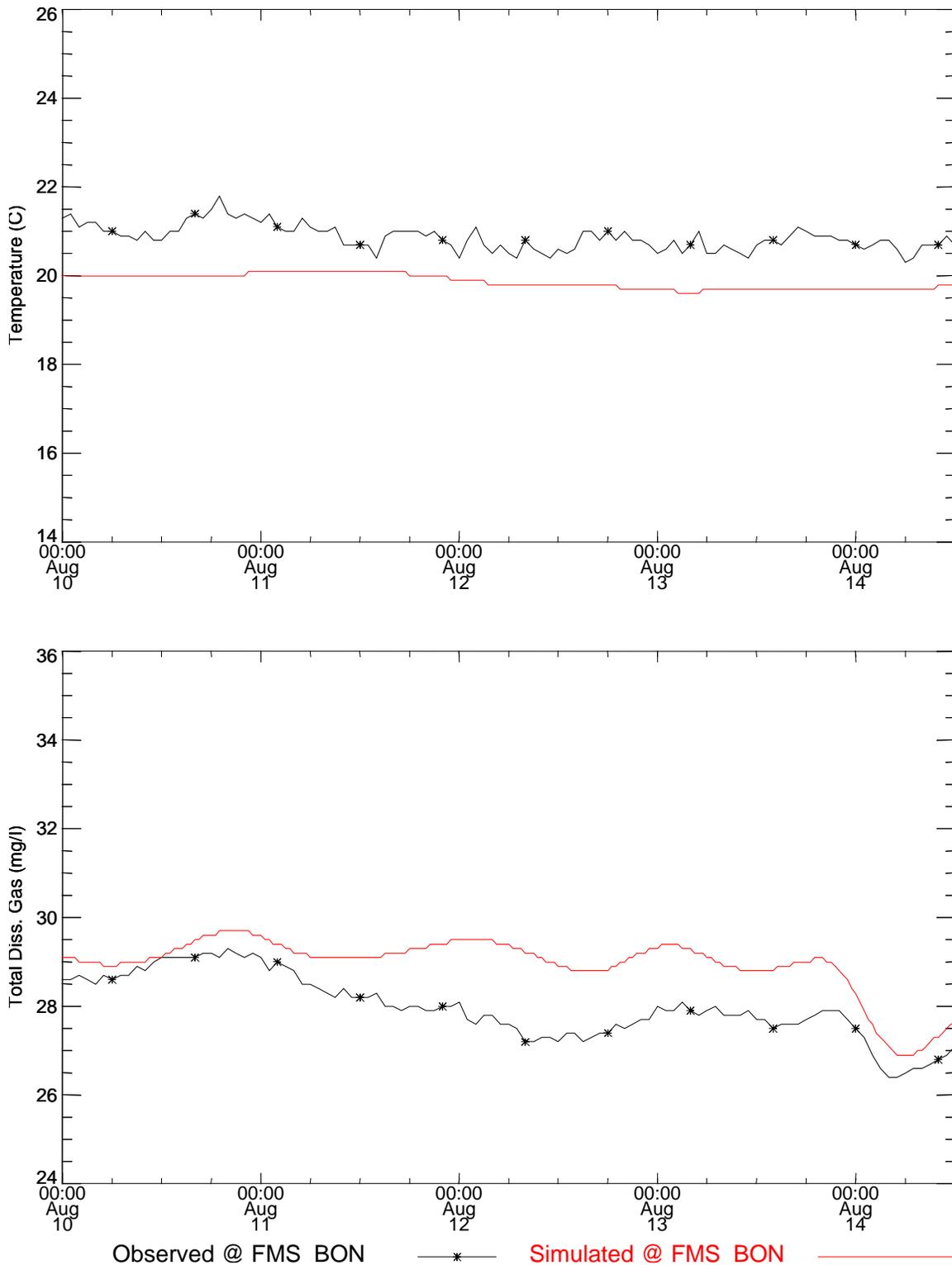


Figure 112. Temperature and total dissolved gas time series comparisons near the fixed monitor BON for the Summer 1996 study period (TM-BC).

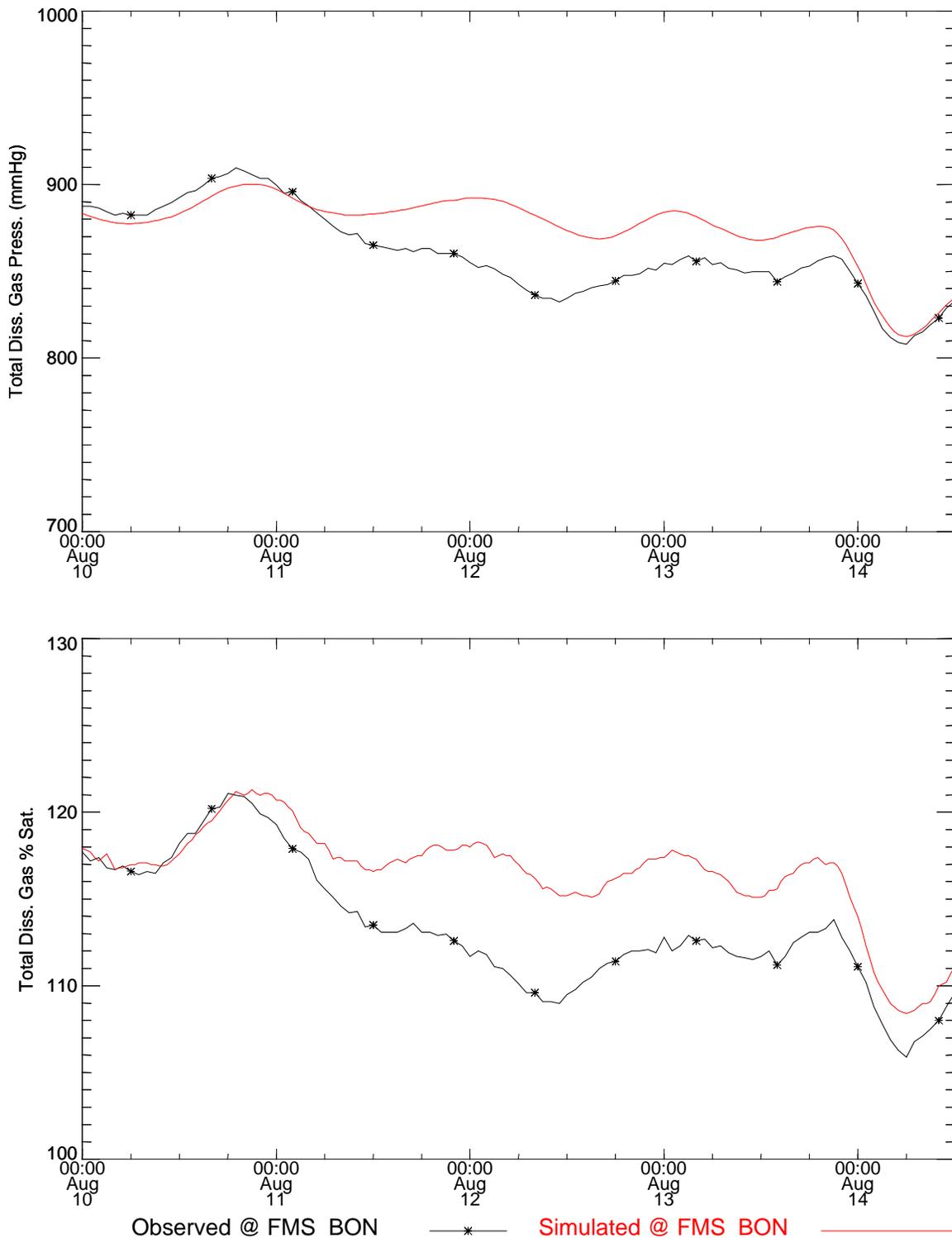


Figure 113. Total dissolved gas pressure and saturation time series comparisons near the fixed monitor BON for the Summer 1996 study period (TM-BC).

Table 53. Statistical summary of measurements and simulations near fixed monitor BON during the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_BON	20.86	19.87	0.27	0.16	1.02
Concentration FMS_BON	27.98	28.95	0.72	0.65	1.1
Gas Pressure FMS_BON	860.55	875.55	24.64	20.28	22.3
% Saturation FMS_BON	113.32	116.51	3.62	2.81	3.83

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

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_BON	60.37	52.07	88.94	79.72

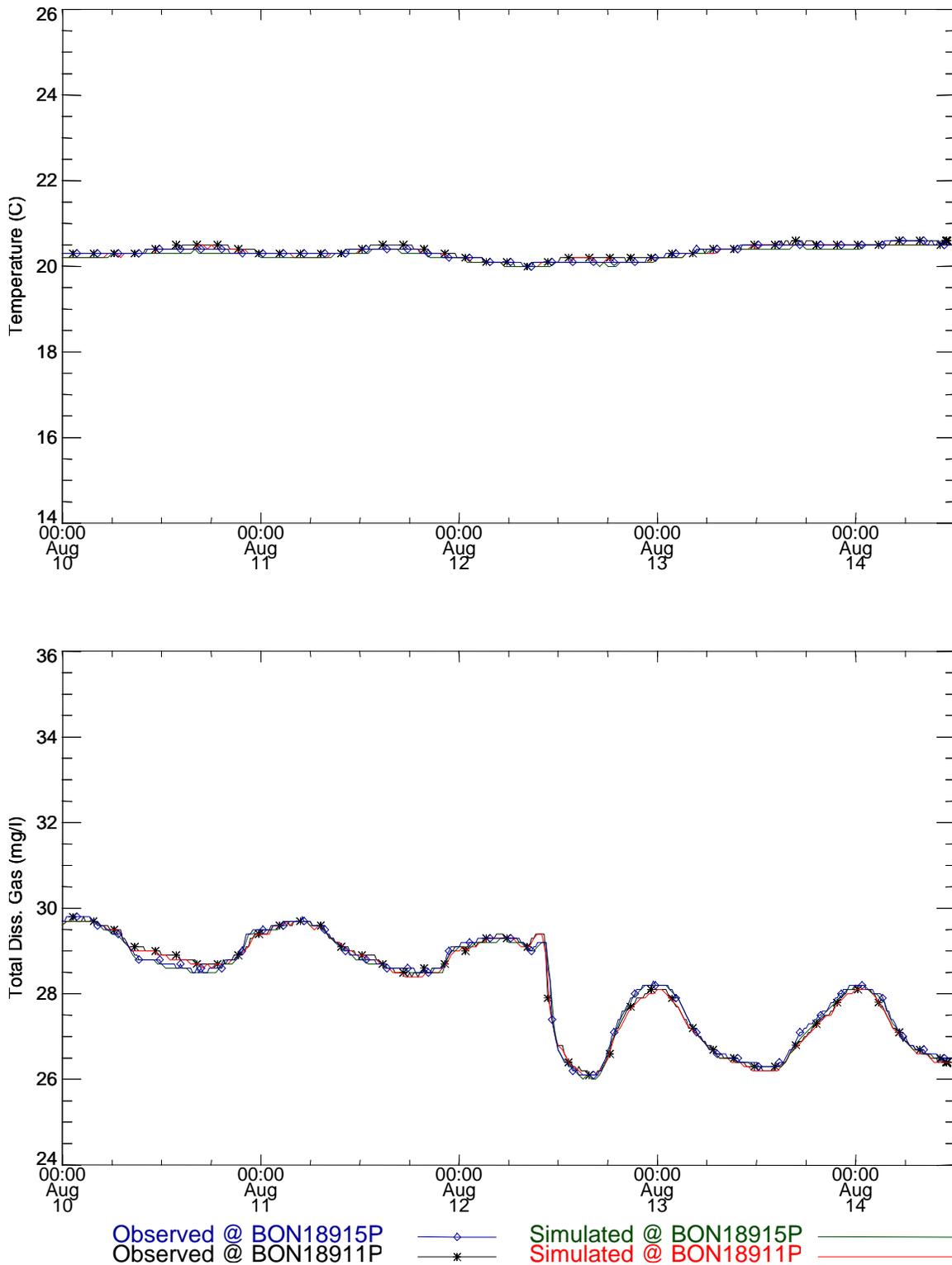


Figure 114. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 189.1 for the Summer 1996 study period (TM-BC).

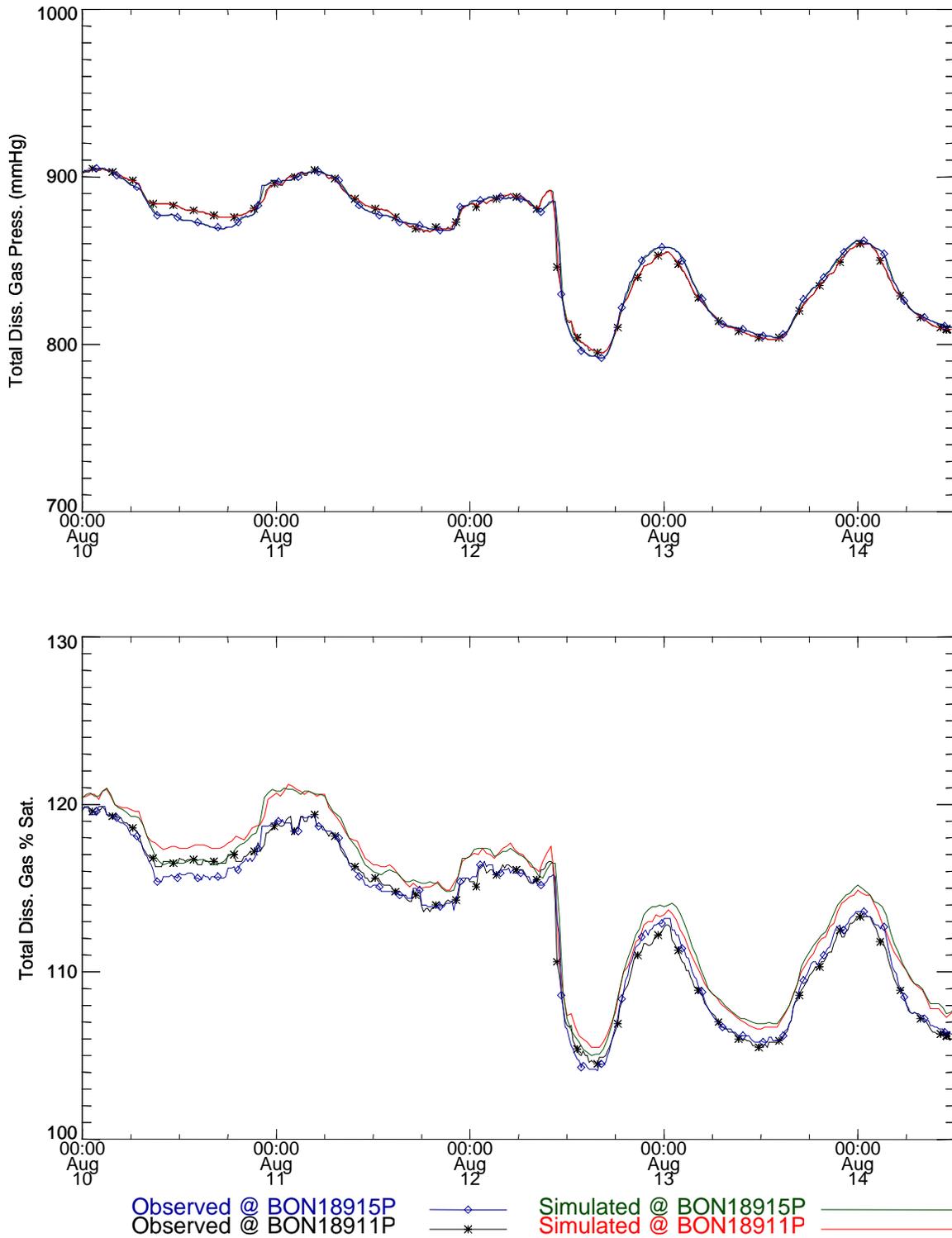


Figure 115. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 189.1 for the Summer 1996 study period (TM-BC).

Table 55. Statistical summary of measurements and simulations near Columbia River mile 189.1 during the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON18911P	20.36	20.31	0.15	0.15	0.07
BON18915P	20.33	20.27	0.15	0.14	0.08
Concentration					
BON18911P	28.18	28.14	1.17	1.17	0.06
BON18915P	28.2	28.15	1.14	1.14	0.07
Gas Pressure					
BON18911P	858.43	858.4	34	34.02	0.3
BON18915P	858.4	858.43	33.29	33.3	0.63
% Saturation					
BON18911P	113.04	114.23	4.58	4.63	1.25
BON18915P	113.04	114.24	4.48	4.53	1.25

Table 56. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 189.1 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON18911P	100	100	100	100
BON18915P	100	100	100	100

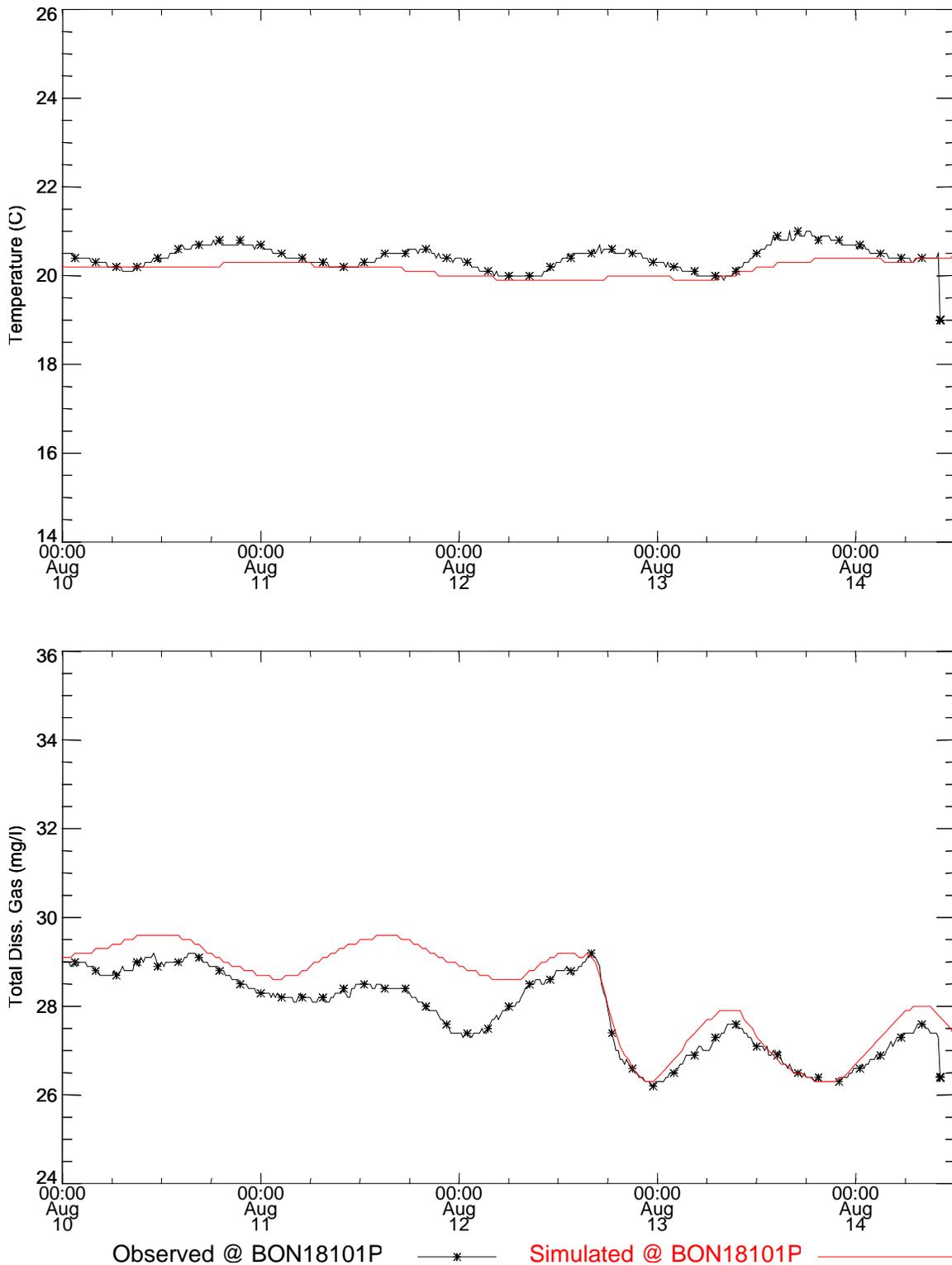


Figure 116. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 181.0 for the Summer 1996 study period (TM-BC).

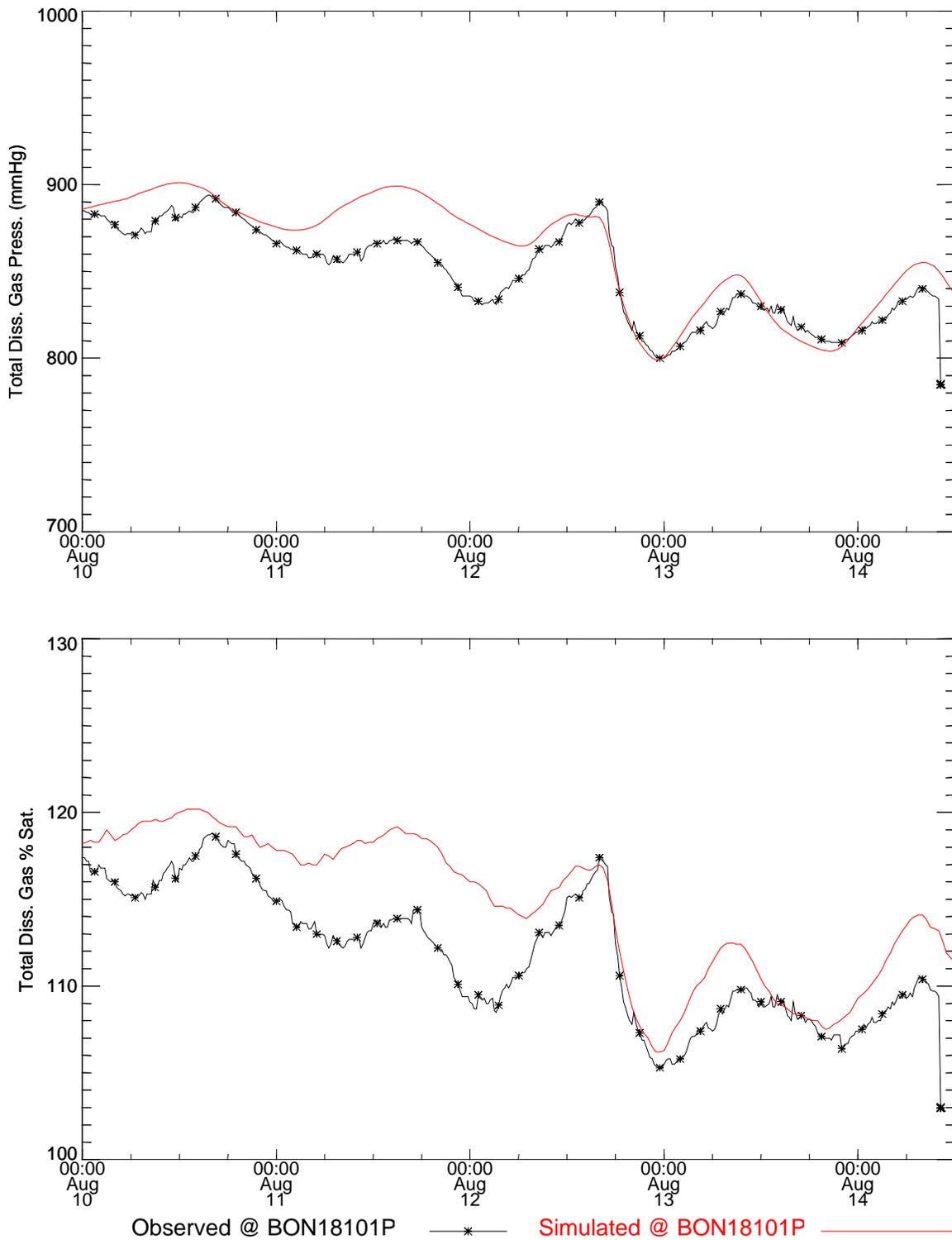


Figure 117. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 181.0 for the Summer 1996 study period (TM-BC).

Table 57. Statistical summary of measurements and simulations near Columbia River mile 181.0 during the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON18101P	20.39	20.15	0.31	0.17	0.39
Concentration BON18101P	27.83	28.35	0.91	1.07	0.66
Gas Pressure BON18101P	848.47	862.11	27.6	31.54	20.03
% Saturation BON18101P	111.73	114.72	3.84	4.15	3.58

Table 58. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River mile 181.0 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON18101P	98.16	84.79	94.01	82.03

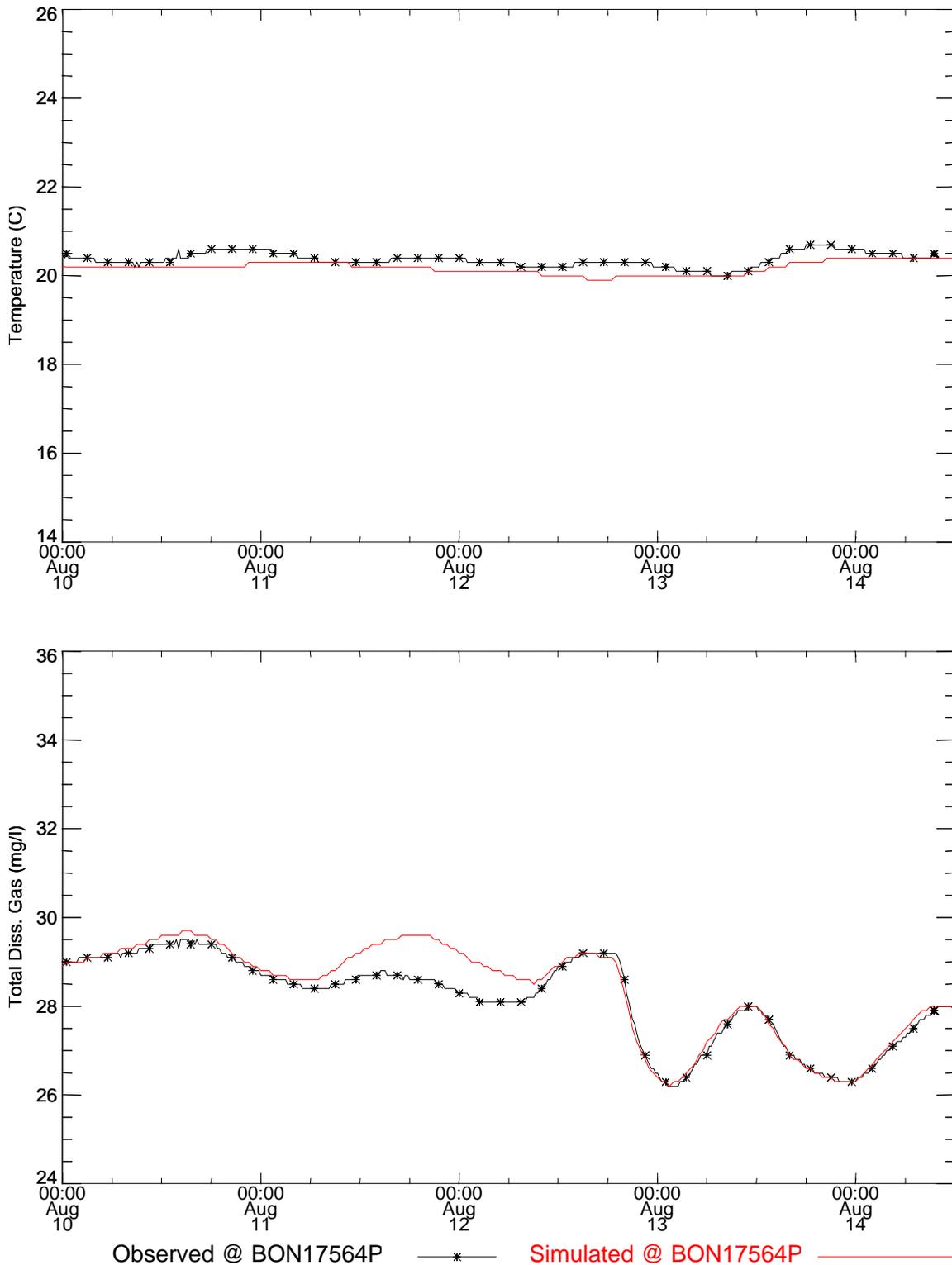


Figure 118. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 175.6 for the Summer 1996 study period (TM-BC).

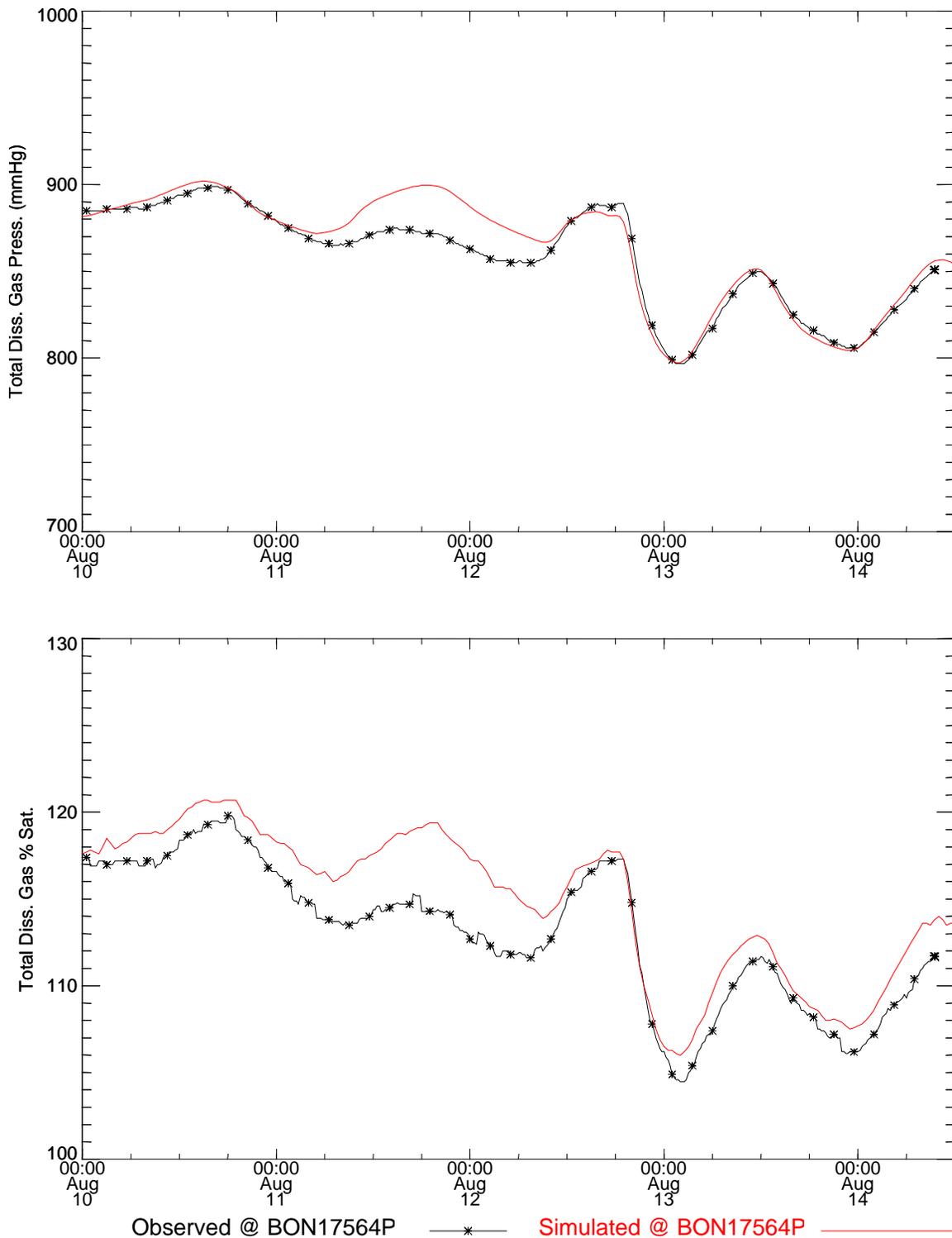


Figure 119. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 175.6 for the Summer 1996 study period (TM-BC).

Table 59. Statistical summary of measurements and simulations near Columbia River mile 175.6 during the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON17564P	20.37	20.18	0.16	0.14	0.22
Concentration BON17564P	28.16	28.38	0.96	1.07	0.38
Gas Pressure BON17564P	858.04	863.57	28.77	31.82	10.93
% Saturation BON17564P	112.99	114.91	3.98	4.21	2.3

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 175.6 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON17564P	100	100	100	99.08

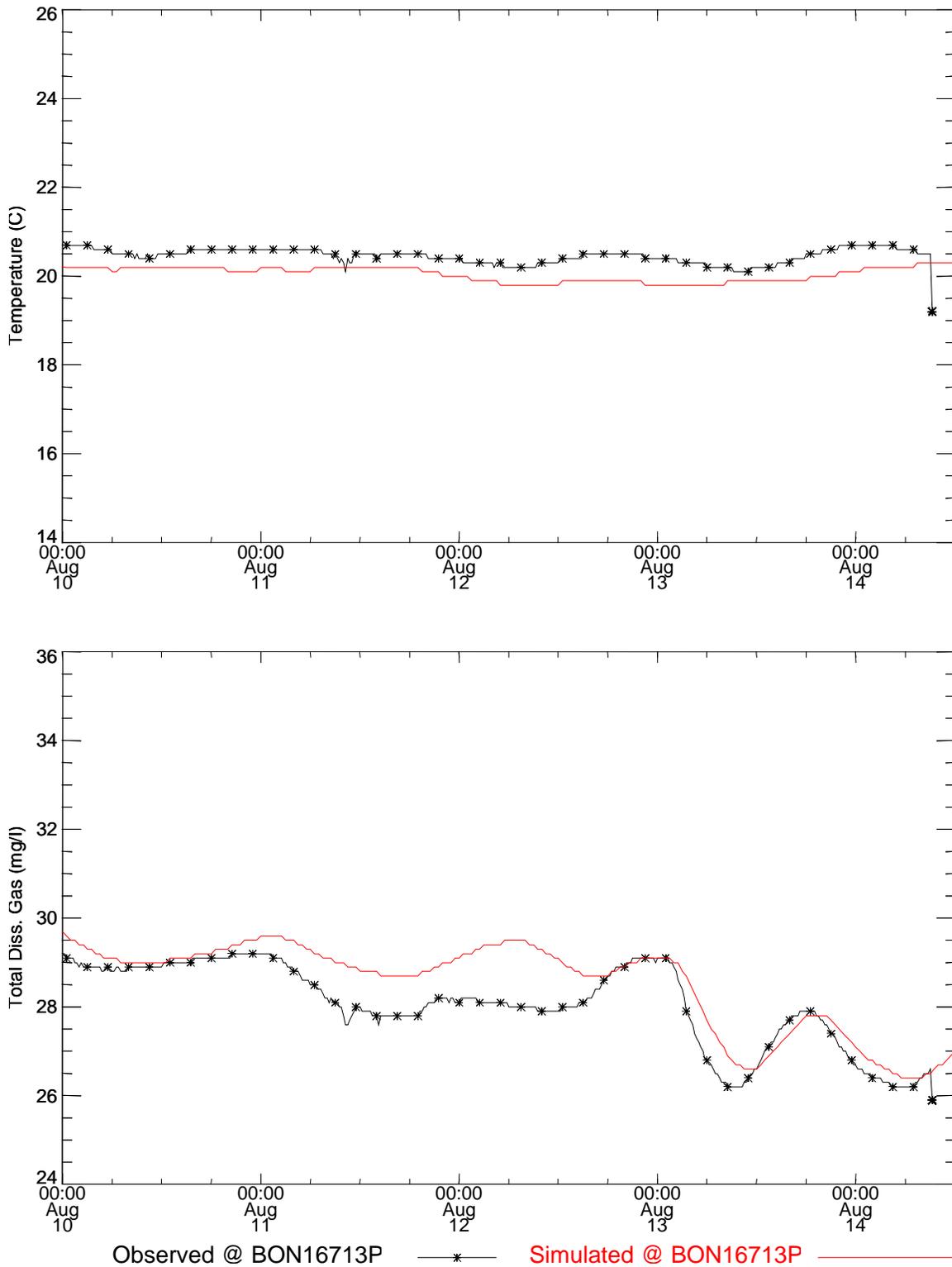


Figure 120. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 167.1 for the Summer 1996 study period (TM-BC).

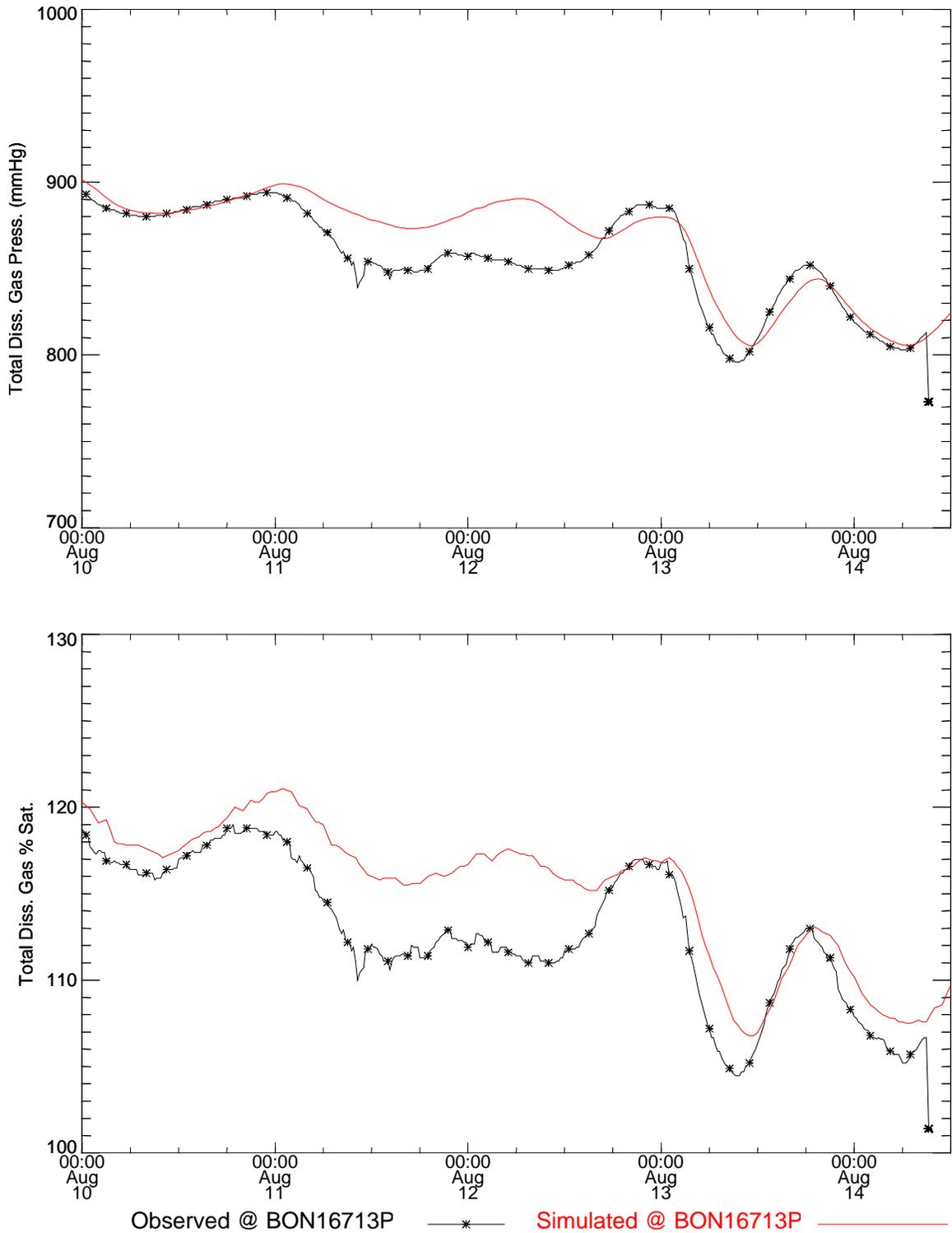


Figure 121. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 167.1 for the Summer 1996 study period (TM-BC).

Table 61. Statistical summary of measurements and simulations near Columbia River mile 167.1 during the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON16713P	20.43	20.05	0.26	0.16	0.47
Concentration BON16713P	28	28.51	0.97	1	0.68
Gas Pressure BON16713P	854.28	865.32	30.87	29.73	18.7
% Saturation BON16713P	112.5	115.15	4.36	4.01	3.31

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 167.1 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON16713P	97.24	88.48	94.01	87.56

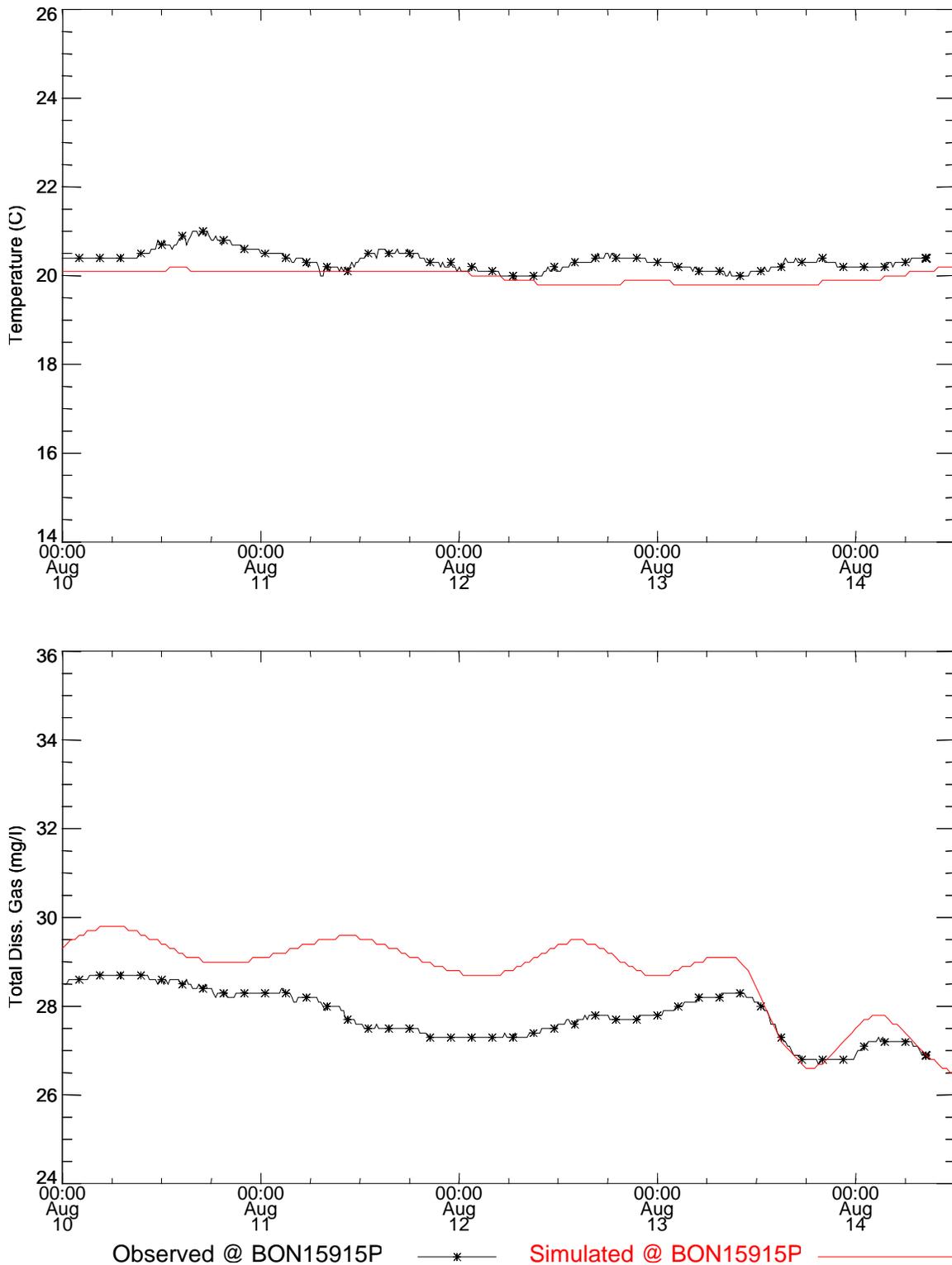


Figure 122. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 159.1 for the Summer 1996 study period (TM-BC).

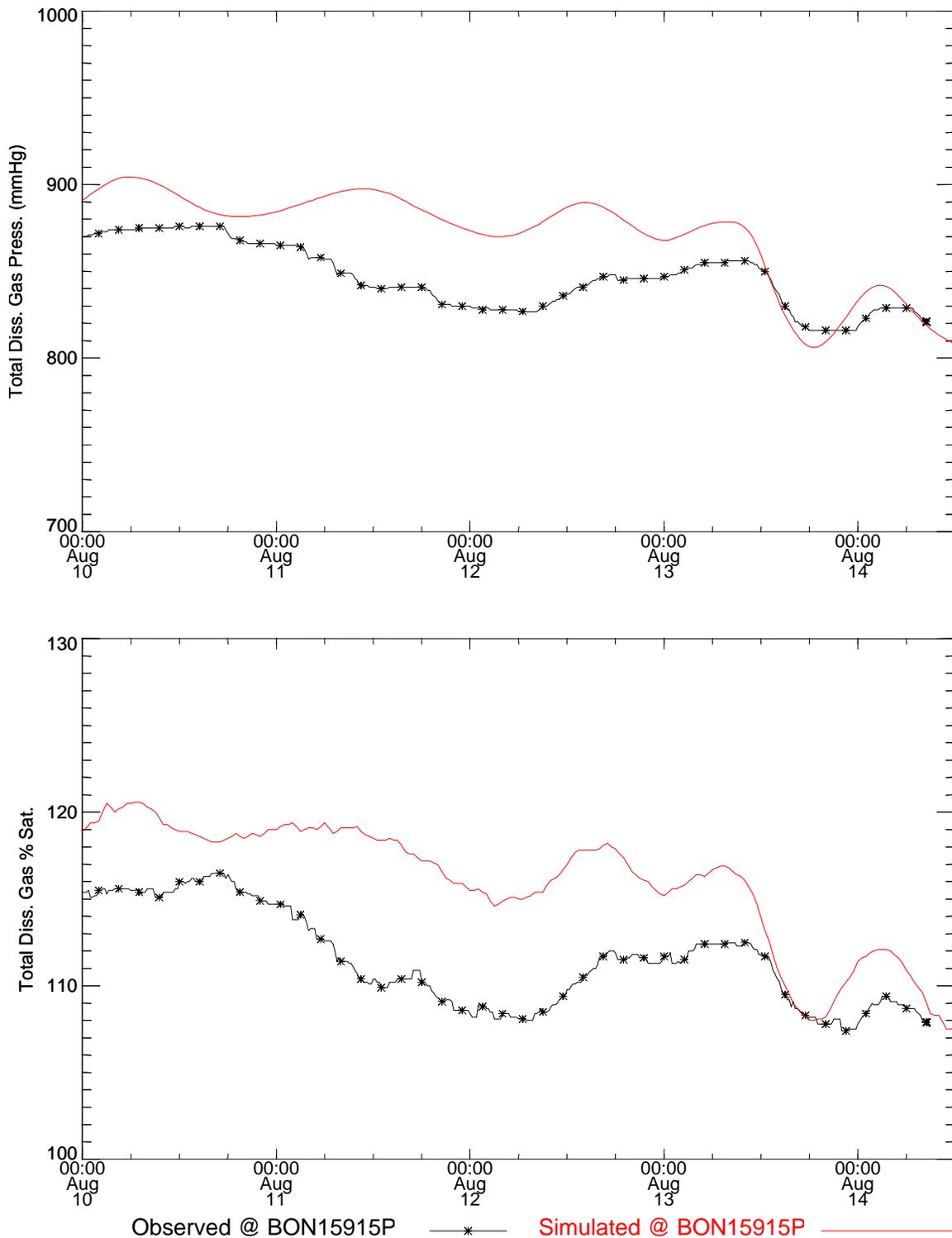


Figure 123. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 159.1 for the Summer 1996 study period (TM-BC).

Table 63. Statistical summary of measurements and simulations near Columbia River mile 159.1 during the Summer 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature BON15915P	20.34	19.99	0.22	0.14	0.4
Concentration BON15915P	27.77	28.74	0.58	0.9	1.14
Gas Pressure BON15915P	845.92	871.26	18.66	27.23	31.45
% Saturation BON15915P	111.4	115.93	2.78	3.57	5.12

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 159.1 for the Summer 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON15915P	100	57.6	68.2	60.37

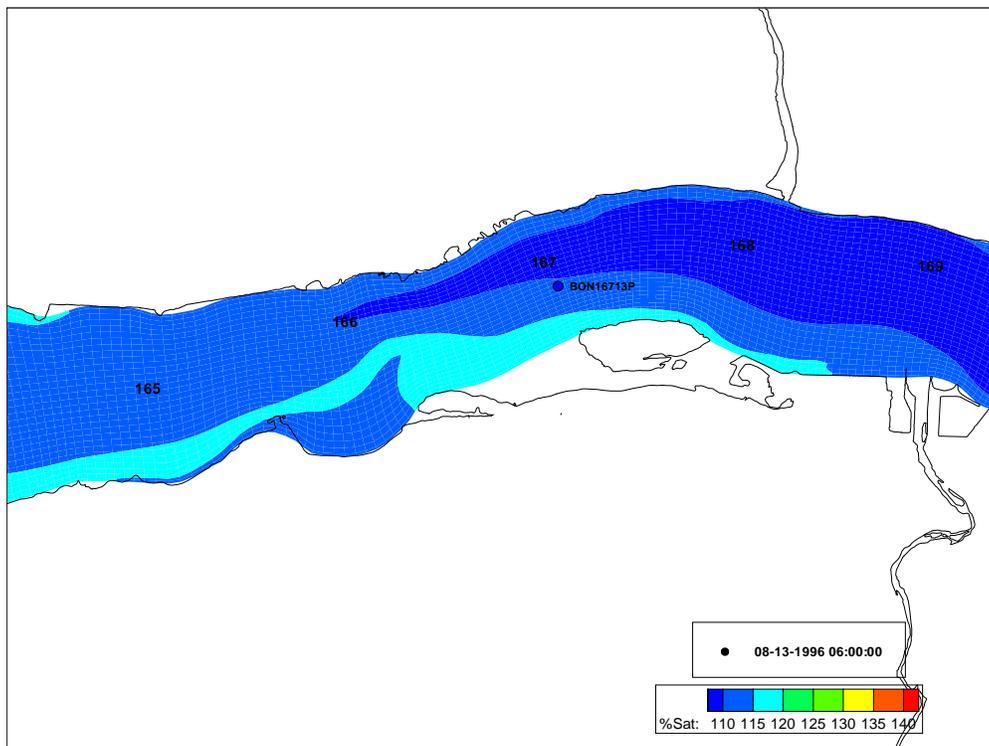


Figure 124. Spatial distribution of dissolved gas near Columbia River Mile 167 during the Summer 1996 study period.

1.4.3 Summer 1997 Simulation

Boundary Conditions using The Dalles 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.

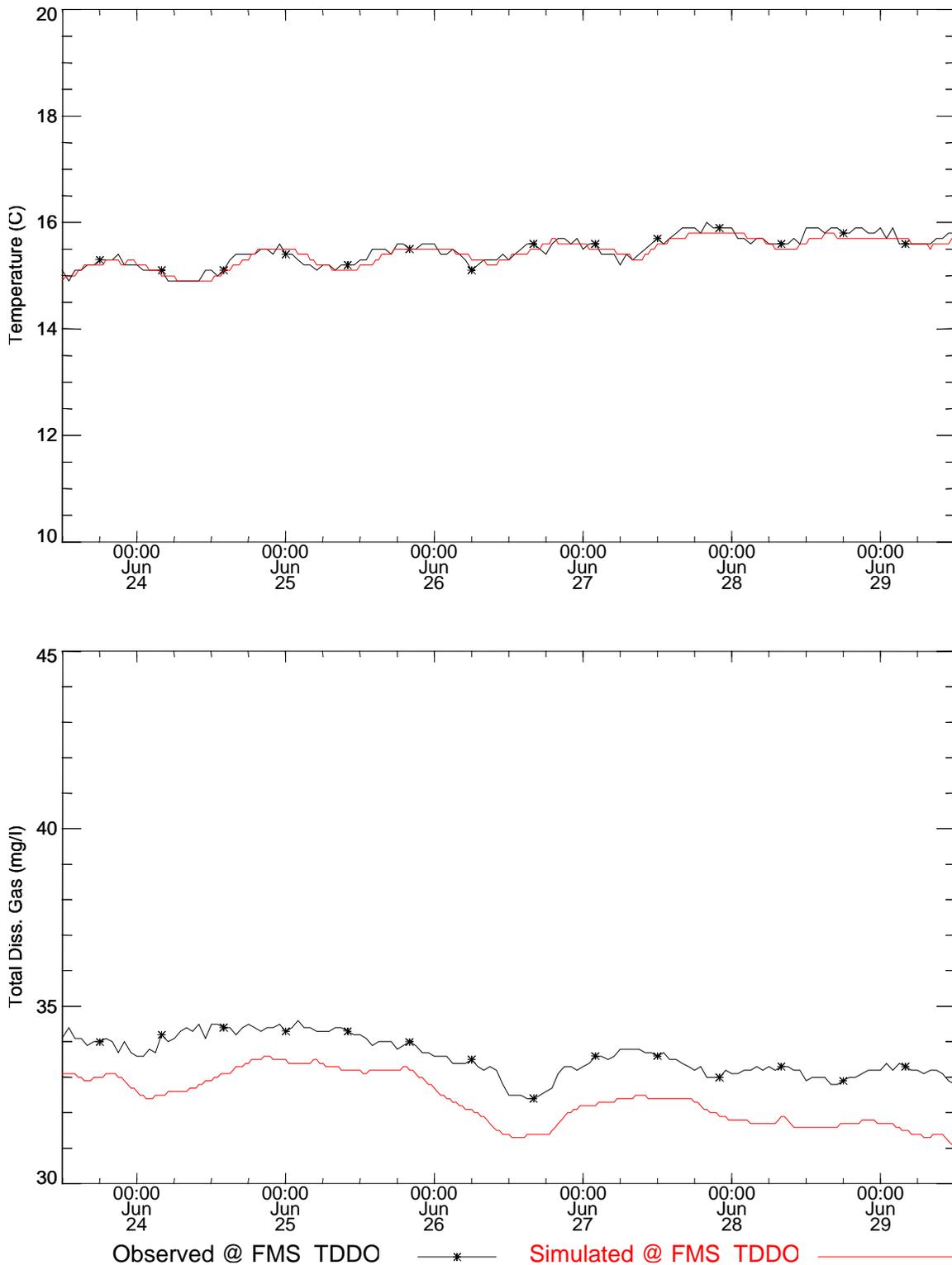


Figure 125. Temperature and total dissolved gas time series comparisons near fixed monitor TDDO for the Summer 1997 study period (FMS-BC).

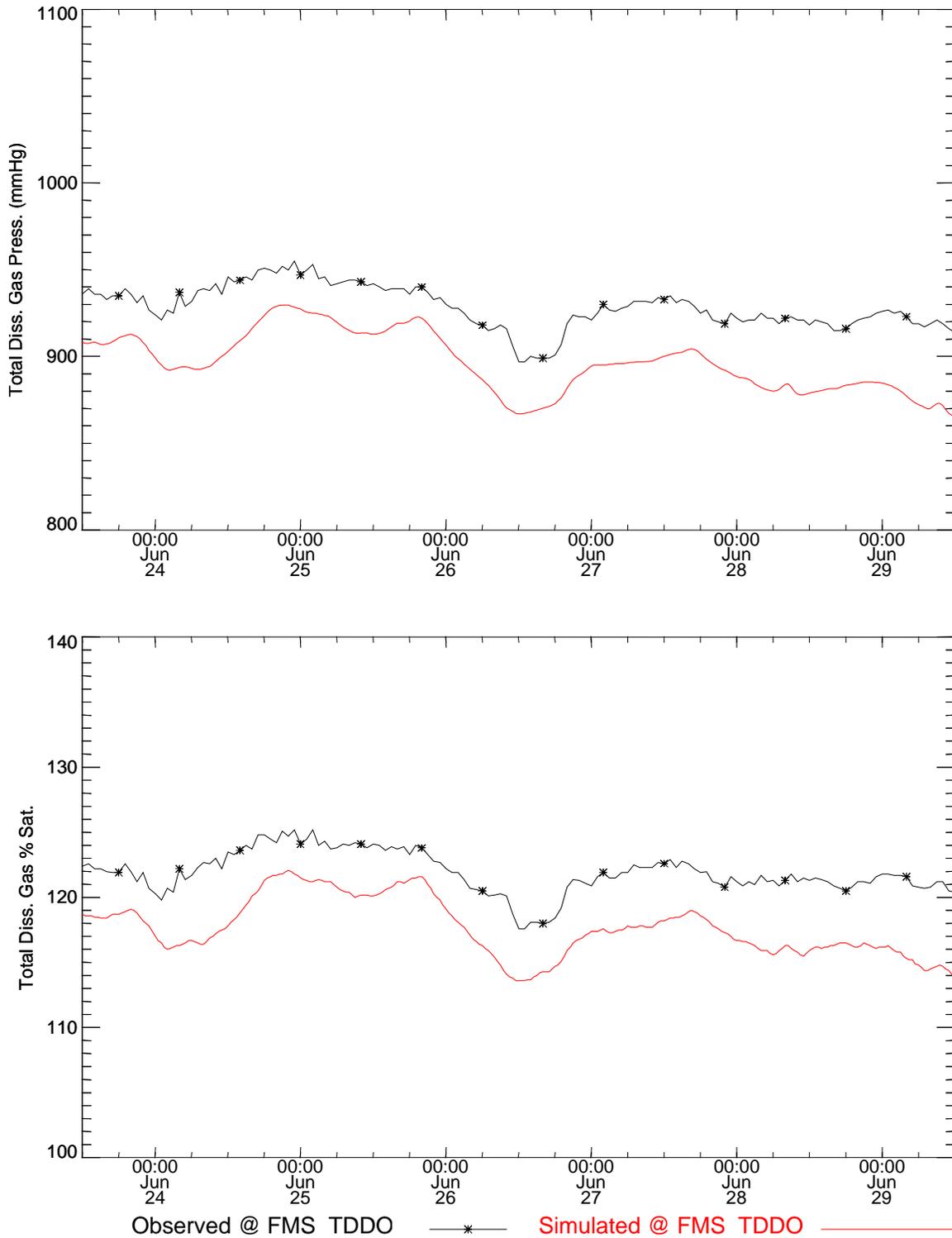


Figure 126. Total dissolved gas pressure and saturation time series comparisons near fixed monitor TDDO for the Summer 1997 study period (FMS-BC).

Table 65. Statistical summary of measurements and simulations near the fixed monitor TDDO for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_TDDO	15.47	15.43	0.27	0.25	0.11
Concentration					
FMS_TDDO	33.6	32.37	0.55	0.7	1.26
Gas Pressure					
FMS_TDDO	928.63	896.5	12.26	16.98	33.1
% Saturation					
FMS_TDDO	121.91	117.65	1.58	2.2	4.39

Table 66. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor TDDO for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_TDDO	100	26.3	76.12	76.47

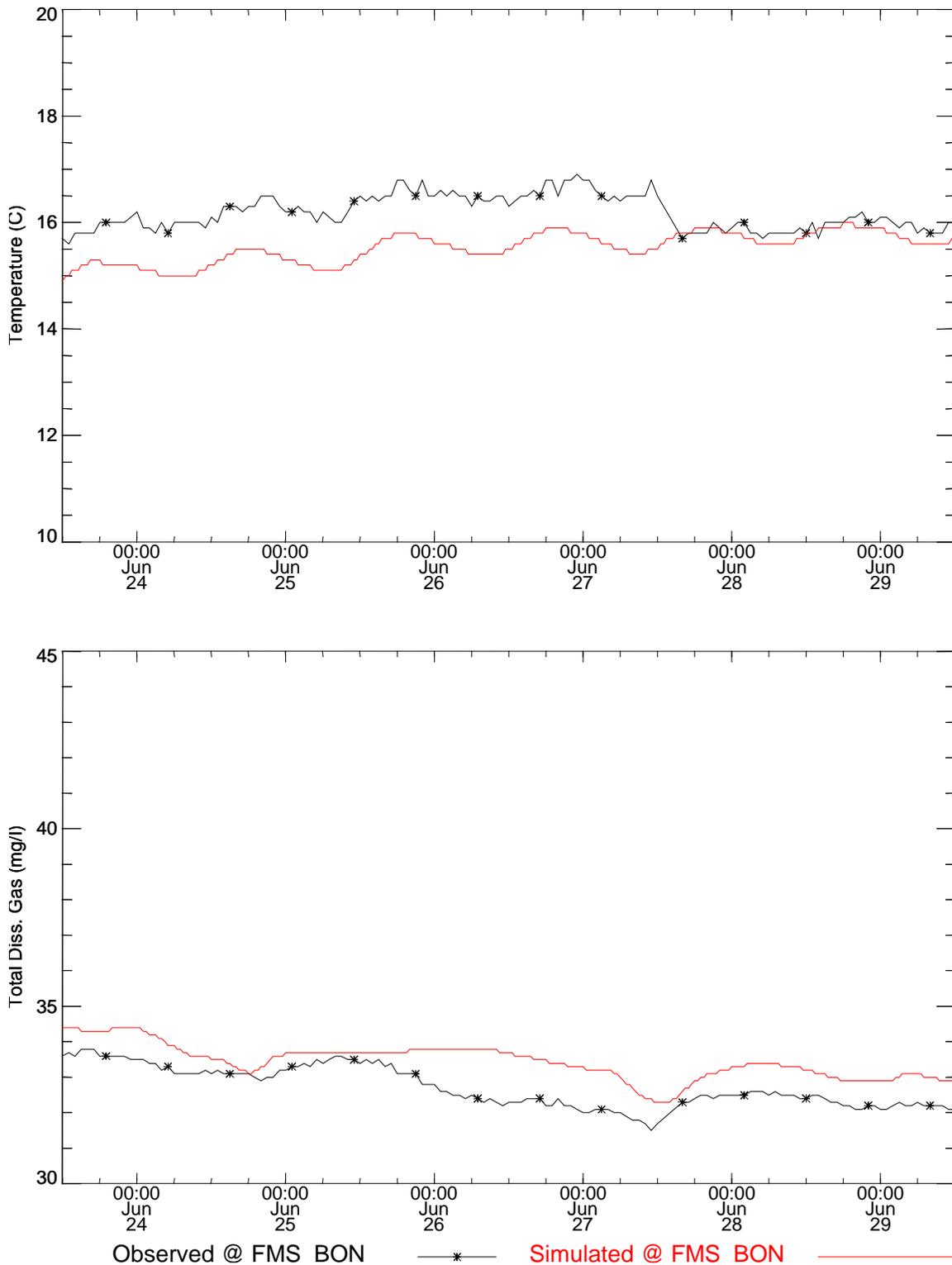


Figure 127. Temperature and total dissolved gas time series comparisons near the fixed monitor BON for the Summer 1997 study period (FMS-BC).

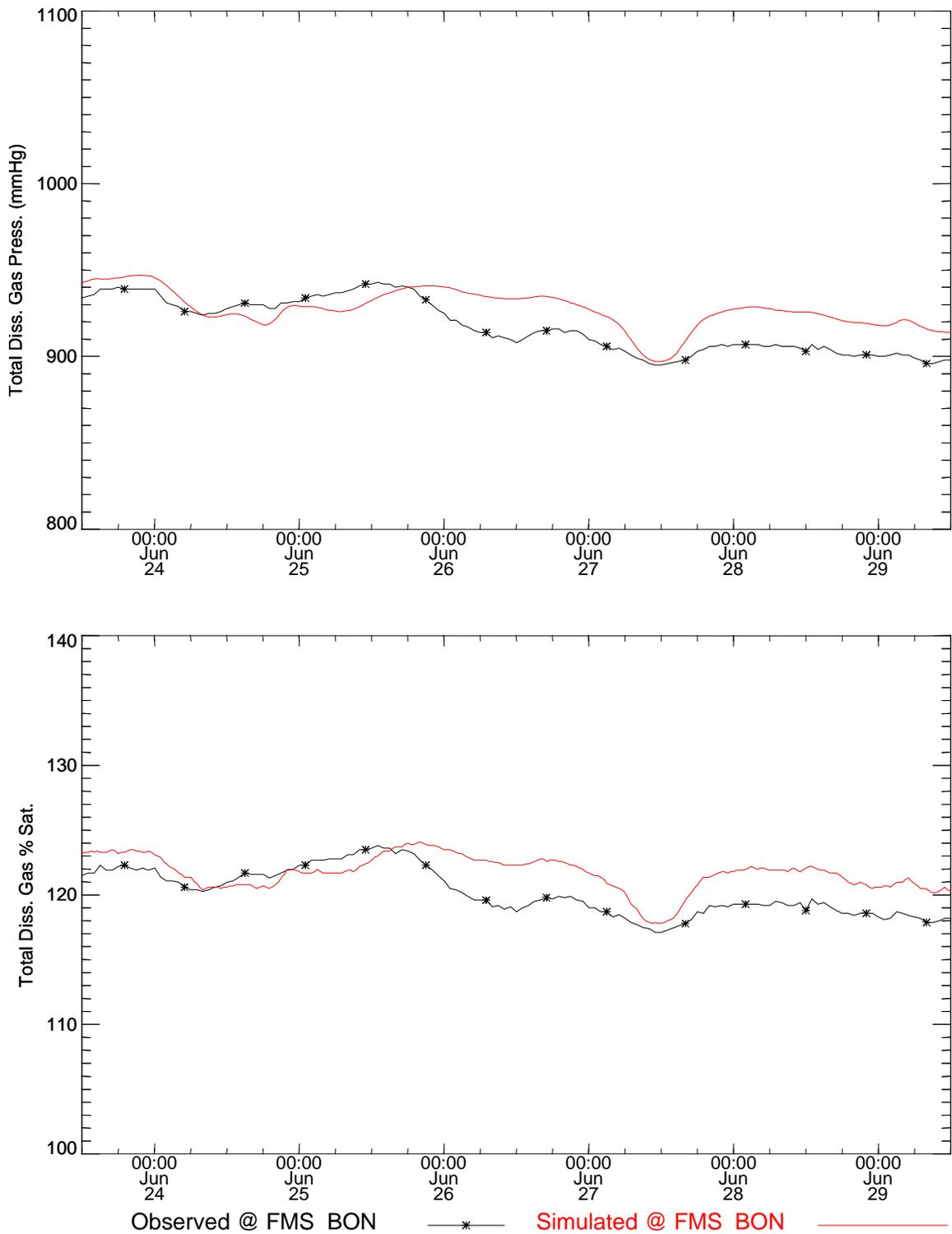


Figure 128. Total dissolved gas pressure and saturation time series comparisons near the fixed monitor BON for the Summer 1997 study period (FMS-BC).

Table 67. Statistical summary of measurements and simulations near the fixed monitor BON for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_BON	16.19	15.53	0.32	0.28	0.76
Concentration FMS_BON	32.71	33.44	0.57	0.49	0.81
Gas Pressure FMS_BON	917.57	927.49	15.3	10.96	14.77
% Saturation FMS_BON	120.18	121.71	1.78	1.35	2.06

Table 68. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near the Bonneville fixed monitor for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_BON	86.16	79.93	100	100

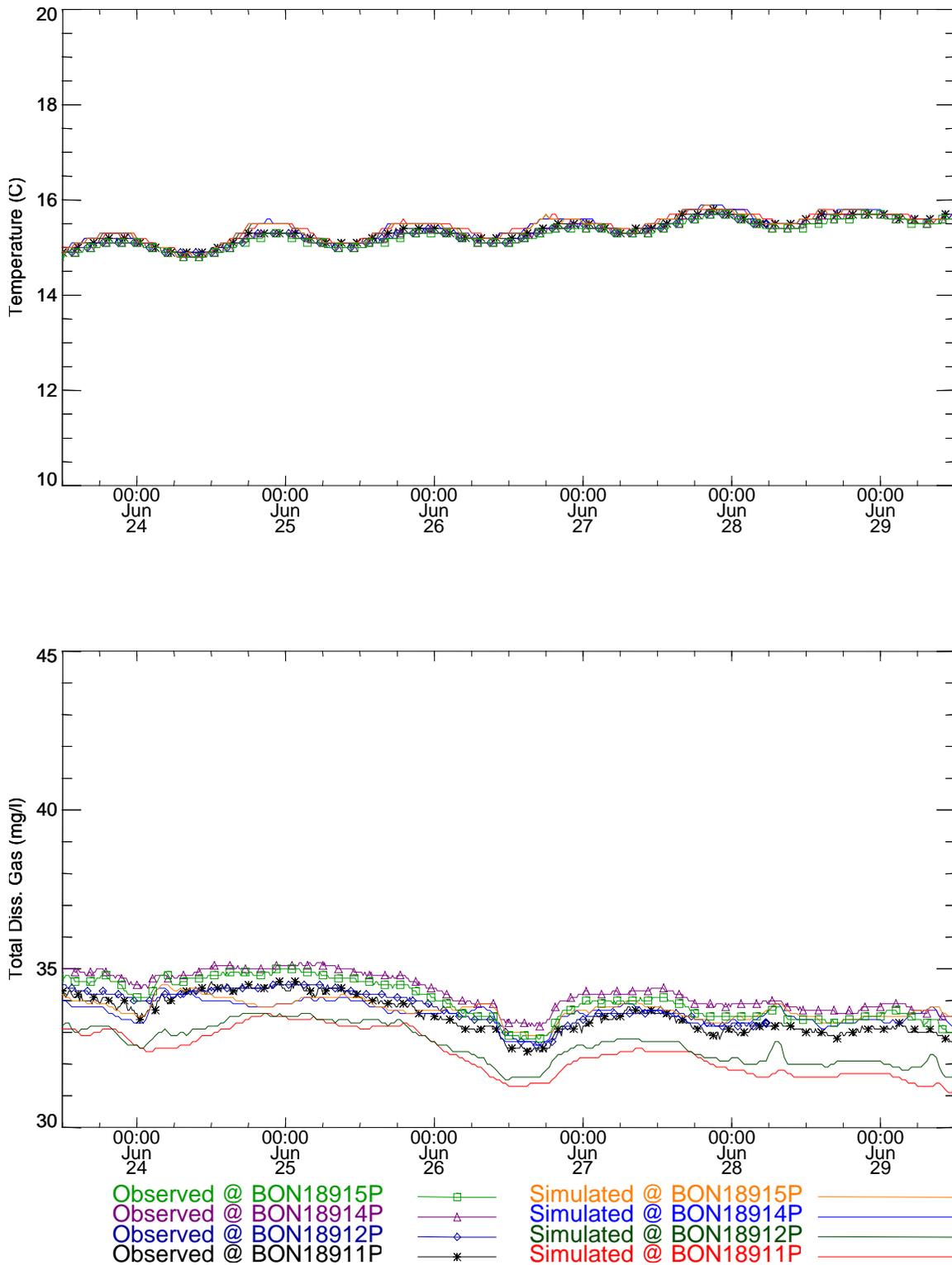


Figure 129. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 189.1 for the Summer 1997 study period (FMS-BC).

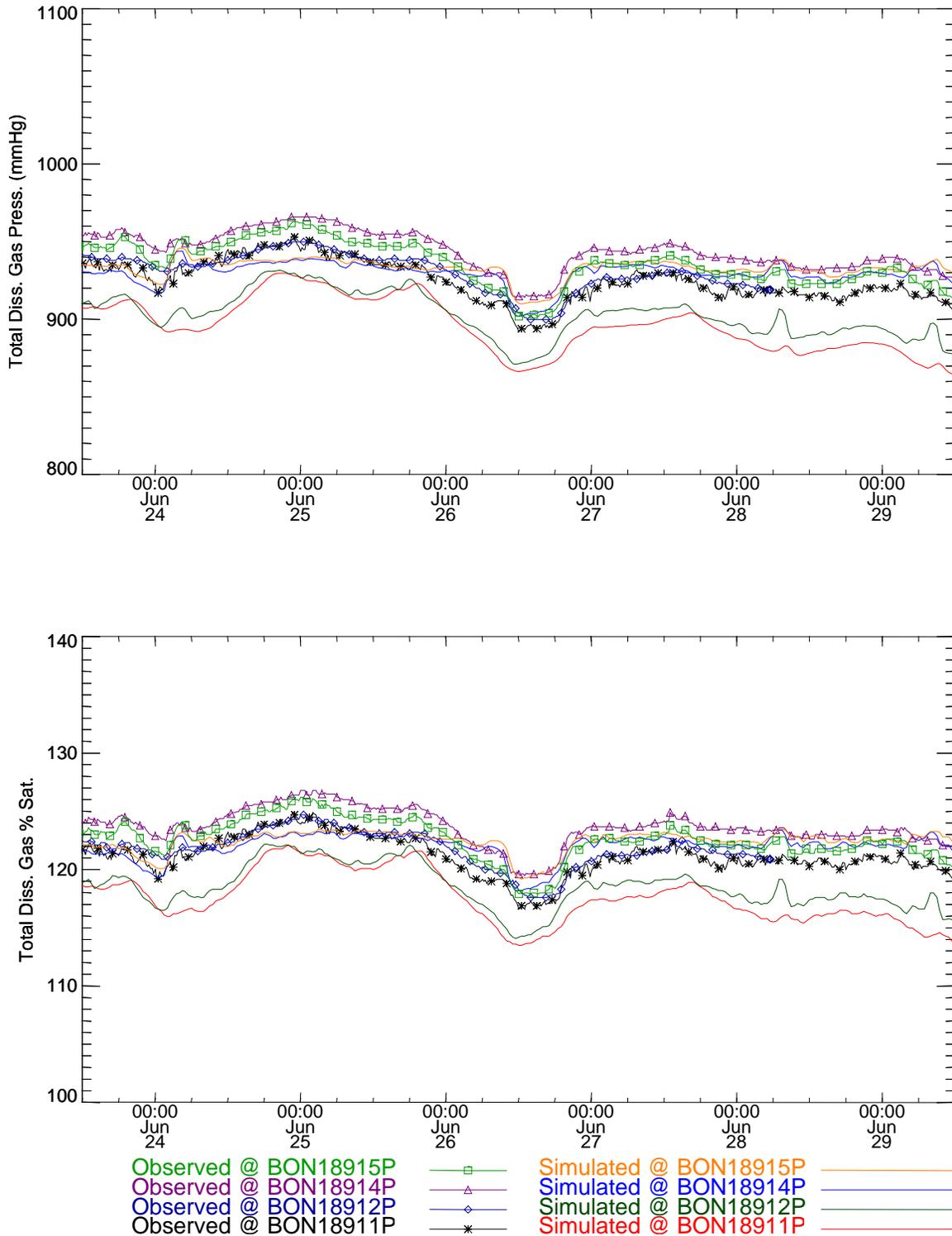


Figure 130. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 189.1 for the Summer 1997 study period (FMS-BC).

Table 69. Statistical summary of measurements and simulations near the Columbia River Mile 189.1 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON18911P	15.36	15.43	0.24	0.25	0.1
BON18912P	15.3	15.41	0.22	0.26	0.15
BON18914P	15.3	15.42	0.25	0.27	0.15
BON18915P	15.28	15.41	0.25	0.26	0.16
Concentration					
BON18911P	33.54	32.35	0.58	0.71	1.22
BON18912P	33.72	32.62	0.52	0.6	1.12
BON18914P	34.29	33.6	0.56	0.36	0.77
BON18915P	34.01	33.72	0.62	0.33	0.49
Gas Pressure					
BON18911P	924.87	896.06	13.27	17.23	29.94
BON18912P	928.17	903.01	11.91	14.3	25.83
BON18914P	944.24	929.66	12.56	7.66	17
BON18915P	935.93	932.9	14.13	6.38	10.69
% Saturation					
BON18911P	121.15	117.58	1.67	2.23	3.76
BON18912P	121.57	118.5	1.47	1.87	3.18
BON18914P	123.69	122	1.56	1.09	2.01
BON18915P	122.59	122.42	1.75	0.91	1.31

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 189.1 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON18911P	100	32.18	83.74	85.81
BON18912P	100	42.56	97.58	98.27
BON18914P	100	75.78	100	100
BON18915P	100	96.89	100	100

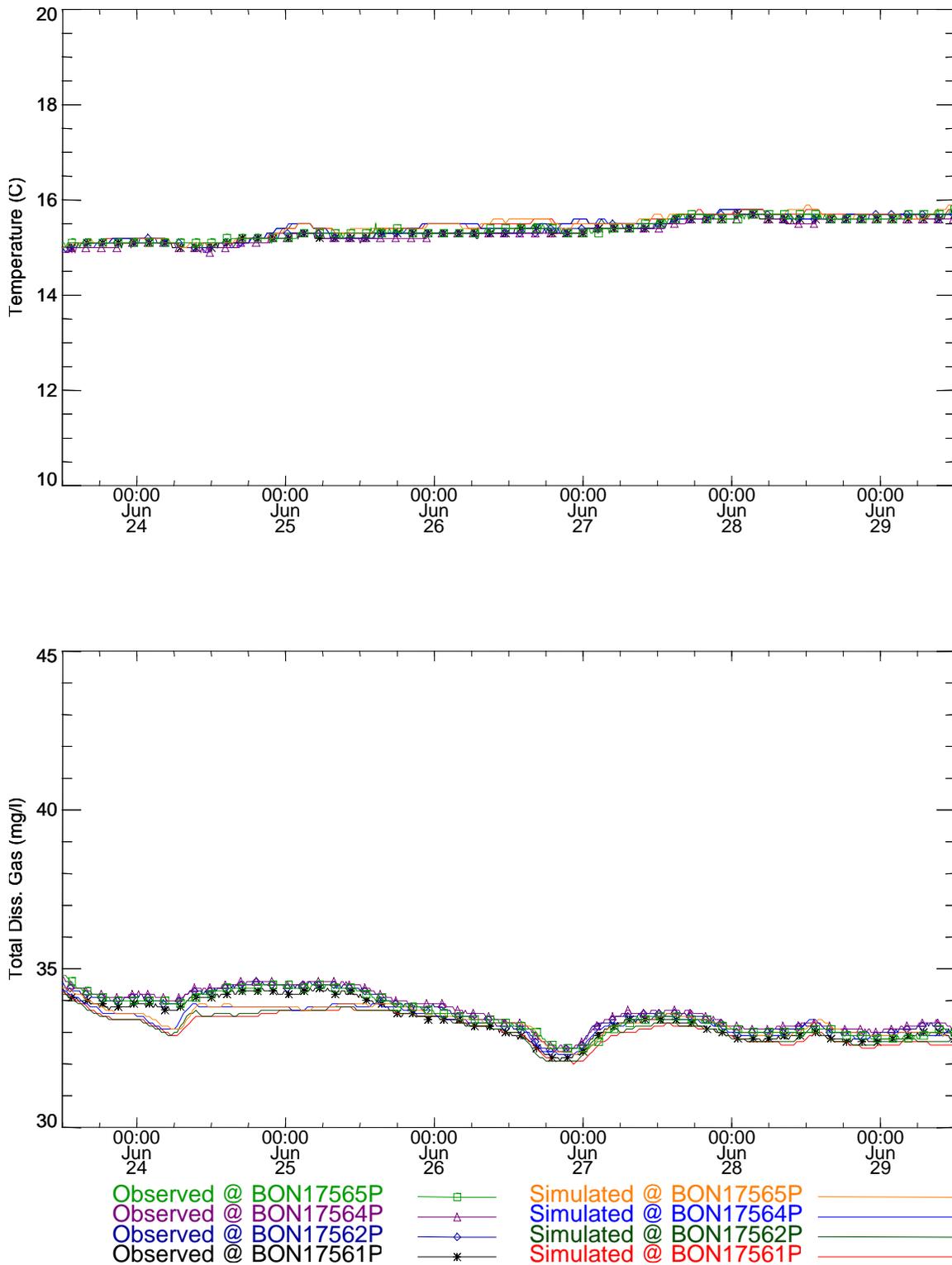


Figure 131. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 175.6 for the Summer 1997 study period (FMS-BC).

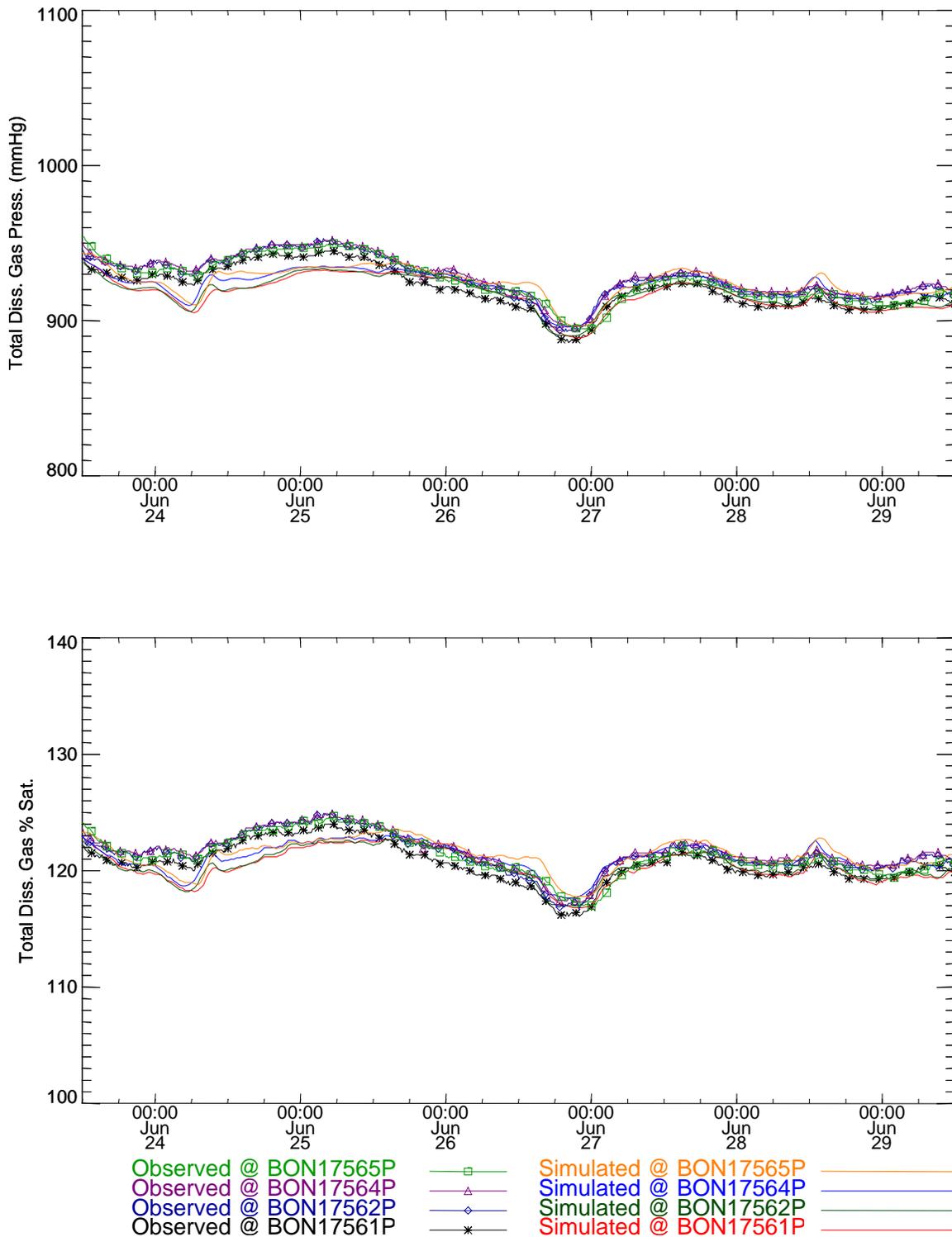


Figure 132. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 175.6 for the Summer 1997 study period (FMS-BC).

Table 71. Statistical summary of measurements and simulations near the Columbia River Mile 175.6 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON17561P	15.35	15.47	0.21	0.23	0.13
BON17562P	15.38	15.44	0.22	0.24	0.1
BON17564P	15.33	15.43	0.22	0.24	0.13
BON17565P	15.39	15.47	0.21	0.23	0.11
Concentration					
BON17561P	33.4	33.13	0.6	0.48	0.38
BON17562P	33.62	33.16	0.6	0.46	0.51
BON17564P	33.71	33.34	0.59	0.43	0.44
BON17565P	33.55	33.38	0.62	0.43	0.33
Gas Pressure					
BON17561P	920.74	917.53	13.8	10.71	8.17
BON17562P	927.2	918.19	13.63	10.18	11.2
BON17564P	929	922.84	13.21	9.06	9.13
BON17565P	925.63	924.69	14.09	9.58	7.86
% Saturation					
BON17561P	120.61	120.4	1.71	1.45	1.05
BON17562P	121.46	120.49	1.69	1.38	1.32
BON17564P	121.69	121.1	1.63	1.25	1.06
BON17565P	121.25	121.34	1.72	1.32	1.02

Table 72. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 175.6 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
BON17561P	100	100	100	100
BON17562P	100	100	100	100
BON17564P	100	100	100	100
BON17565P	100	100	100	100

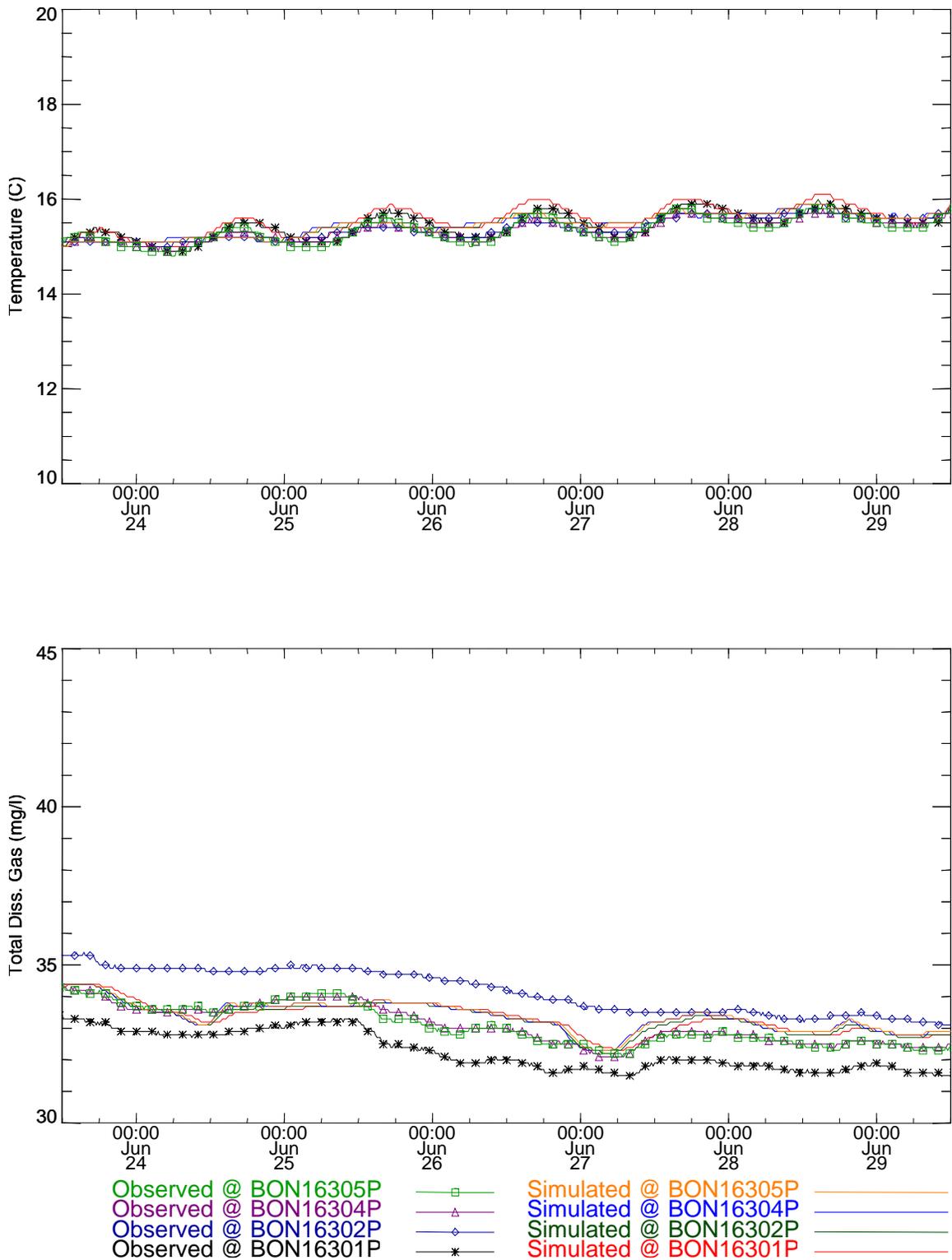


Figure 133. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 163.0 for the Summer 1997 study period (FMS-BC).

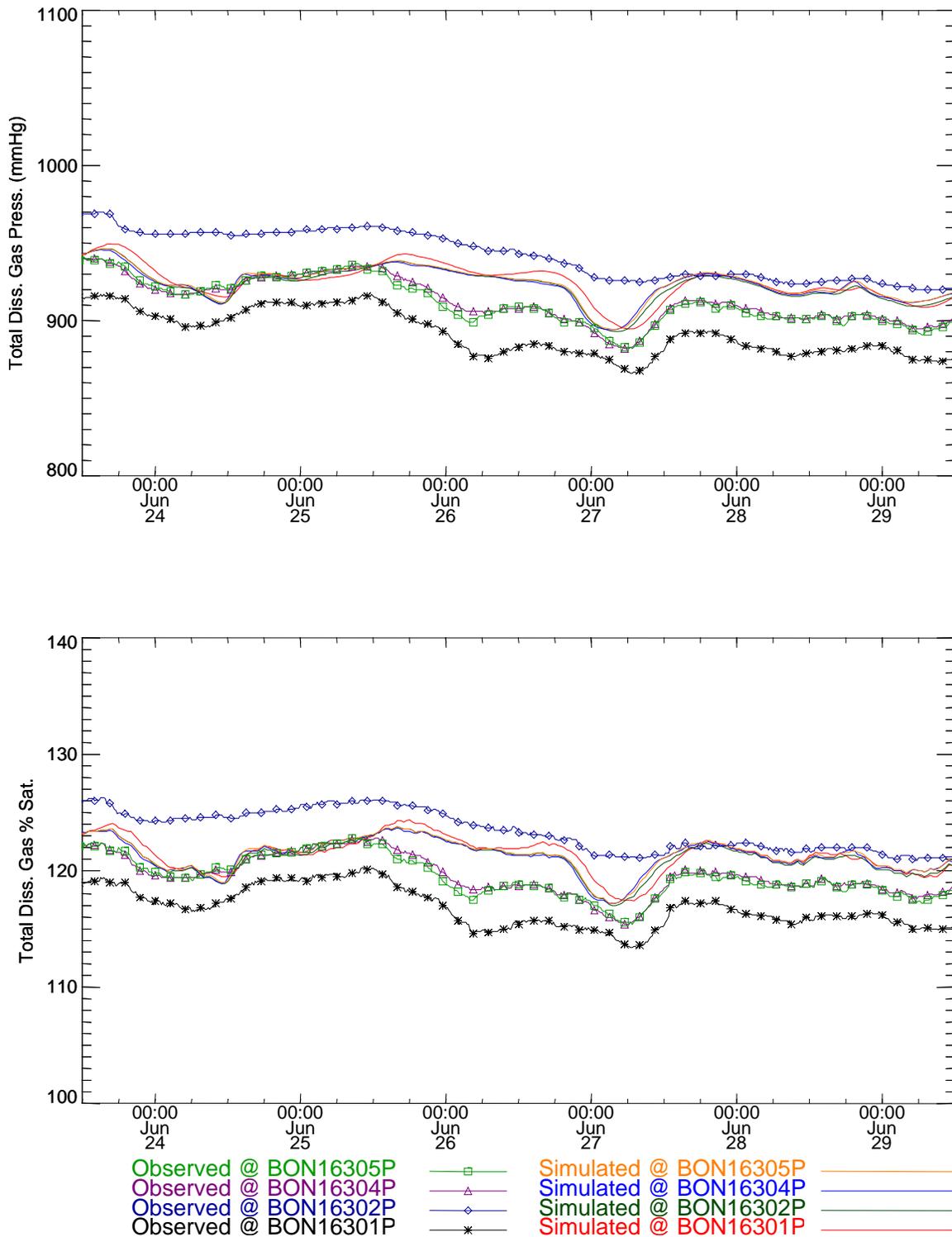


Figure 134. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 163.0 for the Summer 1997 study period (FMS-BC).

Table 73. Statistical summary of measurements and simulations near the Columbia River Mile 163.0 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON16301P	15.45	15.56	0.26	0.29	0.15
BON16302P	15.38	15.48	0.22	0.24	0.13
BON16304P	15.35	15.46	0.22	0.23	0.17
BON16305P	15.34	15.47	0.25	0.24	0.2
Concentration					
BON16301P	32.26	33.33	0.61	0.49	1.13
BON16302P	34.17	33.31	0.69	0.49	0.94
BON16304P	33.11	33.36	0.61	0.47	0.38
BON16305P	33.08	33.38	0.62	0.47	0.45
Gas Pressure					
BON16301P	891.78	925.08	14.39	11.81	34.94
BON16302P	942.27	923.17	15.46	11.21	22
BON16304P	912.85	924.01	14.29	10.7	13.79
BON16305P	911.9	924.63	14.58	10.74	15.75
% Saturation					
BON16301P	116.82	121.4	1.72	1.54	4.8
BON16302P	123.43	121.14	1.73	1.48	2.66
BON16304P	119.57	121.26	1.72	1.43	1.99
BON16305P	119.45	121.34	1.73	1.43	2.24

Table 74. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 163.0 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
BON16301P	100	38.41	61.59	60.9
BON16302P	100	66.44	95.85	96.89
BON16304P	100	100	100	100
BON16305P	100	100	100	100

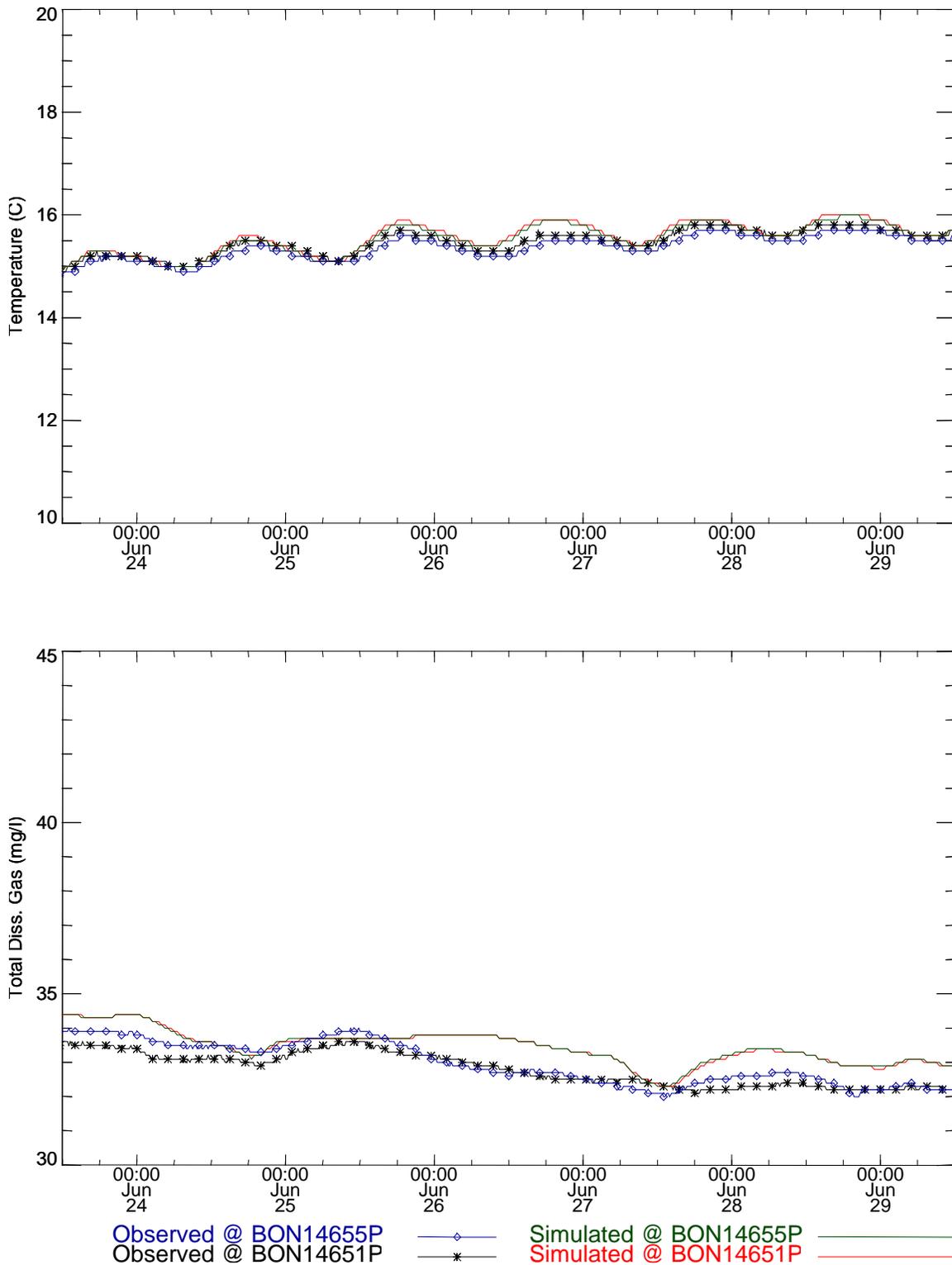


Figure 135. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 146.5 for the Summer 1997 study period (FMS-BC).

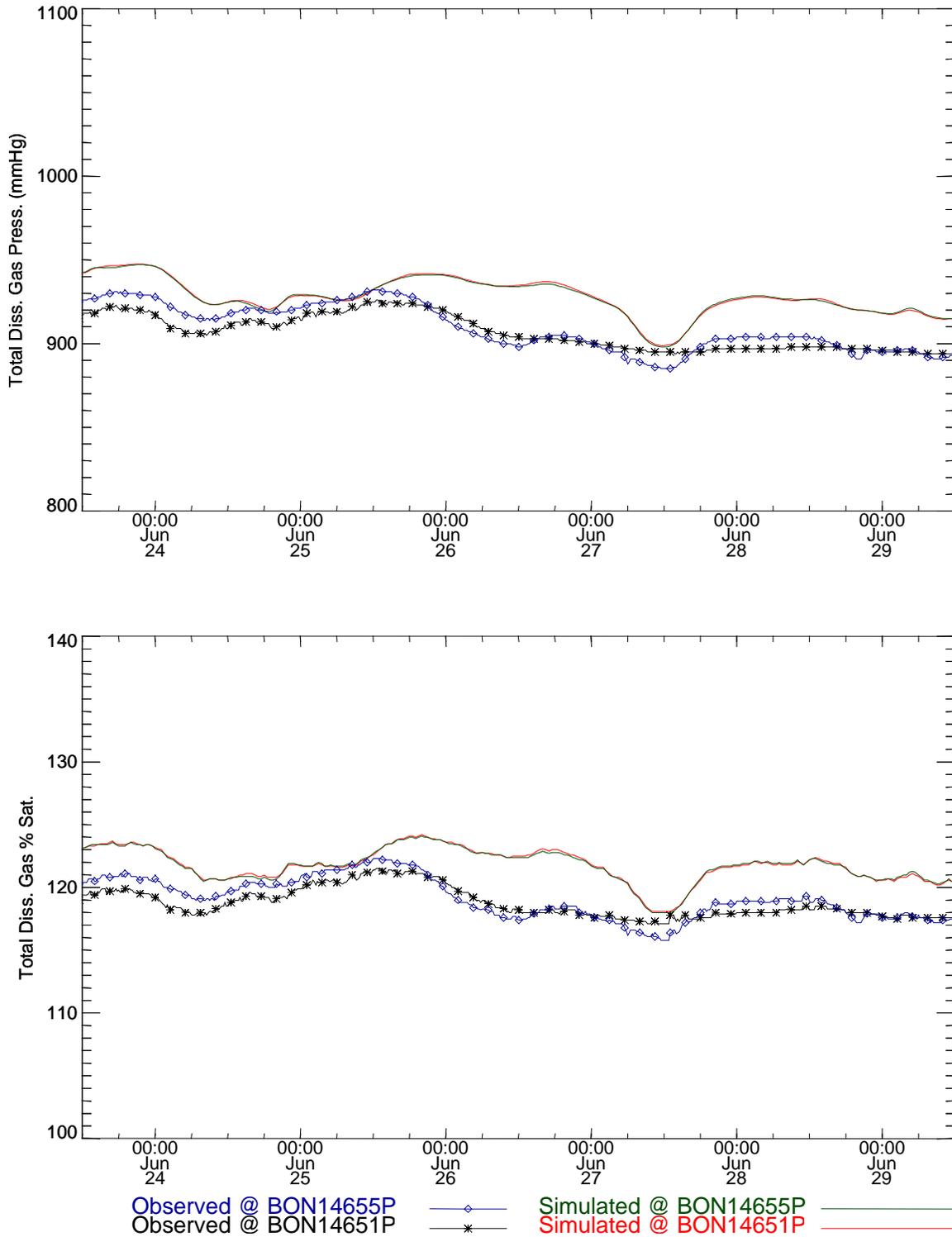


Figure 136. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 146.5 for the Summer 1997 study period (FMS-BC).

Table 75. Statistical summary of measurements and simulations near the Columbia River Mile 146.5 for the Summer 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON14651P	15.47	15.56	0.24	0.29	0.14
BON14655P	15.37	15.54	0.23	0.28	0.2
Concentration					
BON14651P	32.79	33.44	0.48	0.5	0.71
BON14655P	32.95	33.45	0.62	0.49	0.6
Gas Pressure					
BON14651P	906.52	927.98	10.29	11	22.99
BON14655P	909.19	927.81	13.72	10.88	20.94
% Saturation					
BON14651P	118.74	121.78	1.18	1.34	3.22
BON14655P	119.09	121.76	1.61	1.33	2.95

Table 76. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near Columbia River Mile 146.5 for the Summer 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON14651P	100	96.19	100	99.65
BON14655P	100	98.27	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.

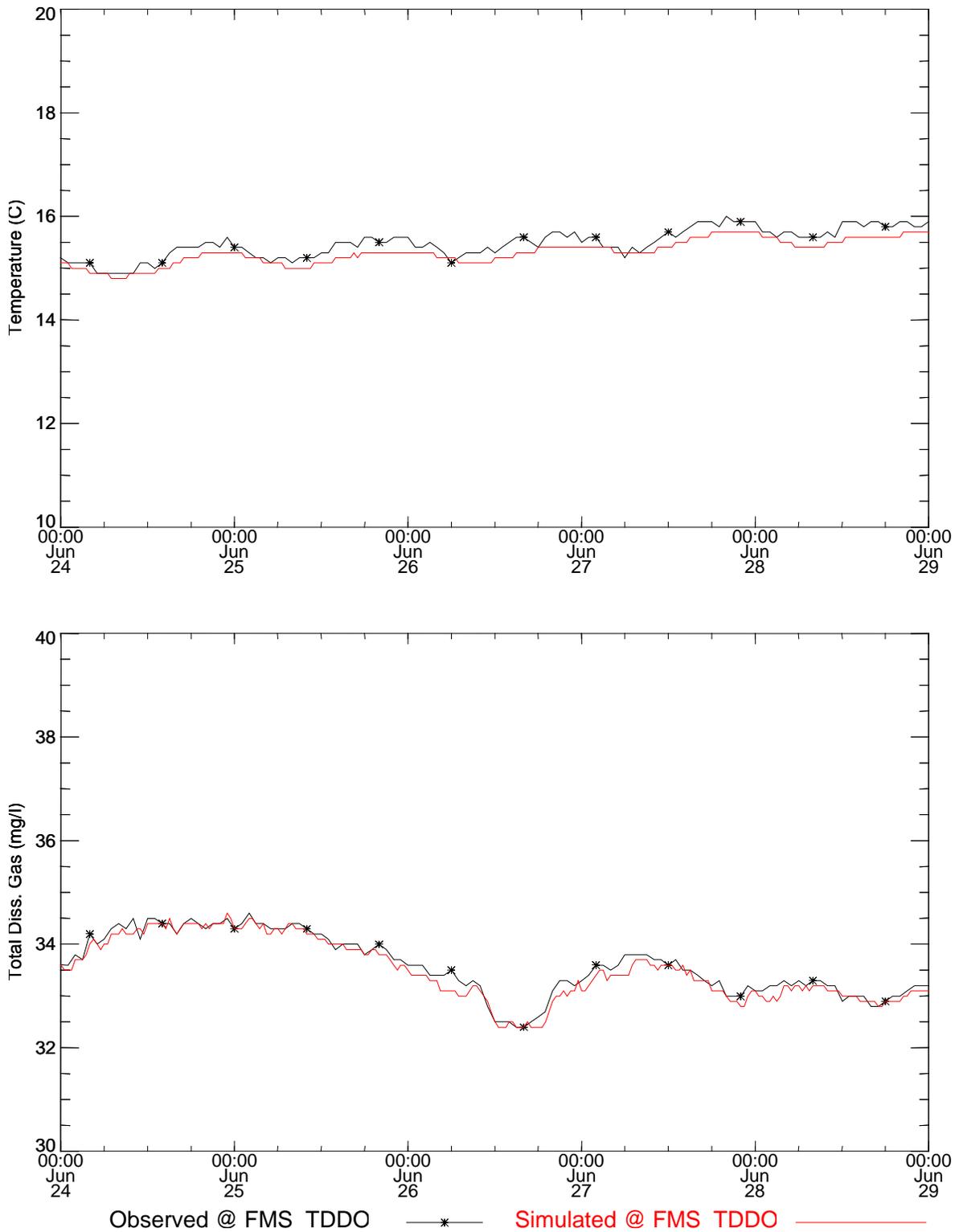


Figure 137. Temperature and total dissolved gas time series comparisons near fixed monitor TDDO for the Summer 1997 study period (TM-BC).

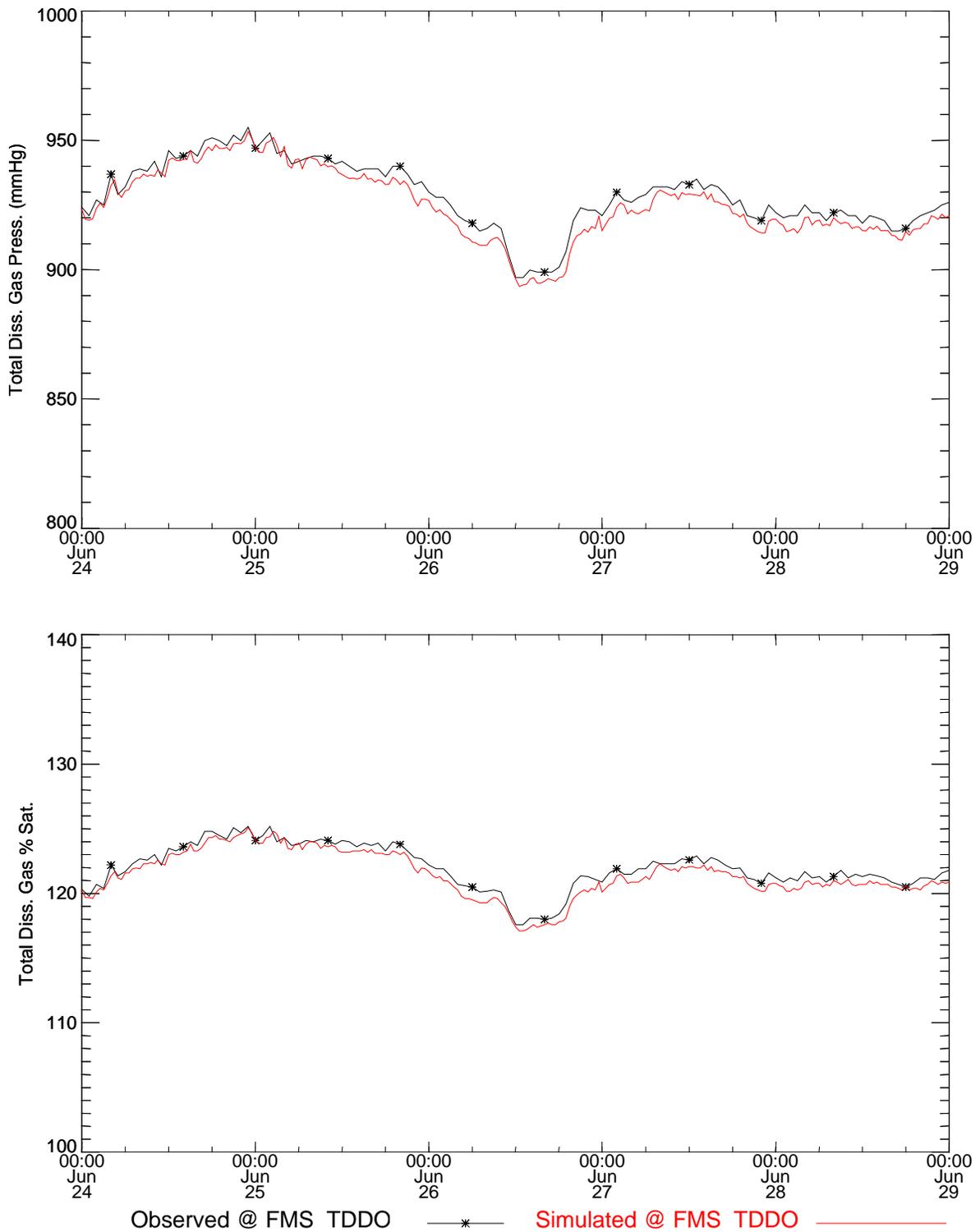


Figure 138. Total dissolved gas pressure and saturation time series comparisons near fixed monitor TDDO for the Summer 1997 study period (TM-BC).

Table 77. Statistical summary of measurements and simulations near fixed monitor TDDO for the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_TDDO	15.48	15.31	0.27	0.23	0.2
Concentration FMS_TDDO	33.6	33.51	0.57	0.59	0.14
Gas Pressure FMS_TDDO	928.83	925.11	12.96	13.7	4.27
% Saturation FMS_TDDO	121.98	121.44	1.7	1.78	0.62

Table 78. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near fixed monitor TDDO for the Summer 1997 study period (TM-BC).

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

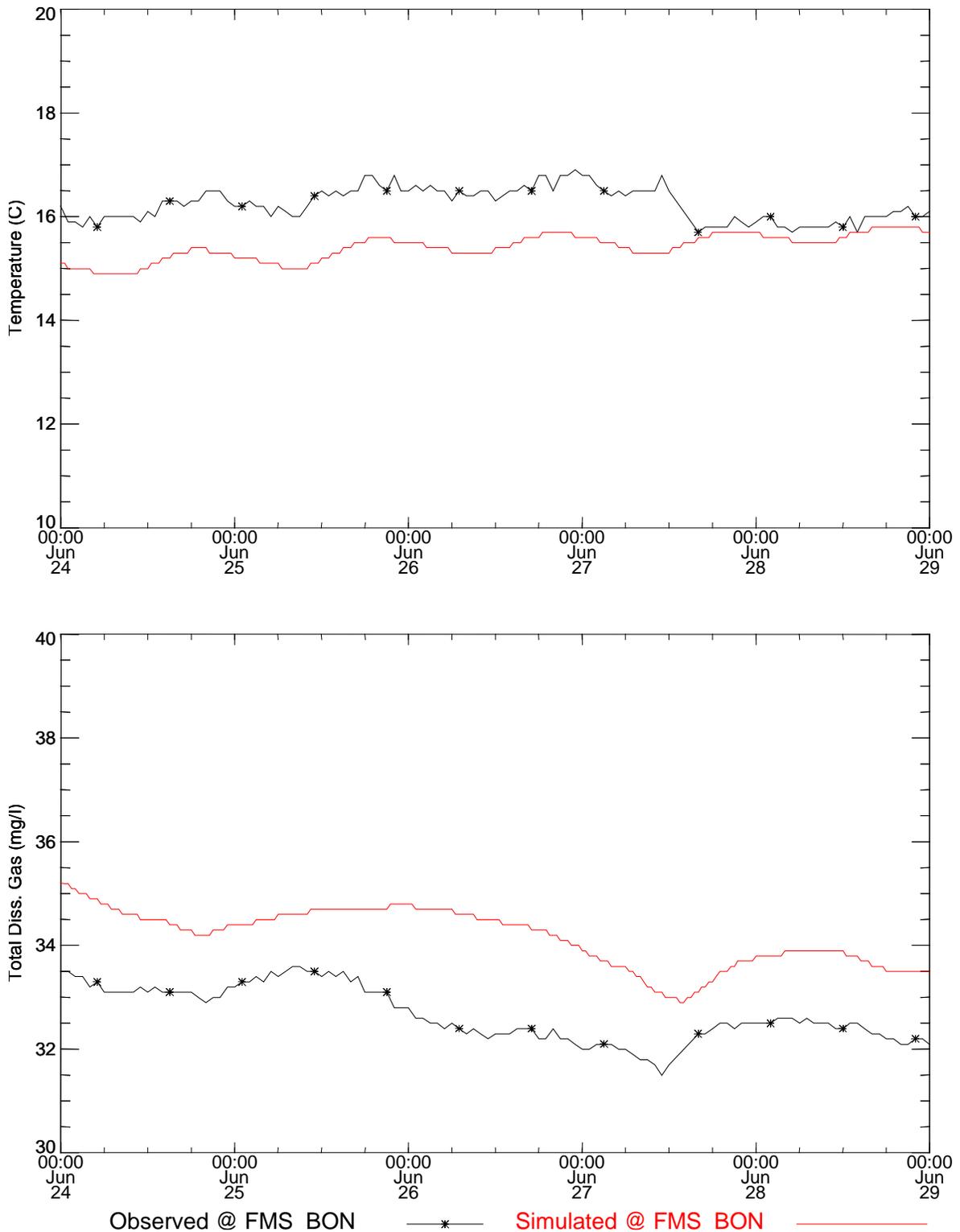


Figure 139. Temperature and total dissolved gas time series comparisons near the fixed monitor BON for the Summer 1997 study period (TM-BC).

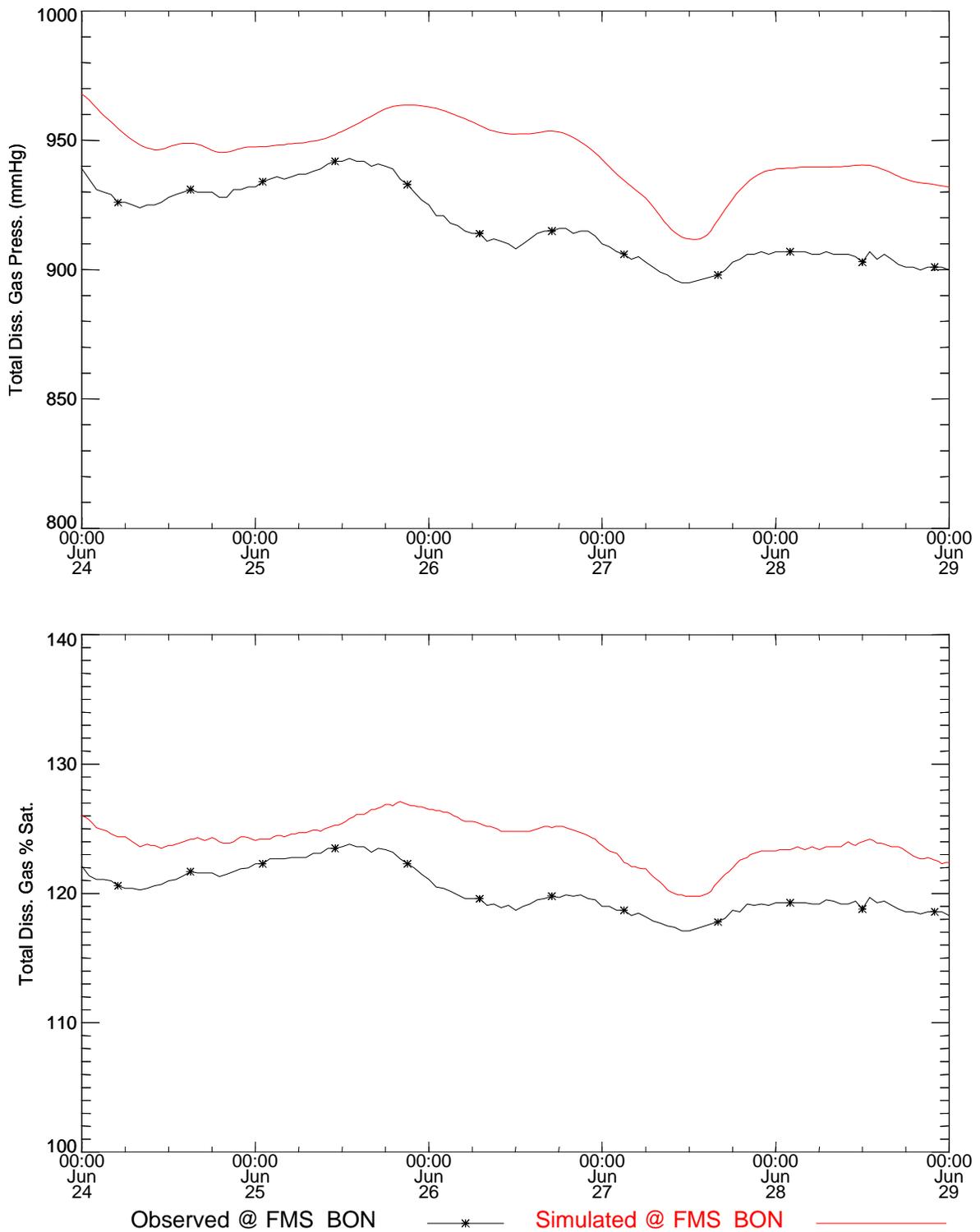


Figure 140. Total dissolved gas pressure and saturation time series comparisons near the fixed monitor BON for the Summer 1997 study period (TM-BC).

Table 79. Statistical summary of measurements and simulations near the fixed monitor BON for the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_BON	16.24	15.41	0.31	0.25	0.92
Concentration					
FMS_BON	32.66	34.16	0.52	0.55	1.54
Gas Pressure					
FMS_BON	917.37	944.75	14.25	12.81	29.01
% Saturation					
FMS_BON	120.2	124.02	1.76	1.64	4.03

Table 80. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements near the fixed monitor BON for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_BON	55.19	7.47	85.89	81.74

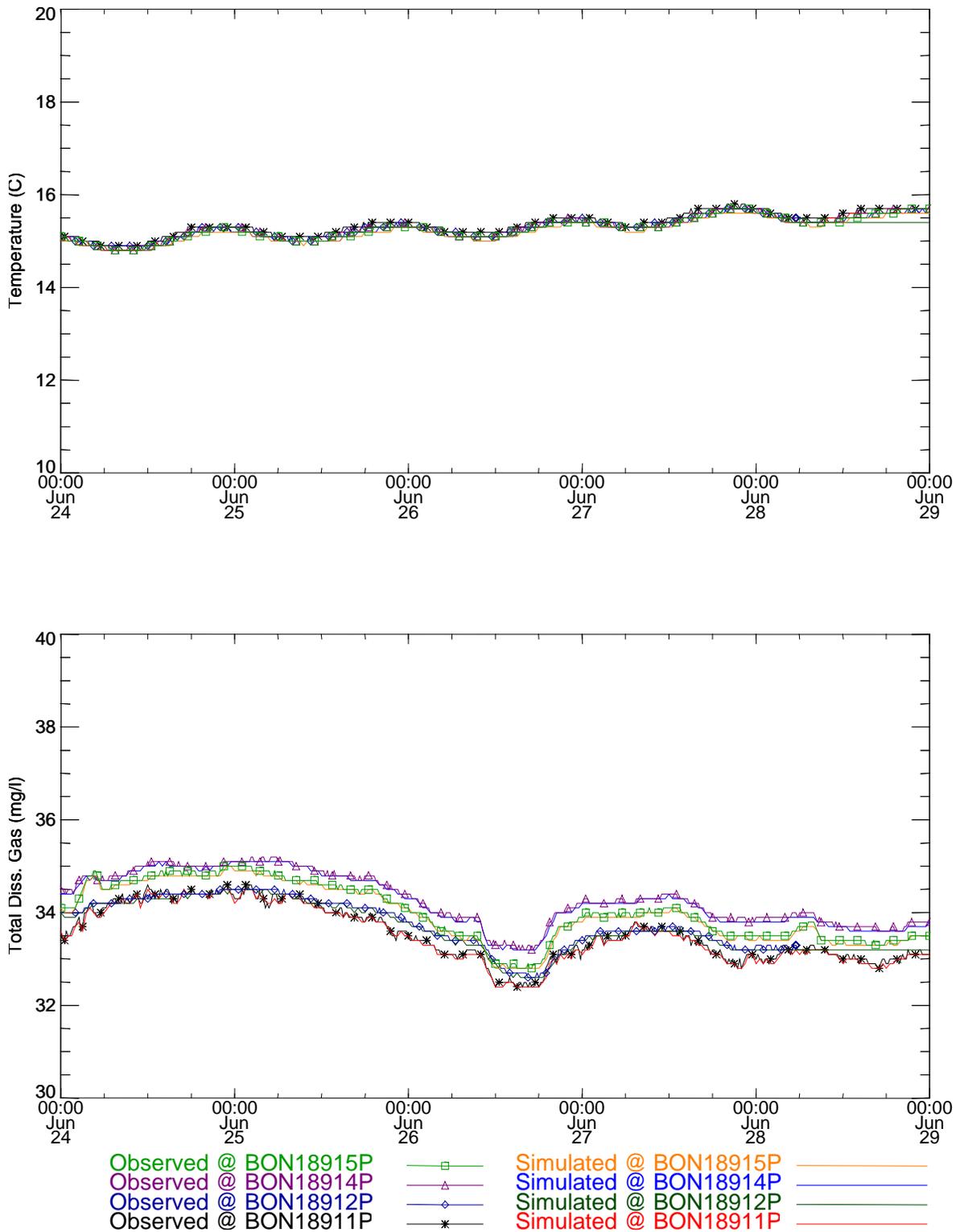


Figure 141. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 189.1 for the Summer 1997 study period (TM-BC).

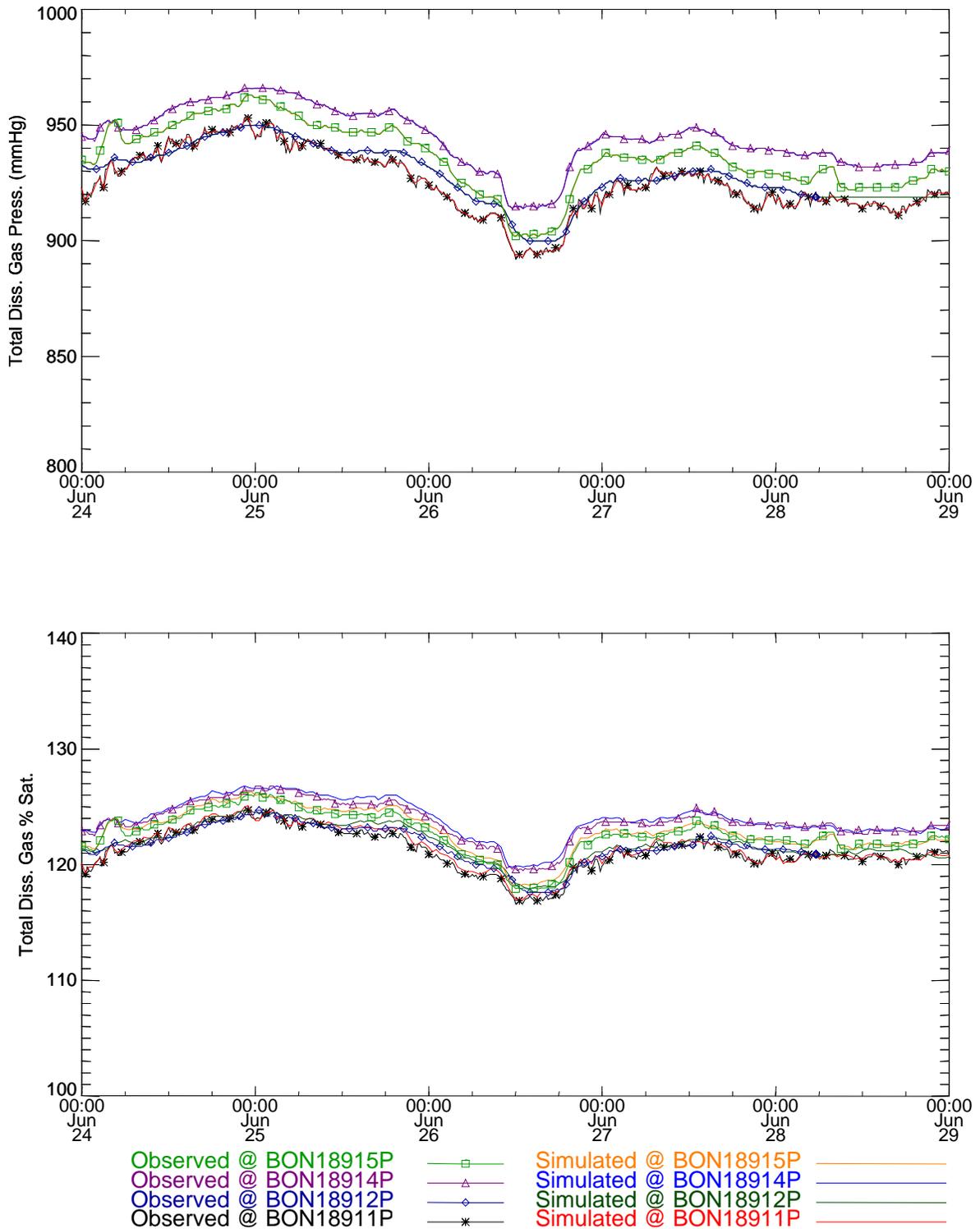


Figure 142. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 189.1 for the Summer 1997 study period (TM-BC).

Table 81. Statistical summary of measurements and simulations near the Columbia River Mile 189.1 for the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON18911P	15.36	15.3	0.23	0.24	0.08
BON18912P	15.3	15.25	0.22	0.21	0.07
BON18914P	15.3	15.25	0.24	0.24	0.07
BON18915P	15.28	15.23	0.24	0.23	0.07
Concentration					
BON18911P	33.55	33.5	0.59	0.59	0.07
BON18912P	33.7	33.65	0.52	0.53	0.07
BON18914P	34.3	34.25	0.55	0.56	0.07
BON18915P	34.01	33.96	0.62	0.62	0.07
Gas Pressure					
BON18911P	925.04	924.95	13.87	13.81	0.76
BON18912P	928.05	928.02	12.27	12.26	0.1
BON18914P	944.35	944.31	12.86	12.85	0.11
BON18915P	935.97	935.95	14.49	14.48	0.13
% Saturation					
BON18911P	121.21	121.42	1.79	1.79	0.33
BON18912P	121.59	121.82	1.59	1.6	0.33
BON18914P	123.75	123.96	1.67	1.67	0.33
BON18915P	122.64	122.86	1.86	1.87	0.33

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 189.1 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
BON18911P	100	100	100	100
BON18912P	100	100	100	100
BON18914P	100	100	100	100
BON18915P	100	100	100	100

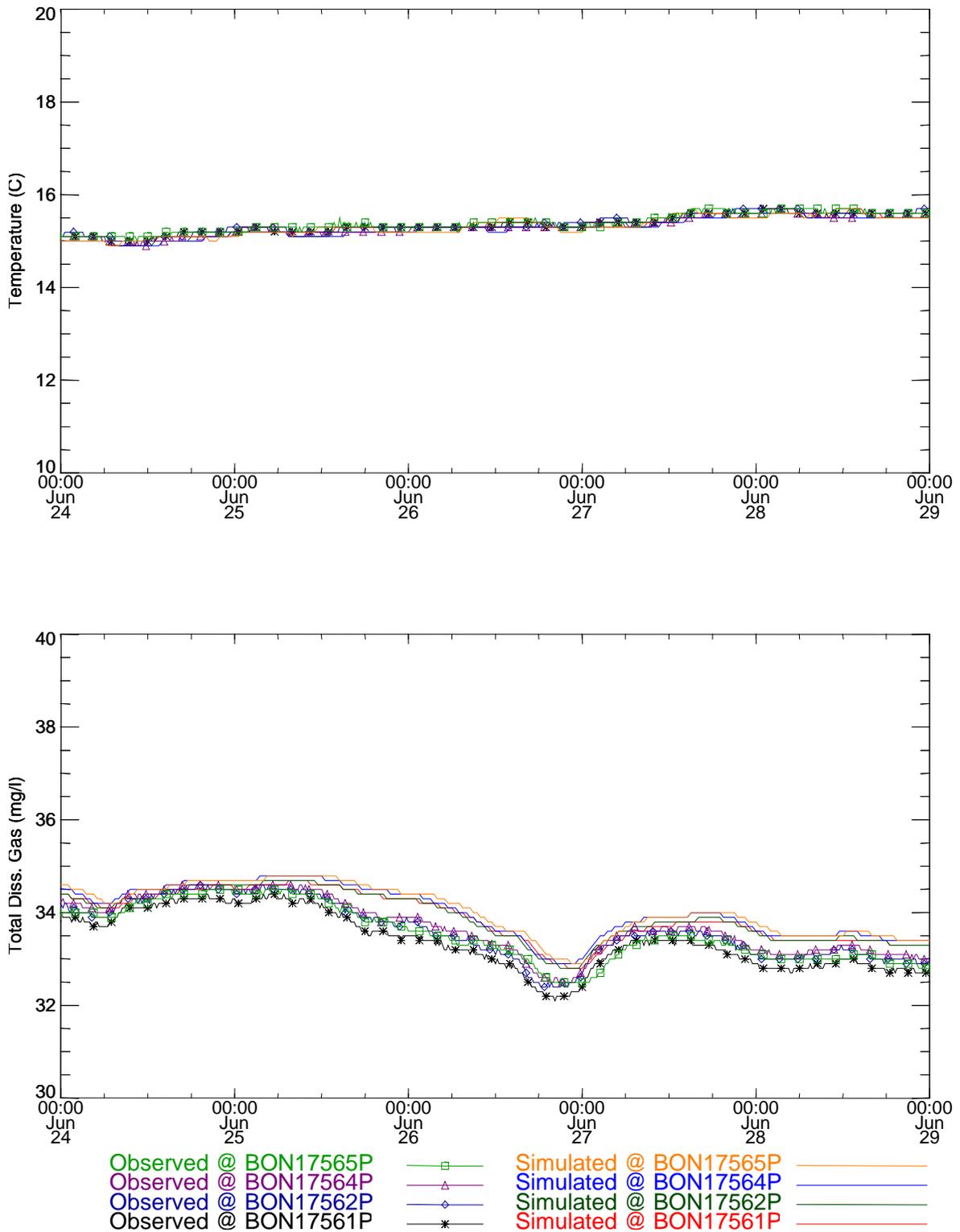


Figure 143. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 175.6 for the Summer 1997 study period (TM-BC).

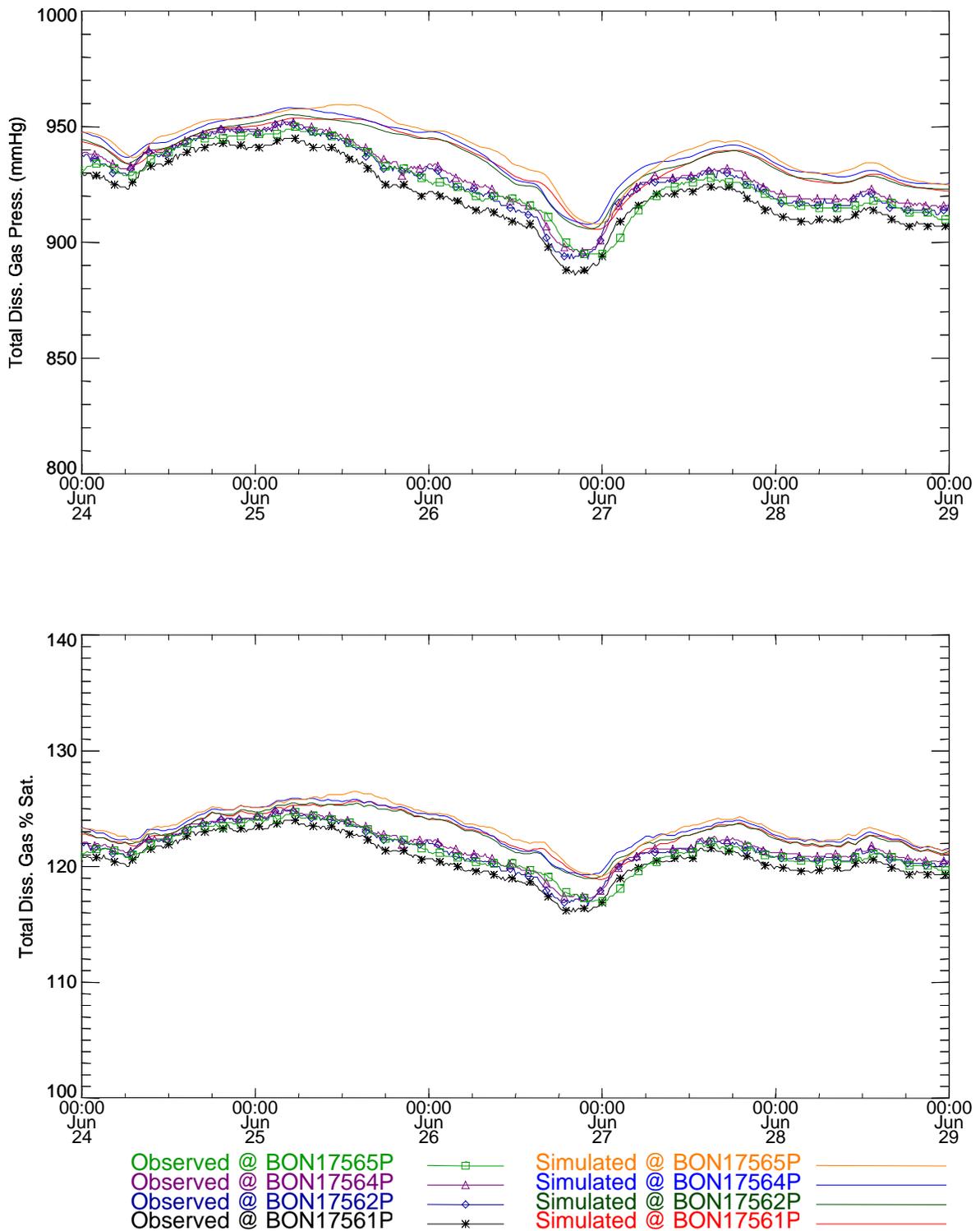


Figure 144. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 175.6 for the Summer 1997 study period (TM-BC).

Table 83. Statistical summary of measurements and simulations near the Columbia River Mile 175.6 for the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON17561P	15.36	15.32	0.19	0.2	0.06
BON17562P	15.37	15.29	0.2	0.2	0.1
BON17564P	15.33	15.28	0.2	0.2	0.07
BON17565P	15.39	15.32	0.19	0.21	0.1
Concentration					
BON17561P	33.39	33.89	0.62	0.53	0.54
BON17562P	33.61	33.91	0.61	0.54	0.35
BON17564P	33.71	34.01	0.6	0.55	0.34
BON17565P	33.55	34.04	0.6	0.54	0.52
Gas Pressure					
BON17561P	920.71	935.8	14.55	12.37	16.35
BON17562P	927.04	935.77	14.36	12.43	9.96
BON17564P	928.86	938.3	13.83	12.65	10.08
BON17565P	925.59	940.01	14.18	12.87	15.09
% Saturation					
BON17561P	120.65	122.85	1.85	1.65	2.38
BON17562P	121.48	122.84	1.83	1.64	1.54
BON17564P	121.71	123.18	1.76	1.67	1.57
BON17565P	121.28	123.4	1.81	1.72	2.22

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 175.6 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
BON17561P	100	100	100	100
BON17562P	100	100	100	100
BON17564P	100	100	100	100
BON17565P	100	100	100	100

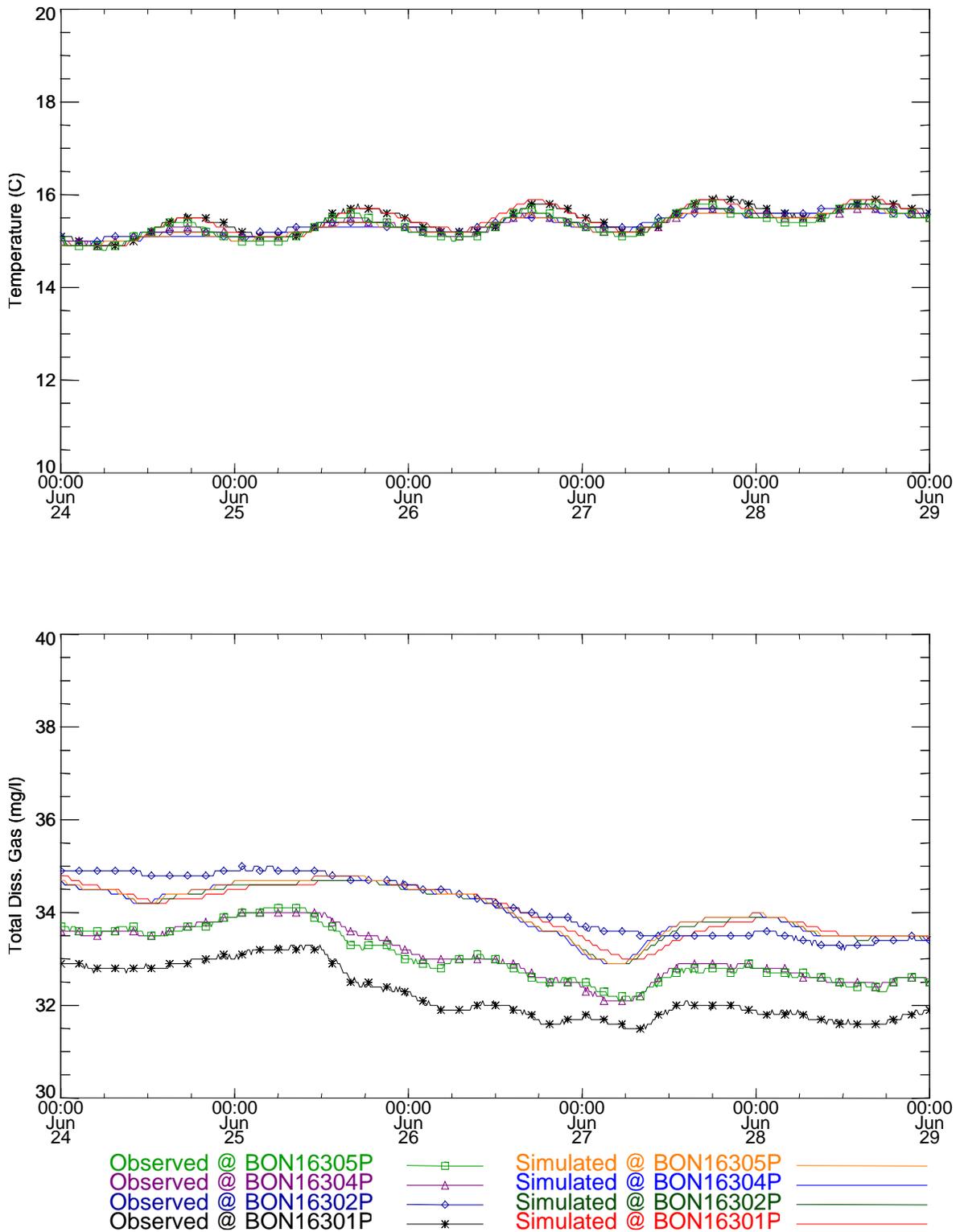


Figure 145. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 163.0 for the Summer 1997 study period (TM-BC).

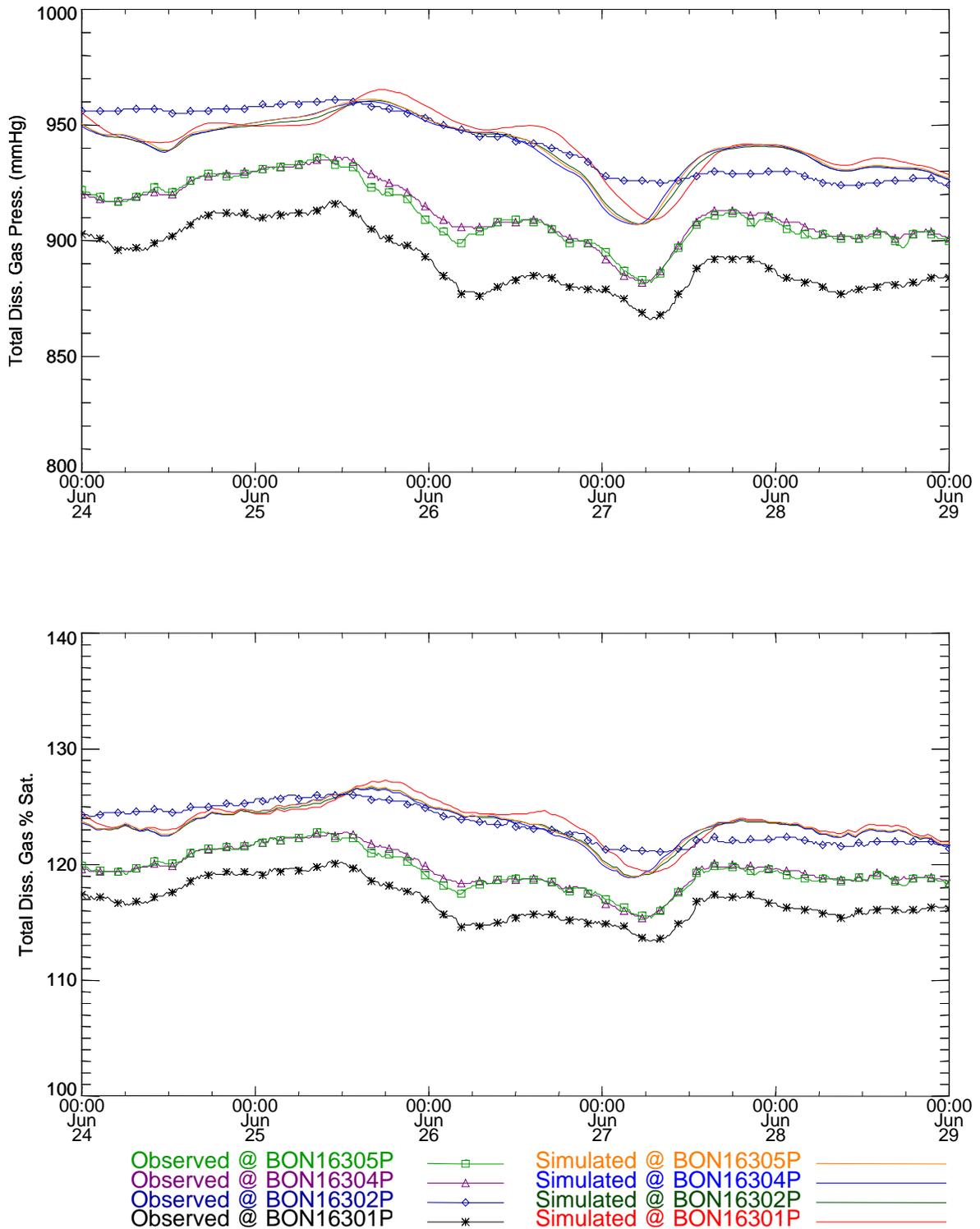


Figure 146. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 163.0 for the Summer 1997 study period (TM-BC).

Table 85. Statistical summary of measurements and simulations near the Columbia River Mile 163.0 for the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON16301P	15.46	15.45	0.27	0.29	0.07
BON16302P	15.38	15.35	0.21	0.23	0.07
BON16304P	15.35	15.32	0.22	0.22	0.09
BON16305P	15.35	15.33	0.26	0.22	0.11
Concentration					
BON16301P	32.24	34.05	0.57	0.52	1.85
BON16302P	34.16	34.02	0.63	0.53	0.32
BON16304P	33.09	34.05	0.56	0.54	0.99
BON16305P	33.05	34.07	0.57	0.54	1.05
Gas Pressure					
BON16301P	891.27	942.48	13.43	12.7	52.22
BON16302P	942.28	940.08	13.96	12.6	8.51
BON16304P	912.36	940.22	13.33	12.73	28.49
BON16305P	911.31	940.74	13.33	12.79	30.39
% Saturation					
BON16301P	116.79	123.73	1.71	1.71	7.08
BON16302P	123.47	123.41	1.63	1.69	1.04
BON16304P	119.55	123.43	1.72	1.71	3.97
BON16305P	119.41	123.5	1.69	1.72	4.22

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 3.0 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
BON16301P	100	0	3.32	1.24
BON16302P	100	100	100	100
BON16304P	100	73.44	92.12	88.8
BON16305P	100	56.43	84.65	82.99

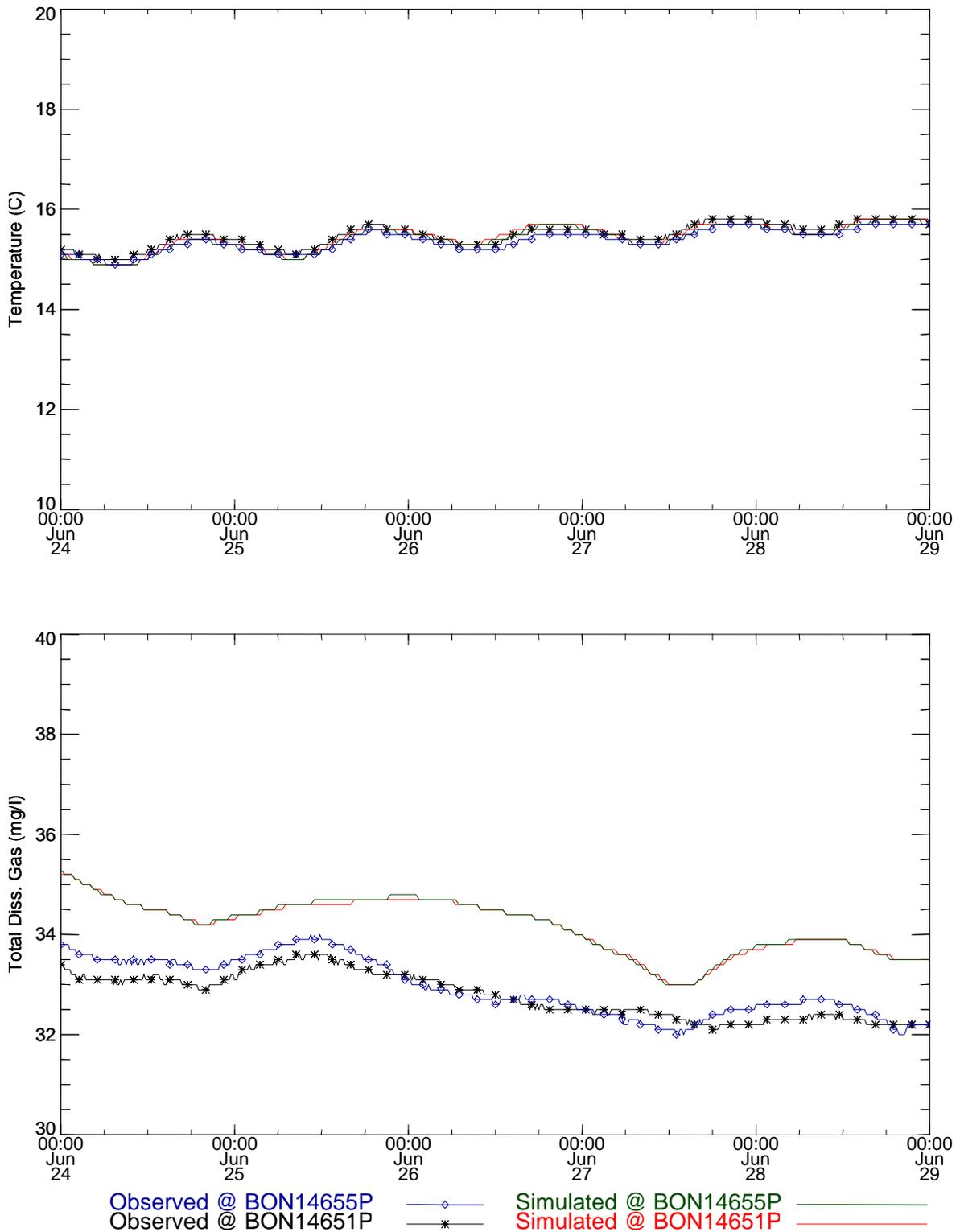


Figure 147. Temperature and total dissolved gas time series comparisons near the Columbia River Mile 146.5 for the Summer 1997 study period (TM-BC).

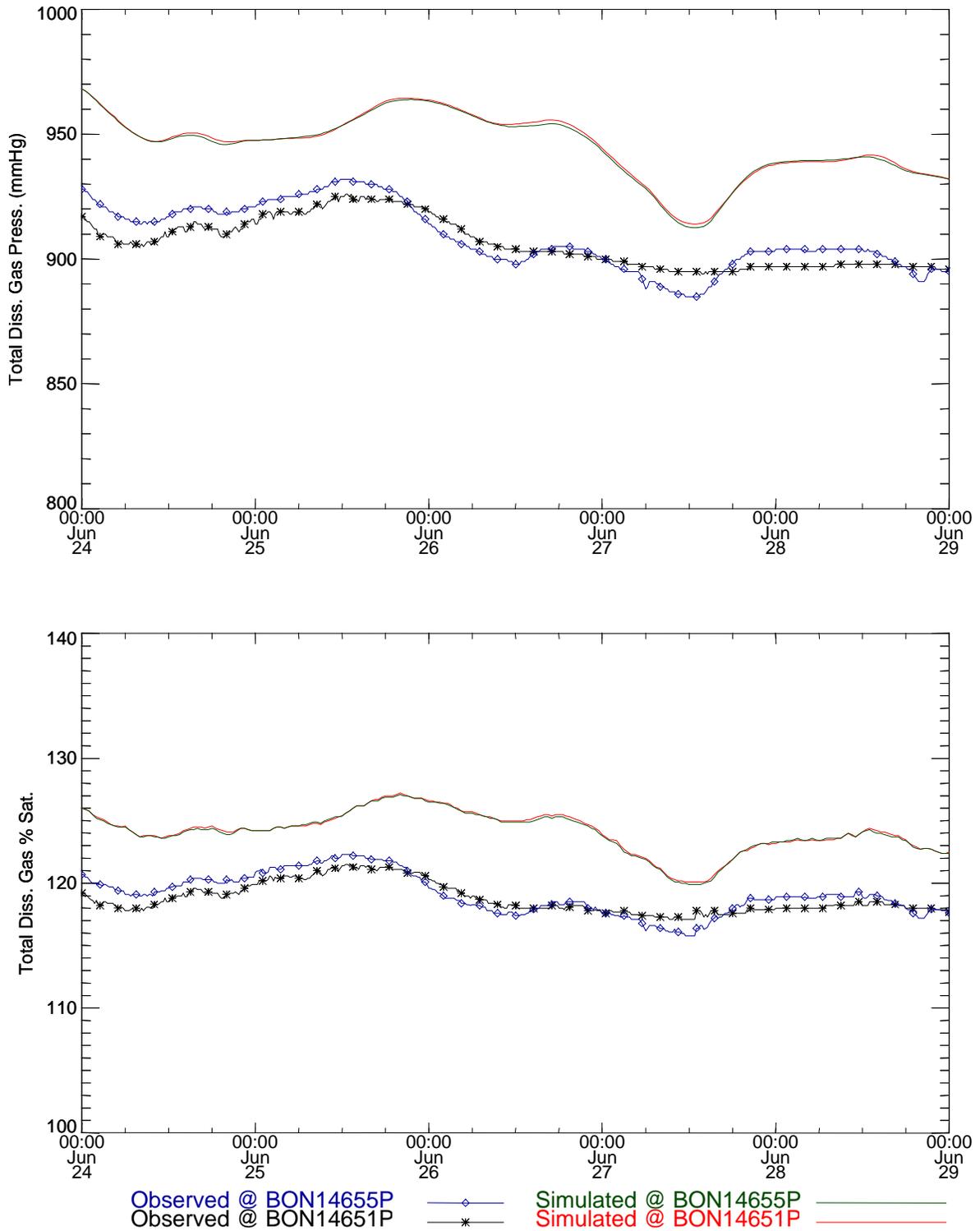


Figure 148. Total dissolved gas pressure and saturation time series comparisons near Columbia River Mile 146.5 for the Summer 1997 study period (TM-BC).

Table 87. Statistical summary of measurements and simulations near the Columbia River Mile 146.5 for the Summer 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
BON14651P	15.49	15.44	0.23	0.26	0.09
BON14655P	15.38	15.41	0.22	0.25	0.08
Concentration					
BON14651P	32.77	34.16	0.45	0.54	1.42
BON14655P	32.93	34.17	0.56	0.55	1.28
Gas Pressure					
BON14651P	906.37	945.55	9.74	12.76	40.07
BON14655P	908.76	945.1	12.77	12.81	37.5
% Saturation					
BON14651P	118.76	124.13	1.21	1.63	5.49
BON14655P	119.08	124.07	1.61	1.64	5.15

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 146.5 for the Summer 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
BON14651P	100	14.52	42.74	39.42
BON14655P	100	32.78	62.66	57.68

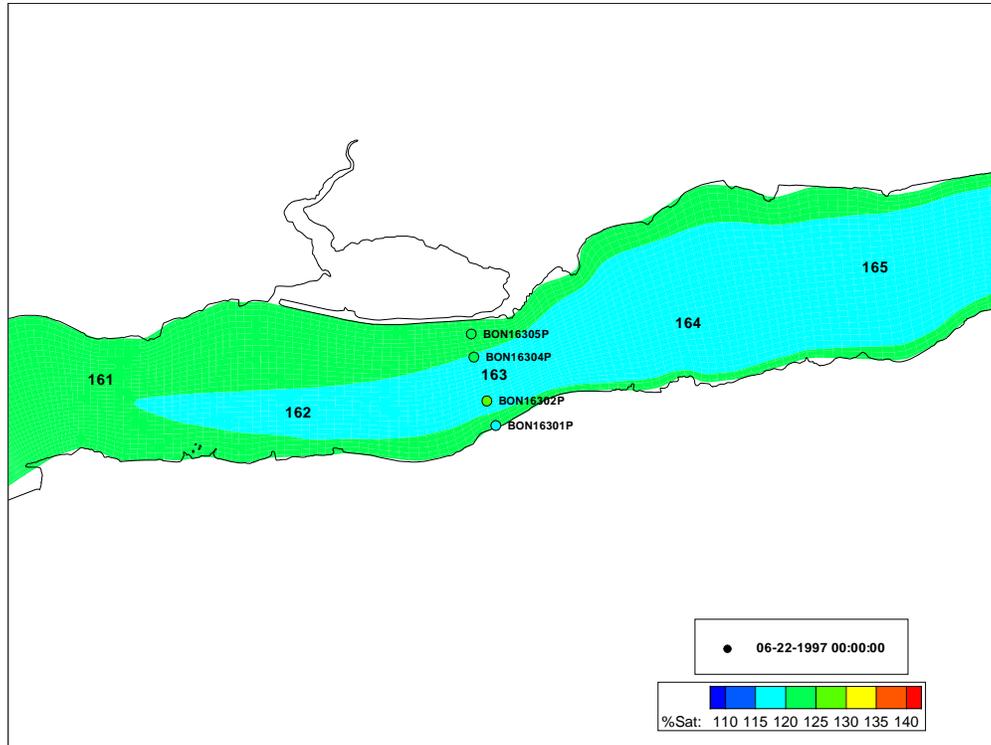


Figure 149. Spatial distribution of dissolved gas near Columbia river mile 163 during the Summer 1997 study period.

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.

Appendix A. Bonneville Pool Data Sources

A.1 Bathymetry

Bathymetric data for the Columbia River was gathered from the various sources shown in Table 89. The primary source was Bonneville pool survey, during which elevations were measured at a relatively fine spacing over the entire pool, except in the restricted areas below The Dalles dam and above Bonneville dam. 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 Bonneville pool is shown in Figure 150. Once the surface was produced, it was “sampled” at the necessary grid locations to produce the bathymetry required by the hydrodynamic model grid

Table 89. Columbia River bathymetry data sets used to create the Bonneville pool bathymetric surface. Listed Figure numbers refer to the map which shows the survey location(s).

Bathymetric Data Set	Source	Survey Date	Approximate Rivermile	
			Start	End
Tidal Reach Survey (Tidbath, Figure 152)	George Kalli (Portland)	unknown	5.0	145.1
Bonneville Pool Survey (Figure 151)	George Kalli (Portland)	unknown	148.0	191.7
Bonneville Spillway (bonn-n.xyz and bonn-s.xyz, Figure 152)	Kim Fodrea (Portland)	1996	145.5	145.5
Bonneville Tailrace (Bod026a.xyz, Figure 152))	Gregg Bertrand (Portland)	unknown	144.5	145.5
Bonneville North Powerhouse Tailrace (Bon271.xyz, Figure 152))	Gregg Bertrand (Portland)	unknown	145.5	145.7
Bonneville North Powerhouse Forebay (Bon227.xyz, Figure 152))	Gregg Bertrand (Portland)	unknown	145.7	146.0
Bonneville South Powerhouse Forebay (Bon023.xyz, Figure 152))	Gregg Bertrand (Portland)	unknown	145.3	146.0
Bonneville Forebay North Channel (Bon271.xyz) , Figure 152)	Gregg Bertrand (Portland)	unknown	146.1	146.8
Bonneville Forebay Main Channel (Bon225, Figure 152))	Mike Cristler (Portland)	1990	146.2	148.0
The Dalles Pool Survey (Figure 151)	George Kalli (Portland)	unknown	191.8	216.5
The Dalles Tailrace Survey (Figure 151)	Gregg Bertrand (Portland)	1981	191.0	192.5
Digitized NOAA Navigation Charts (Figure 151 and Figure 152)	Battelle	unknown	various	various

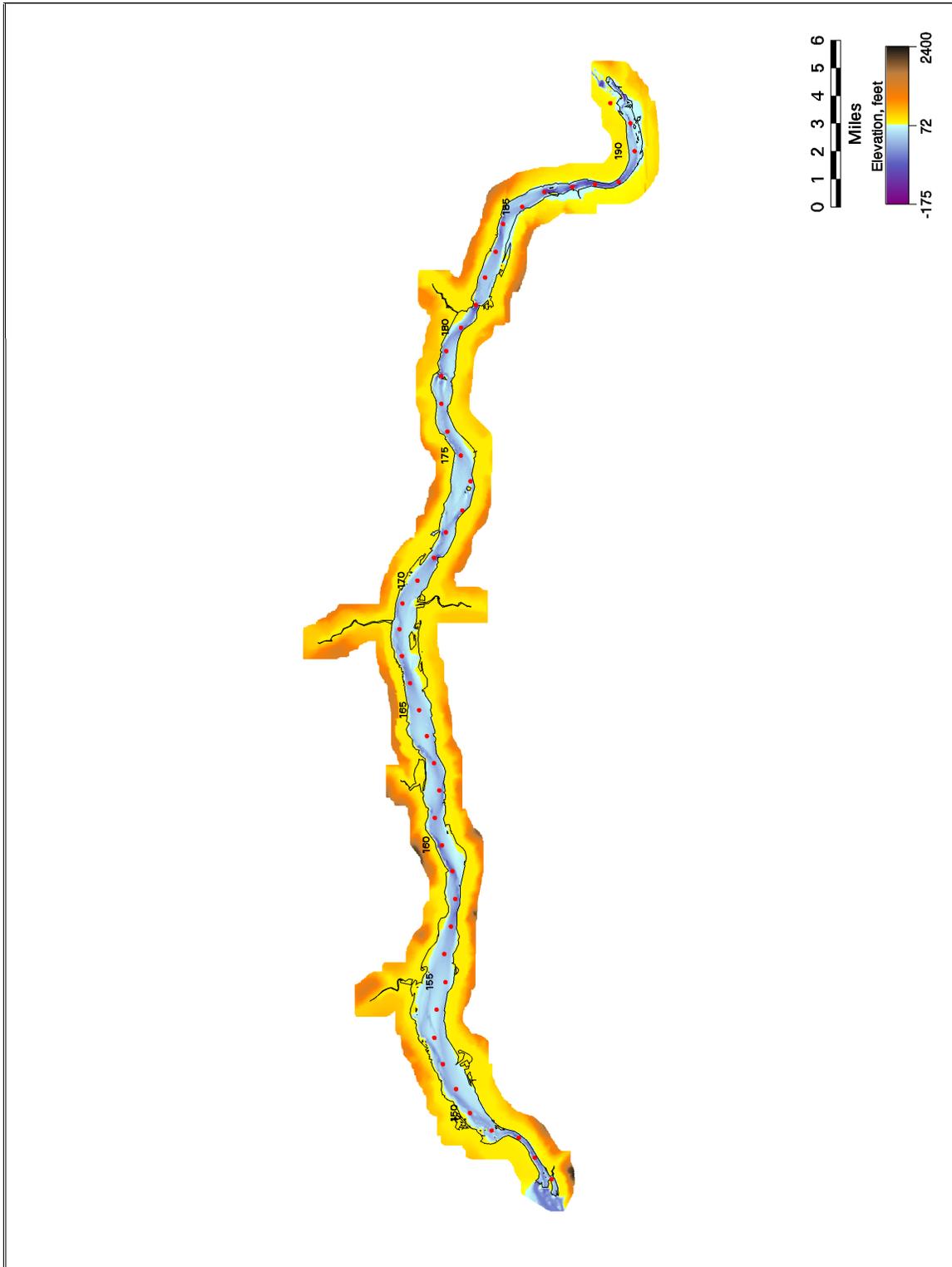


Figure 150. Color representation of Bonneville pool bathymetric surface.

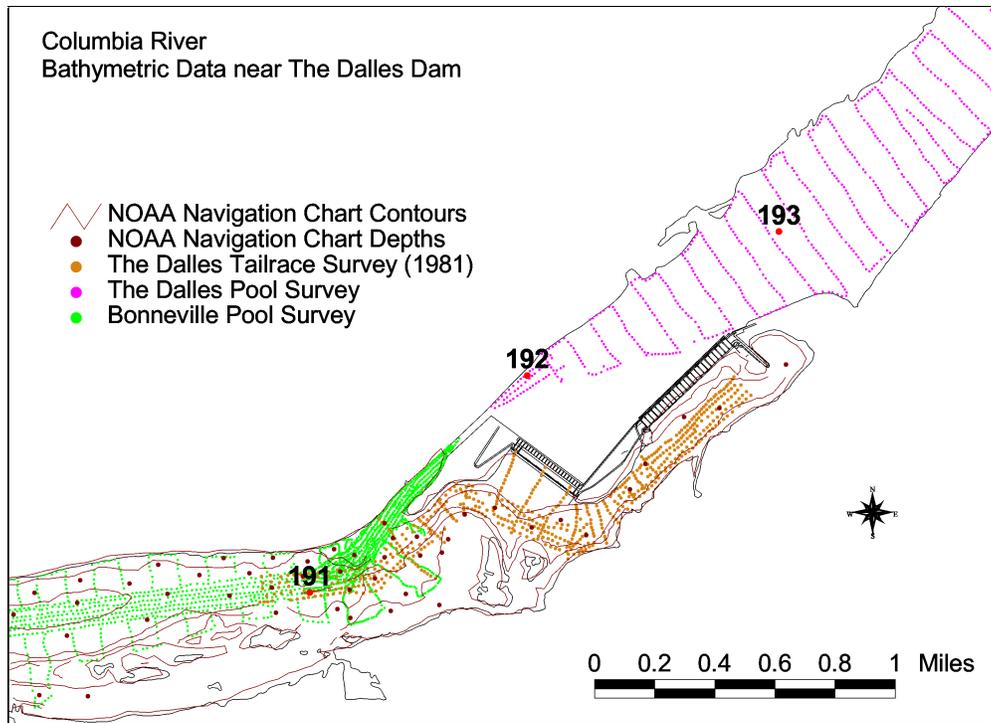


Figure 151. Bathymetric data near The Dalles Dam.

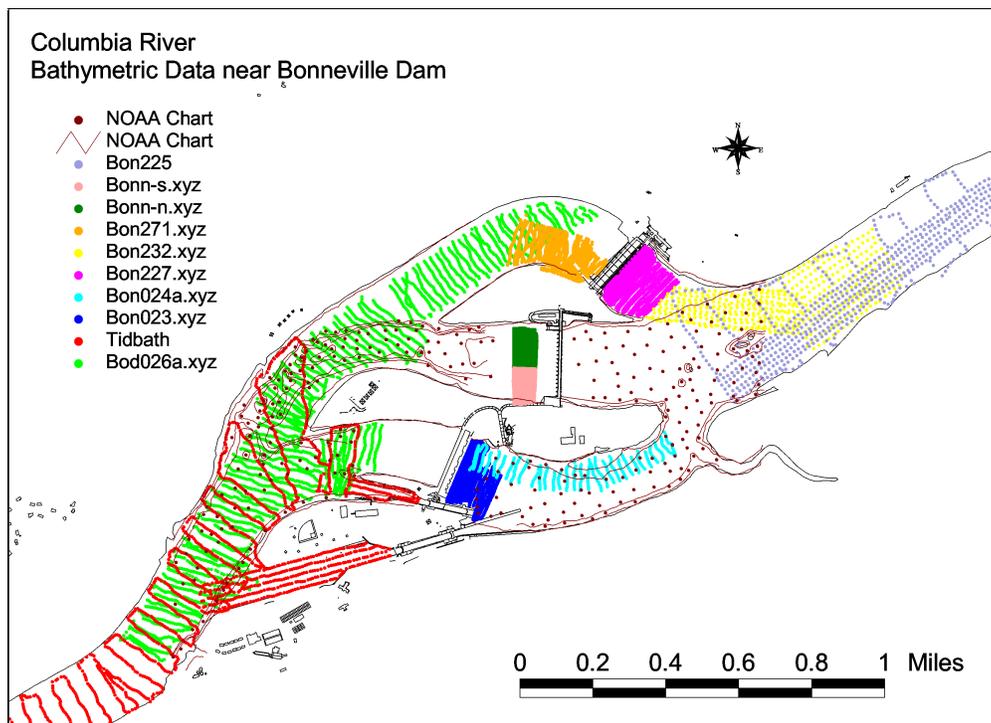


Figure 152. Bathymetric data near Bonneville dam.

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 Bonneville pool area are shown in Figure 153. 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 The Dalles dam model boundary.

The dissolved gas pool studies performed in Bonneville Pool to date are shown in Table 90 and their durations are shown graphically in Figure 154. During these studies water temperature and TDG pressures were measured at several locations within Bonneville pool. 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.

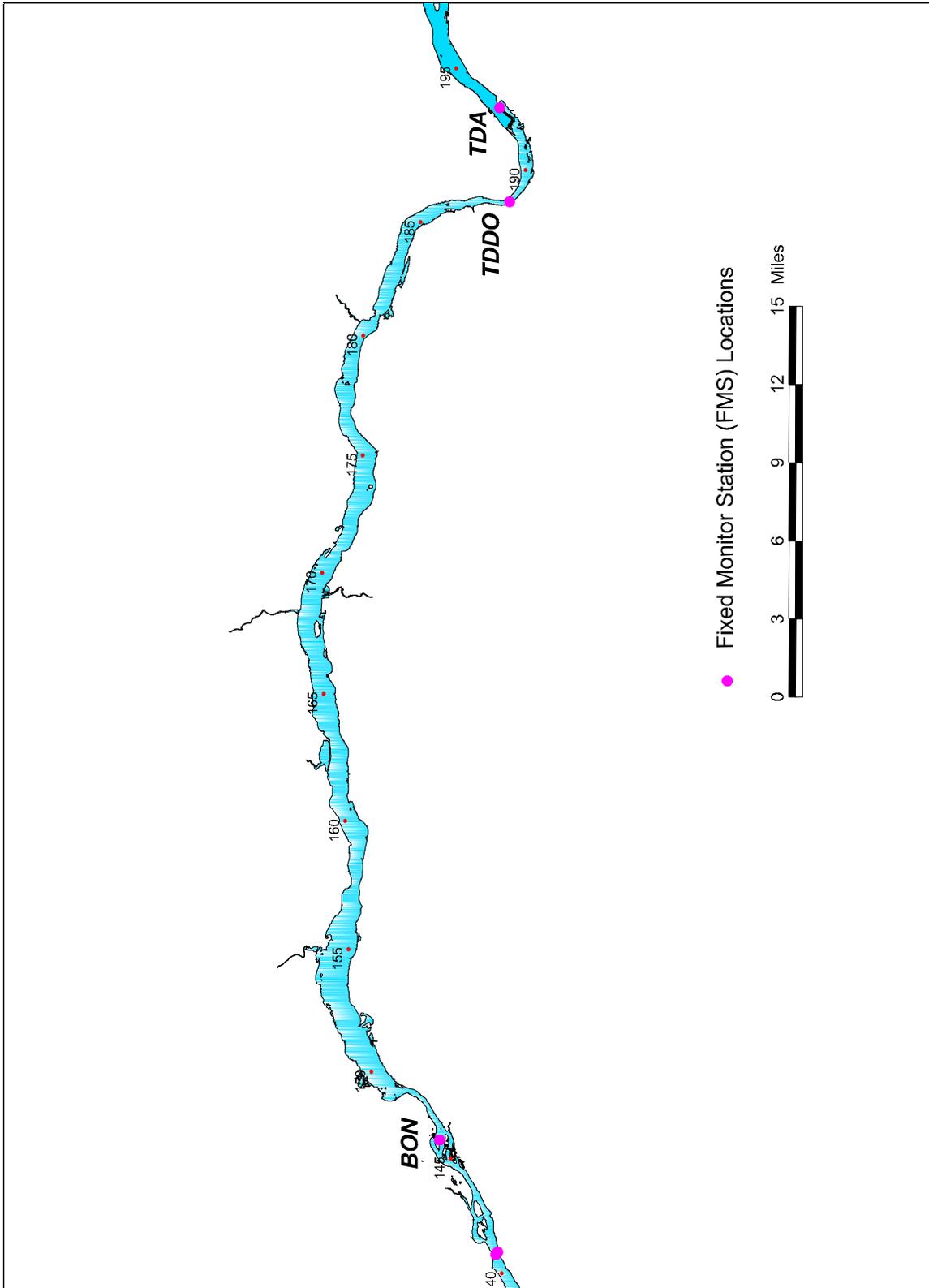


Figure 153. FMS locations in and around Bonneville pool.

Table 90. Dates of dissolved gas field studies in Bonneville pool.

STUDY SET	Start	End
BON SPR 96	6/6/96 9:09:00 AM	6/17/96 5:54:00 PM
BON SUM 96	8/3/96 12:30:00 PM	8/15/96 11:21:00 AM
BON TDA SUM 97	6/19/97 4:00:00 PM	7/7/97 11:30:00 AM

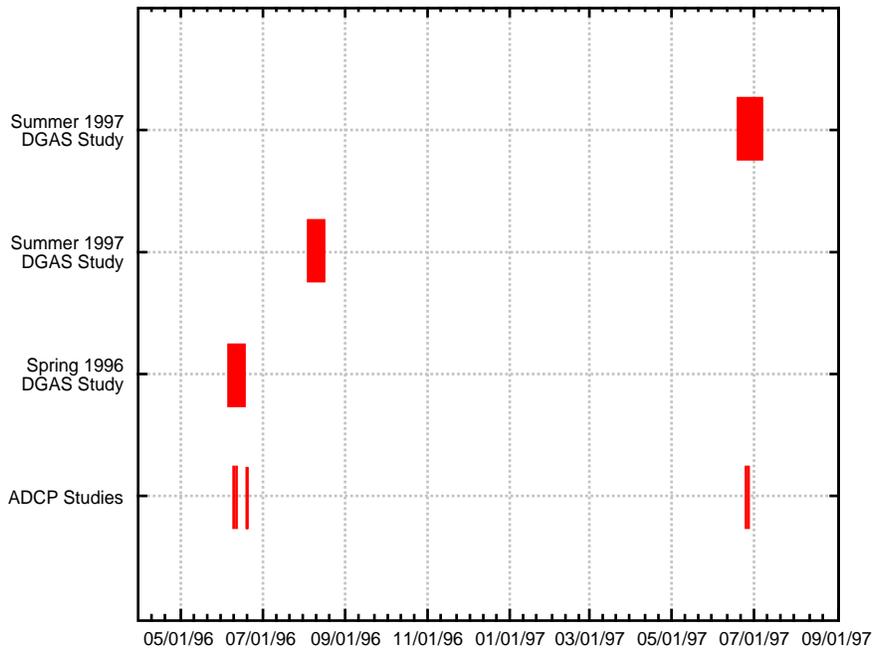


Figure 154. Dates and durations of dissolved gas and ADCP velocity studies in Bonneville Pool

A.2.2 ADCP Velocity Measurements

As shown in Figure 154, 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 155 through Figure 167 show the measurements made as small arrows. The measurements were thinned for clarity in those figures: only one arrow in three was drawn.

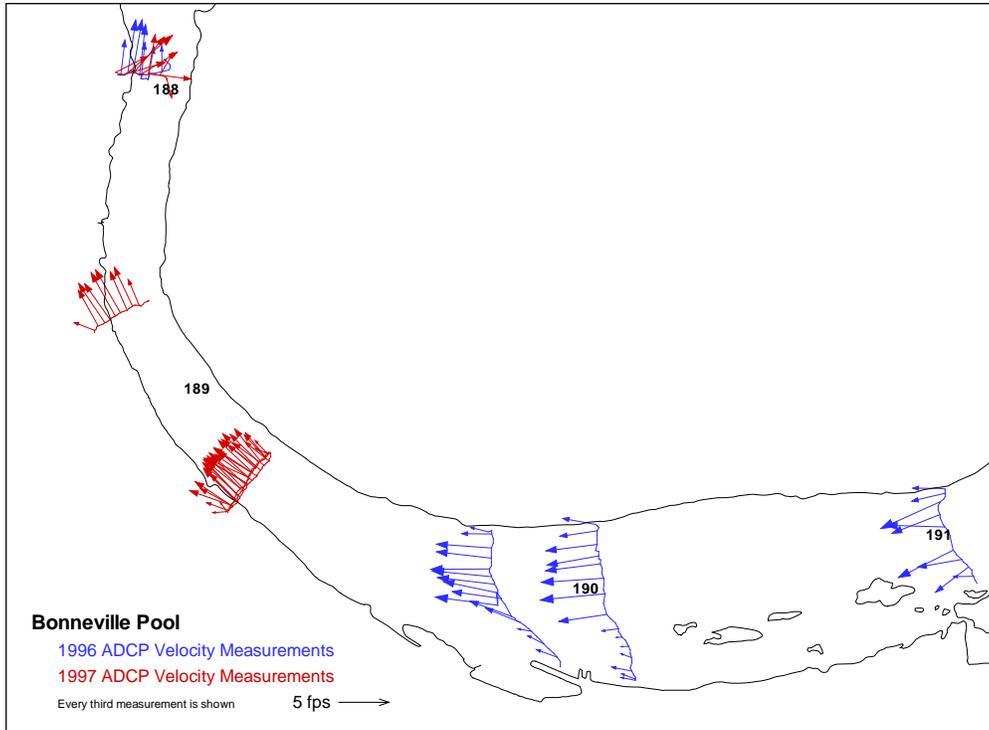


Figure 155. Bonneville pool ADCP velocity measurements near The Dalles.

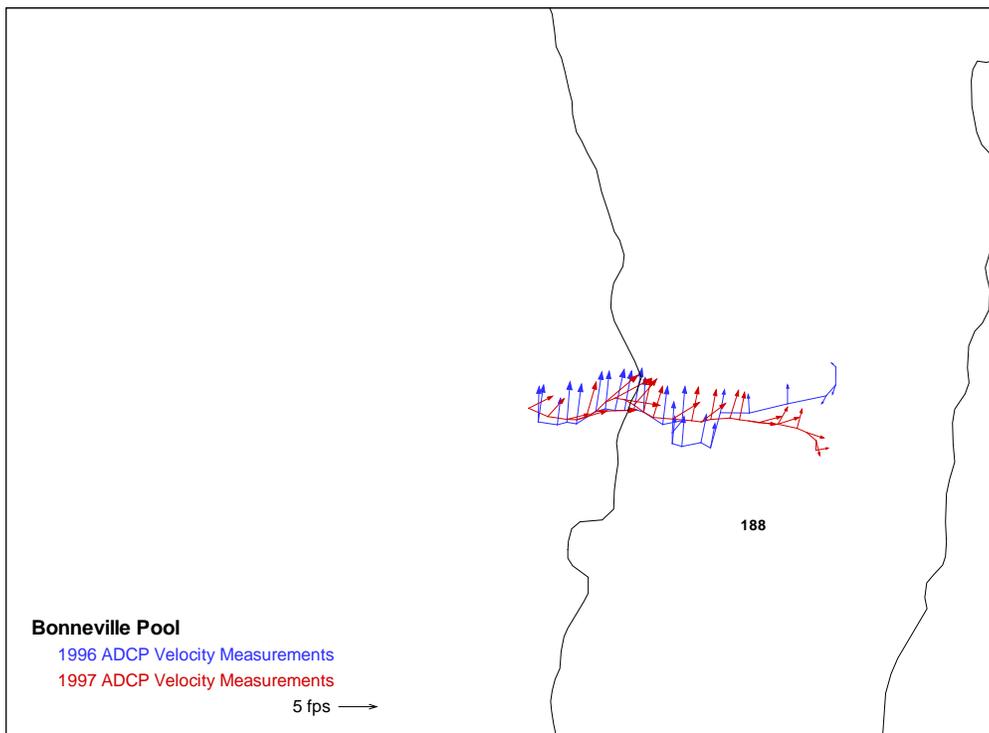


Figure 156. Bonneville pool ADCP velocity measurements near Columbia River mile 188.

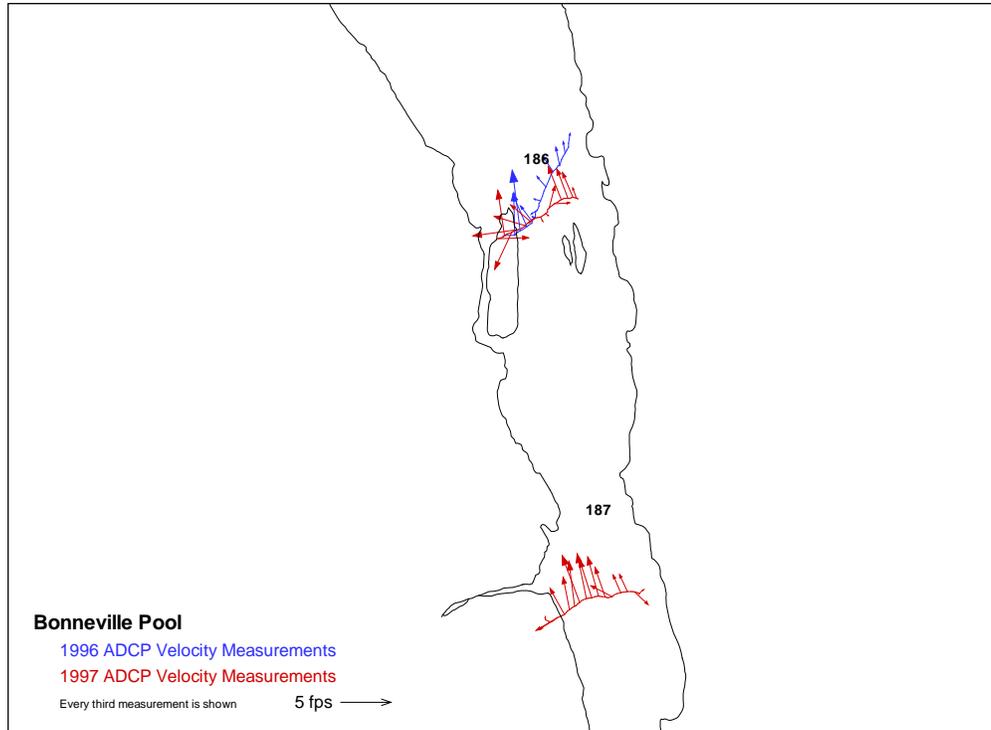


Figure 157. Bonneville pool ADCP velocity measurements near Rocky Island.

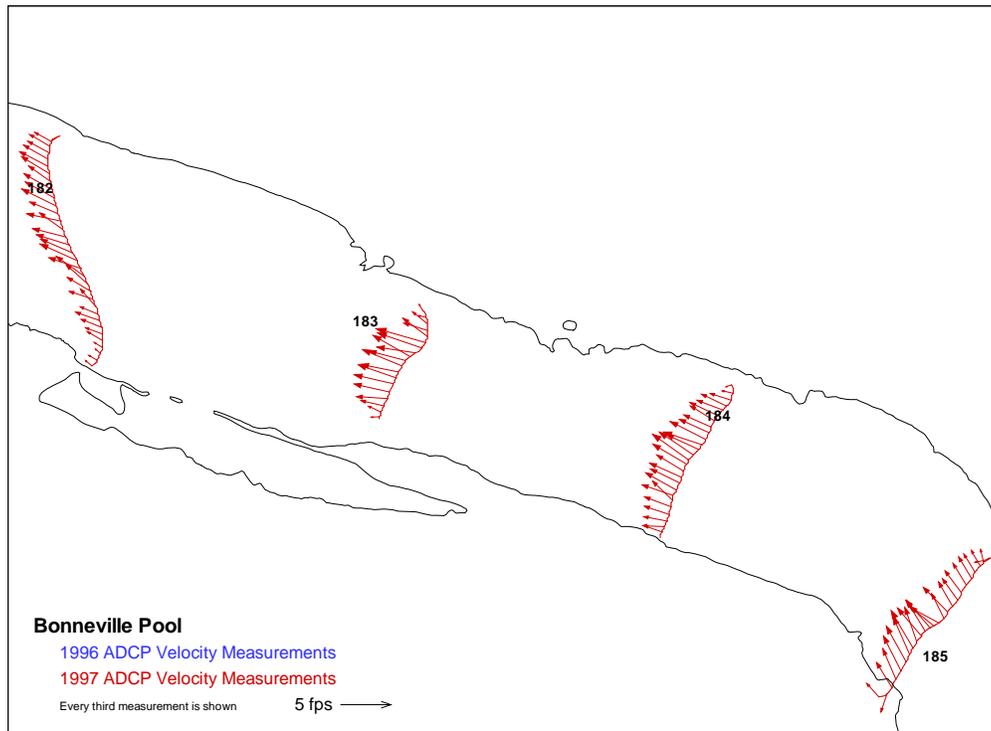


Figure 158. Bonneville pool ADCP velocity measurements near Rowena.

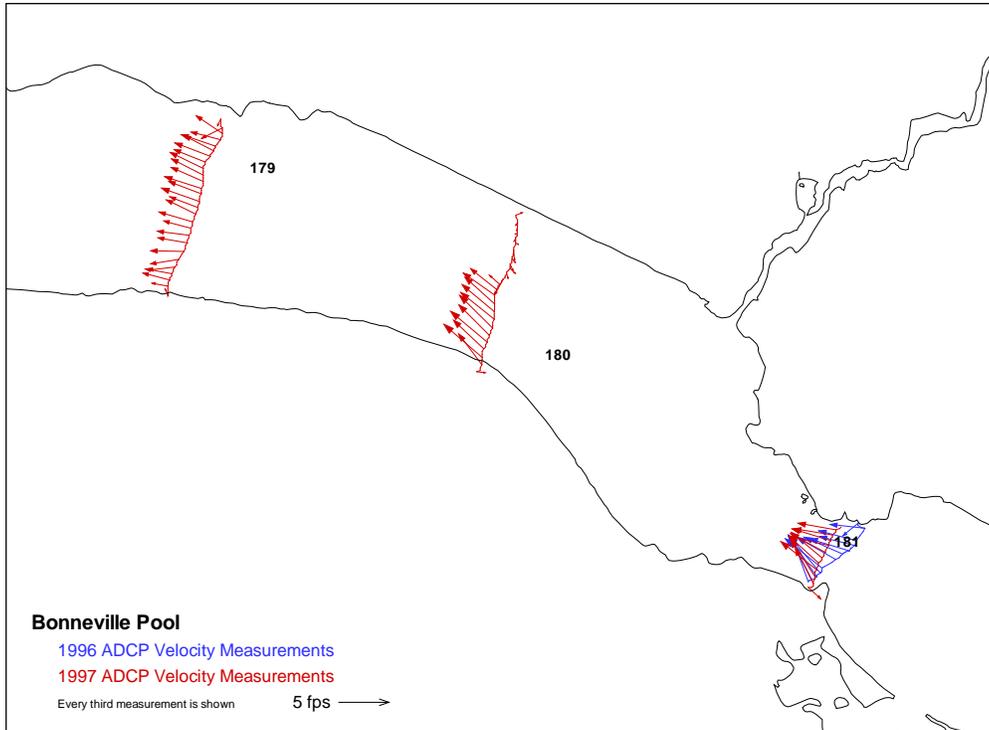


Figure 159. Bonneville pool ADCP velocity measurements near Lyle.

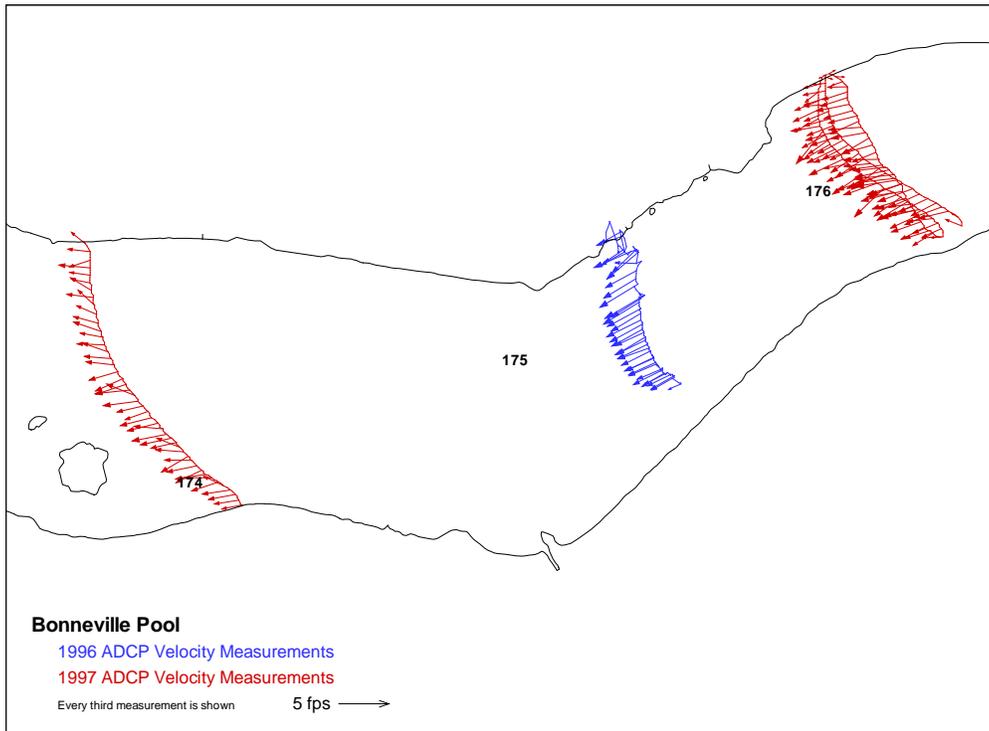


Figure 160. Bonneville pool ADCP velocity measurements near Eighteenmile Island.

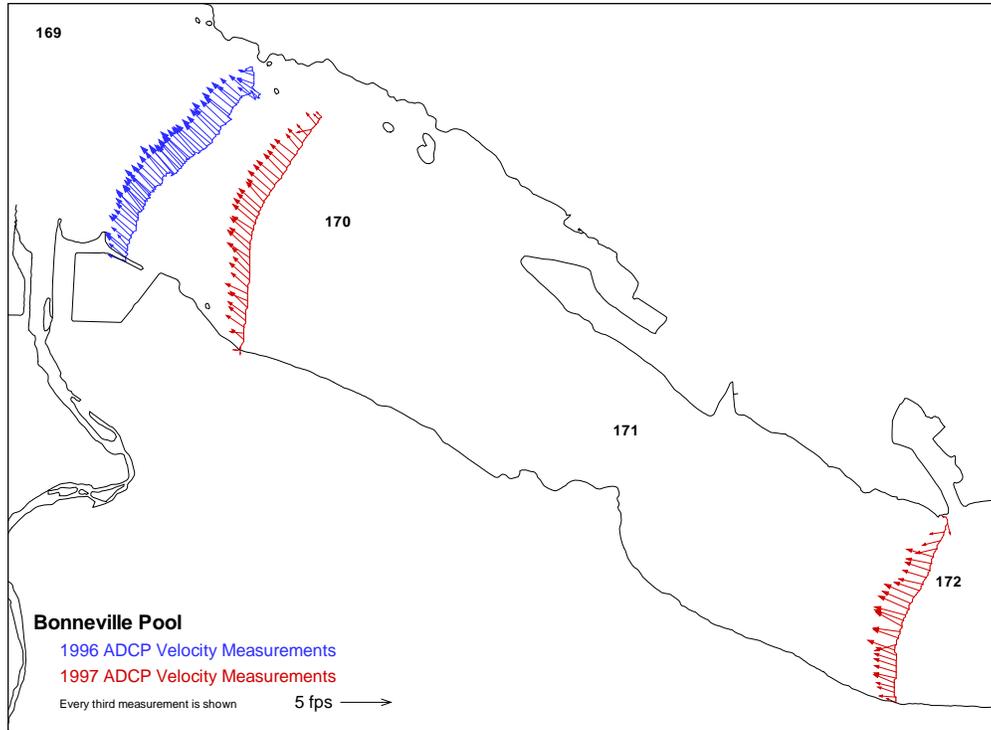


Figure 161. Bonneville pool ADCP velocity measurements near Hood River.

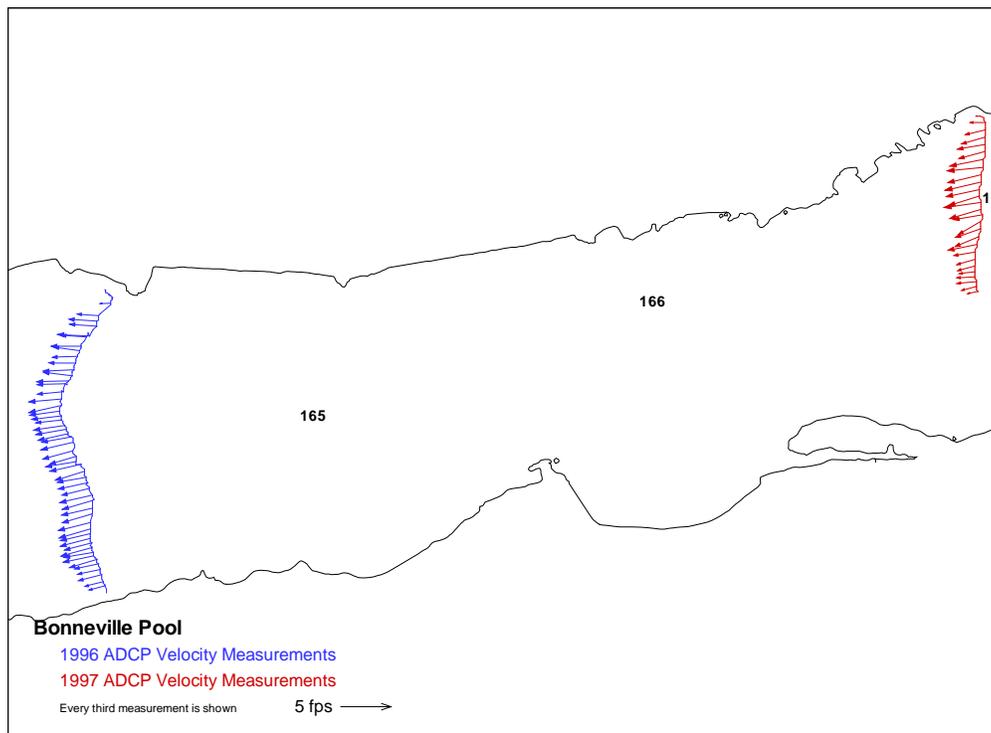


Figure 162. Bonneville pool ADCP velocity measurements near Columbia river mile 166.

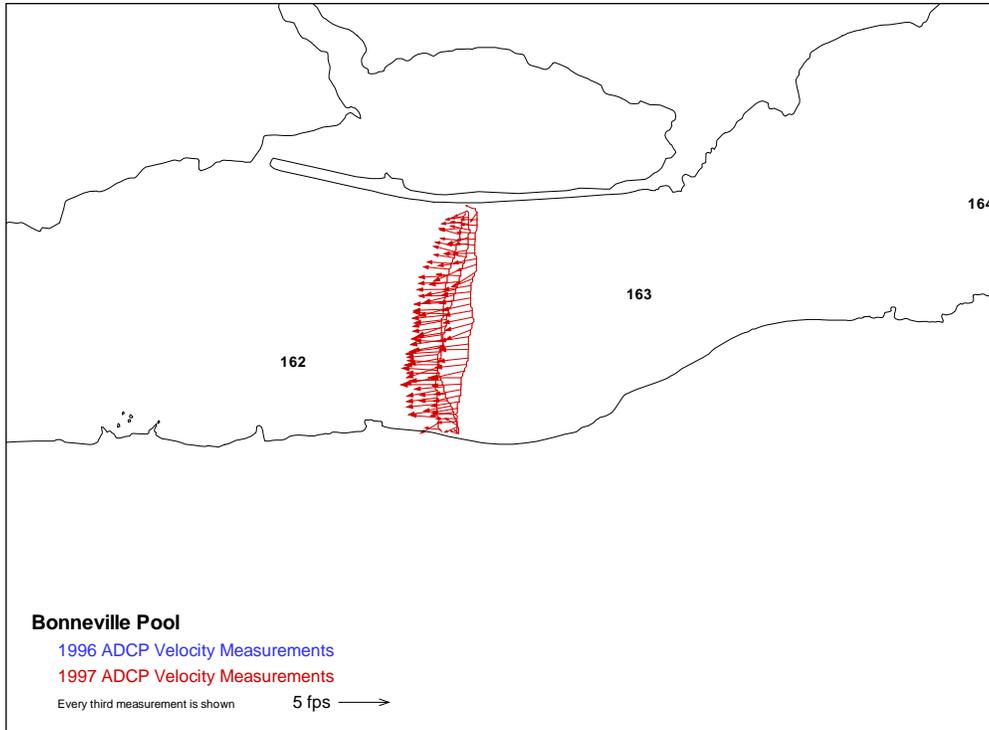


Figure 163. Bonneville pool ADCP velocity measurements near Drano Lake.

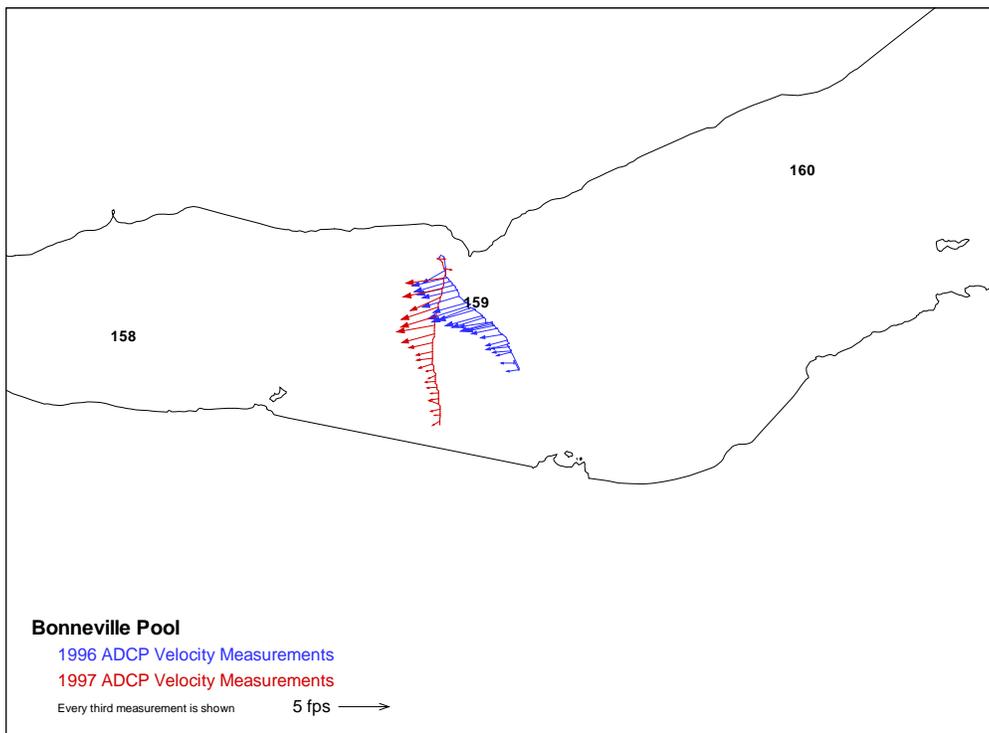


Figure 164. Bonneville pool ADCP velocity measurements near Viento State Park.

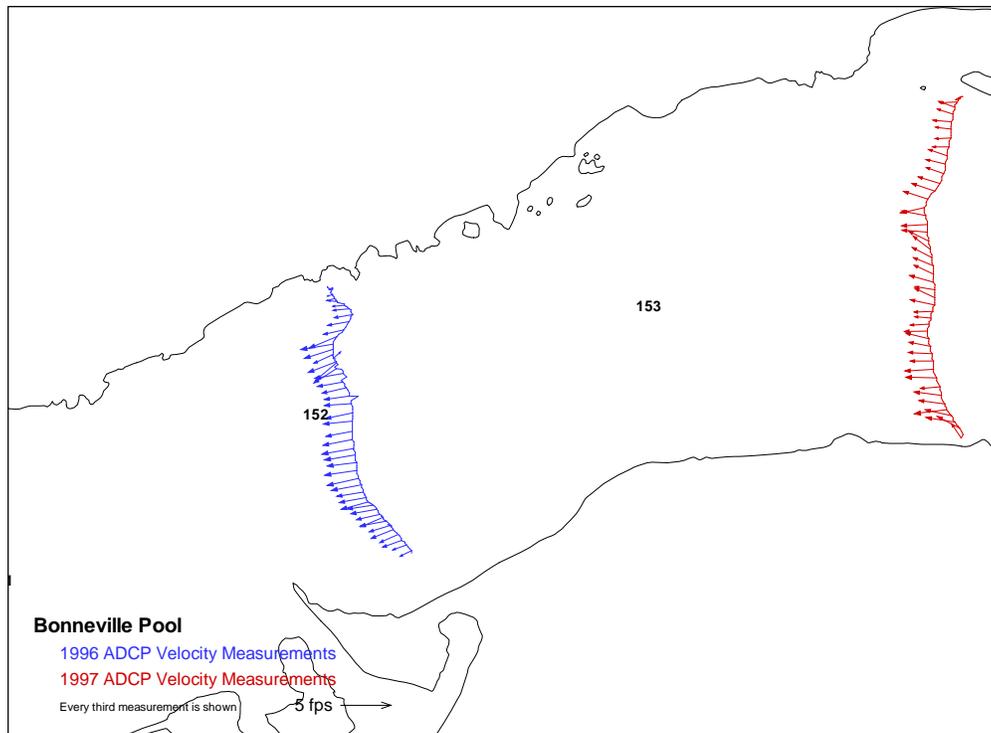


Figure 165. Bonneville pool ADCP velocity measurements near Carson.

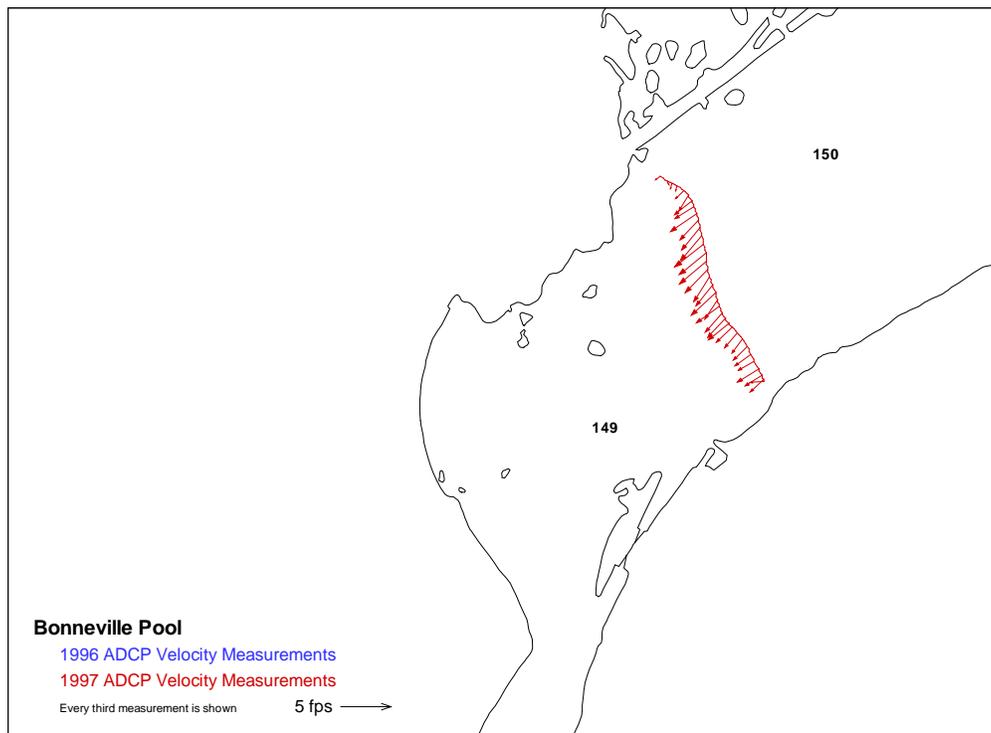


Figure 166. Bonneville pool ADCP velocity measurements Cascade Locks.

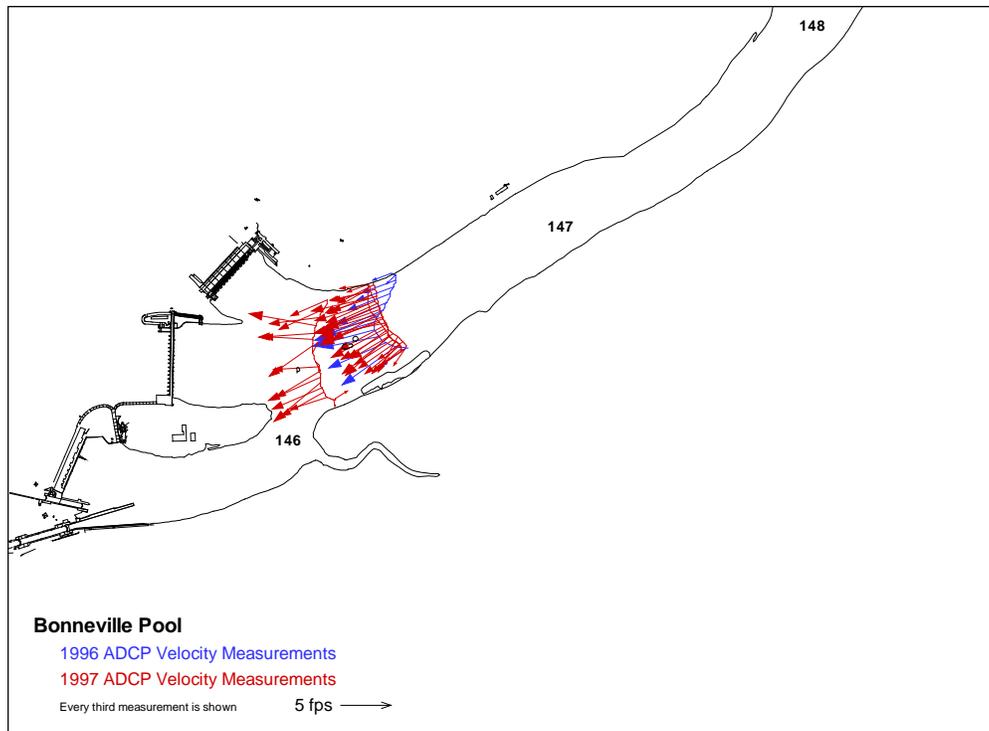


Figure 167. Bonneville pool ADCP velocity measurements near Bonneville dam.

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 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 Bonneville Pool Study

B.1 Dissolved Gas Data

The Spring 1996 Bonneville pool study began on June 6 and ended on June 17. A total of 17 stations were used. These stations, and their records are listed in Table 91. Station locations are shown in Figure 168.

Table 91. Dissolved gas monitor stations, and their records, used during the Spring 1996 study period.

Station	Record Start	Record End	Temperature Records	Pressure Records
TDADTDP	6/6/96 9:09:00 AM	6/17/96 5:41:00 PM	1078	1078
BON19175P	6/9/96 12:03:00 AM	6/14/96 7:51:00 AM	505	505
BON19001P	6/10/96 9:30:00 AM	6/14/96 8:00:00 AM	379	378
BON19005P	6/10/96 12:15:00 PM	6/14/96 1:00:00 PM	388	388
BON19003P	6/10/96 12:45:00 PM	6/14/96 8:00:00 AM	366	365
BON19135P	6/10/96 2:45:00 PM	6/14/96 8:45:00 AM	361	361
BON18781P	6/10/96 3:15:00 PM	6/11/96 9:45:00 AM	75	74
BON18785P	6/10/96 3:30:00 PM	6/14/96 1:45:00 PM	378	377
BON18095P	6/11/96 10:30:00 AM	6/16/96 7:00:00 AM	448	448
BON18101P	6/11/96 11:00:00 AM	6/16/96 7:15:00 AM	466	465
BON17564P	6/11/96 11:45:00 AM	6/16/96 6:45:00 AM	461	461
BON16964P	6/11/96 12:00:00 PM	6/15/96 7:45:00 AM	368	0
BON16442P	6/11/96 1:45:00 PM	6/16/96 8:15:00 AM	458	458
BON15915P	6/11/96 2:15:00 PM	6/16/96 8:00:00 AM	455	454
BON15232P	6/11/96 3:00:00 PM	6/16/96 7:45:00 AM	452	452
BON14651P	6/11/96 4:15:00 PM	6/16/96 7:30:00 AM	446	446
TDA19261P	6/13/96 5:14:00 PM	6/17/96 5:54:00 PM	383	383

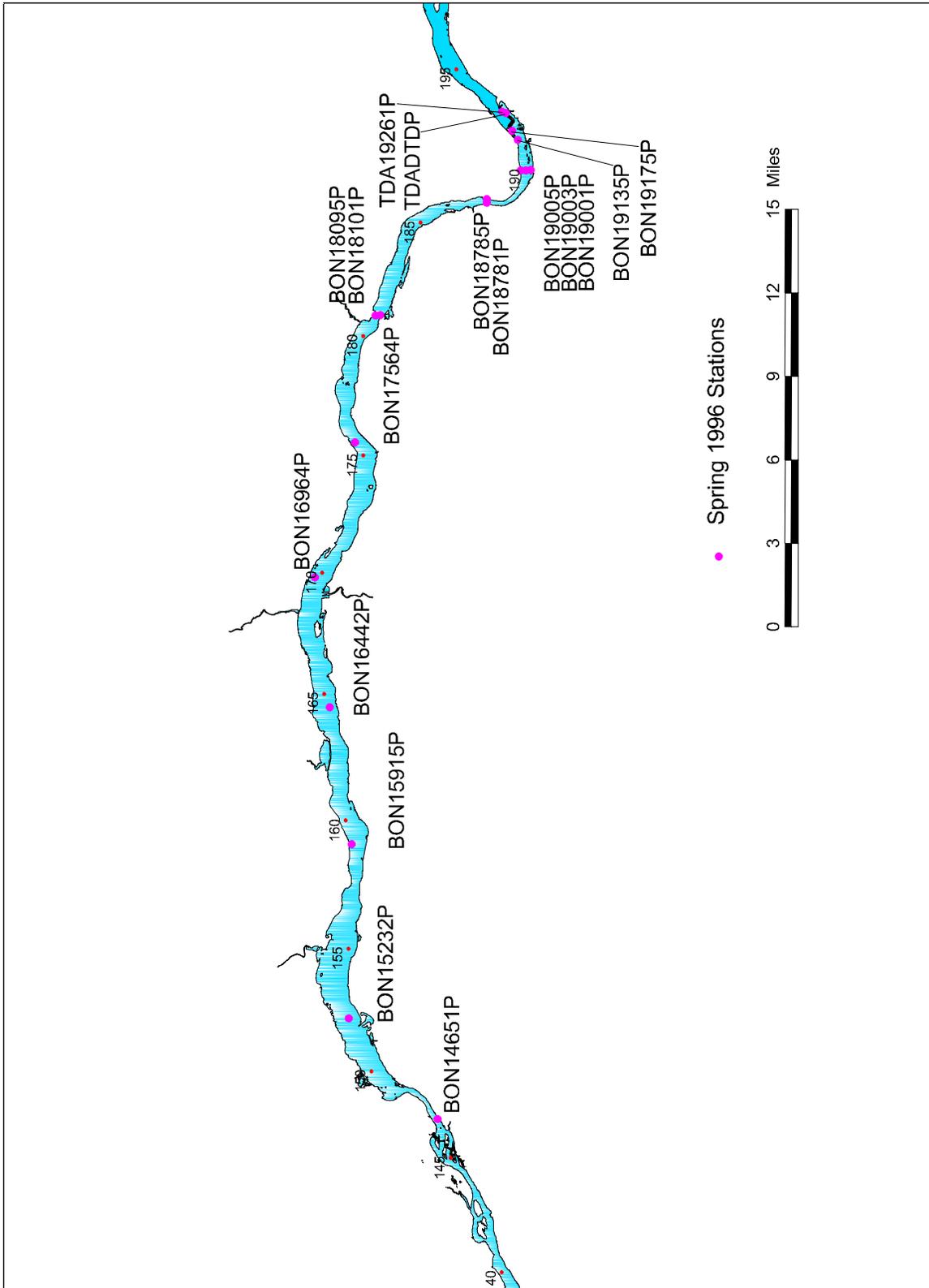


Figure 168. Dissolved gas monitor locations during the Spring 1996 study.

B.2 Velocity Data

Velocity measurements were made along a total of 12 transects during the Spring 1996 study period. The transects are summarized in Table 92. Supplied measurement locations are shown in Figure 169.

Table 92. Summary of ADCP transects made during the Spring 1996 study period.

Date Label	Average		Number of Measurements
	Velocity	Depth	
06-09-1996 10:13:00	4.6	51.5	27
06-09-1996 10:50:00	3.5	36.5	43
06-09-1996 11:40:00	4.3	52.6	45
06-09-1996 12:41:00	4.0	124.1	24
06-09-1996 13:12:00	2.3	77.8	36
06-12-1996 11:04:00	4.2	81.6	34
06-12-1996 12:00:00	3.1	45.7	115
06-12-1996 12:59:00	2.9	39.3	182
06-12-1996 13:52:00	2.7	34.5	162
06-12-1996 14:36:00	2.8	60.0	77
06-12-1996 15:39:00	2.3	40.2	140
06-19-1996 11:04:00	4.8	60.8	41

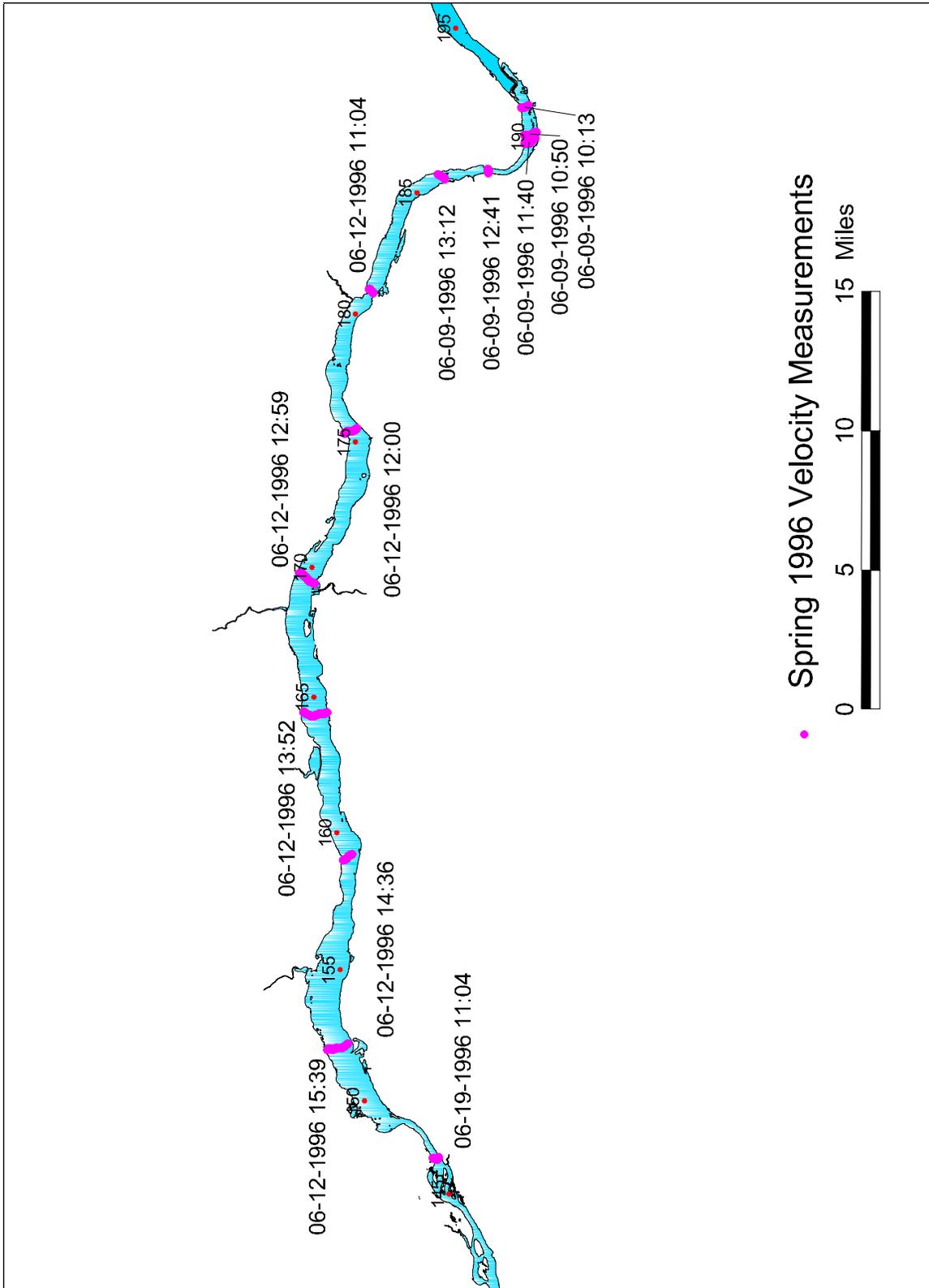


Figure 169. Locations of ADCP velocity measurements during the Spring 1996 study period.

B.3 The Dalles Dam Model Boundary

B.3.1 Dam Operations

CHROMS operations data was used to establish the flow at The Dalles dam model boundary and stage at the Bonneville dam model boundary. This data provided hourly spillway flow and power house flow. Hourly total spill and powerhouse flows for the Spring 1996 study period are shown in Figure 170. For the FMS-BC and ADCP comparison simulations, these flows were uniformly distributed across the corresponding parts of model grid block 1 and 2. For the TM-BC simulation, the upper grid boundary was located at row 25 of grid block 3, where the sum of spill and powerhouse flow was used to establish a flow boundary condition.

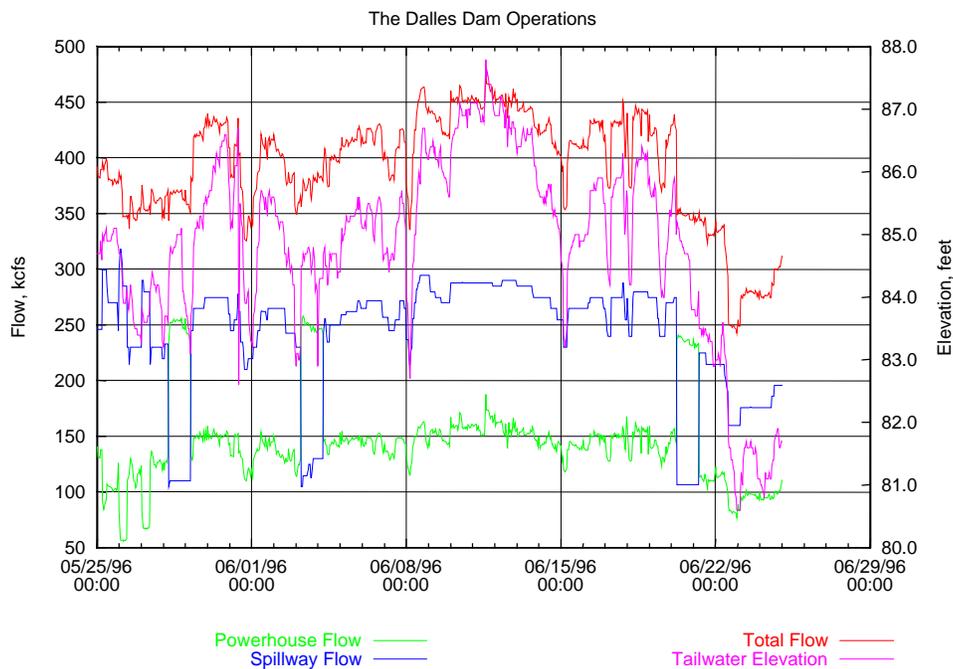


Figure 170. The Dalles dam operations during the Spring 1996 study.

B.3.2 Water Quality

Initially, data from the permanent fixed monitor located in The Dalles dam forebay (station name "TDA") was used to establish temperature at The Dalles dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 171) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 172) was used to compute TDG concentrations (Figure 173) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 172 and Figure 173, respectively) were estimated using the TDG sourcing function for The Dalles dam.

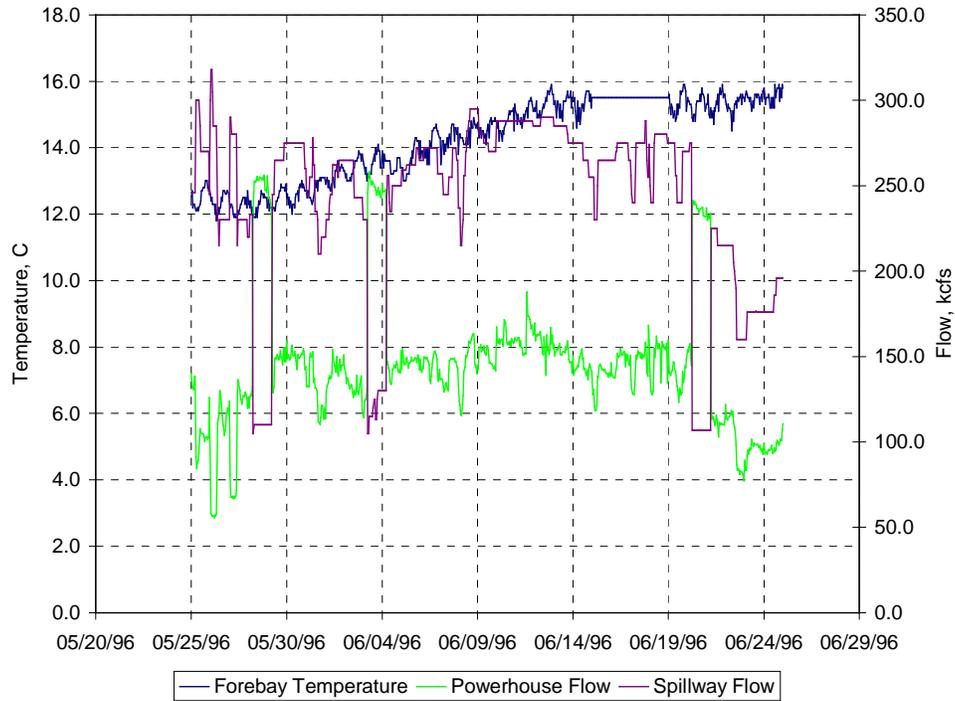


Figure 171. The Dalles forebay water temperature during the Spring 1996 study.

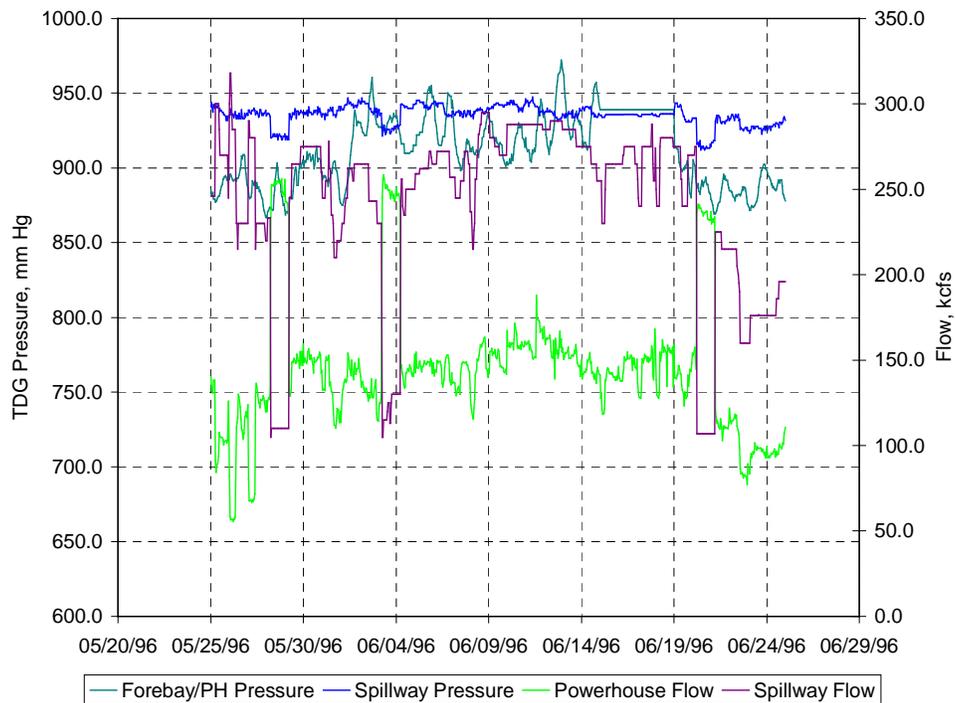


Figure 172. The Dalles forebay TDG pressure during the Spring 1996 study period.

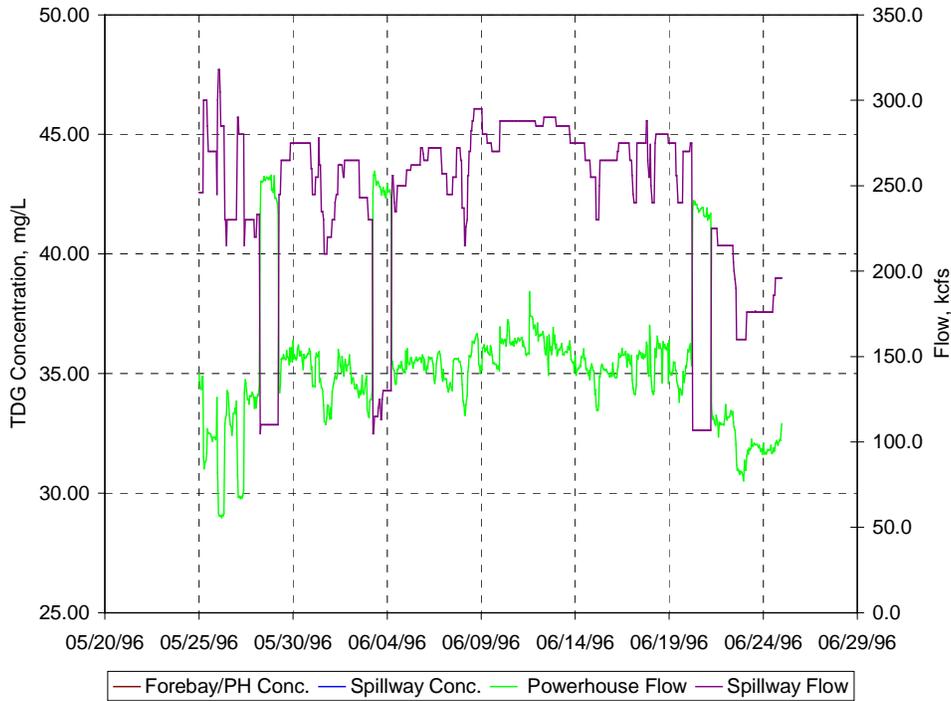


Figure 173. Computed TDG concentration in The Dalles forebay during the Spring 1996 study.

Temperature and dissolved gas concentrations were also established at The Dalles dam boundary using the temporary pool study monitors. Six temporary monitors were located in The Dalles tailrace during the Spring 1996 study period. In this case, the upstream transport simulation boundary was established at grid row 83 of block 3 (shown in blue in). Temporary monitor TDG concentrations and temperatures were applied as follows along that row of the model grid:

- BON19005P to columns 1 to 10;
- BON19003P to columns 11 to 22; and
- BON19001P to columns 23 to 29.

Stations BON19135P, BON19175P, and TDADTDP were not used.

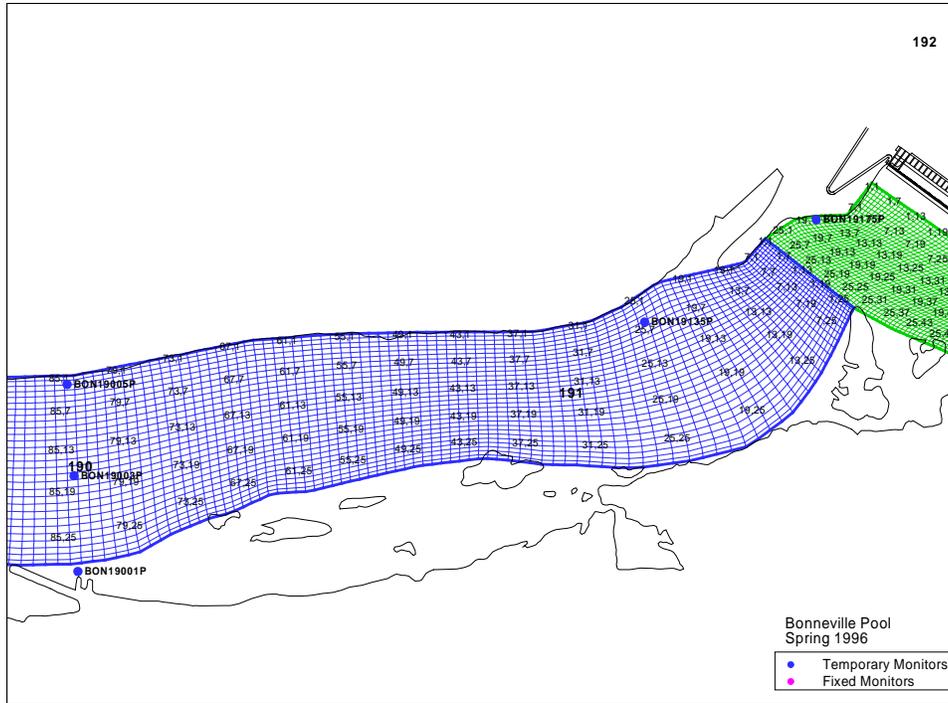


Figure 174. Locations, relative to the model grid, of upstream temporary monitors during the Spring 1996 study period.

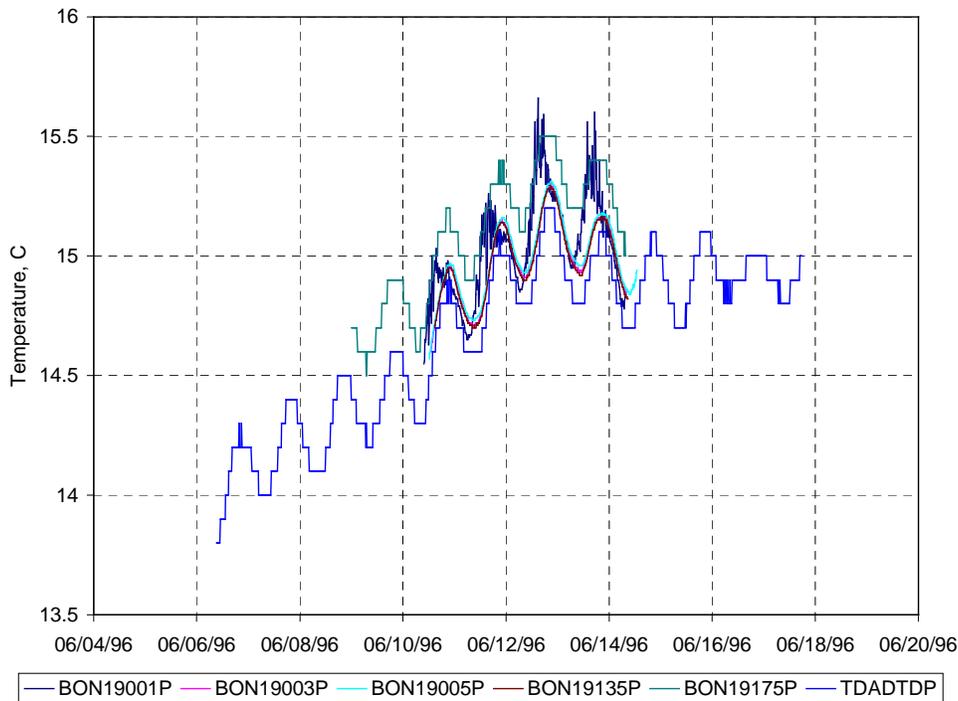


Figure 175. Temperatures measured by temporary monitors near The Dalles dam during the Spring 1996 study period.

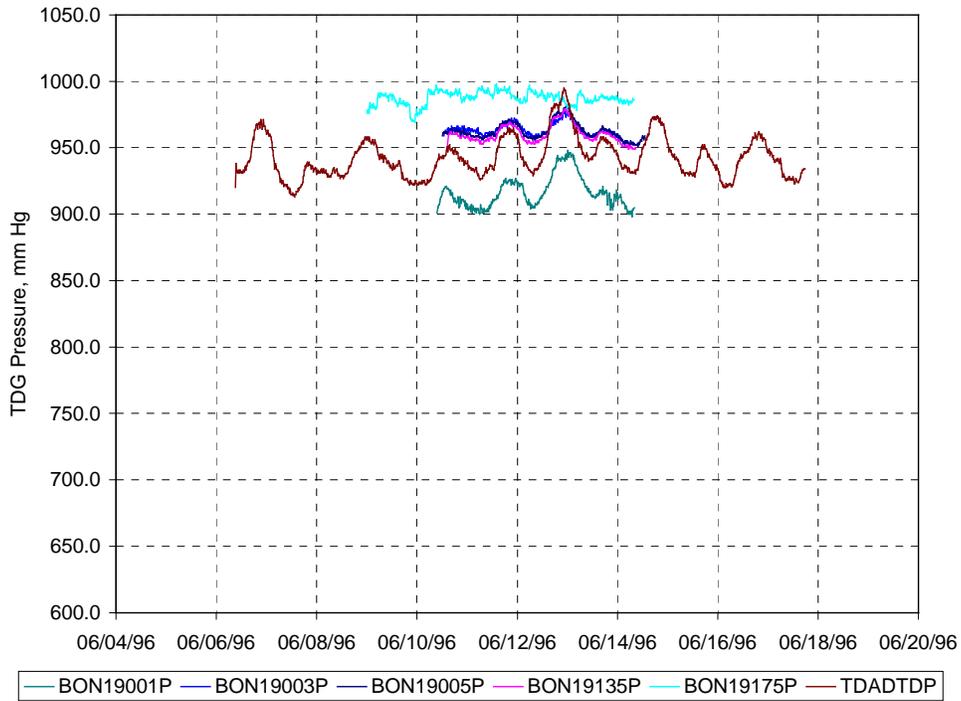


Figure 176. TDG pressures measured by temporary monitors near The Dalles dam during the Spring 1996 study period.

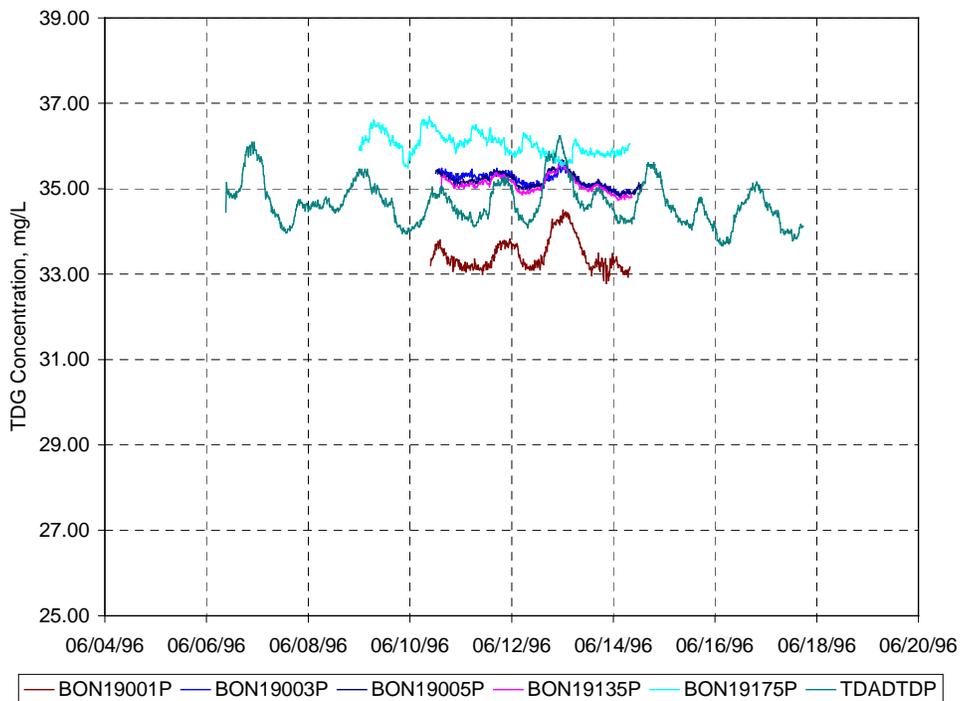


Figure 177. TDG concentrations computed from temporary monitor data near The Dalles dam during the Spring 1996 study period.

B.4 Bonneville Dam Boundary Operations

Forebay stage for Bonneville dam was obtained from hourly CHROMS operations data and is shown in Figure 178.

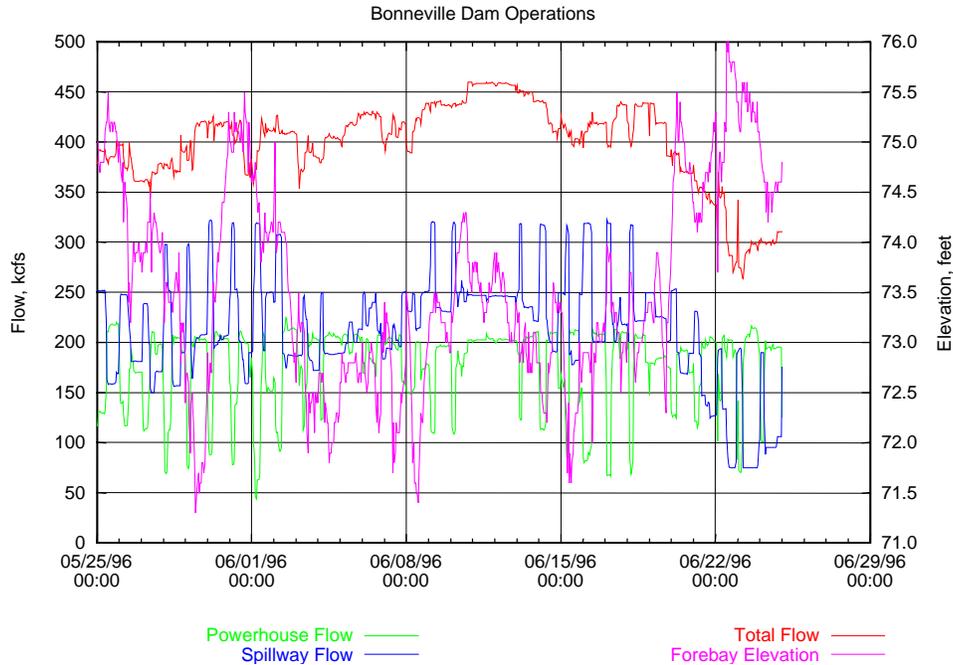


Figure 178. Bonneville operations during the Spring 1996 study period.

B.5 Weather

Atmospheric conditions were considered constant over the entire pool. The Dalles, Oregon, air and dew point temperature (Figure 179) and wind speed (Figure 180) were used from the NWS weather database. Barometric pressure measured by the TDA FMS (also shown in Figure 179) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for part the Spring 1996 study. The available radiation data was extended using NWS The Dalles dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 181.

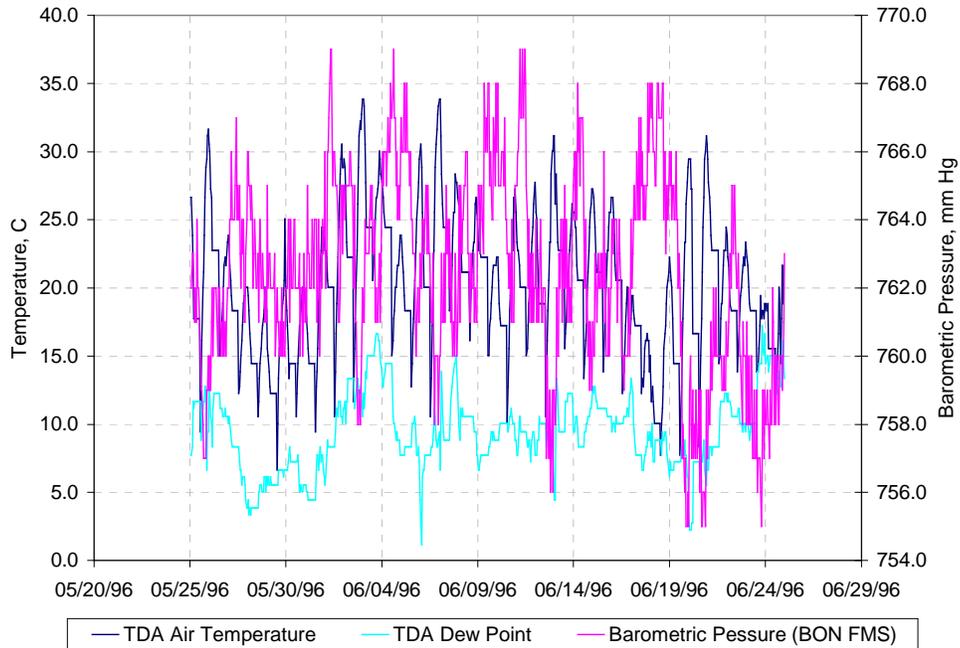


Figure 179. Air temperature, dew point, and barometric pressure used during the Spring 1996 study period.

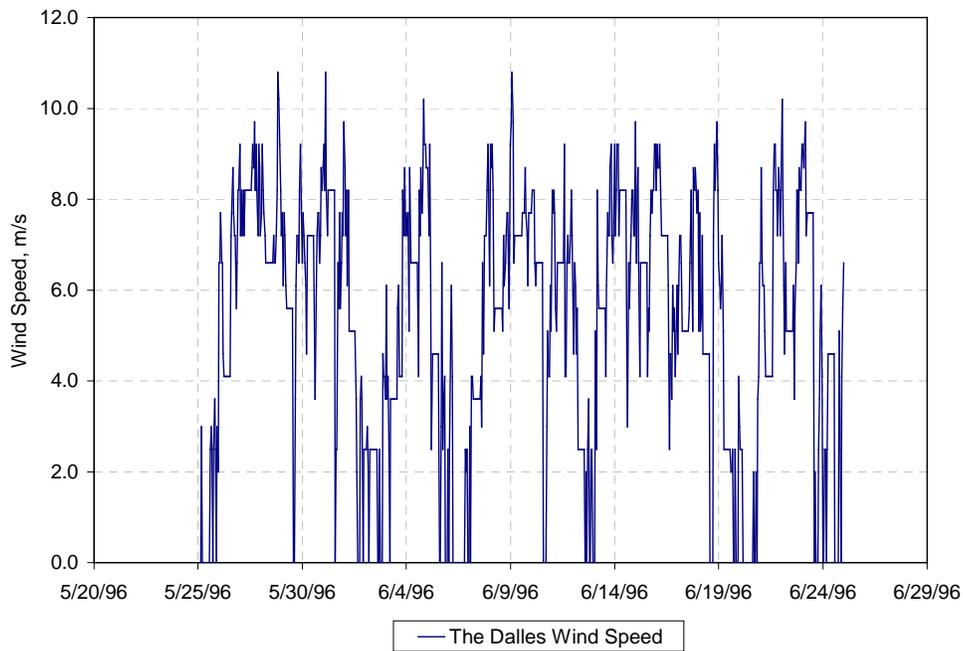


Figure 180. Wind speed used during the Spring 1996 study period.

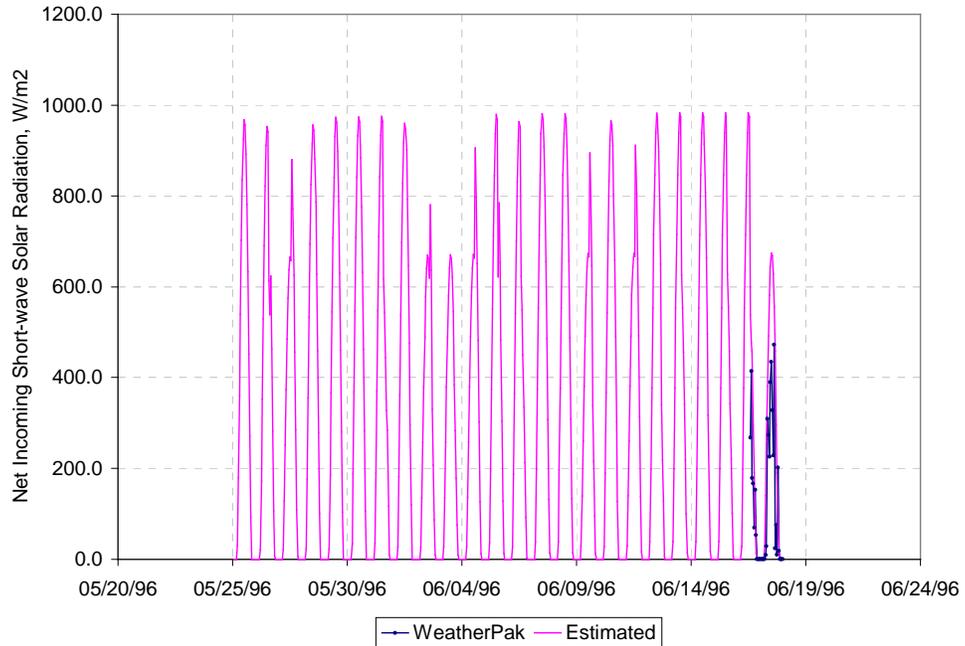


Figure 181. Net incoming short-wave solar radiation based estimated total radiation used during the Spring 1996 study period.

Appendix C. Summer 1996 Bonneville Pool Study

C.1 Dissolved Gas Data

The Summer 1996 Bonneville pool study began on August 3 and ended on August 7. A total of 12 stations were used. These stations, and their records are listed in Figure 103. Station locations are shown in Figure 182.

Table 93. Dissolved gas monitor stations, and their records, used during the Summer 1996 study period.

Station	Record Start	Record End	Temperature Records	Pressure Records
BON15915	8/3/96 12:30:00	8/14/96 8:30:00	1041	1041
BON14651	8/3/96 1:15:00	8/8/96 3:15:00	441	441
BON17564	8/3/96 1:30:00	8/14/96 9:30:00	1041	1041
BON18101	8/3/96 2:15:00	8/14/96 10:15:00	1040	1040
BON16713	8/3/96 4:00:00	8/14/96 9:15:00	1030	1030
BON18911	8/7/96 8:15:00	8/14/96 11:00:00	684	684
BON18915	8/7/96 8:45:00	8/14/96 12:30:00	688	688
TDADTDP	8/7/96 9:22:00	8/15/96 10:57:00	766	766
BON19134	8/7/96 10:00:00	8/14/96 12:45:00	684	684
BON19135	8/7/96 10:15:00	8/14/96 1:00:00	649	484
BON19175	8/7/96 11:32:00	8/15/96 11:21:00	759	758
TDA19252	8/7/96 9:39:00	8/15/96 11:14:00	766	766

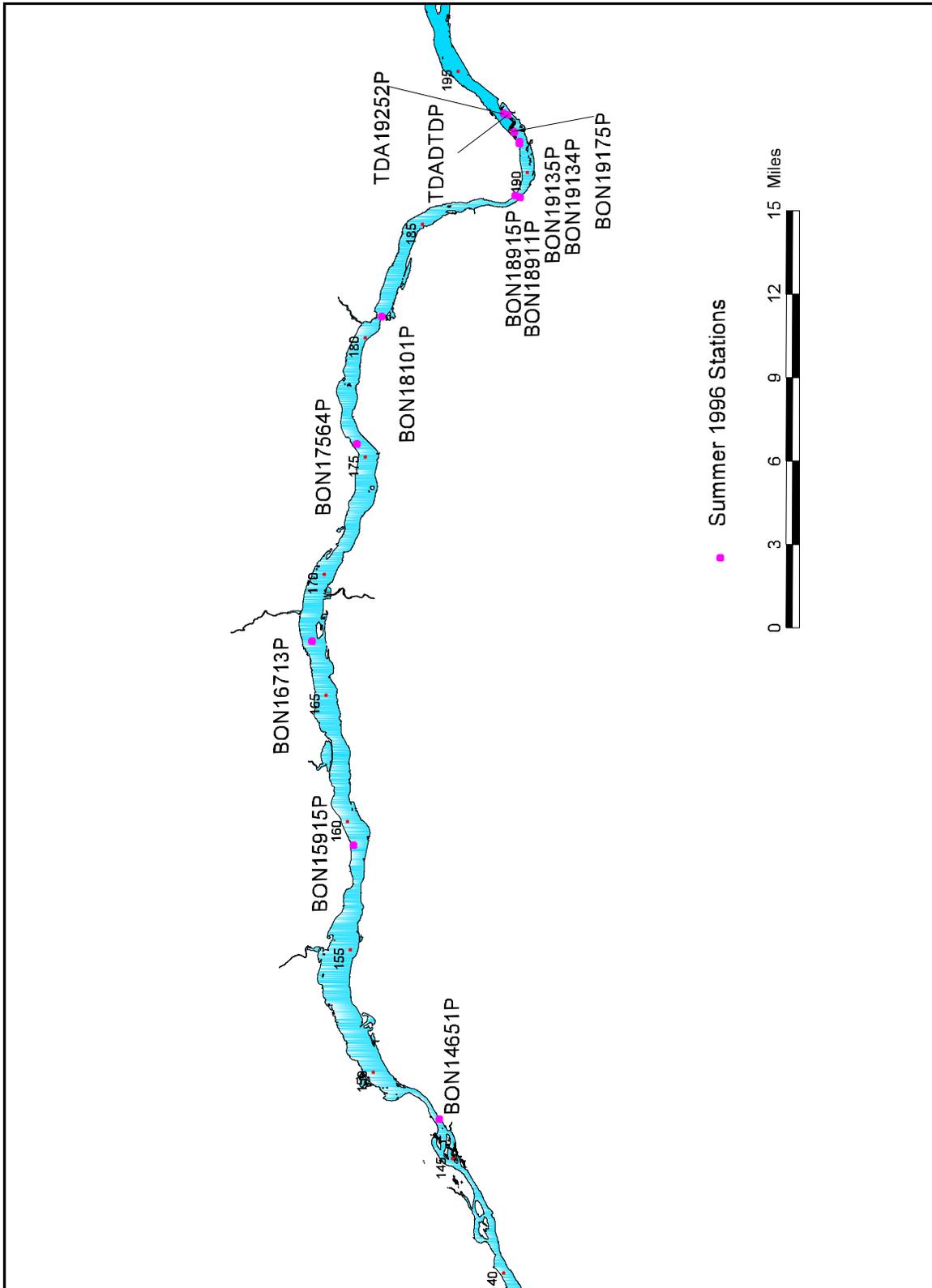


Figure 182. Dissolved gas monitor locations during the Summer 1996 study.

C.2 Velocity Data

No velocity measurements were made during the Summer 1996 study period.

C.3 The Dalles Dam Model Boundary

C.3.1 Dam Operations

CHROMS operations data was used to establish the flow at The Dalles dam model boundary and stage at the Bonneville dam model boundary. This data provided hourly spillway flow and power house flow. Hourly total spill and powerhouse flows for the Summer 1996 study period are shown in Figure 183. For the FMS-BC and ADCP comparison simulations, these flows were uniformly distributed across the corresponding parts of model grid block 1 and 2. For the TM-BC simulation, the upper grid boundary was located at row 25 of grid block 3, where the sum of spill and powerhouse flow was used to establish a flow boundary condition.

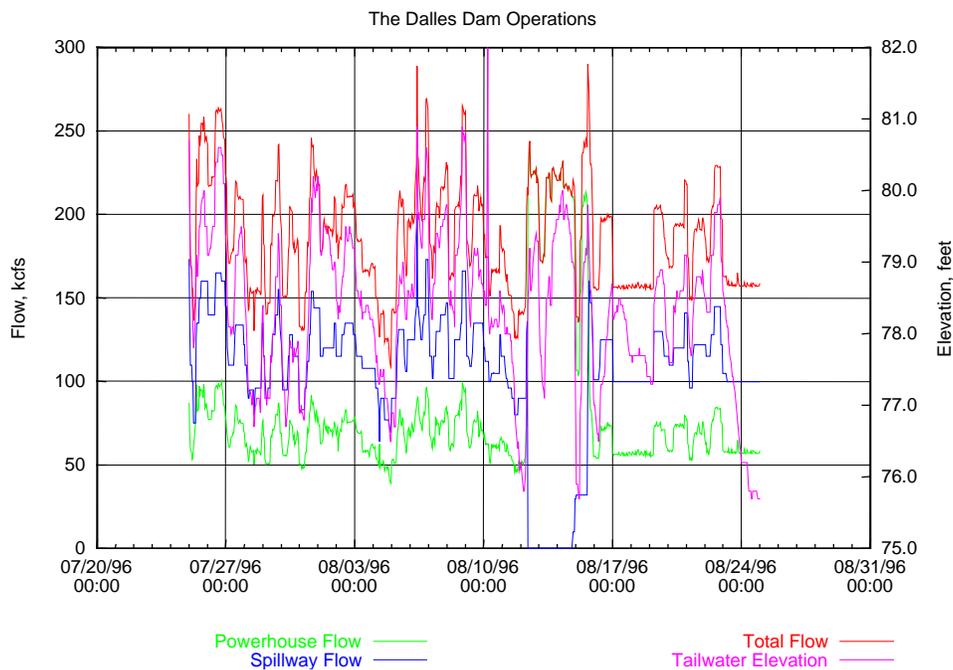


Figure 183. Bonneville dam operations during the Summer 1996 study.

C.3.2 Water Quality

Initially, data from the permanent fixed monitor located in The Dalles dam forebay (station name "TDA") was used to establish temperature at The Dalles 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 power house flow. Spillway TDG gas pressures and concentrations (also shown in

Figure 185 and Figure 185, respectively) were estimated using the TDG sourcing function for The Dalles dam.

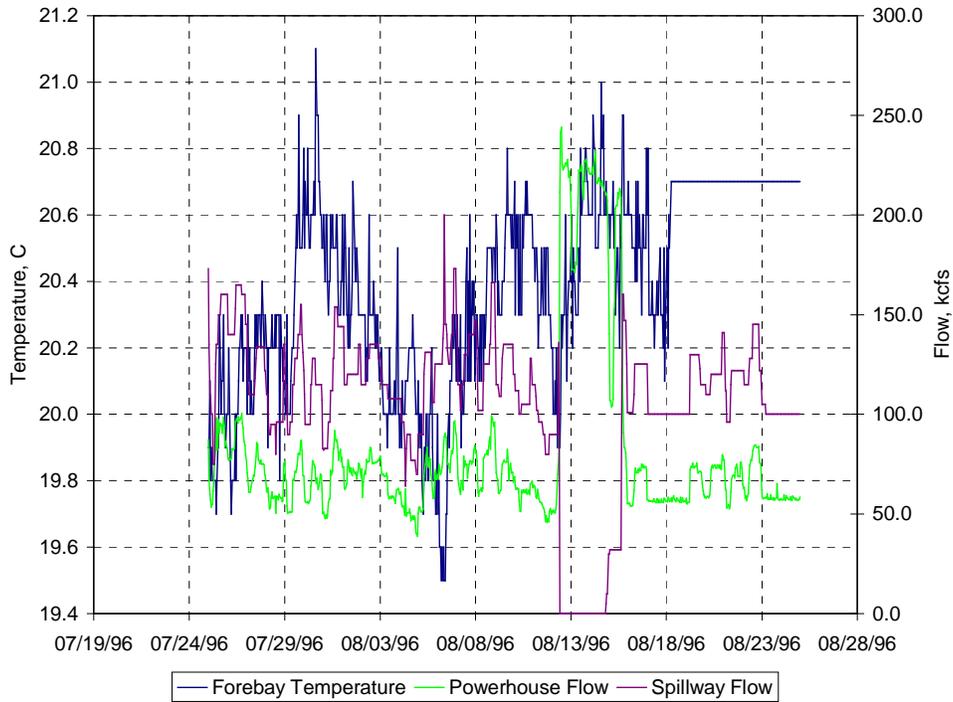


Figure 184. Bonneville forebay water temperature during the Summer 1996 study.

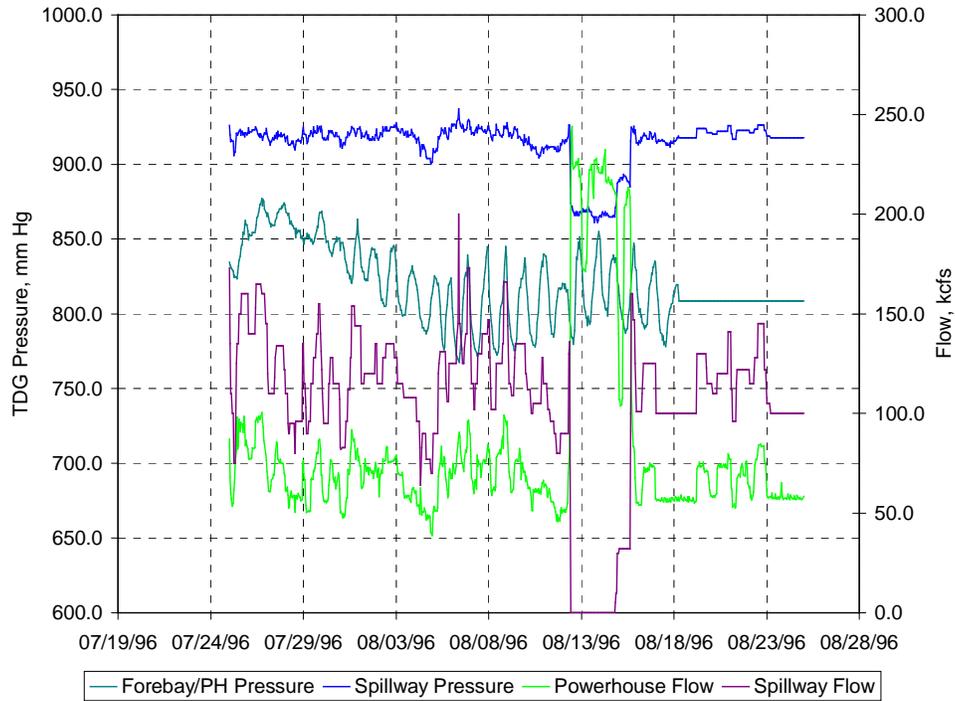


Figure 185. Bonneville forebay TDG pressure during the Summer 1996 study.

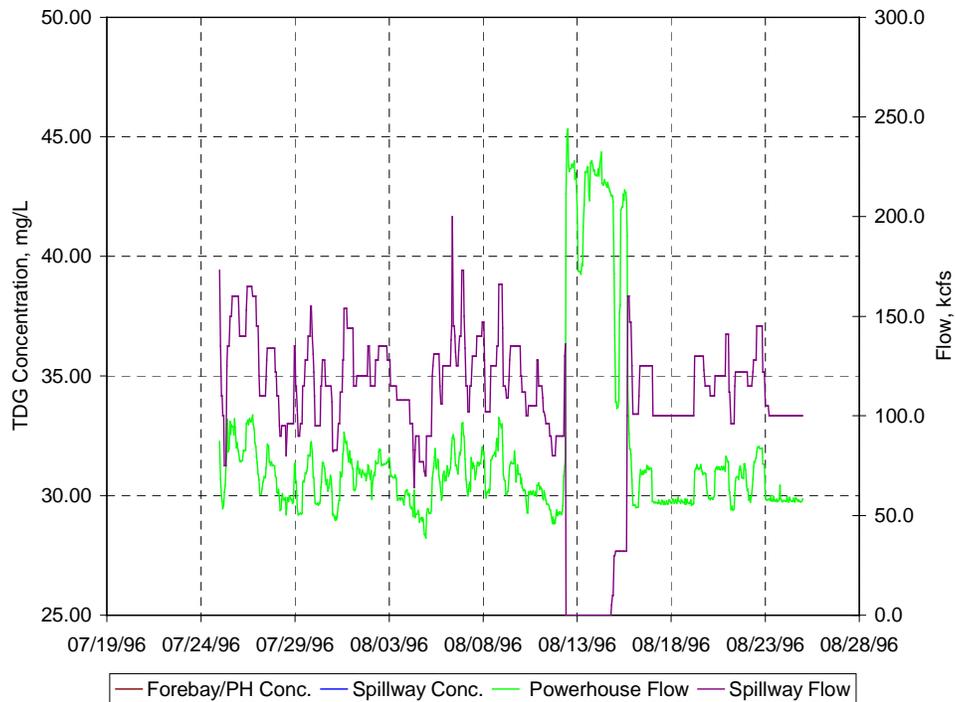


Figure 186. Computed TDG concentration in the Bonneville forebay during the Summer 1996 study.

The Dalles dam model boundary temperature and dissolved gas concentrations were also established at The Dalles dam boundary using the temporary pool study monitors. Six temporary monitors were located in The Dalles tailrace during the Summer 1996 study period, as shown in . In this case, the upstream transport simulation boundary was established at grid row 130 of block 3 (shown in blue in Figure 187). Temporary monitor TDG concentrations and temperatures were applied as follows along that row of the model grid:

- BON18915P to columns 1 to 20; and
- BON18915P to columns 21 to 29.

Stations BONDTDP, BON19134P, BON19135P, and BON19175P were not used.

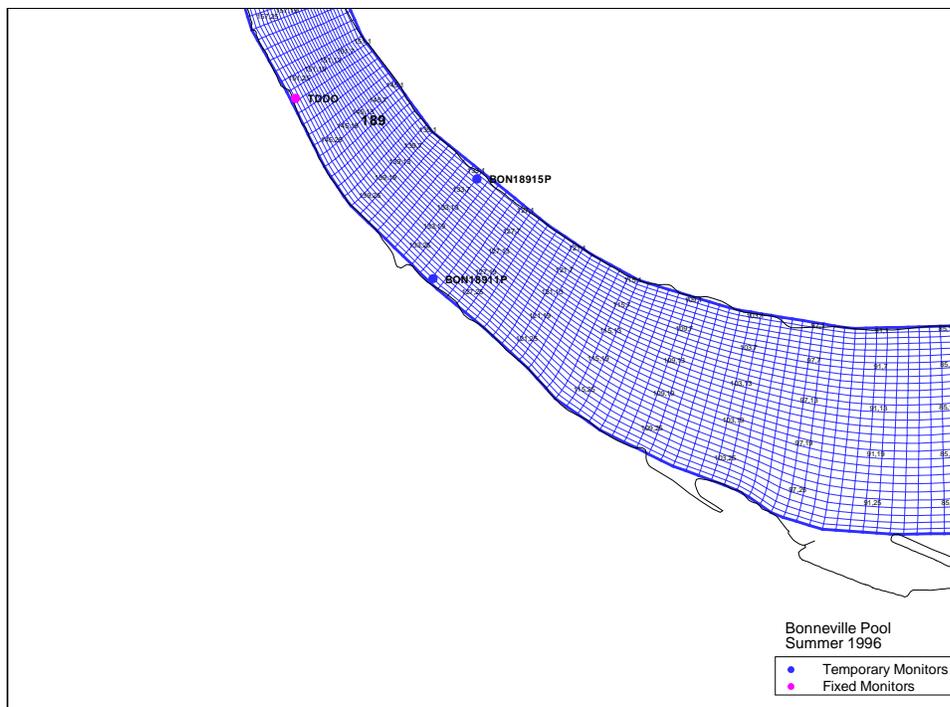


Figure 187. Locations, relative to the model grid, of temporary monitors during the Summer 1996 study period.

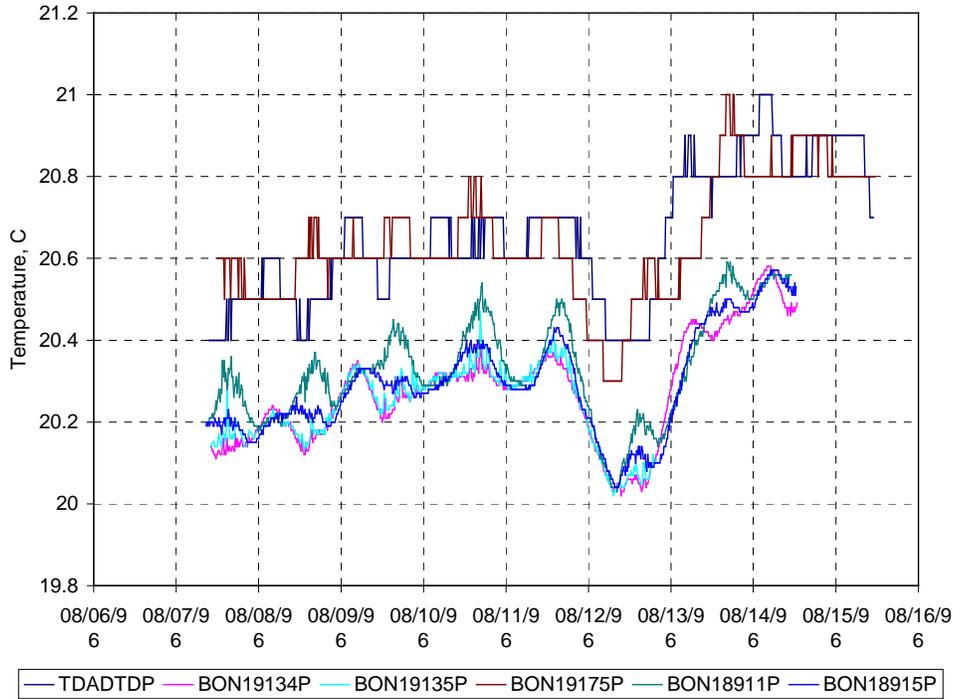


Figure 188. Temperatures measured by temporary monitors near The Dalles dam during the Summer 1996 study period.

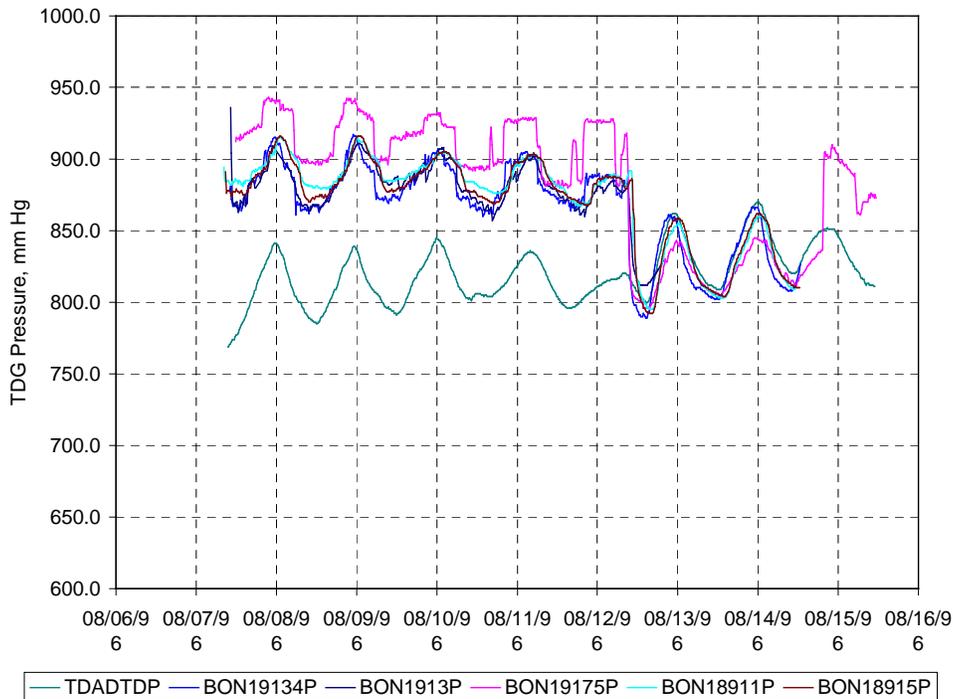


Figure 189. TDG pressures measured by temporary monitors near The Dalles dam during the Summer 1996 study period.

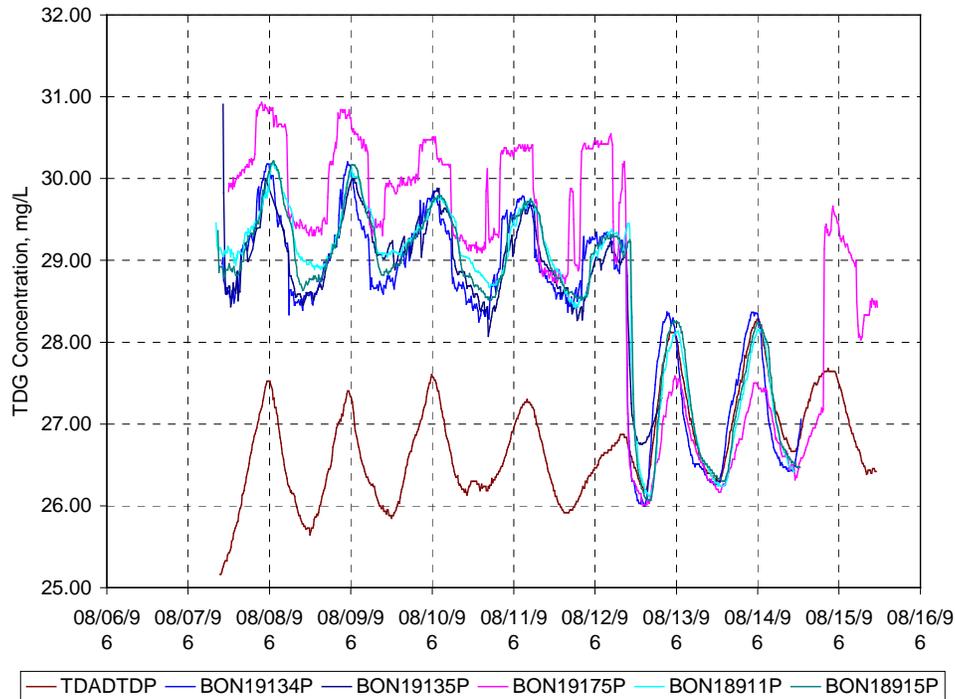


Figure 190. TDG concentrations computed from temporary monitor data near The Dalles dam during the Summer 1996 study period.

C.4 Bonneville Dam Boundary Operations

Forebay stage for Bonneville dam was obtained from hourly CHROMS operations data and is shown in Figure 191.

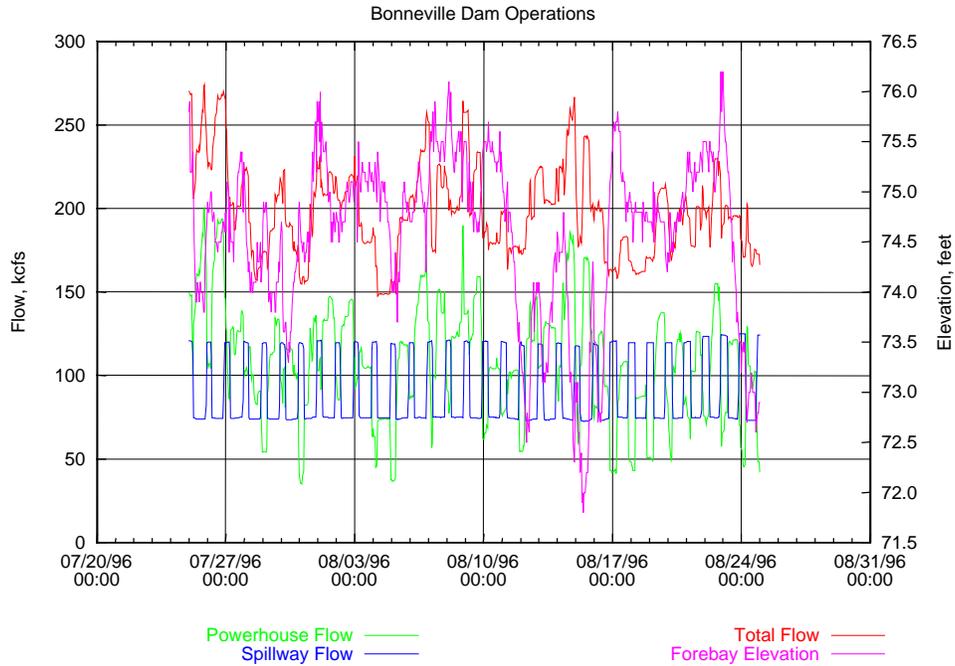


Figure 191. Bonneville dam operations during the Summer 1996 study period.

C.5 Weather

Atmospheric conditions were considered constant over the entire pool. The Dalles, 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 TDA 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 the Summer 1996 study. The available radiation data was extended using NWS The Dalles 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.

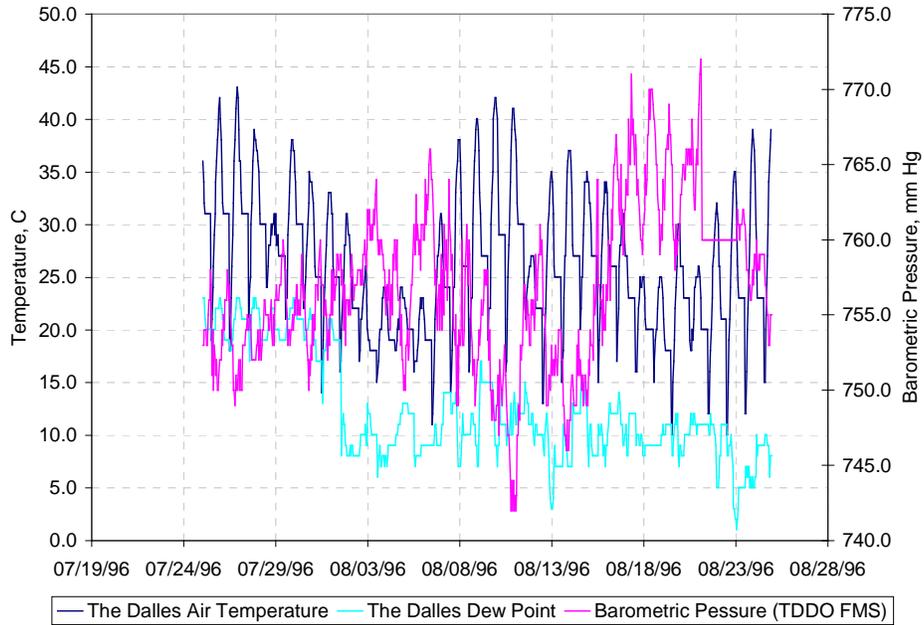


Figure 192. Air temperature, dew point, and barometric pressure used during the Summer 1996 study period.

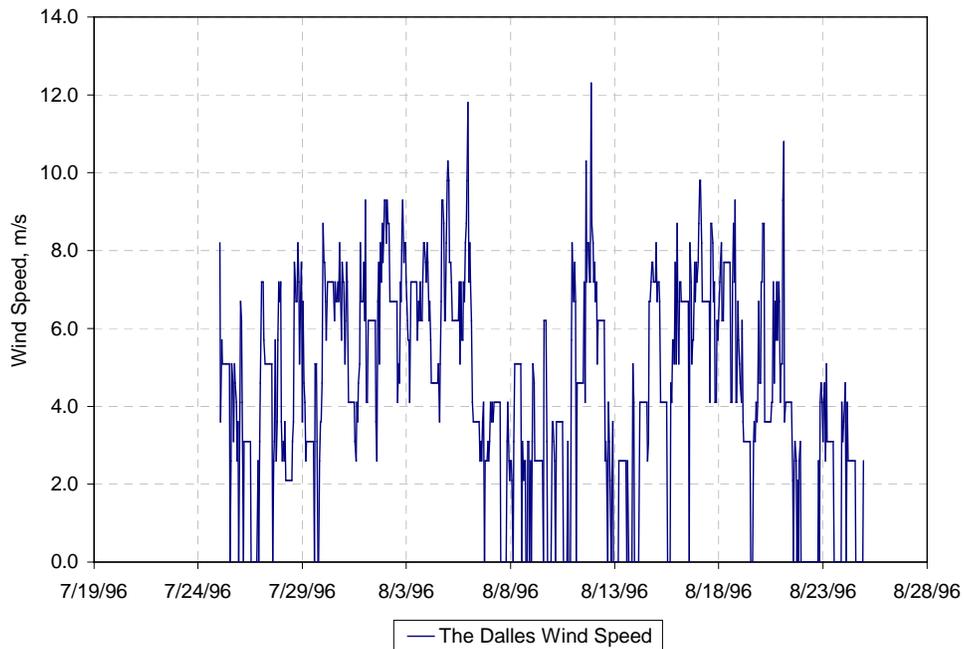


Figure 193. Wind speed used during the Summer 1996 study period.

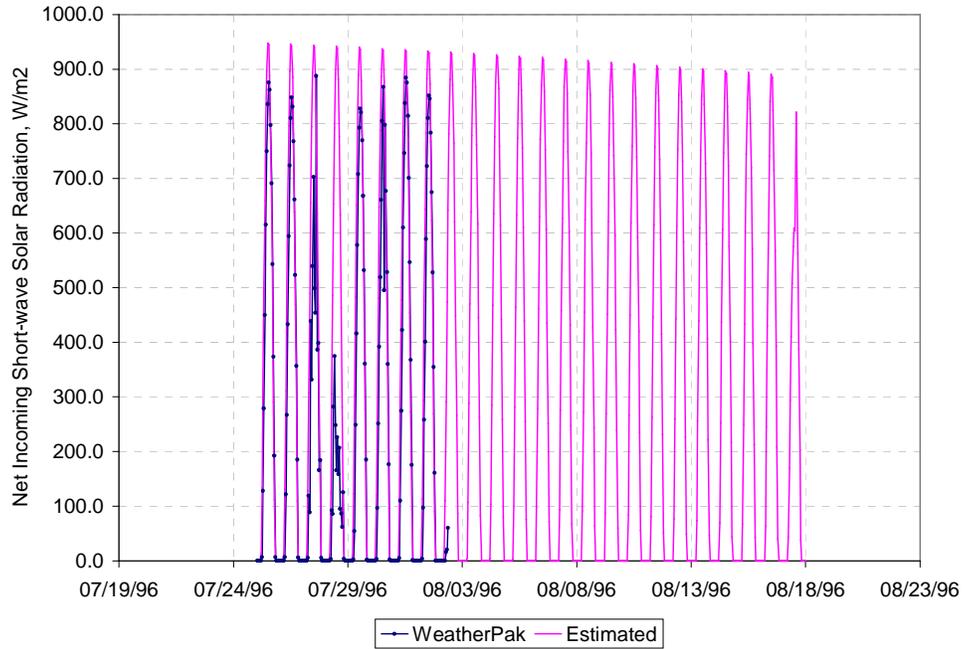


Figure 194. Net incoming short-wave solar radiation based estimated total radiation used during the Summer 1996 study period.

Appendix D. Summer 1997 Bonneville Pool Study

D.1 Dissolved Gas Data

The Summer 1997 Bonneville pool study began on June 20 and ended on June 30. A total of 14 stations were used. These stations, and their records are listed in Table 94. Station locations are shown in Figure 195.

Table 94. Dissolved gas monitor stations, and thier records, used during the Summer 1997 study period.

Station	Record Start	Record End	Temperature Records	Pressure Records
BON16305P	6/20/97 4:00:00 PM	6/30/97 8:00:00 AM	929	929
BON16304P	6/20/97 4:00:00 PM	6/30/97 8:30:00 AM	931	931
BON16302P	6/20/97 4:00:00 PM	6/30/97 8:15:00 AM	930	930
BON16301P	6/20/97 4:00:00 PM	6/30/97 8:00:00 AM	929	929
BON14655P	6/20/97 4:00:00 PM	6/30/97 6:45:00 AM	924	924
BON14651P	6/20/97 4:00:00 PM	6/30/97 6:45:00 AM	924	924
BON18912P	6/21/97 9:00:00 AM	6/28/97 5:30:00 AM	659	659
BON18915P	6/21/97 9:30:00 AM	6/30/97 11:30:00 AM	873	873
BON18914P	6/21/97 9:30:00 AM	6/30/97 12:00:00 PM	875	875
BON18911P	6/21/97 9:45:00 AM	6/30/97 11:30:00 AM	872	871
BON17565P	6/21/97 10:45:00 AM	6/30/97 9:30:00 AM	860	817
BON17564P	6/21/97 11:15:00 AM	6/30/97 10:15:00 AM	861	861
BON17562P	6/21/97 11:15:00 AM	6/30/97 10:00:00 AM	860	860
BON17561P	6/21/97 11:30:00 AM	6/30/97 9:45:00 AM	858	858

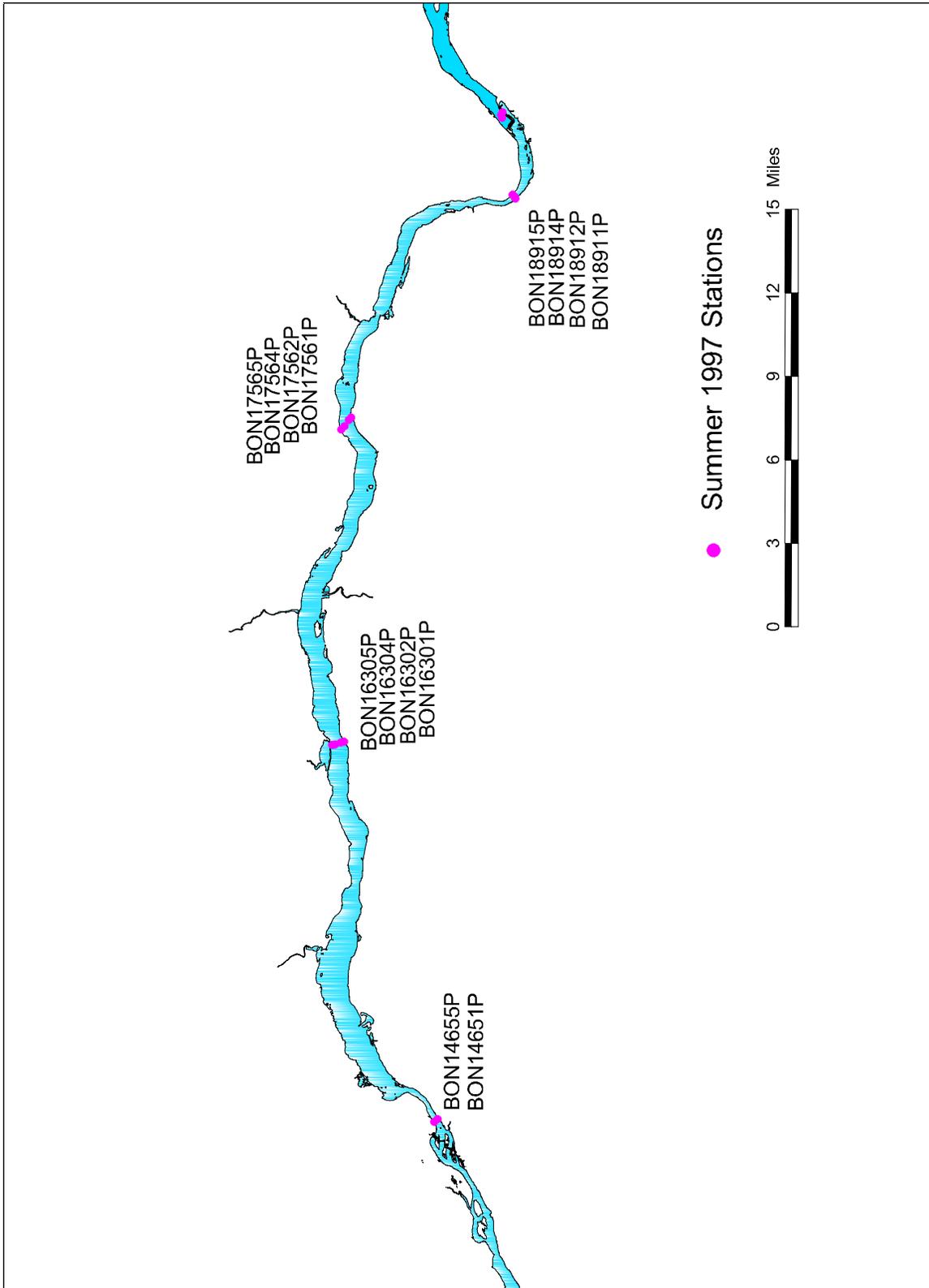


Figure 195. Dissolved gas monitor locations during the Summer 1997 study.

D.2 Velocity Data

Velocity measurements were made along a total of 31 transects during the Summer 1997 study period. The transects are summarized in Table 95. Supplied measurement locations are shown in Figure 196.

Table 95. Summary of ADCP transects made during the Summer 1997 study period.

Date Label	Average		Number of Measurements
	Velocity	Depth	
06-25-1997 06:19:00	3.9	91.5	34
06-25-1997 06:28:00	4.0	91.2	34
06-25-1997 06:38:00	4.0	90.2	35
06-25-1997 07:01:00	3.8	109.3	29
06-25-1997 07:16:00	3.8	131.0	26
06-25-1997 07:31:00	2.9	83.3	47
06-25-1997 08:08:00	2.5	80.1	44
06-25-1997 08:30:00	2.9	51.8	76
06-25-1997 08:49:00	2.9	54.6	78
06-25-1997 09:11:00	3.1	64.4	57
06-25-1997 09:33:00	2.6	49.8	99
06-25-1997 09:53:00	4.0	99.5	33
06-25-1997 10:09:00	2.2	48.5	76
06-25-1997 10:30:00	3.0	46.9	82
06-25-1997 10:57:00	2.8	47.5	84
06-25-1997 11:12:00	2.9	43.7	96
06-25-1997 11:27:00	2.7	46.3	90
06-25-1997 11:59:00	2.8	36.4	134
06-26-1997 06:47:00	2.4	44.0	91
06-26-1997 07:12:00	2.2	37.9	115
06-26-1997 07:36:00	2.5	42.7	79
06-26-1997 08:12:00	2.4	41.3	106
06-26-1997 08:26:00	2.5	40.8	105
06-26-1997 08:45:00	2.8	41.3	104
06-26-1997 09:12:00	1.9	51.7	69
06-26-1997 09:42:00	2.2	30.8	137
06-26-1997 10:15:00	2.3	47.4	100
06-26-1997 10:37:00	4.9	65.6	37
06-26-1997 10:45:00	4.9	62.0	37
06-26-1997 10:52:00	4.9	67.4	36
06-26-1997 11:01:00	4.1	61.1	52

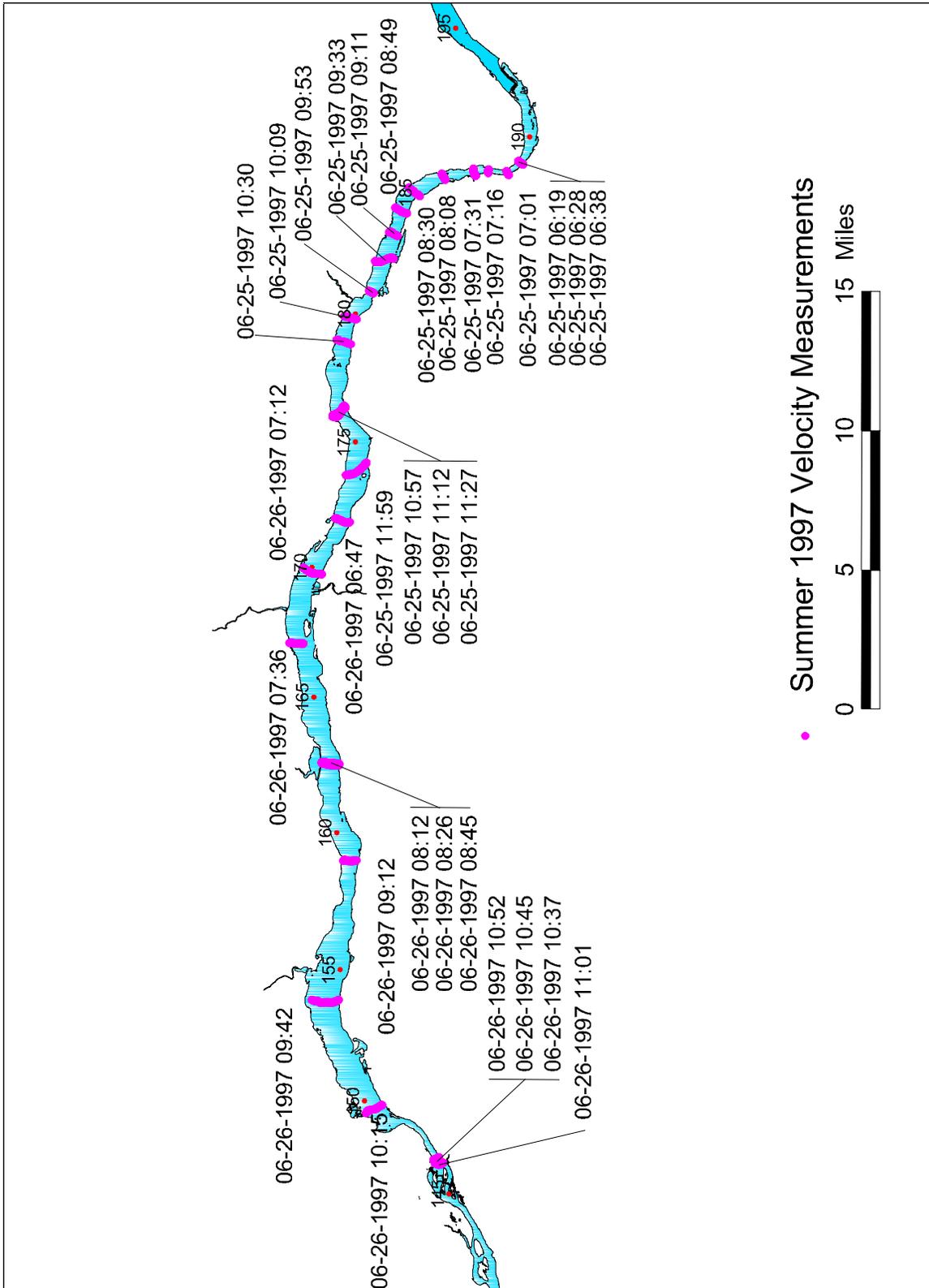


Figure 196. Locations of ADCP velocity measurements during the Summer 1997 study period.

D.3 The Dalles Dam Model Boundary

D.3.1 Dam Operations

CHROMS operations data was used to establish the flow at The Dalles dam model boundary and stage at the Bonneville dam model boundary. This data provided hourly spillway flow and power house flow. Hourly total spill and powerhouse flows for the Summer 1997 study period are shown in Figure 197. These flows were uniformly distributed across the corresponding part of the model grid.

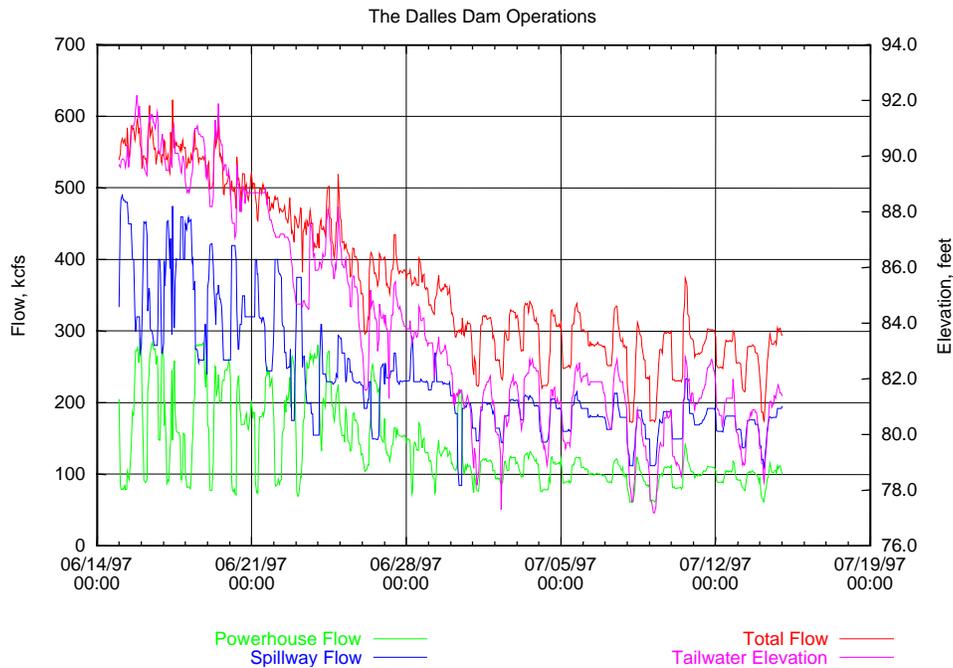


Figure 197. The Dalles dam operations during the Summer 1997 study.

D.3.2 Water Quality

Initially, data from the permanent fixed monitor located in The Dalles dam forebay (station name "TDA") was used to establish temperature at The Dalles dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 198) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 199) was used to compute TDG concentrations (Figure 200) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 199 and Figure 200, respectively) were estimated using the TDG sourcing function for John Day dam.



Figure 198. Bonneville forebay water temperature during the Summer 1997 study.

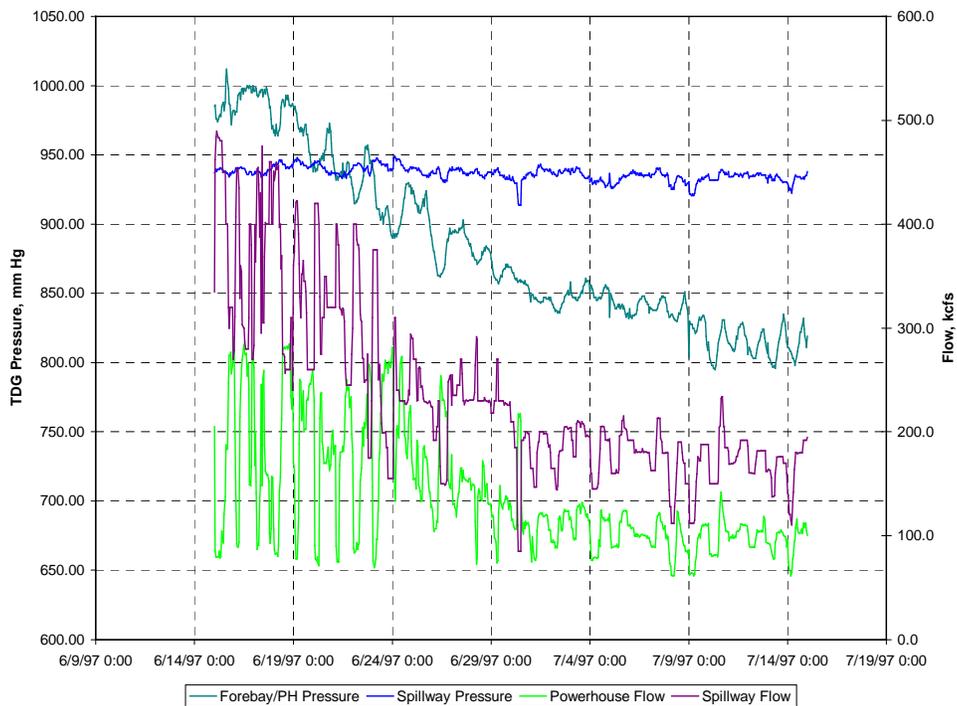


Figure 199. Bonneville forebay TDG pressure during the Summer 1997 study.

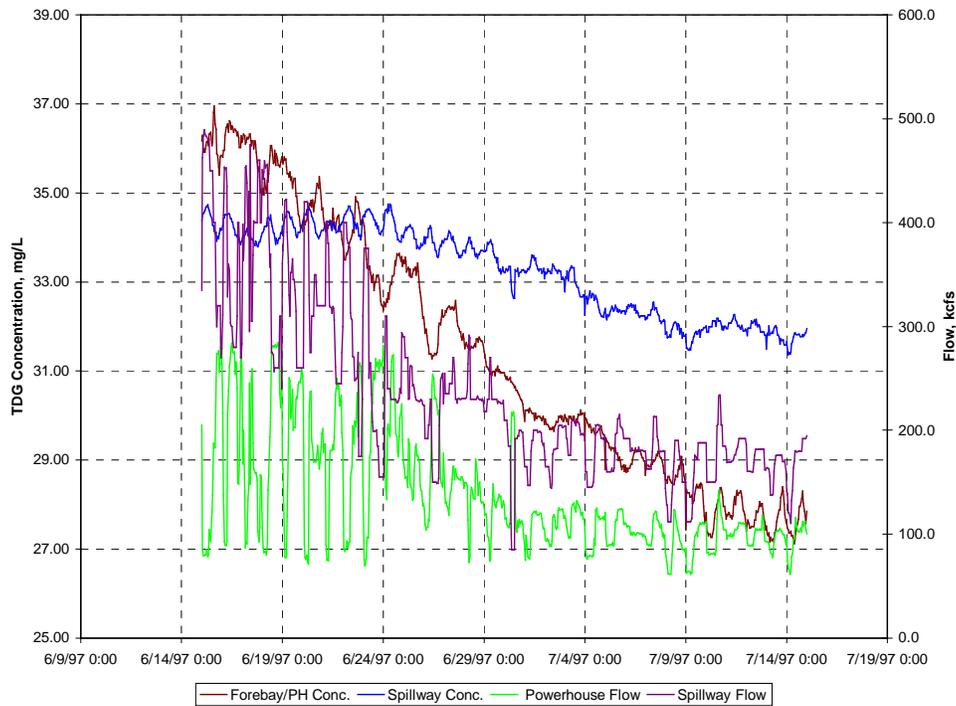


Figure 200. Computed TDG concentration in the Bonneville forebay during the Summer 1997 study.

The Dalles dam model boundary temperature and dissolved gas concentrations were also established at The Dalles dam boundary using the temporary pool study monitors. Four temporary monitors were located in The Dalles tailrace during the Summer 1997 study period. In this case, the upstream transport simulation boundary was established at grid row 134 of block 3 (shown in blue in Figure 201). Temporary monitor TDG concentrations and temperatures were applied as follows along that row of the model grid:

- BON18915P to columns 1 to 6;
- BON18914P to columns 7 to 14; and
- BON18912P to columns 15 to 24; and
- BON18911P to columns 25 to 29.

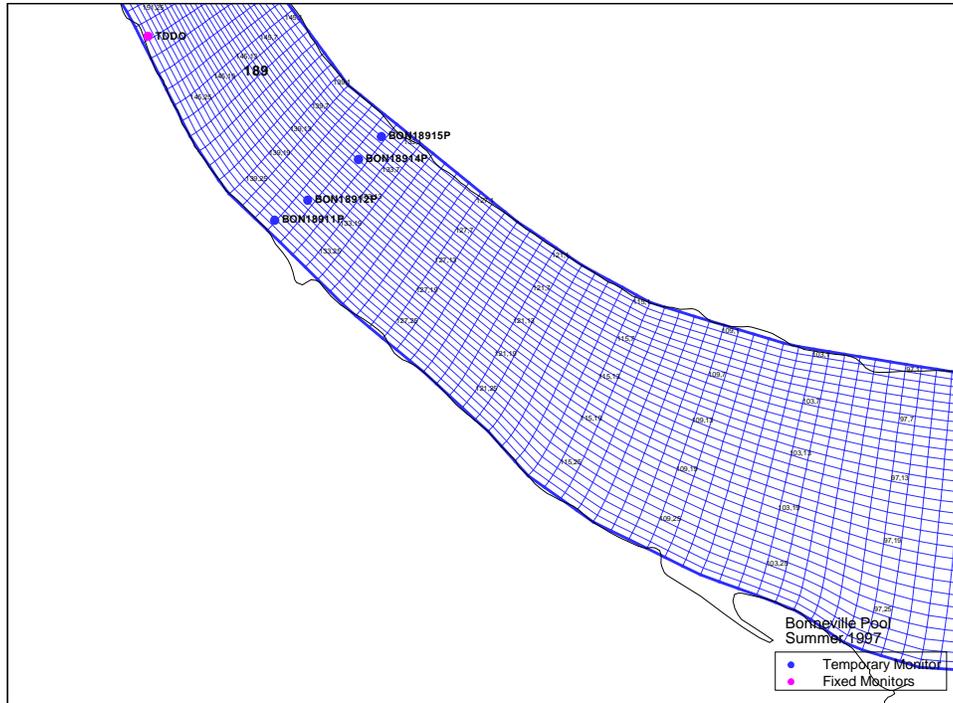


Figure 201. Locations, relative to the model grid, of temporary monitors during the Summer 1997 study period.

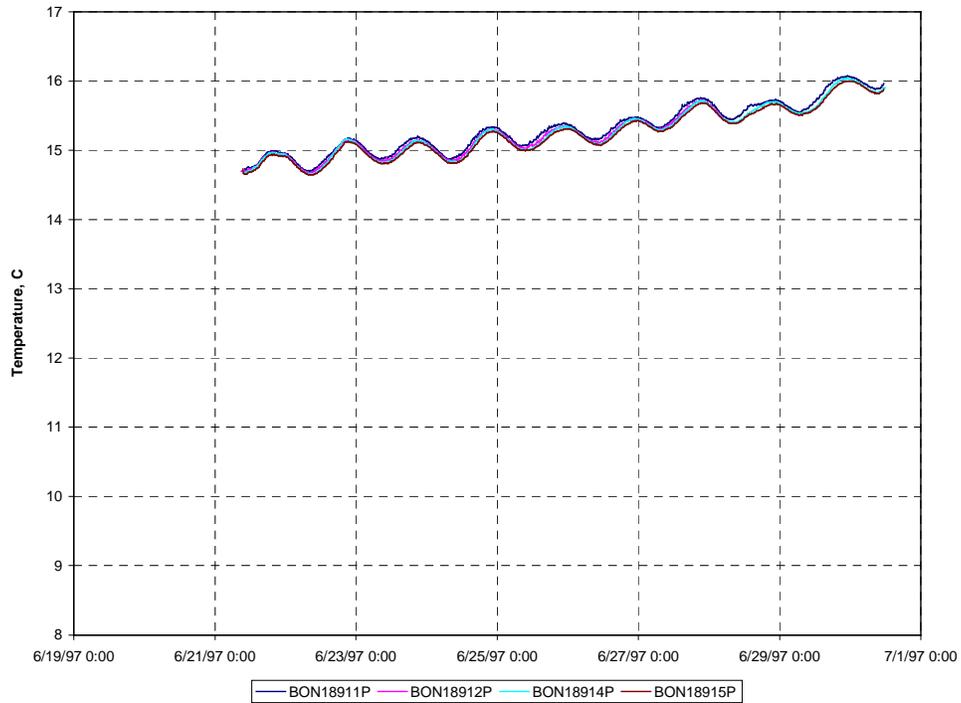


Figure 202. Water temperature measured by temporary monitors below The Dalles dam during the Summer 1997 study.

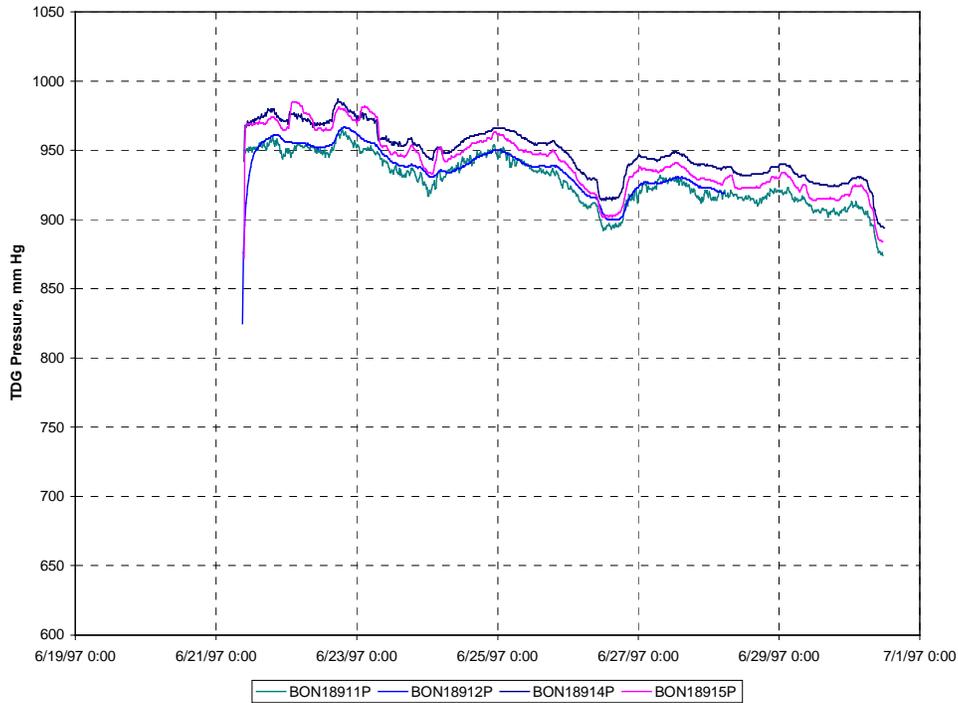


Figure 203. TDG pressure measured by temporary monitors below The Dalles dam during the Summer 1997 study period.

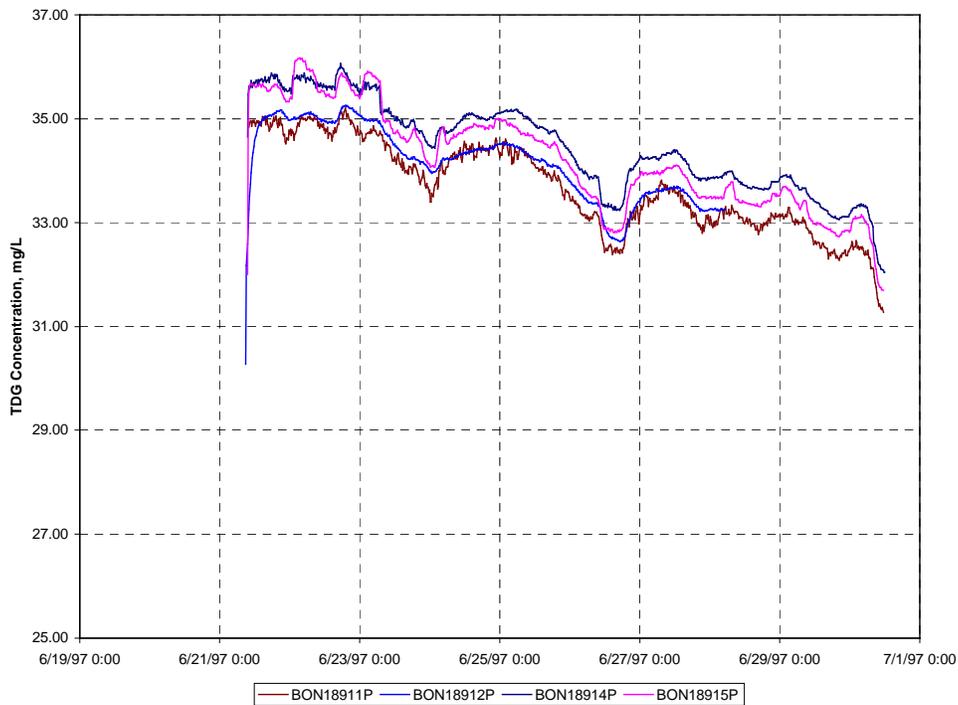


Figure 204. TDG concentration computed using temperature and pressure measured by temporary monitors below The Dalles during the Summer 1997 study.

D.4 Bonneville Dam Boundary Operations

Forebay stage for Bonneville dam was obtained from hourly CHROMS operations data and is shown in Figure 205.

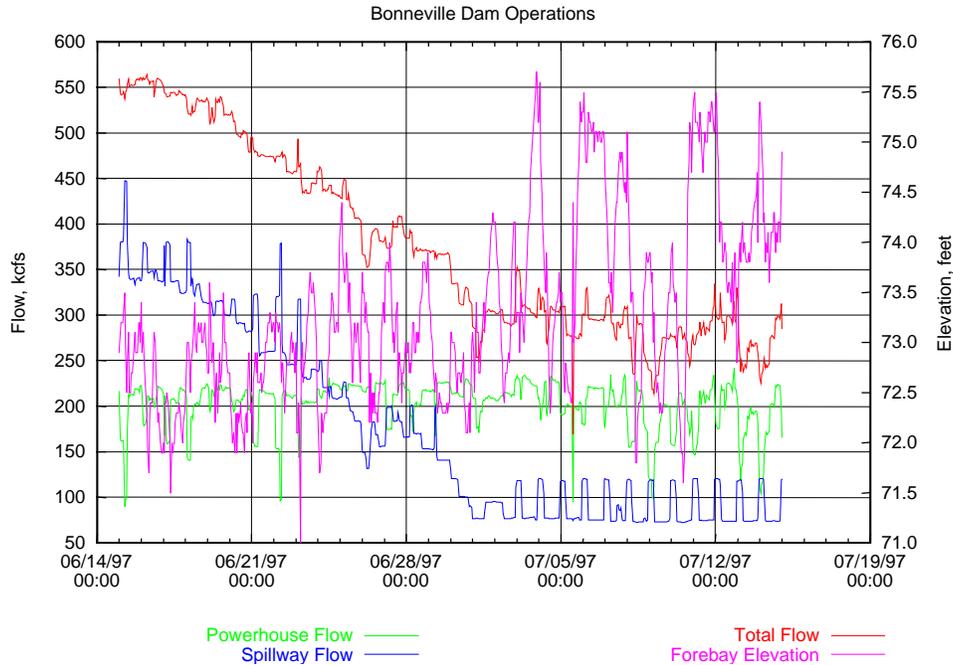


Figure 205. Bonneville dam operations during the Summer 1997 study period.

D.5 Weather

Atmospheric conditions were considered constant over the entire pool. The Dalles, Oregon, air and dew point temperature (Figure 206) and wind speed (Figure 207) were used from the NWS weather database. Barometric pressure measured by the TDA FMS (also shown in Figure 206) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for part the Summer 1997 study. The available radiation data was extended using NWS The Dalles dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 208.

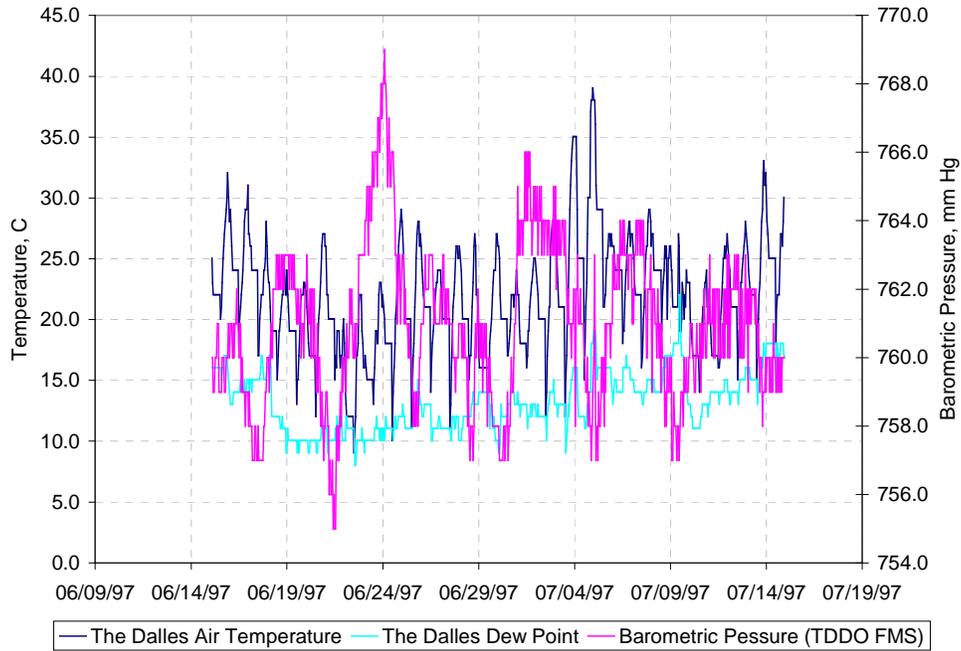


Figure 206. Air temperature, dew point, and barometric pressure used during the Summer 1997 study period.

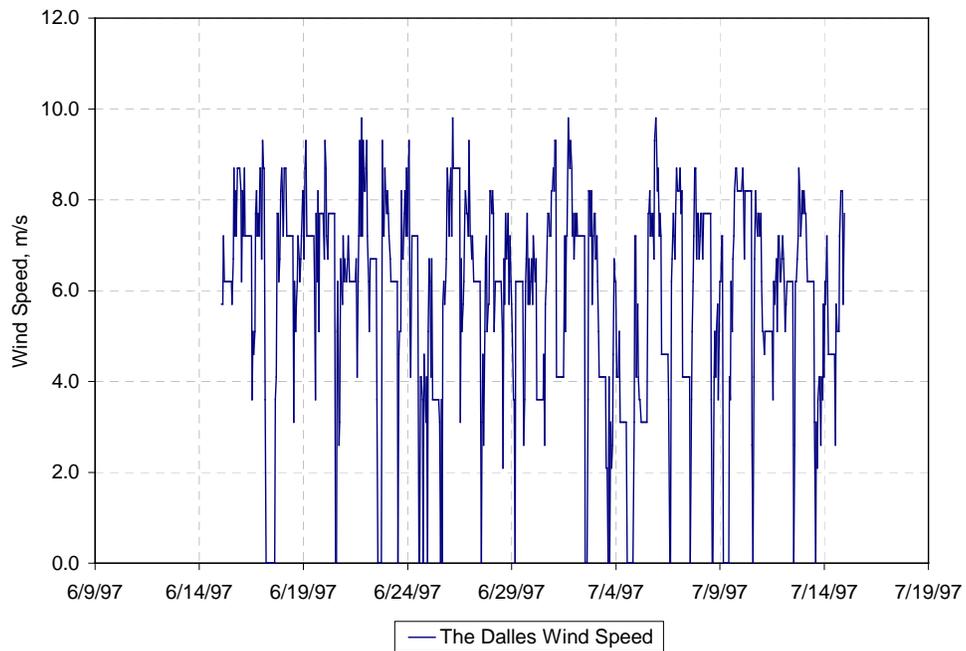


Figure 207. Wind speed used during the Summer 1997 study period.

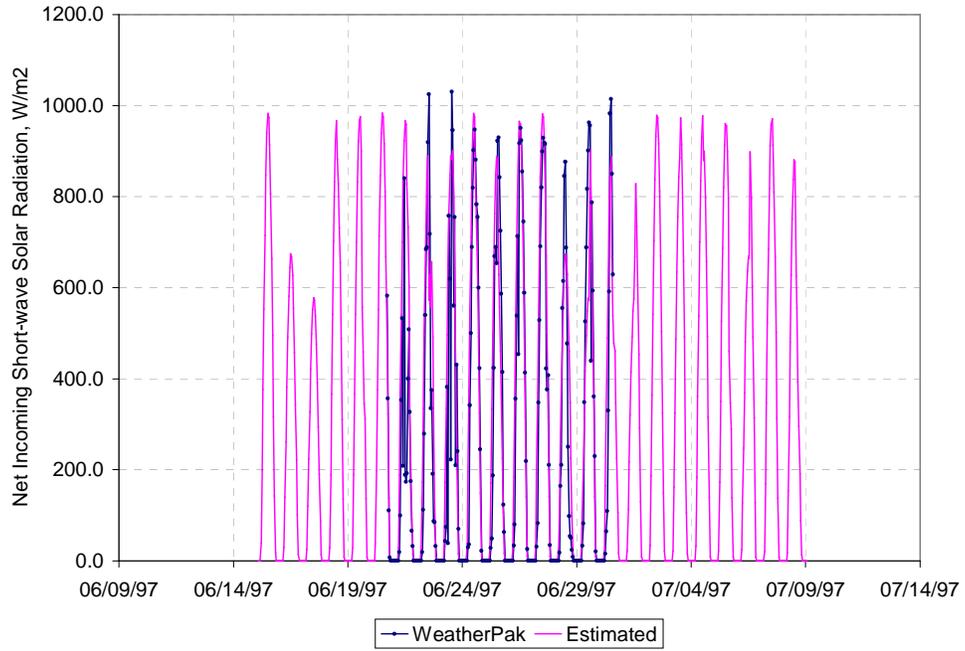


Figure 208. Net incoming short-wave solar radiation based estimated total radiation used during the Summer 1997 study period.