Lake Whatcom Water Quality Model

by

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Acknowledgements

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Introduction

A water quality model of Lake Whatcom, Washington (see Figure 1 and Figure 2)was developed as part of a Total Maximum Daily Load Study for the Washington Department of Ecology. Lake Whatcom is a large natural lake which is listed on the 1998 Washington State 303(d) list of waterbodies which do not meet the criterion for dissolved oxygen. Located next to the city of Bellingham, it is approximately 10 miles long and has a surface area of approximately 5000 acres and a maximum depth of over 100 meters. Eutrophication processes in the lake have been accelerated in recent years perhaps by the availability of nutrients from tributary discharges to the basin. Many of these tributaries have accelerated their nutrient loading to the system as a result of development in the watershed. The lake is being modeled using the Corps of Engineer's model CE-QUAL-W2, which is a two-dimensional, hydrodynamic and water quality model. The project is managed by the Washington Department of Ecology which plans to make recommendations for reduction and allocation of pollutant loads.

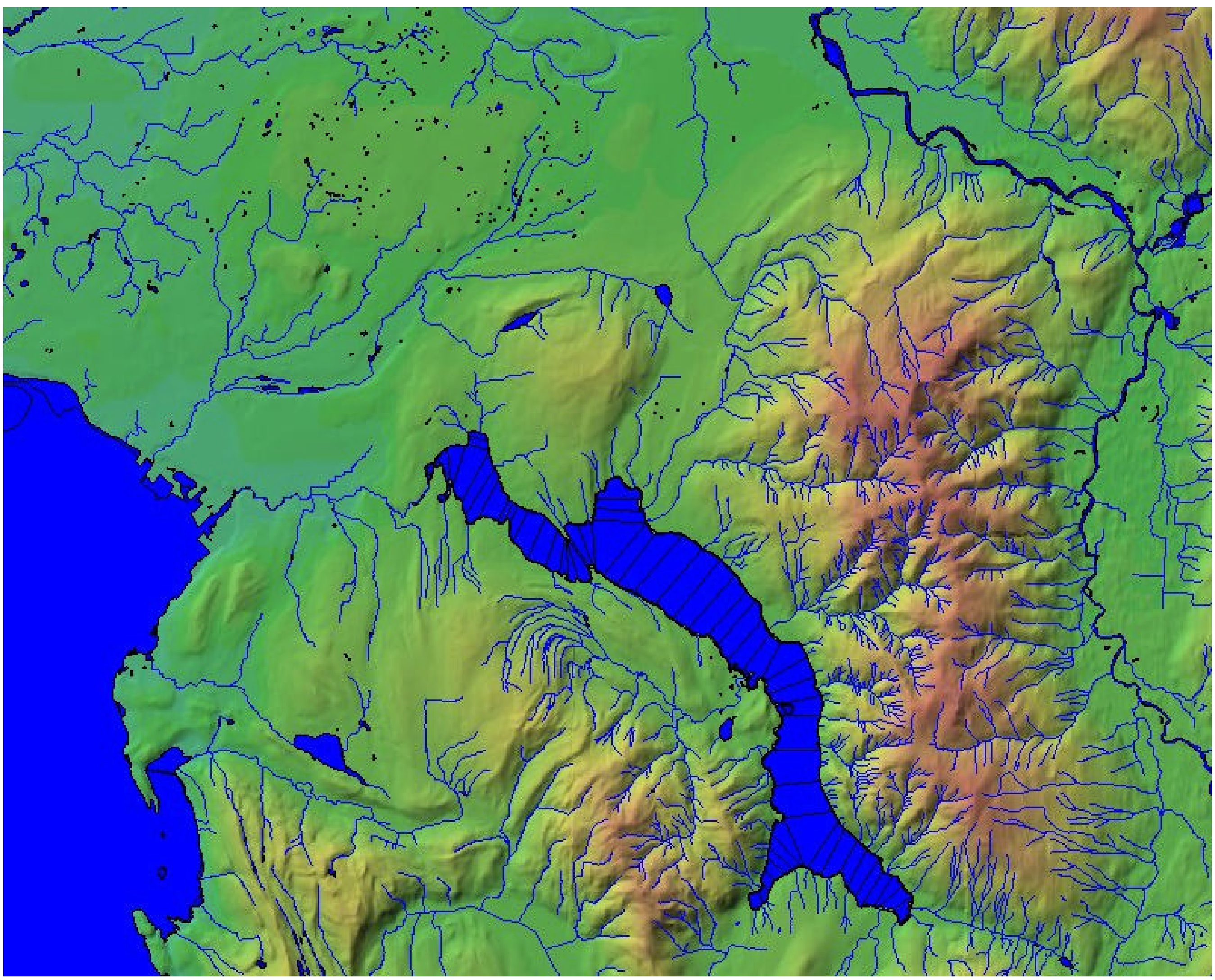

Figure 1. Lake Whatcom and vicinity.

The objectives of this study were then to

- Develop a hydrodynamic and water quality model of Lake Whatcom
- Calibrate the model to field data collected from February 2002 through December 2003
- Use the model to evaluate strategies for water quality improvement

The model chosen for development was CE-QUAL-W2 Version 3.2 (Cole and Wells, 2004). This is a two-dimensional unsteady hydrodynamic, temperature and water quality model that includes typical eutrophication parameters (algae, nutrients, temperature, organic matter, dissolved oxygen, pH). PSU, under the support of the Corps of Engineers Waterways Experiment Station, is a center for development of this modeling tool.

In order to model the system, the following data were required:

- Lake Whatcom outflow rates
- Tributary inflows, temperatures, and water quality
- Groundwater inflows, temperatures, and water quality
- Precipitation rates, temperatures, and water quality
- Meteorological conditions
- Bathymetry

This report summarizes model development. Information provided in this report was organized in the following sections:

- Model Selection
- Model Forcing Data
- Hydrodynamic Calibration
- Temperature Calibration
- Water Quality Calibration
- Scenarios
- Summary

Also discussed are issues relative to the calibration effort. Calibration focused on model predictions of hydrodynamics (flow and water level), temperature, and water quality. The model calibration period was from February 14, 2002 to December 31, 2003.

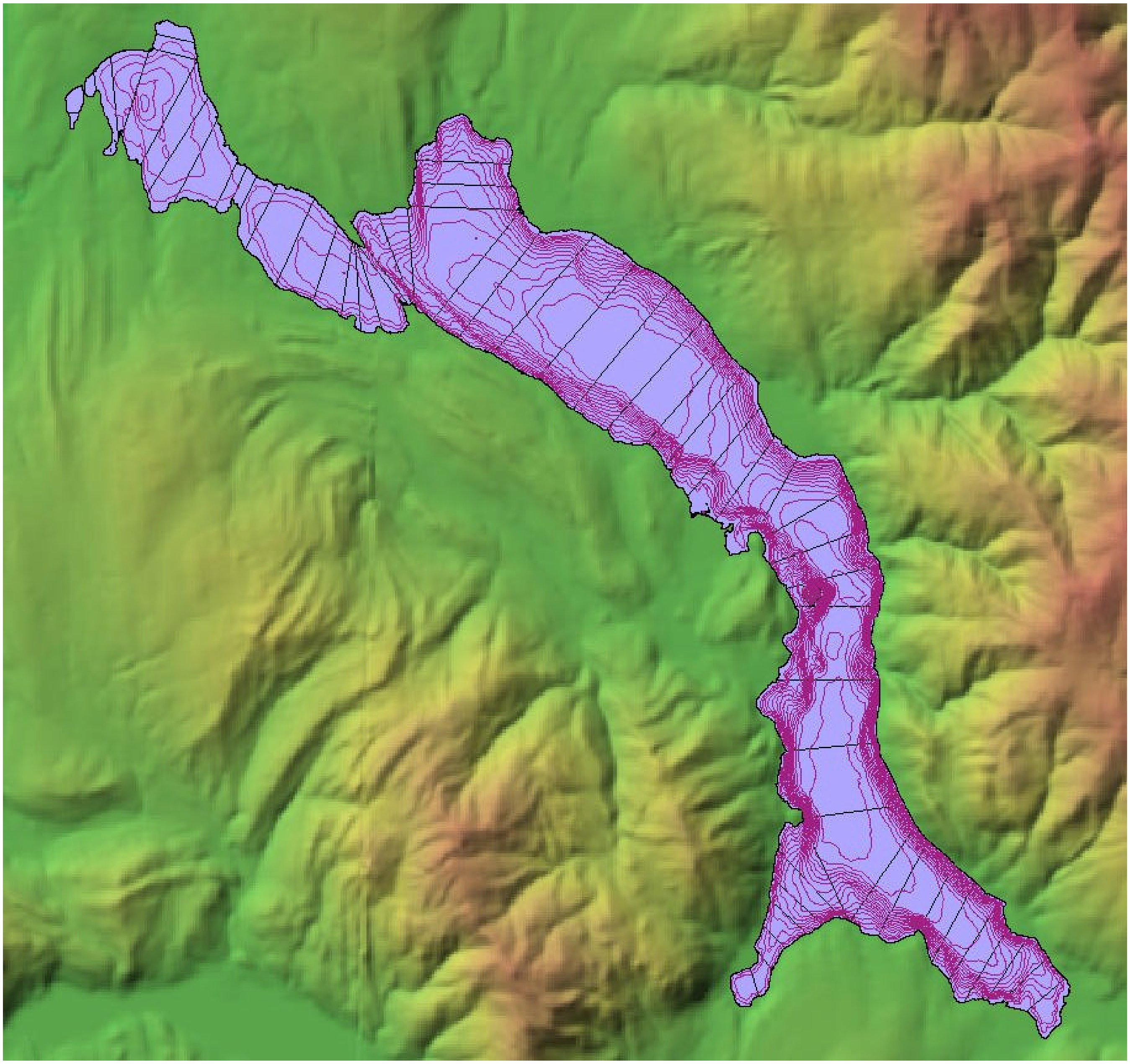

Figure 2. Topography around Lake Whatcom.

Model Selection

Selection of the appropriate water quality model is a function of properly identifying the water quality problem ("conceptualization") and selecting a model which appropriately describes the water quality changes in the water body, is theoretically valid, and can be easily adapted to site-specific physical characteristics of the water body.

The performance of a mathematical model in predicting the existing and future water quality dynamics of a system is dependent on the following steps:

(i) identification of the problem
(ii) selection of model type and relationship of model to the problem
(iii) computational representation
(iv) model response studies or model sensitivity analyses
(v) model calibration
(vi) application of model to evaluate management strategies

Because there are many water quality models available, a choice of the appropriate model would be made after considering the following questions: What physical processes are represented in the model and which are ignored? How are physical processes included in the model? What processes are represented by model coefficients? For example in defining the problem, the following questions could be asked:

(i) What are the dominant physical processes at work and can the chosen model represent those processes? (such as, how does the water move? Is there stratification, wind-driven currents, and/or selective withdrawal?)
(ii) What are the spatial and temporal scales of these processes and can the model represent them? (such as, is steady-state representation adequate, is 1-D, 2-D, or 3-D spatial discretization necessary?)

The choice of the proper model is also based on answering
(1) site specific questions (physical characteristics of the each system component - river or reservoir reach, water quality cycles, algal types),
(2) management objectives (required accuracy, use for future studies),
(3) project resources (data availability, staff constraints, time limitations).

The model chosen for Lake Whatcom was the Corps of Engineers model CE-QUAL-W2 Version 3.2. CE-QUAL-W2 Version 3.2 is a dynamic 2-d (x-z) model developed for stratified water-bodies (Cole and Wells, 2004). This is a Corps of Engineers modification of the Laterally Averaged Reservoir Model (Edinger and Buchak 1978). CE-QUAL-W2, whose grid is shown in Figure 3, consists of directly coupled hydrodynamic and water quality transport models. Hydrodynamic computations are influenced by variable water density caused by temperature, salinity, and dissolved and suspended solids. Developed for reservoirs and narrow, stratified estuaries, CE-QUAL-W2 can handle a branched and/or looped system with flow and/or head boundary conditions. With two dimensions depicted, point and non-point loading can be spatially distributed. Relative to other 2-D models, CE-QUAL-W2 is efficient and cost effective to use. This model allows the user to use the ultimate quickest Numerical Scheme for improved numerical accuracy.

In addition to temperature, CE-QUAL-W2 Version 3.2 can simulate many water quality variables. Primary physical processes included are surface heat transfer, short-wave and long-wave radiation and penetration, convective mixing, wind and flow induced mixing, entrainment of ambient water by pumped-storage inflows, inflow density stratification as impacted by temperature and dissolved and suspended solids. Major chemical and biological processes in CE-QUAL-W2 include: the effects of DO of atmospheric exchange, photosynthesis, respiration, organic matter decomposition, nitrification, and chemical oxidation of reduced substances; uptake, excretion, and regeneration of phosphorus and nitrogen and nitrification-denitrification under aerobic and anaerobic conditions; carbon cycling and alkalinity-pH-CO2 interactions; trophic relationships for total phytoplankton; accumulation and decomposition of detritus and organic sediment; and coliform bacteria mortality.

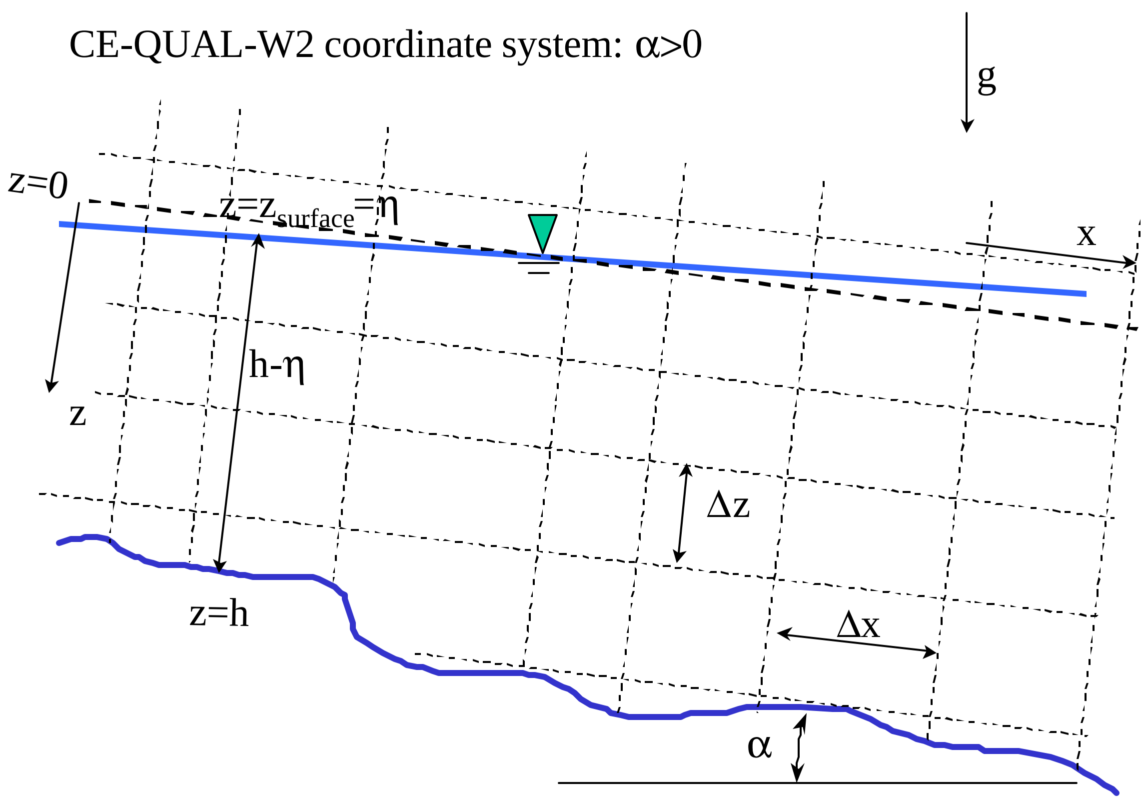

Figure 3. Coordinate system for CE-QUAL-W2 Version 3.2.

Models, such as WQRSS (Smith 1978), HEC-5Q (Corps of Engineers 1986), and HSPF (Donigian, et al. 1984), have been developed for river basin modeling but have serious limitations. One issue is that the HEC-5Q (similar to WQRSS) and HSPF models incorporate a one-dimensional, longitudinal river model with a one-dimensional, vertical reservoir model (one-dimensional for temperature and water quality and zero dimensional for hydrodynamics). The modeler must choose the location of the transition from 1-D longitudinal to 1-D vertical. Besides the limitation of not solving for the velocity field in the stratified, reservoir system, any point source inputs to the reservoir section are spread over the entire longitudinal distribution of the reservoir layer.

Also, other one-dimensional reservoir models, such as the HEC WQRRS (Water Quality River-Reservoir Simulation) model and the Corps's CE-QUAL-R1, are also not adequate to compute 2-D circulation within pool areas. These models conceptualize a pool as well mixed in each horizontal slab, i.e., over the length and the width of the system. By making this assumption, the vertical and longitudinal circulation patterns within a pool cannot be resolved.

Based on the depth Lake Whatcom, a one-dimensional reservoir model would not be adequate because of possible longitudinal and vertical gradients in water quality.

For this project, the CE-QUAL-W2 River Basin Model Version 3.2 (as schematized in Figure 4) was the most appropriate for modeling Lake Whatcom since it contains the following elements:

- Two-dimensional, dynamic hydrodynamics and water quality capable of replicating any density stratified environment.
- The model is a state-of-the-art tool with features not found in other models

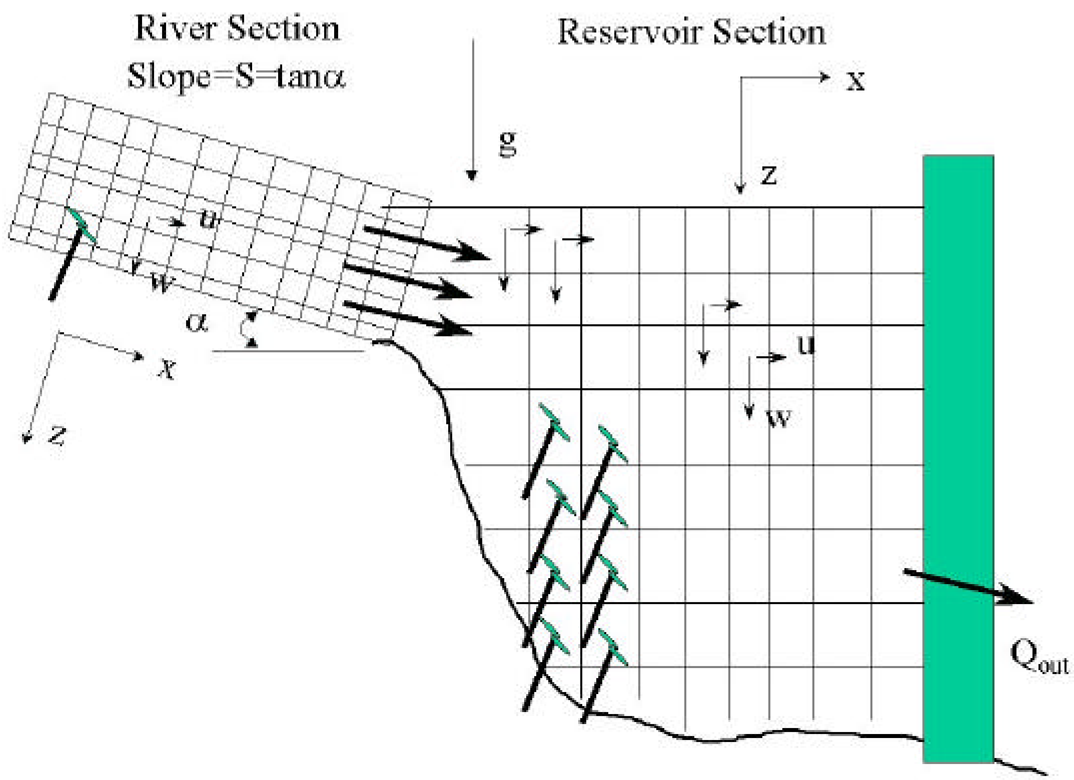

Figure 4. Conceptual schematic of river-reservoir connection in CE-QUAL-W2 Version 3.

This model has been under development for many years and is a public-domain code maintained by the Corps of Engineers, Waterways Experiments Station (WES), located in Vicksburg, Mississippi. Version 3.2 has and is undergoing rigorous testing and has been successfully applied to many river basin systems. Further information about CE-QUAL-W2 Version 3 is shown at http://www.ce.pdx.edu/w2.

Model Water Quality Constituents

The following water quality constituents were simulated in the Lake Whatcom model:

- Inorganic Suspended Solids (ISS)
- Dissolved Inorganic Phosphorus (PO4-P)

- Ammonia Nitrogen (NH4-N)
- Nitrate-nitrite Nitrogen (NOx-N)
- Labile Dissolved Organic Matter (LDOM)
- Refractory Dissolved Organic Matter (RDOM)
- Labile Particulate Organic Matter (LPOM)
- Refractory Particulate Organic Matter (RPOM)
- 3 Algae Compartments
- Dissolved Oxygen
- Total Inorganic Carbon (TIC)
- Alkalinity
- Labile Dissolved Organic Matter Phosphorus (LDOM-P)
- Refractory Dissolved Organic Matter Phosphorus (RDOM-P)
- Labile Particulate Organic Matter Phosphorus (LPOM-P)
- Refractory Particulate Organic Matter Phosphorus (RPOM-P)
- Labile Dissolved Organic Matter Nitrogen (LDOM-N)
- Refractory Dissolved Organic Matter Nitrogen (RDOM-N)
- Labile Particulate Organic Matter Nitrogen (LPOM-N)
- Refractory Particulate Organic Matter Nitrogen (RPOM-N)

Water quality cycles are described in the user's manual (Cole and Wells, 2004). However, the phosphorus and nitrogen organic matter compartments (LDOM-P, RDOM-P, LPOM-P, RPOM-P, LDOM-N, RDOM-N, LPOM-N, RPOM-N) were added specially to the Lake Whatcom model and represent the phosphorus and nitrogen mass contained in LDOM, RDOM, LPOM and RPOM. This allowed the model user to set dynamic values of N and P in all tributaries associated with organic matter and to track these quantities within the domain of the CE-QUAL-W2.

The 3 algae compartments correspond to 3 groups of algae species. Algae group 1 represents Chrysophyta (mostly diatoms), algae group 2 represents Chlorophyta (greens), and algae group 3 are Cyanobacteria (blue-greens).

Model Forcing Data and Bathymetry

The model forcing data consists of the boundary conditions for all inflows (flow rate, temperature and water quality data) and the system meteorology. The model bathymetry is also required to develop a model grid for the numerical simulation.

Water quality monitoring sites from which data were used for model development were identified in Figure 5 and were described in Table 1.

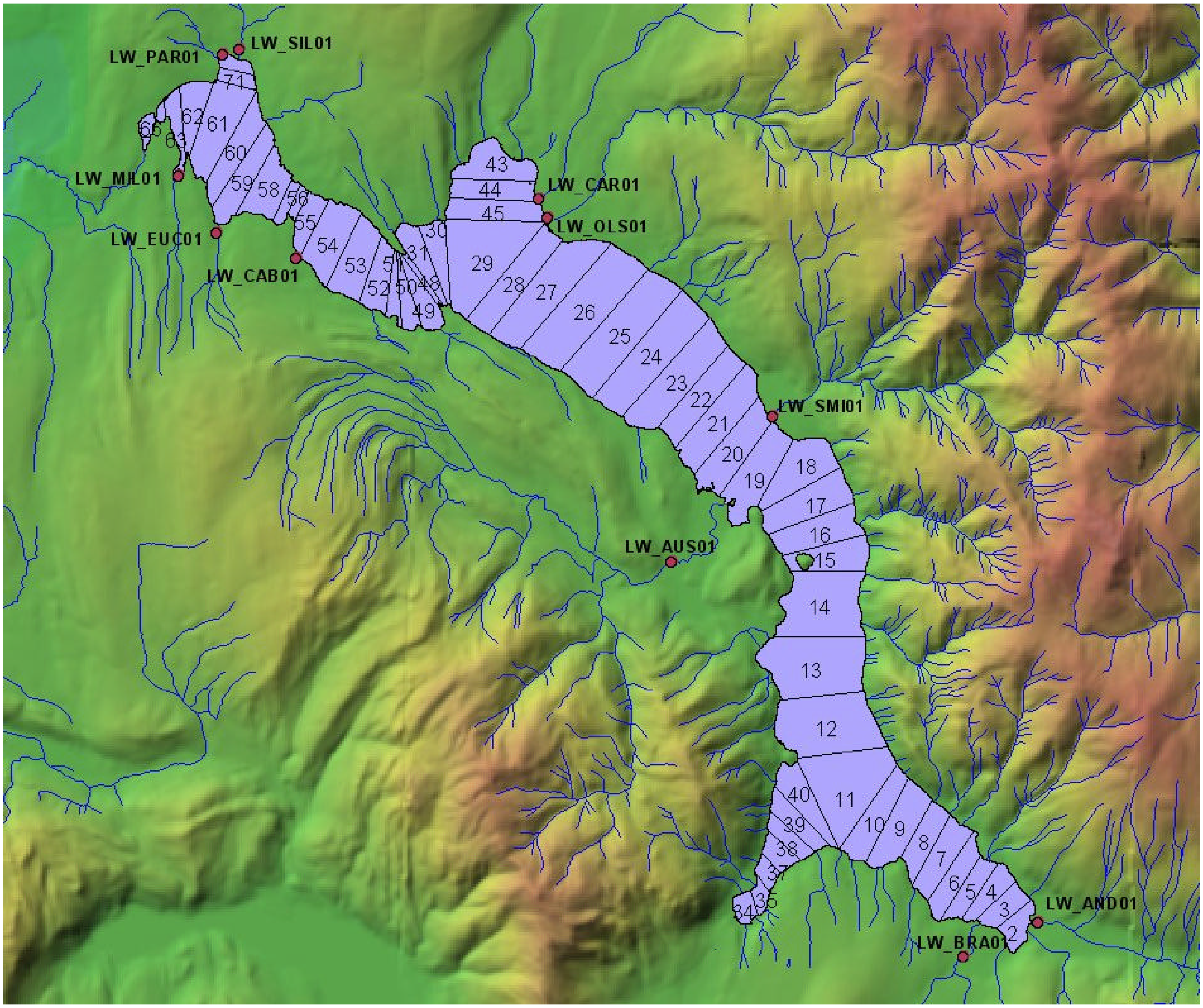

Figure 5. Monitoring sites at Lake Whatcom

Table 1. Monitoring sites		
Site ID	**Description**	**Parameters**
LW_AND01	Anderson Creek	Flow, Temperature, Water Quality
LW_AUS01	Austin Creek	Flow, Temperature, Water Quality
LW_BRA01	Brannian Creek	Flow, Temperature, Water Quality
LW_CAR01	Carpenter Creek	Flow, Temperature, Water Quality
LW_EUC01	Euclid Creek	Flow, Temperature, Water Quality
LW_MIL01	Mill Wheel	Flow, Temperature, Water Quality
LW_OLS01	Olsen Creek	Flow, Temperature, Water Quality
LW_SIL01	Silver Creek	Flow, Temperature, Water Quality
LW_SMI01	Smith Creek	Flow, Temperature, Water Quality
LW1	Basin 1	Temperature, Water Quality
LW2	Basin 2	Temperature, Water Quality
LW3	Basin 3, north	Temperature, Water Quality

Table 1. Monitoring sites		
Site ID	**Description**	**Parameters**
LW4	Basin 3, south	Temperature, Water Quality
Intake	Basin 2, near water intake	Temperature, Water Quality

Model Geometry

Bathymetry

The Lake Whatcom bathymetry, as shown in Figure 6, was developed by the Washington Department of Ecology. [Data source??]

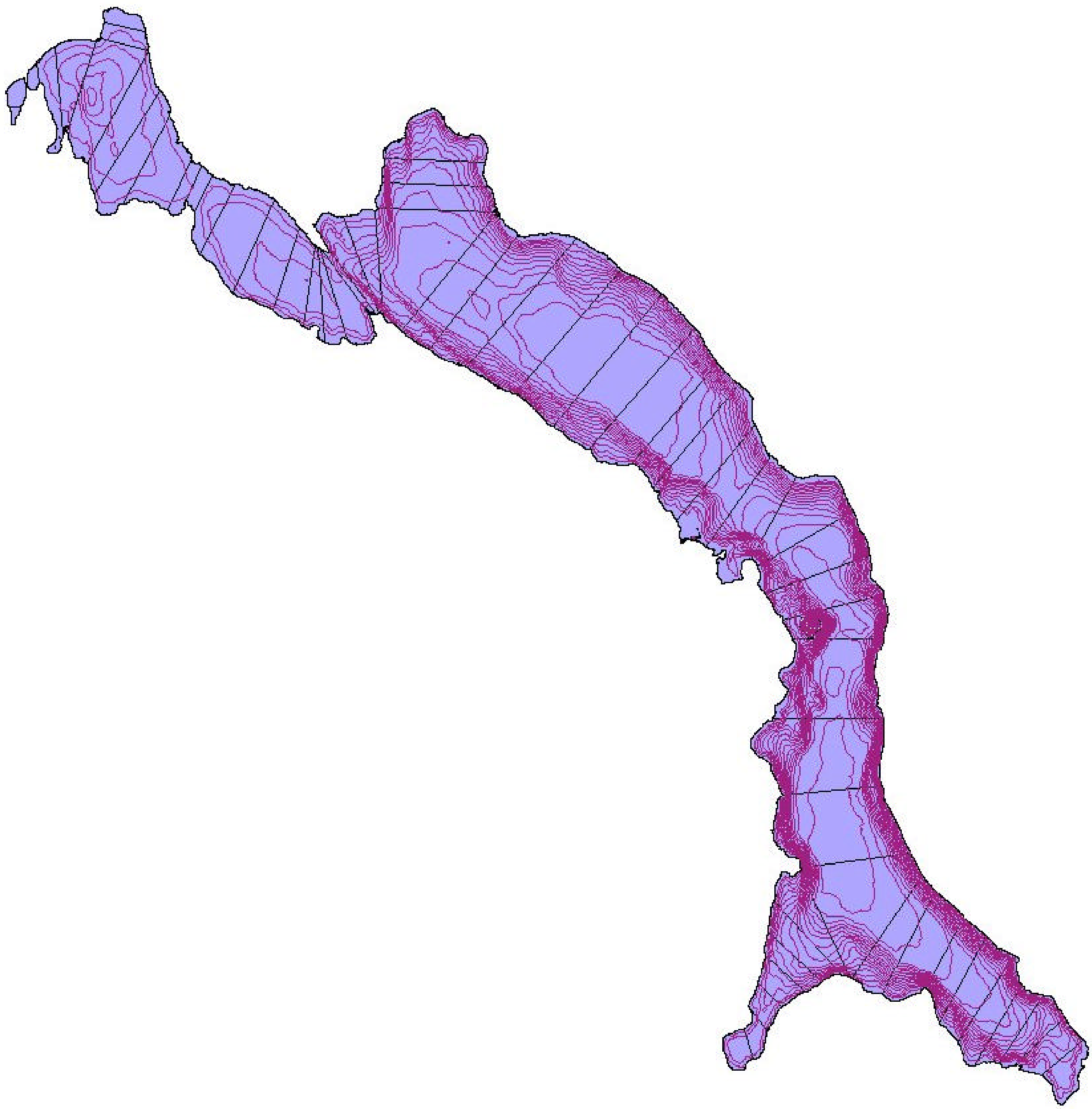

Figure 6. Lake Whatcom bathymetry

Grid Layout

A plan view of the CE-QUAL-W2 grid layout, shown in Figure 7, was also developed from the model bathymetry by Washington Ecology.

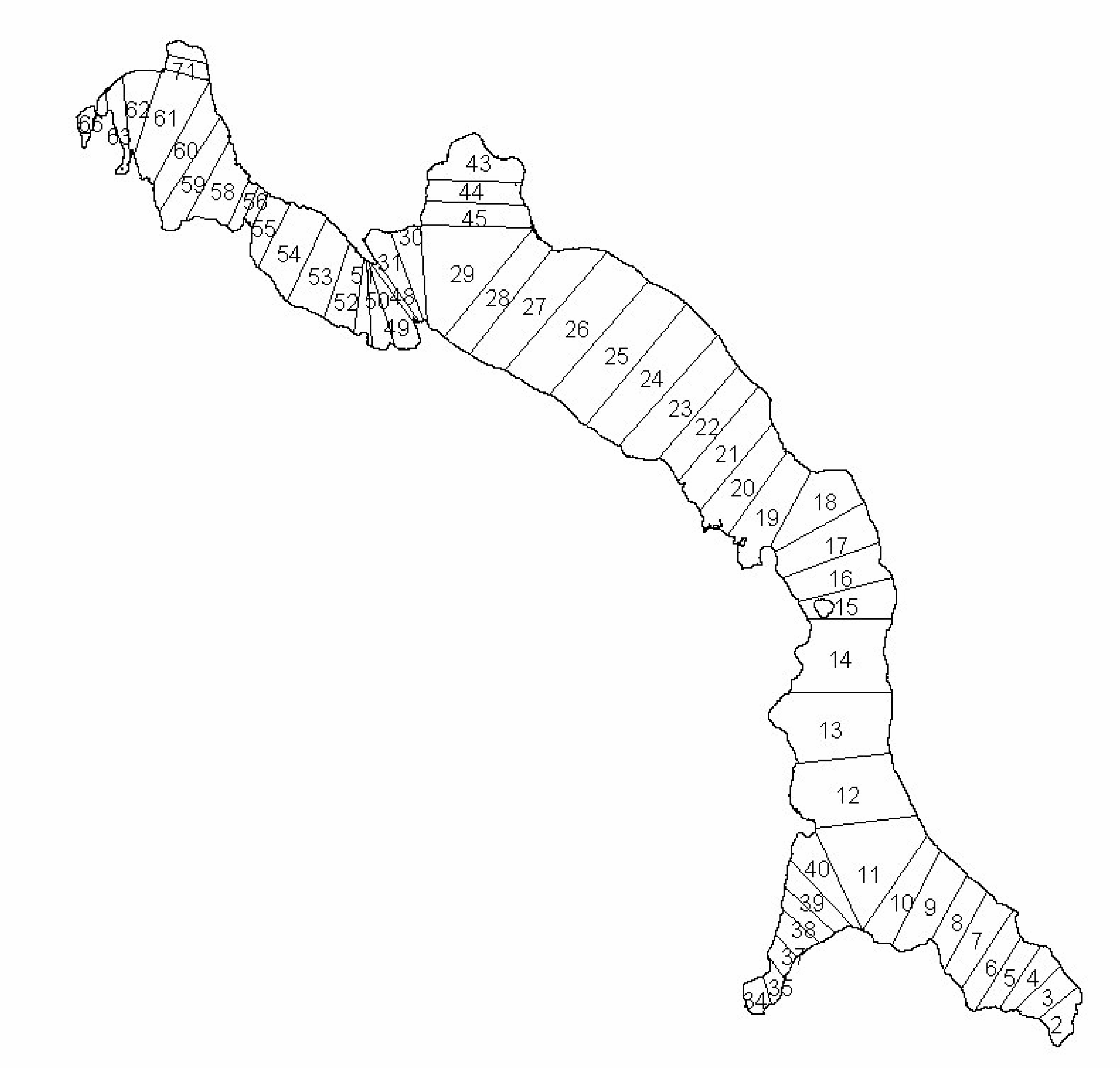

Figure 7. Plan view of the Lake Whatcom model grid.

The model was divided into five branches and two water bodies. Branches 1 through 3 simulated basin 3 and branches 4 and 5 represented basins 1 and 2. The length of the model segments ranged from 16 meters to 821 meters. Model layers have a thickness of 1 or 3 meters. 3 meter layer thicknesses were used only in the deeper sections of Basin 3. Model layers were shown in Figure 8.

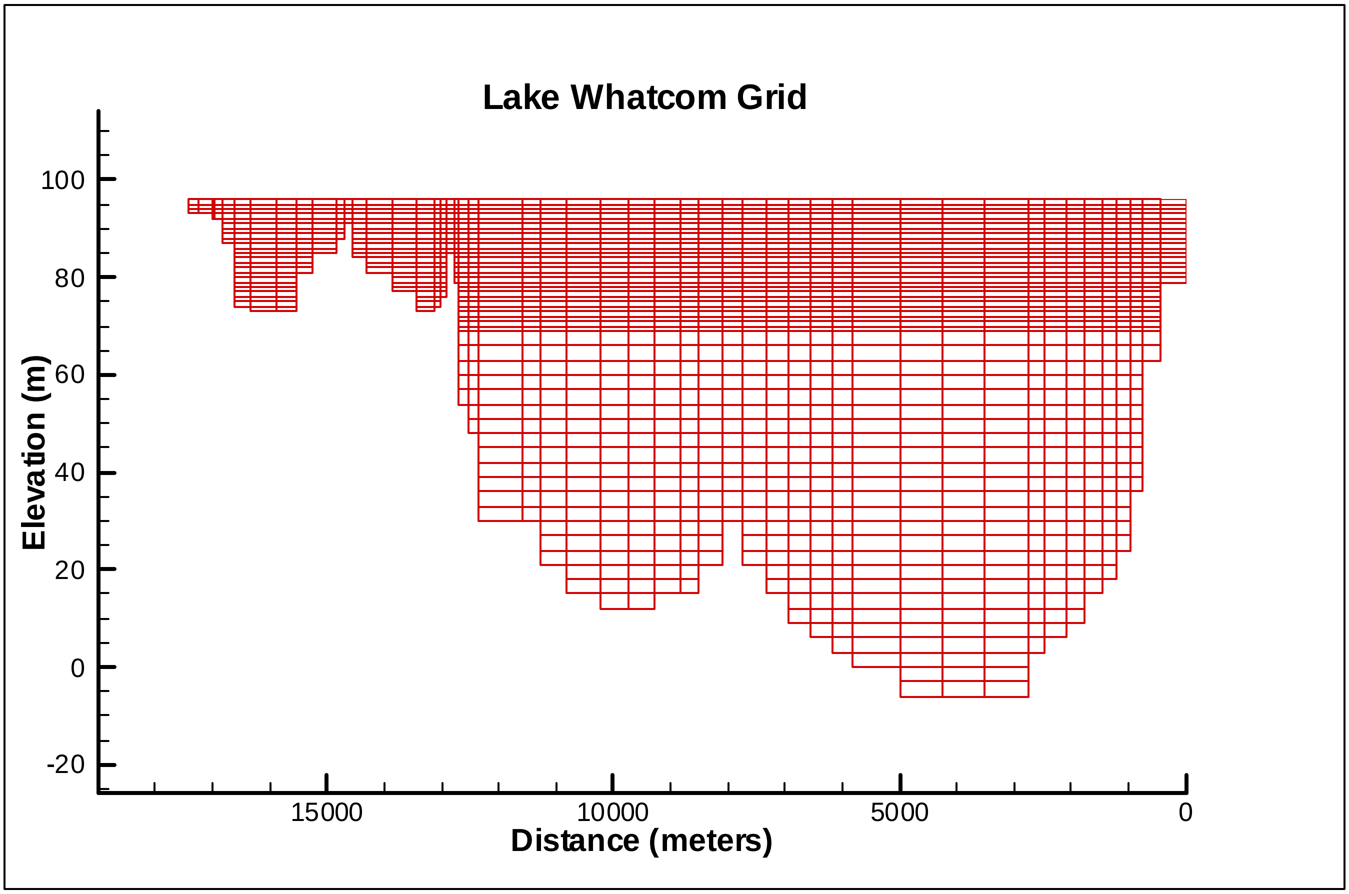

Figure 8. Layer elevations of Lake Whatcom model. Only layers below the full pool elevation are shown.

In the CE-QUAL-W2 model, the model user must specify the characteristics and connectivity of the model grid. The following parameters were used in the Lake Whatcom model (see Cole and Wells, 2004, for detailed explanation of model grid characteristics):

IMP (# of segments): 68
KMP (# of vertical layers): 105
NWB (# of water-bodies): 2
NBR (# of branches): 5

The branch layout was specified by these parameters for each branch (as specified in the w2_con.npt control file – see Cole and Wells, 2004).

Lake Whatcom outflow

The downstream boundary condition was the outflow from Lake Whatcom (Figure 9). Outflow data were obtained from the City of Bellingham.

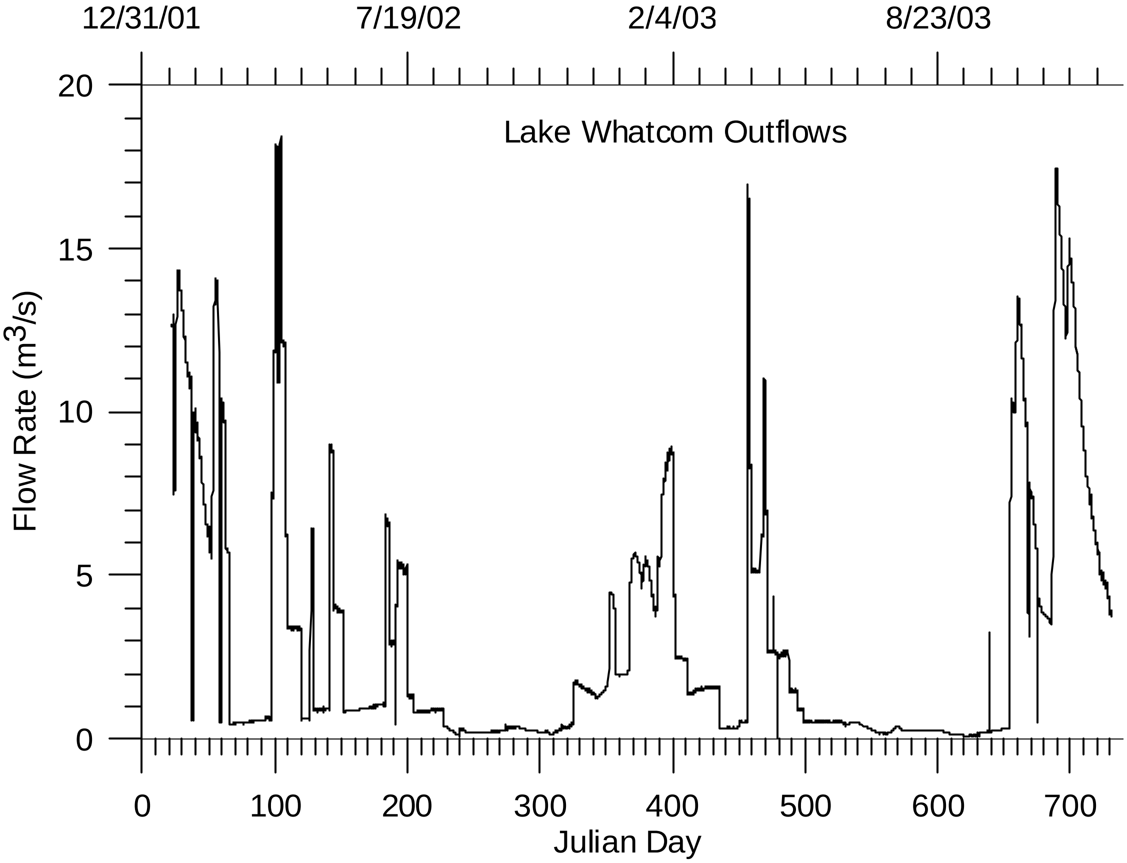

Figure 9. Lake Whatcom Outflow

Tributaries

A total of 22 point tributaries of Lake Whatcom were simulated in the model. Table 2 lists these tributaries and their model inflow segment. The watersheds of the tributaries were shown in Figure 10. Continuous flow and temperature data were available for the following creeks: Austin, Anderson, Brannian, Carpenter, Euclid, Mill Wheel, Olsen, Silver, and Smith. Flows for un-gauged watersheds were estimated by calculating the area proportional flow based on a nearby gauged creek. Figure 11 through Figure 14 show the tributary flow rates.

Temperature files were developed using measured data and a simple response temperature model. For those creeks or watersheds without measured data, the data from an adjacent watershed were used (Table 3). All temperature probes were removed the first week of November 2003, and afterwards the tributary temperatures were estimated using a simple response temperature model developed by the Department of Ecology. October 2003 temperature data were used to calibrate this model and model absolute mean errors were all less than 1 degree Celsius. Figure 15 through Figure 18 show the tributary temperatures.

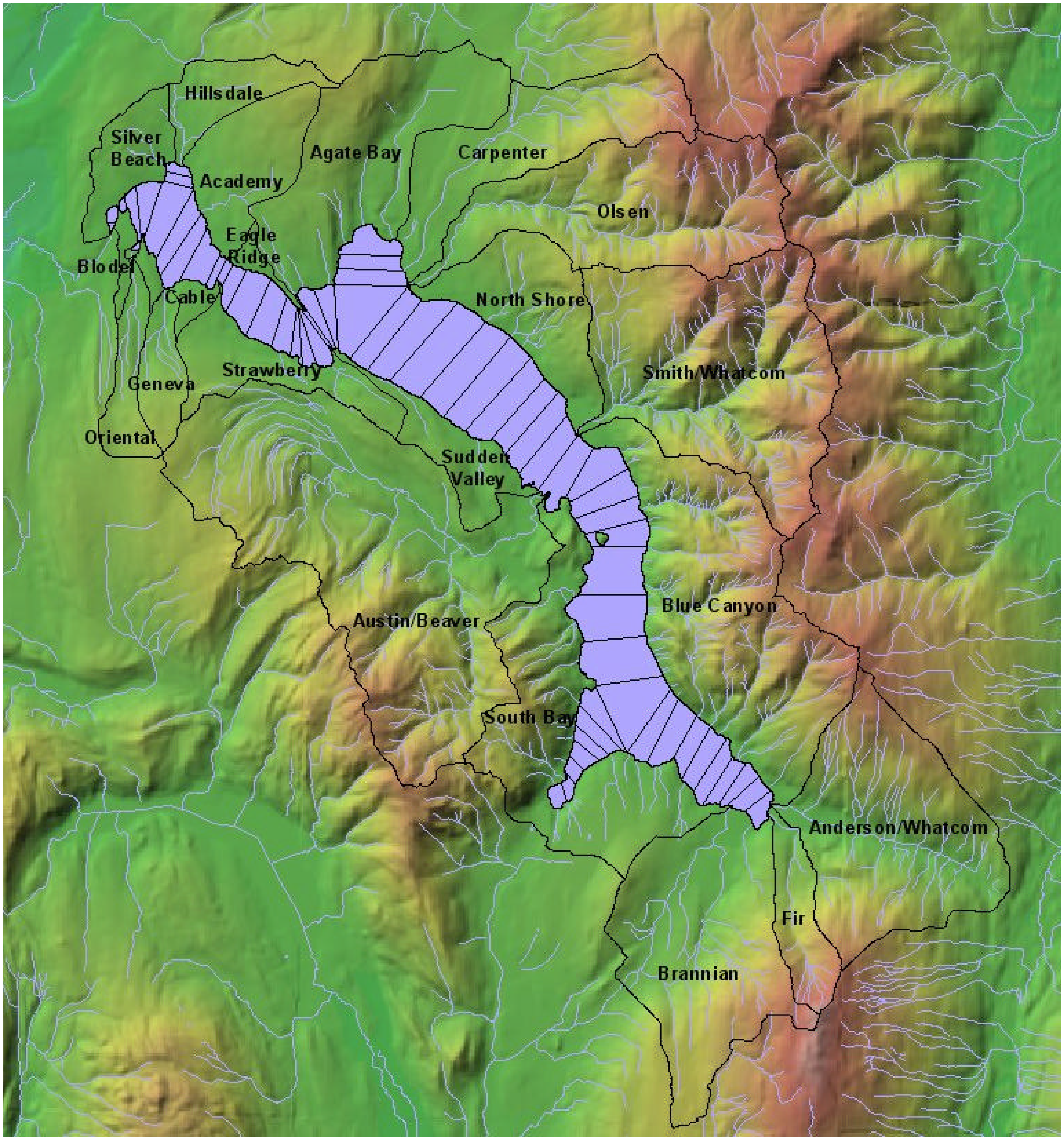

Figure 10. Watersheds of Lake Whatcom tributaries.

Table 2. Lake Whatcom model point tributaries and inflow segments.

Tributary #	Inflow Segment #	Watershed
1	29	Agate Bay
2	45	Carpenter
3	66	Hillsdale
4	60	Academy

Tributary #	Inflow Segment #	Watershed
5	66	Silver Beach
6	28	Olsen
7	63	Blodel
8	55	Eagle Ridge
9	25	North Shore
10	20	Smith
11	60	Donavan
12	62	Mill Wheel
13	57	Cable
14	49	Strawberry
15	59	Euclid
16	23	Sudden Valley
17	19	Austin
18	5	Blue Canyon
19	11	South Bay
20	2	Anderson
21	2	Fir
22	4	Brannian

Table 3. Method to fill in the watersheds without data

No data watershed	Corresponding data watershed
Academy	Euclid
Agate Bay	Carpenter
South Bay	Brannian
Blodel	Mill Wheel
Blue Canyon	Smith
Cable	Euclid
Donavan	Euclid
Eagle Ridge	Euclid
Fir	Brannian
Hillsdale	Silver Beach
North Shore	Carpenter
Strawberry	Euclid
Sudden Valley	Euclid

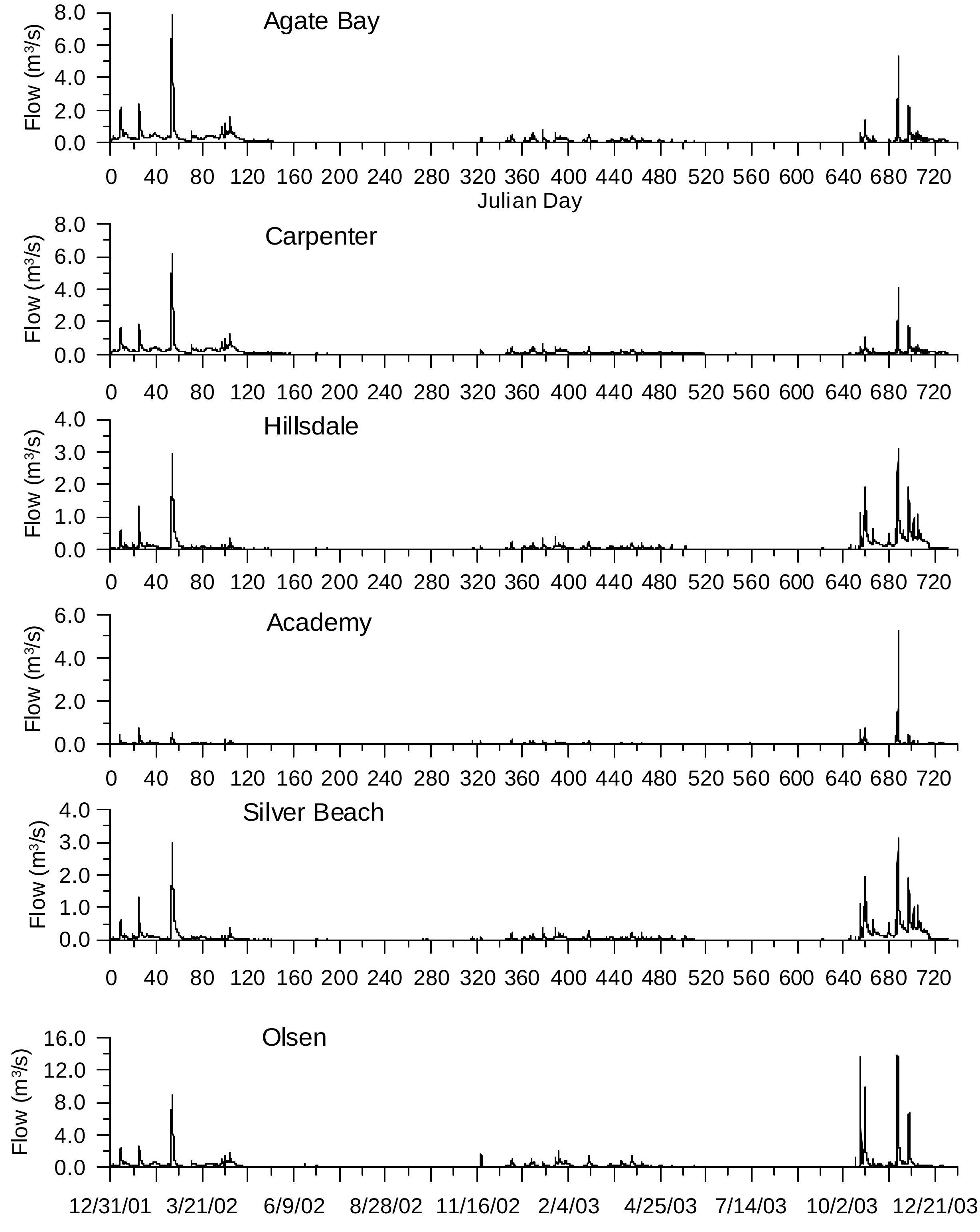

Figure 11. Tributary flow rates.

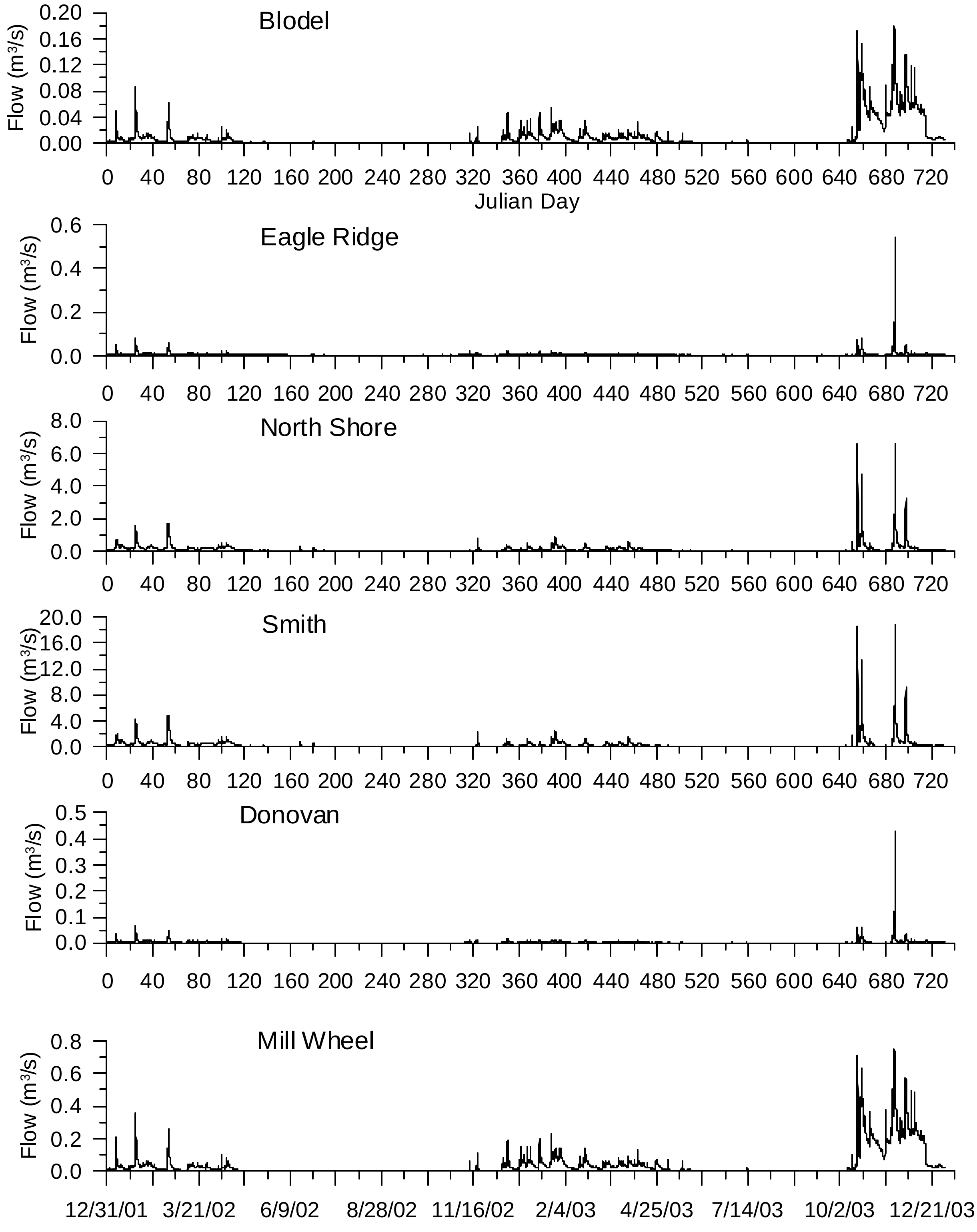

Figure 12. Tributary flow rates (continued).

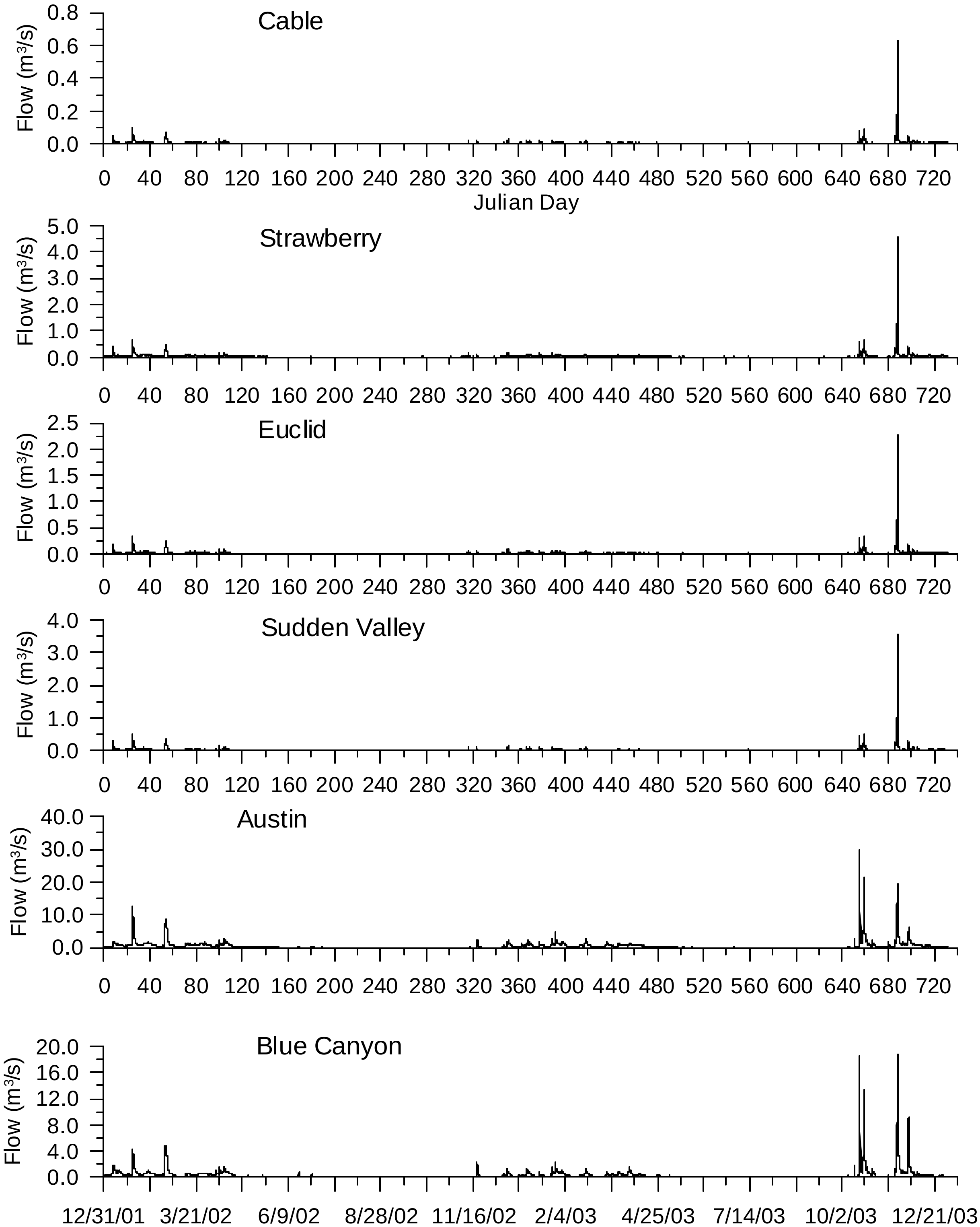

Figure 13. Tributary flow rates (continued).

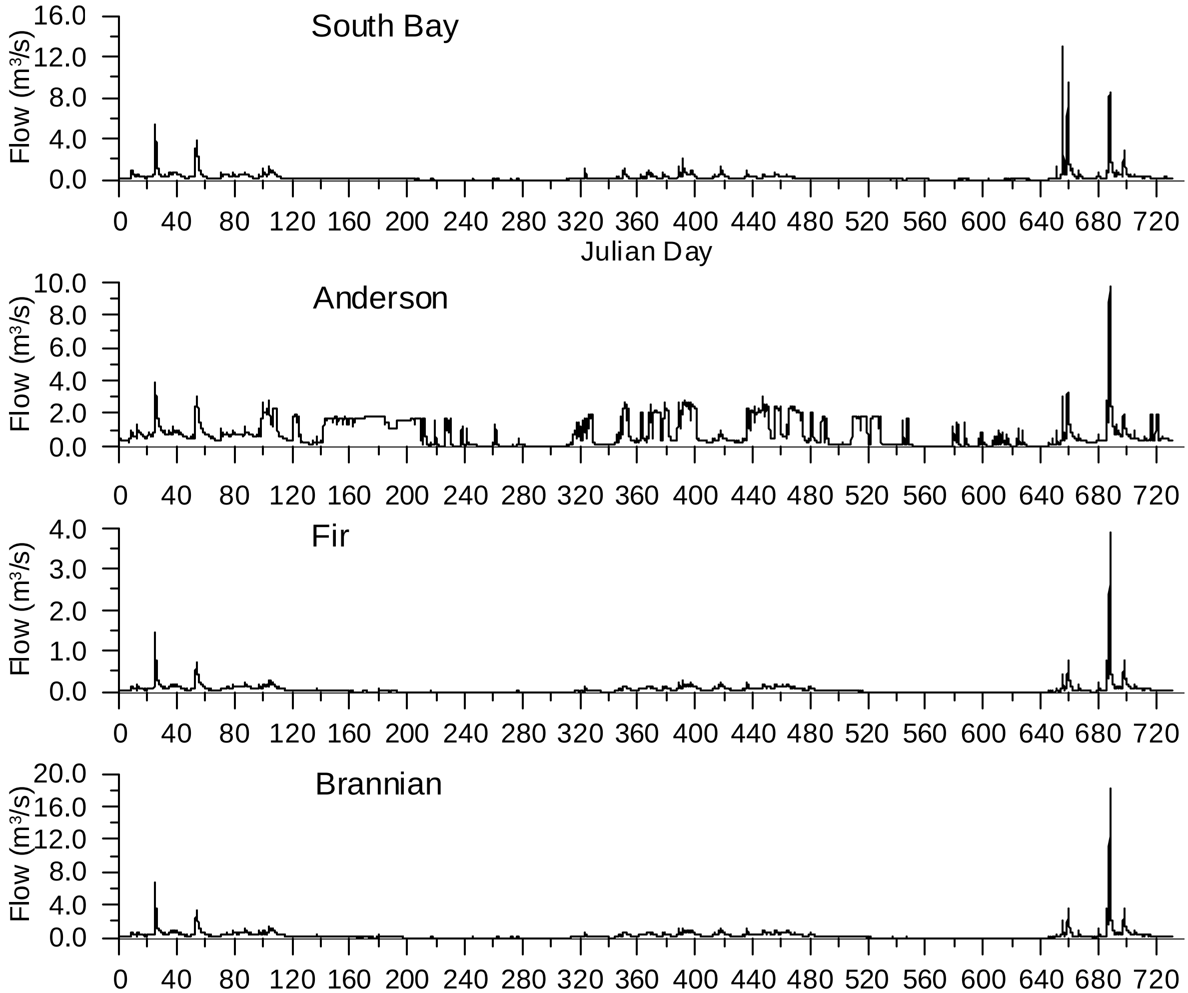

Figure 14. Tributary flow rates (continued).

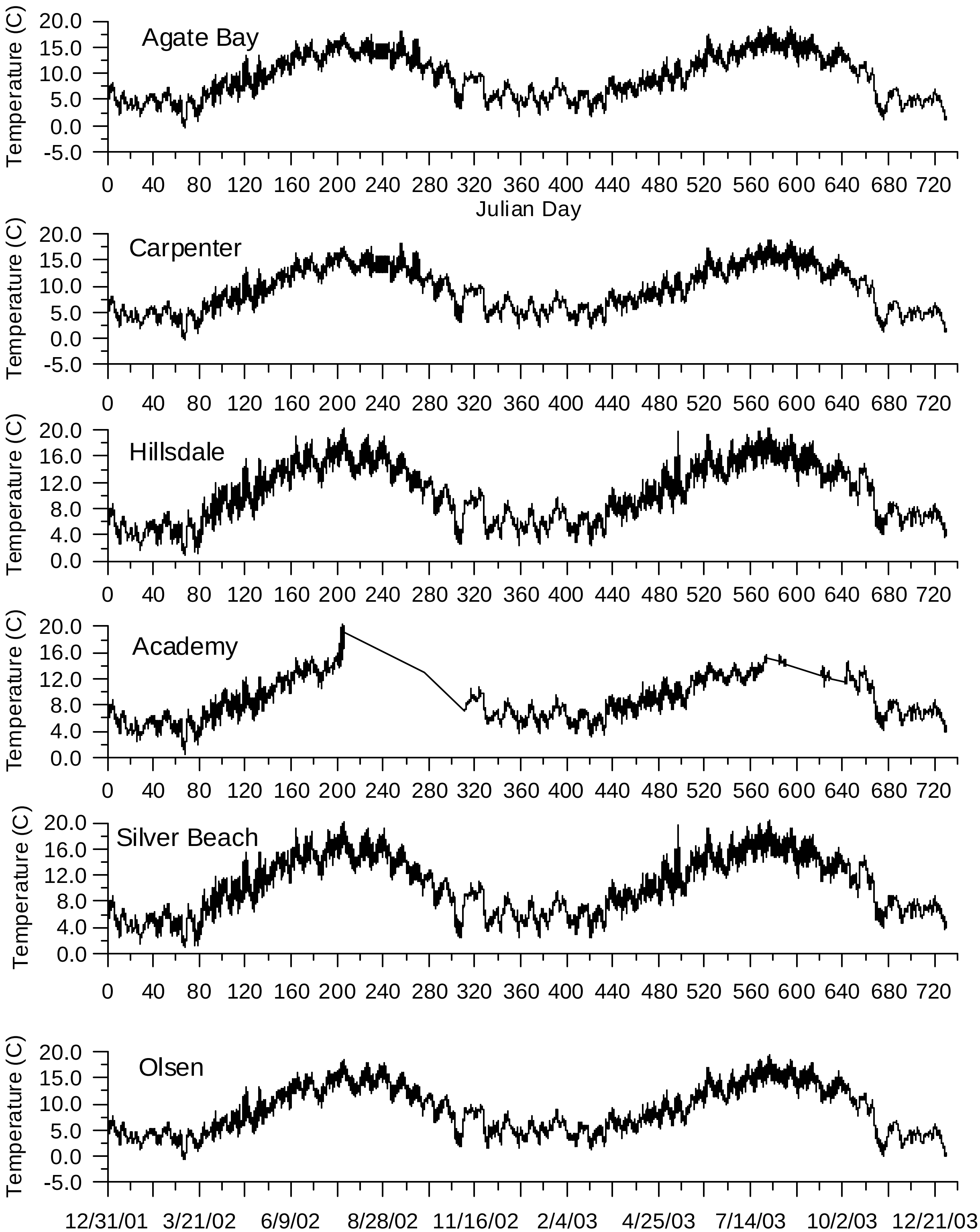

Figure 15. Tributary temperatures (data gaps correspond to periods of zero flow).

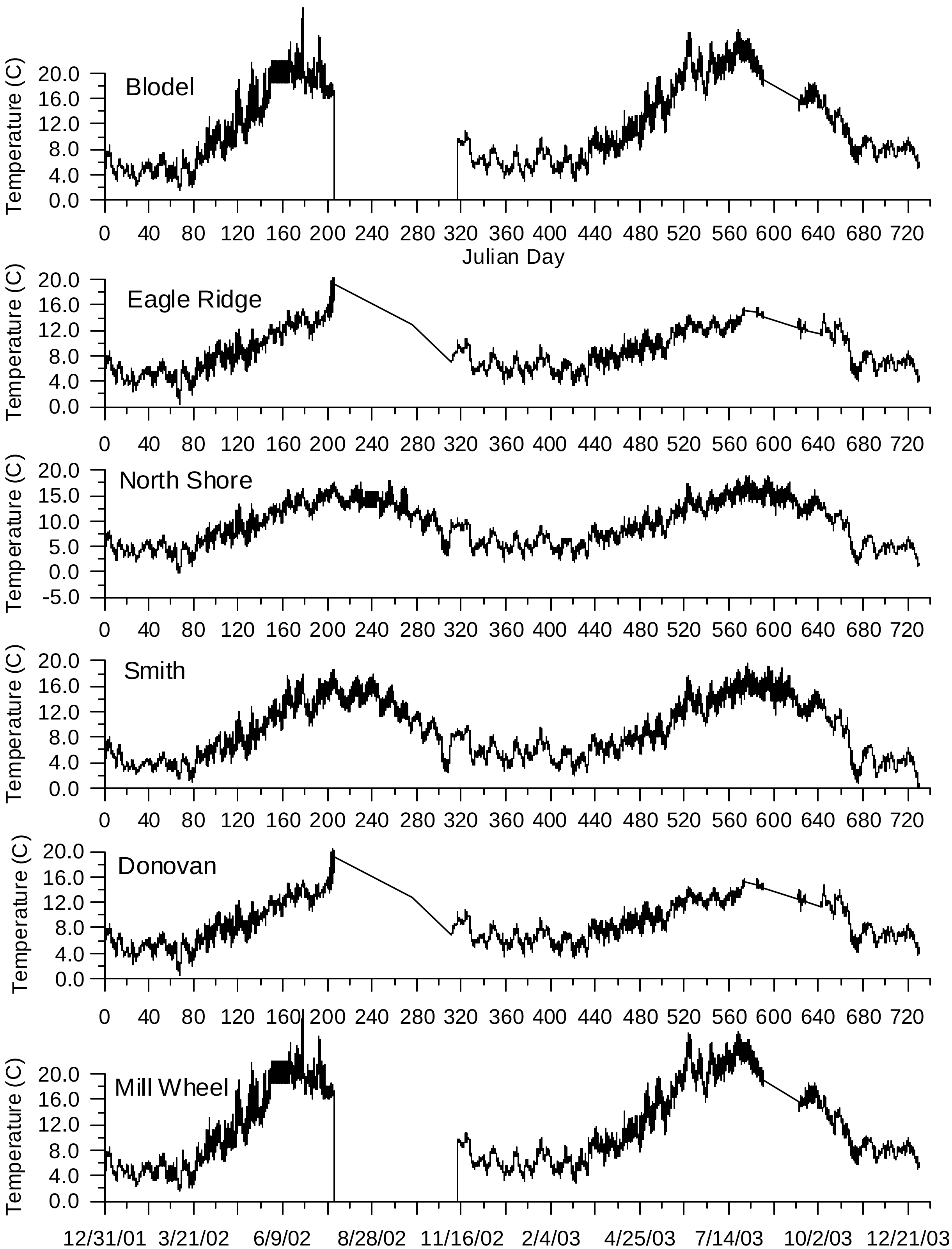

Figure 16. Tributary temperatures (data gaps correspond to periods of zero flow).

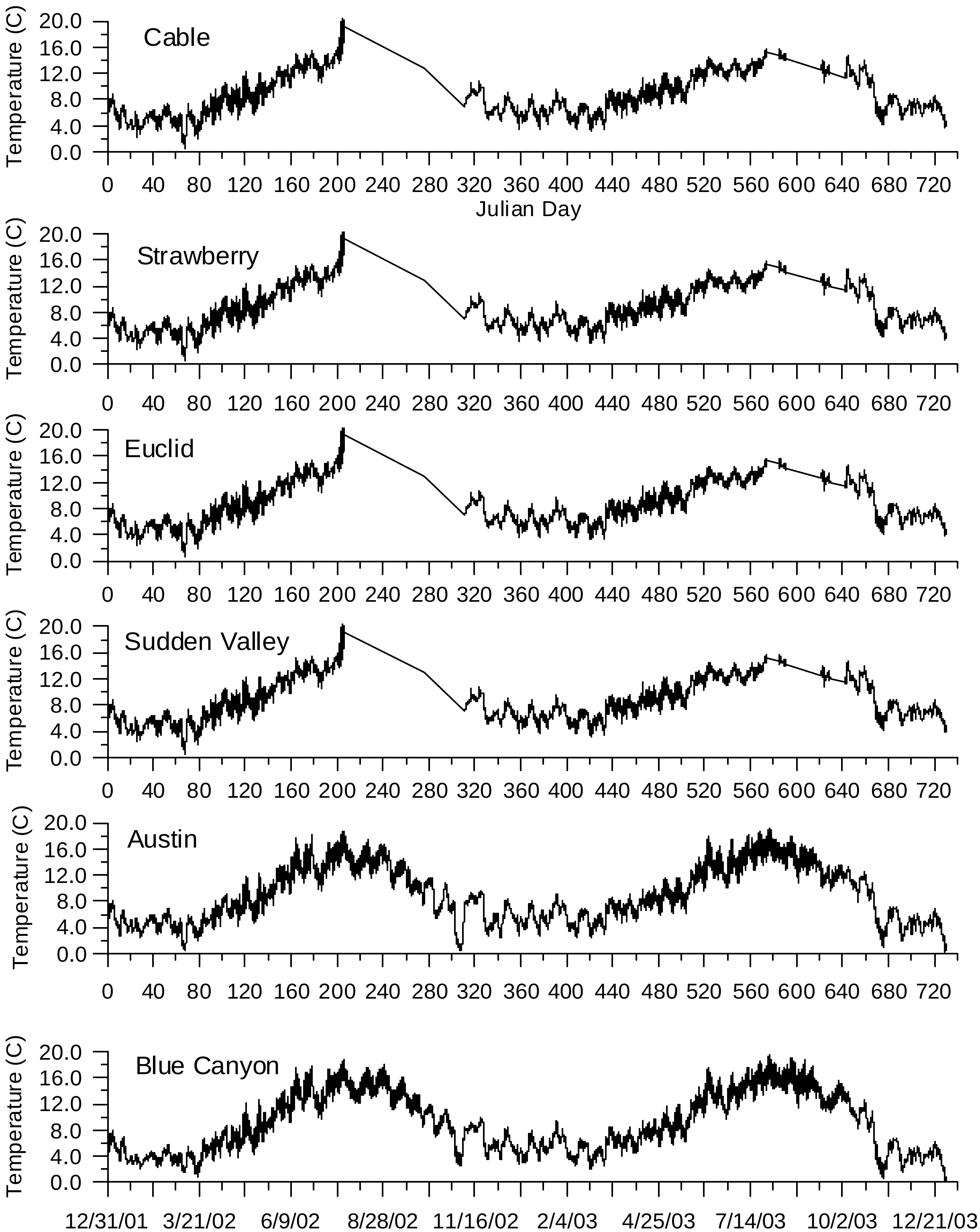

Figure 17. Tributary temperatures (data gaps correspond to periods of zero flow).

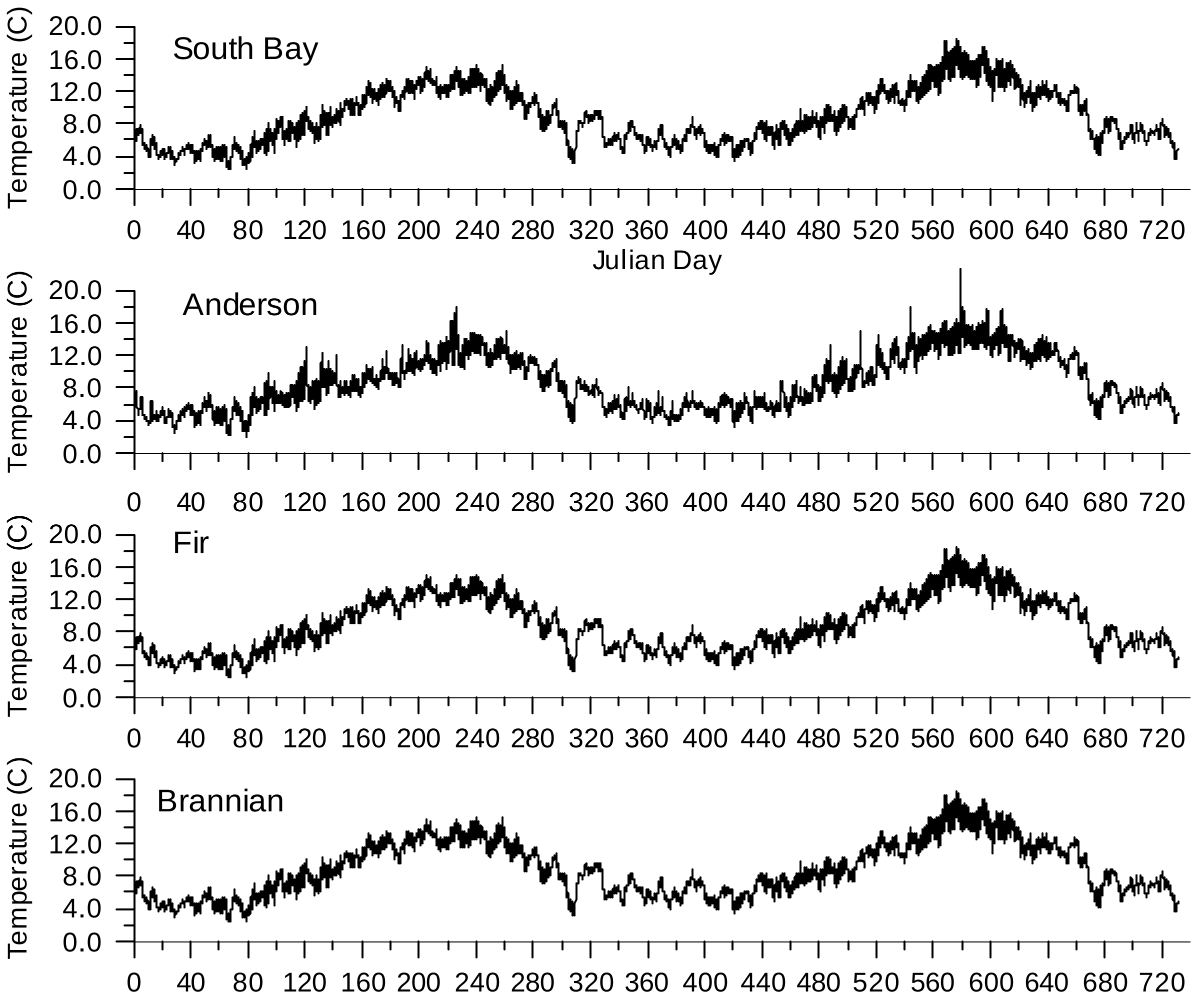

Figure 18. Tributary temperatures (data gaps correspond to periods of zero flow).

Constituent data were available for the Anderson, Austin, Brannian, Carpenter, Euclid, Mill Wheel, Olsen, Silver and Smith watersheds. Constituent files were developed from data and using regressions fitted to the data. These regressions were developed by the Department of Ecology. For watersheds that lacked data, the constituent file of a similar watershed was used (Table 3). Constituent concentrations for the tributaries were shown in Figure 19 through Figure 54.

The equations used in developing the constituent files for the tributaries were shown below:

Algae:

$$\sum \Phi_{algae} = \Phi_{algae(total)} = \Phi_{Chl\_a(total)} \times \mathrm{Algae\_to\_Chla\_ratio} \times \mathrm{species\_fraction} \qquad (1)$$

Algae_to_Chla_Ratio = 100, this is the ratio between algae biomass and chlorophyll a mass
Species_fraction = 0.6 for species 1 (diatoms), 0.3 for species group 2(greens), 0.1 for species group 3 (blue-greens)

Total Organic Matter (TOM)

$$\Phi_{TOM} = \frac{\Phi_{TOC}}{d_C} - \sum \Phi_{algae} \qquad (2)$$

$d_C = 0.45$, carbon-biomass ratio
Φ_{TOC}: Total Organic Carbon, from regression

Dissolved Organic Matter (DOM)

$$\Phi_{DOM} = \frac{\Phi_{DOC}}{d_C} \qquad (3)$$

Φ_{DOC}: Dissolved Organic Carbon

POM (particulate organic matter) or Detritus:

$$\Phi_{POM} = \Phi_{TOM} - \Phi_{DOM} \qquad (4)$$

LDOM (Labile Dissolved Organic Matter)

$$\Phi_{LDOM} = f_{LDOM}\Phi_{DOM} \qquad (5)$$

$f_{LDOM} = 0.50$

RDOM (Refractory Dissolved Organic matter)

$$\Phi_{RDOM} = (1 - f_{LDOM})\Phi_{DOM} \qquad (6)$$

LPOM (labile particulate organic matter)

$$\Phi_{LPOM} = f_{LPOM}\Phi_{POM} \qquad (7)$$

$f_{LPOM} = 0.5$

RPOM (refractory particulate organic matter)

$$\Phi_{RPOM} = (1 - f_{LPOM})\Phi_{POM} \qquad (8)$$

ISS (inorganic suspended solids):

$$\Phi_{ISS} = \Phi_{TNVSS} \qquad (9)$$

Φ_{TNVSS} : Total non-volatile suspended solids, from data

Total Inorganic Carbon:

$$\Phi_{TIC} = function(\Phi_{alk} + pH + Temp) \qquad (10)$$

Φ_{alk} : alkalinity, used regression developed from data

LDOM-P (labile dissolved organic matter – phosphorus):

$$\Phi_{LDOM-P} = \left(\Phi_{TP} - \Phi_{PO4P} - \sum \Phi_{a\lg ae} \times orgp\right) / \Phi_{TOM} \times \Phi_{LDOM} \qquad (11)$$

$orgp$: phosphorus fraction of algae, assumed to be 0.005
Φ_{TP} : Total Phosphorus, used regression developed from data

Φ_{PO4P} : soluble reactive phosphorus, used regression developed from data

RDOM-P (refractory dissolved organic matter – phosphorus):

$$\Phi_{RDOM-P} = \left(\Phi_{TP} - \Phi_{PO4P} - \sum \Phi_{a\lg ae} \times orgp\right) / \Phi_{TOM} \times \Phi_{RDOM} \qquad \textbf{(12)}$$

LPOM-P (labile particulate organic matter – phosphorus):

$$\Phi_{LPOM-P} = \left(\Phi_{TP} - \Phi_{PO4P} - \sum \Phi_{a\lg ae} \times orgp\right) / \Phi_{TOM} \times \Phi_{LPOM} \qquad \textbf{(13)}$$

RPOM-P (refractory particulate organic matter – phosphorus):

$$\Phi_{RPOM-P} = \left(\Phi_{TP} - \Phi_{PO4P} - \sum \Phi_{a\lg ae} \times orgp\right) / \Phi_{TOM} \times \Phi_{RPOM} \qquad \textbf{(14)}$$

LDOM-N (labile dissolved organic matter – nitrogen):

$$\Phi_{LDOM-N} = \left(\Phi_{TPN} - \Phi_{NH3} - \Phi_{NO3+NO2} - \sum \Phi_{a\lg ae} \times orgn\right) / \Phi_{TOM} \times \Phi_{LDOM} \qquad \textbf{(15)}$$

$orgn$: phosphorus fraction of algae, assumed to be 0.08

Φ_{TPN} : Total Persulfate Nitrogen, used regression developed from data

$\Phi_{NO3+NO2}$: nitrite-nitrate, regression developed from data

Φ_{NH3} : ammonia, from data

RDOM-N (refractory dissolved organic matter – nitrogen):

$$\Phi_{RDOM-N} = \left(\Phi_{TPN} - \Phi_{NH3} - \Phi_{NO3+NO2} - \sum \Phi_{a\lg ae} \times orgn\right) / \Phi_{TOM} \times \Phi_{RDOM} \qquad \textbf{(16)}$$

LPOM-N (labile particulate organic matter – nitrogen):

$$\Phi_{LPOM-N} = \left(\Phi_{TPN} - \Phi_{NH3} - \Phi_{NO3+NO2} - \sum \Phi_{a\lg ae} \times orgn\right) / \Phi_{TOM} \times \Phi_{LPOM} \qquad \textbf{(17)}$$

RPOM-N (refractory particulate organic matter – nitrogen):

$$\Phi_{RPOM-N} = \left(\Phi_{TPN} - \Phi_{NH3} - \Phi_{NO3+NO2} - \sum \Phi_{a\lg ae} \times orgn\right) / \Phi_{TOM} \times \Phi_{RPOM} \qquad \textbf{(18)}$$

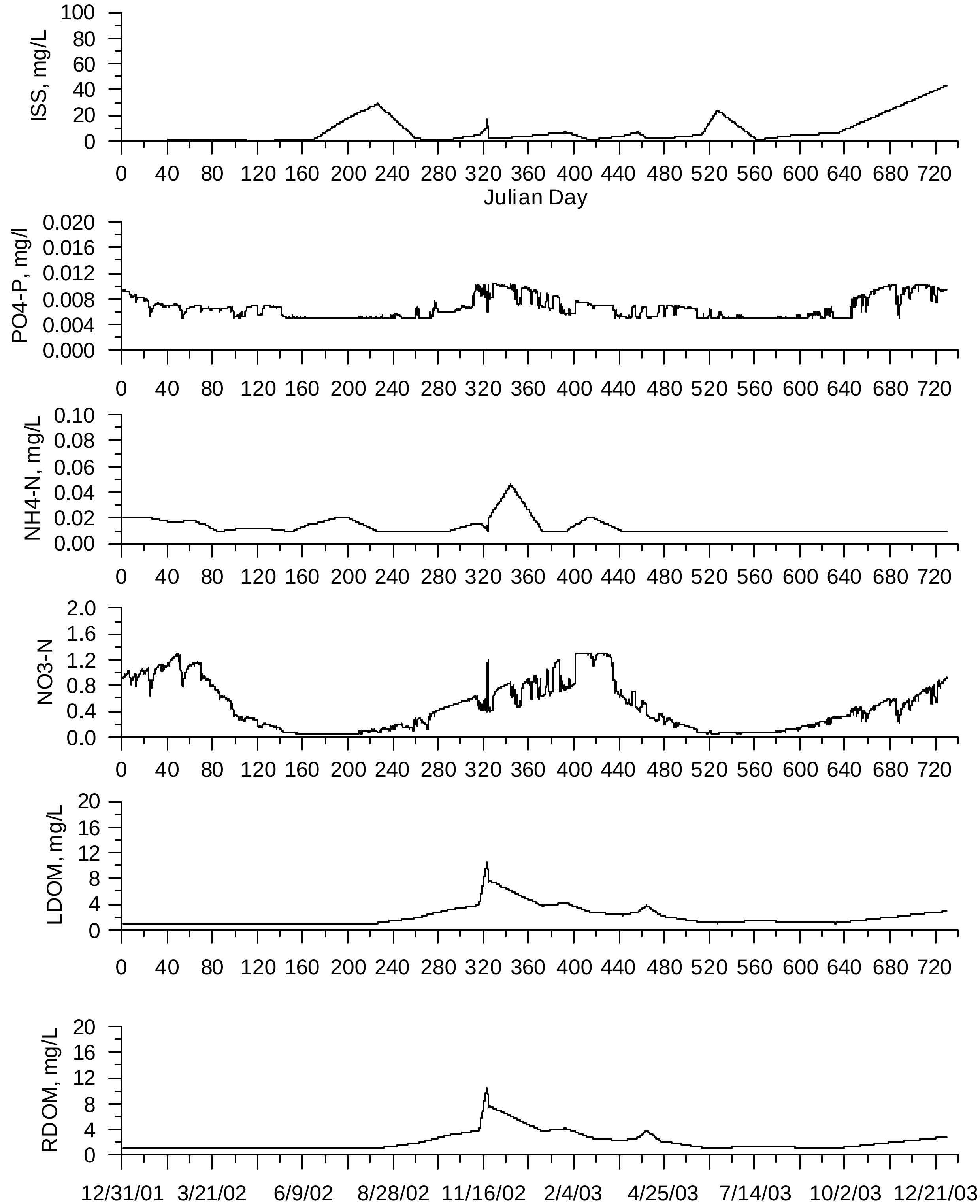

Figure 19. Constituent Concentrations used for Anderson Creek.

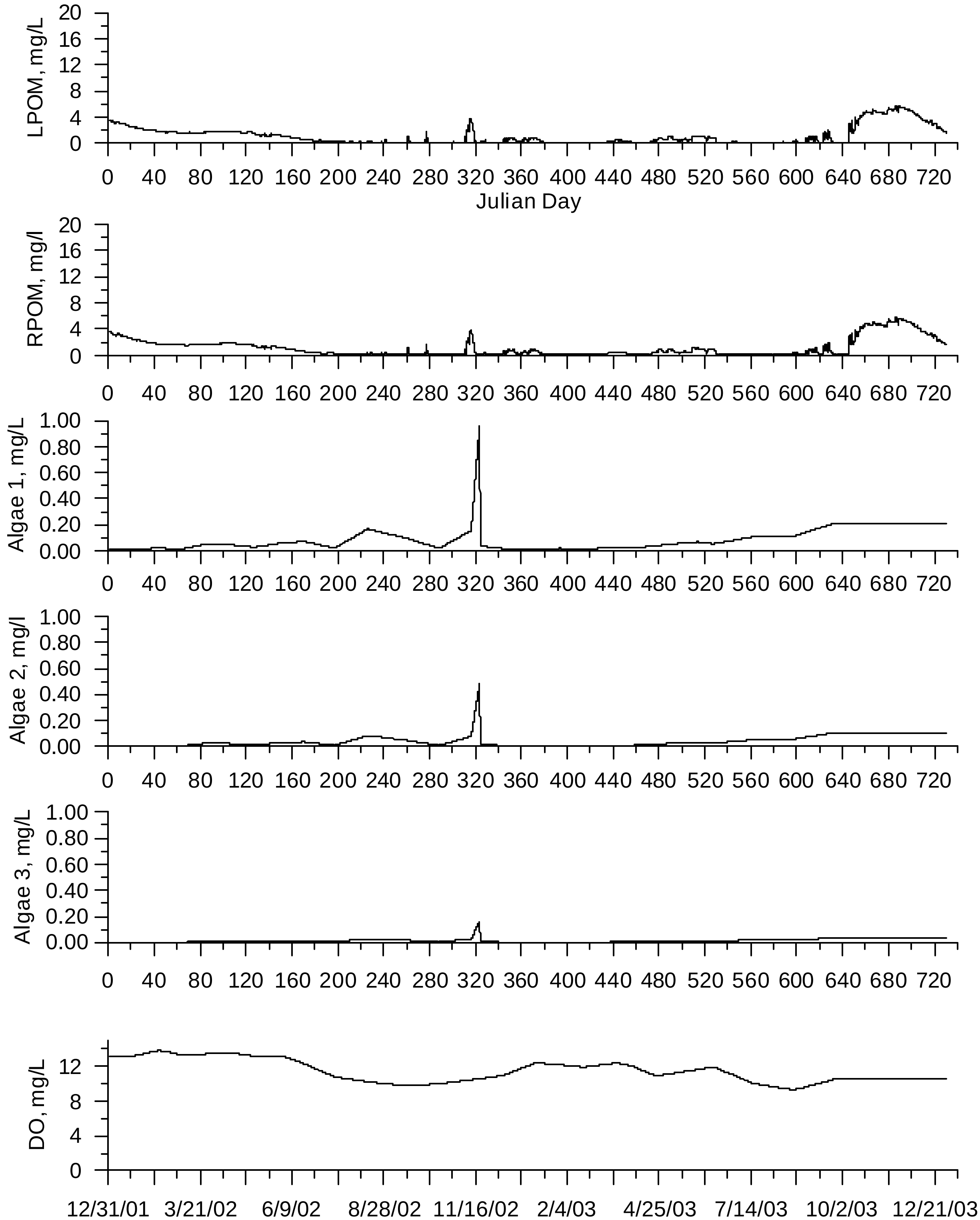

Figure 20. Constituent Concentrations used for Anderson Creek.

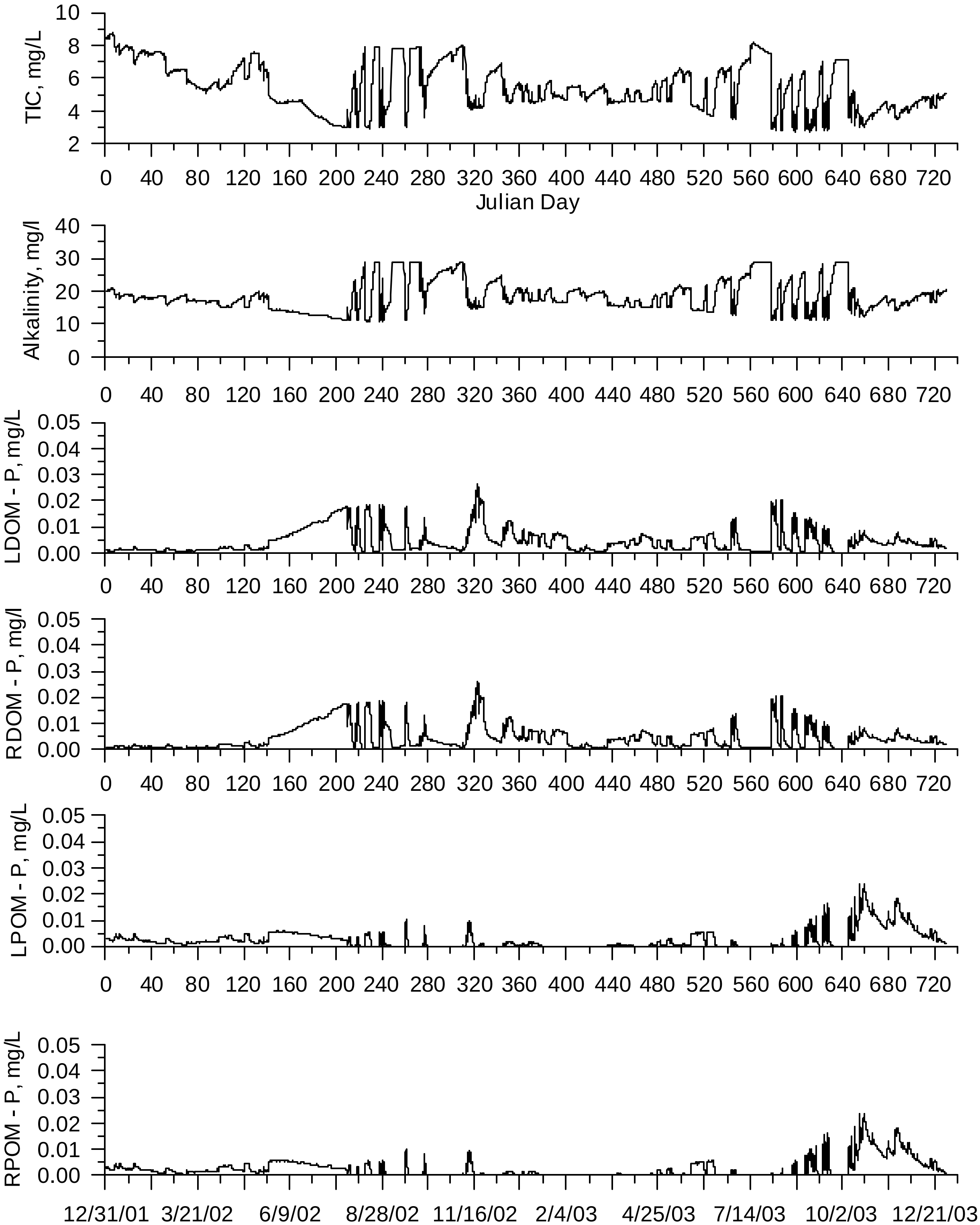

Figure 21. Constituent Concentrations used for Anderson Creek.

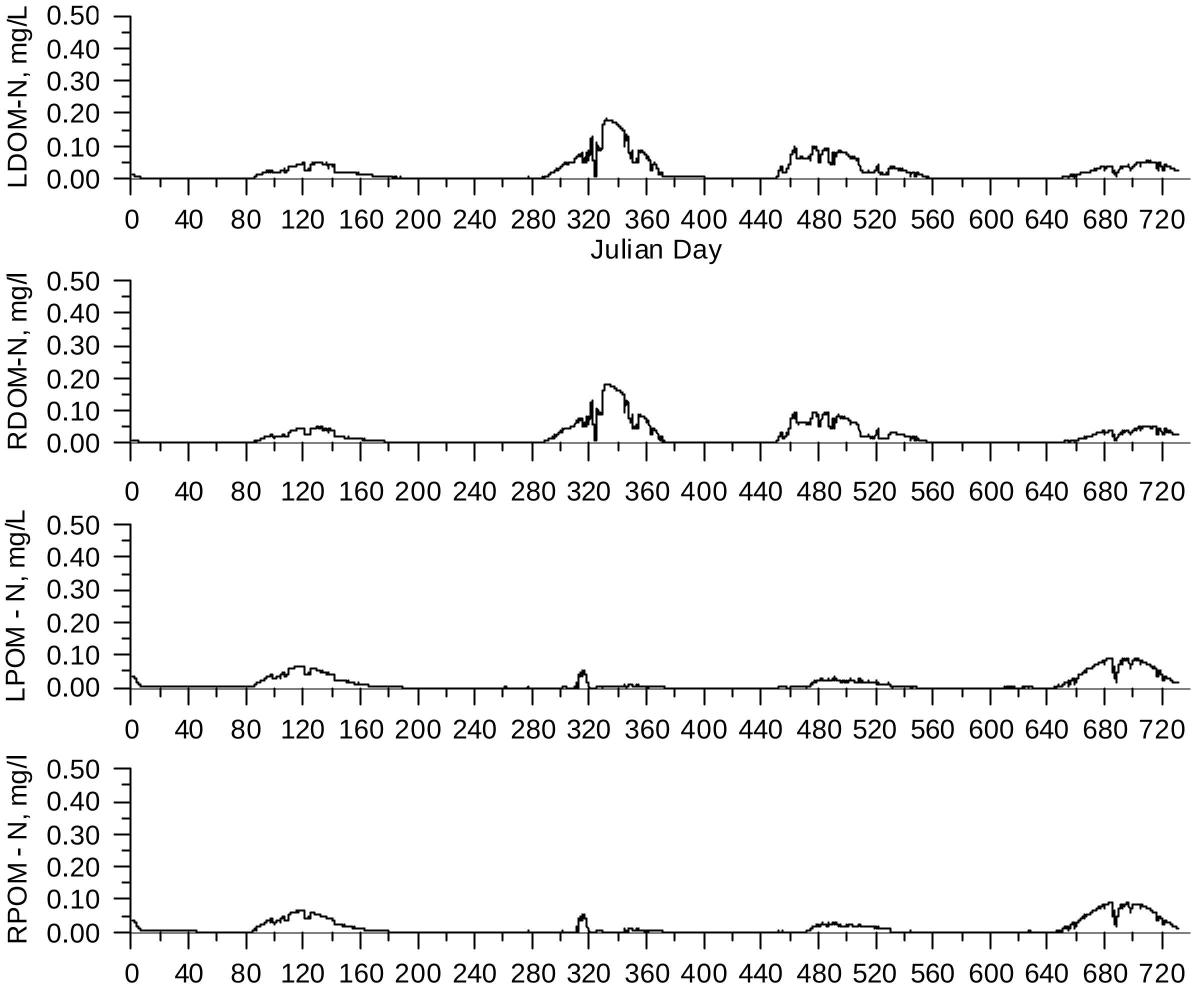

Figure 22. Constituent Concentrations used for Anderson Creek.

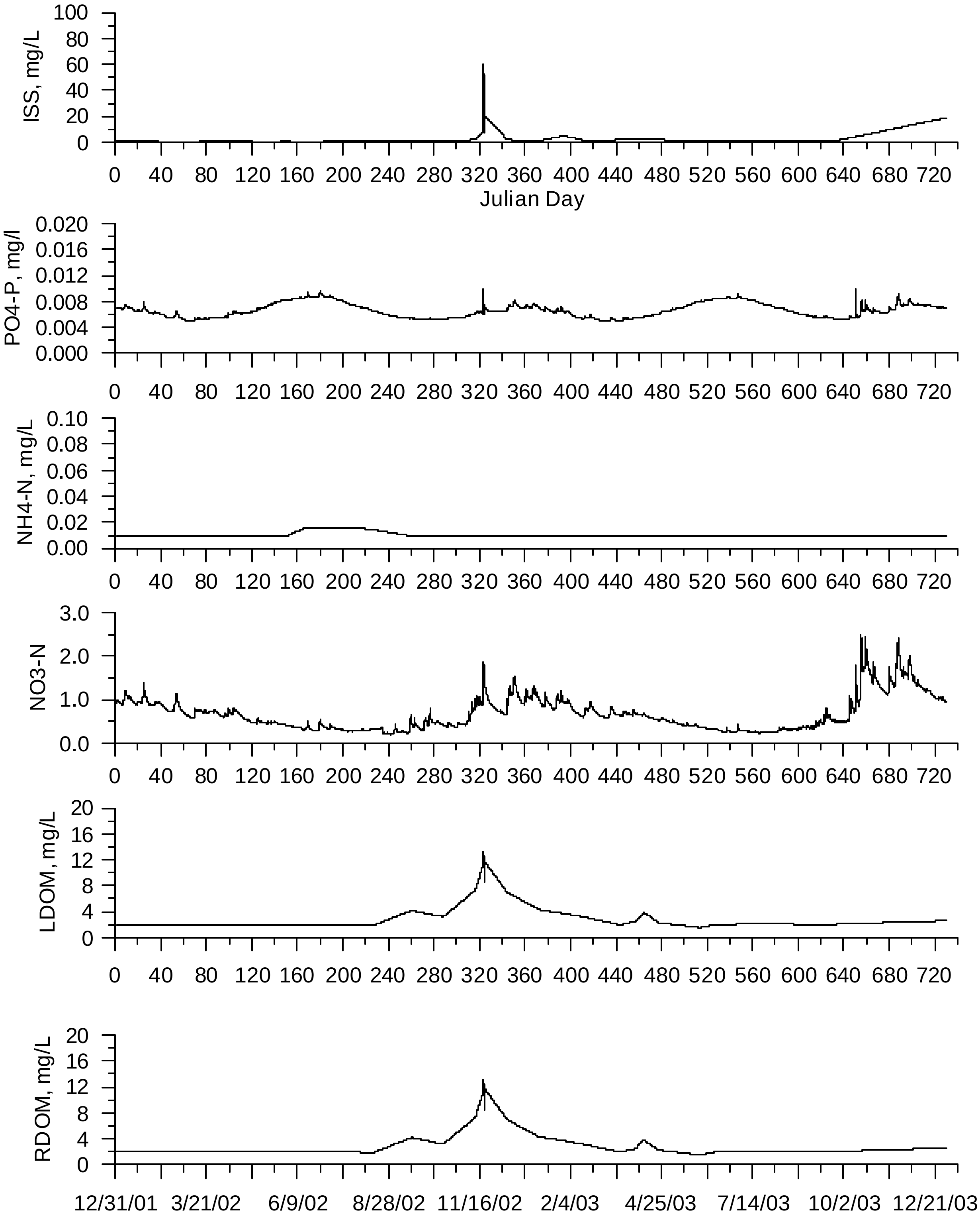

Figure 23. Constituent Concentrations used for Austin Creek.

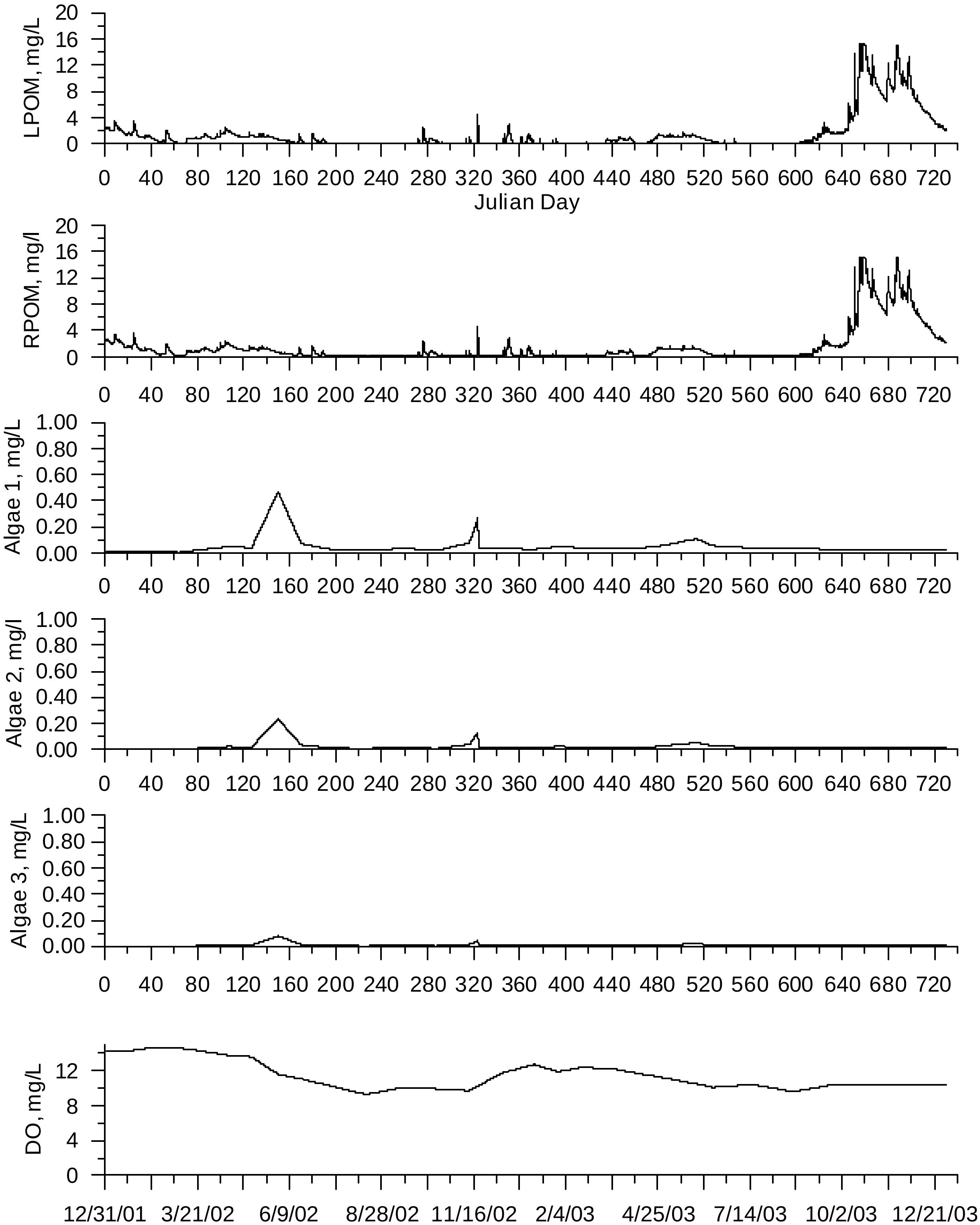

Figure 24. Constituent Concentrations used for Austin Creek.

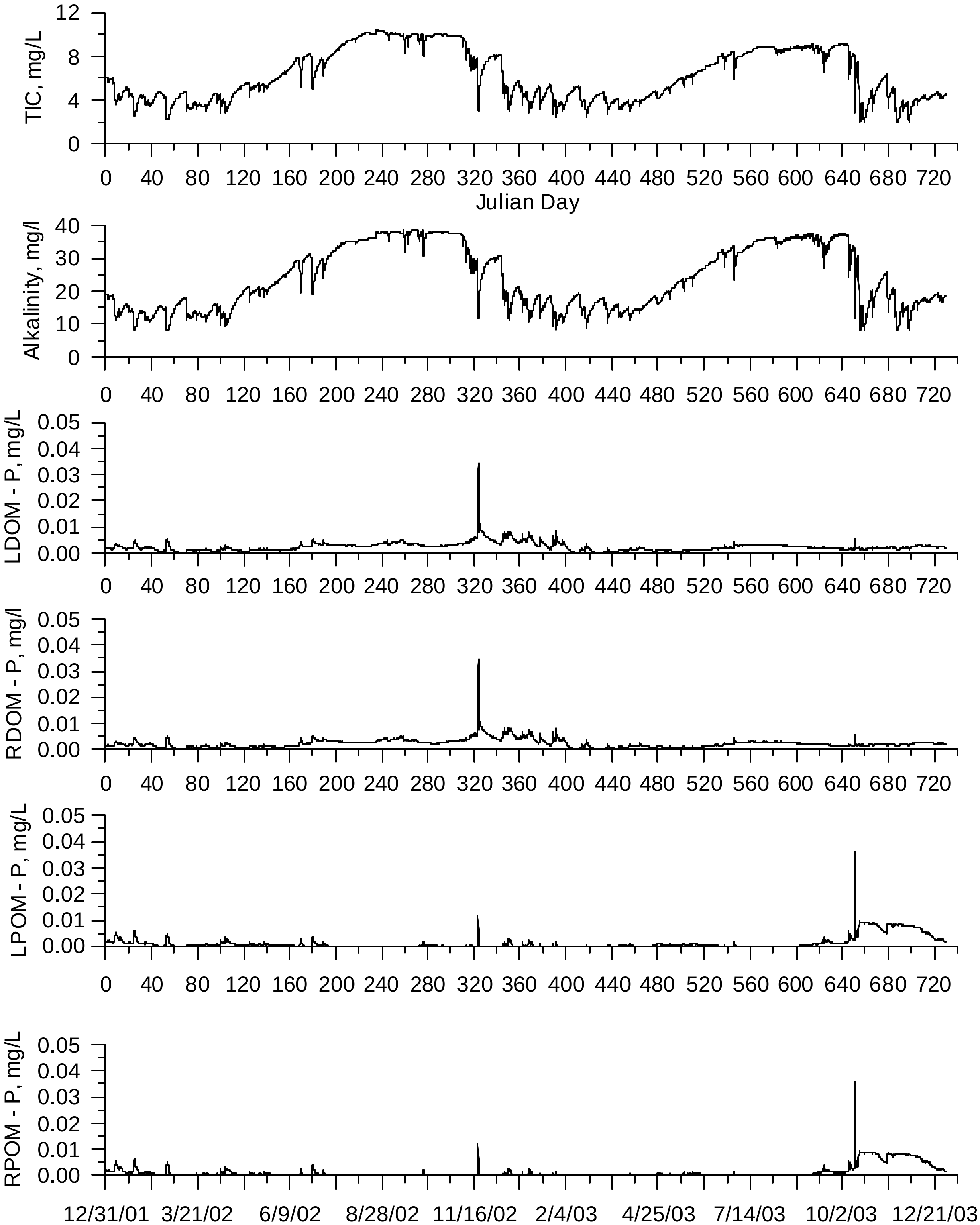

Figure 25. Constituent Concentrations used for Austin Creek.

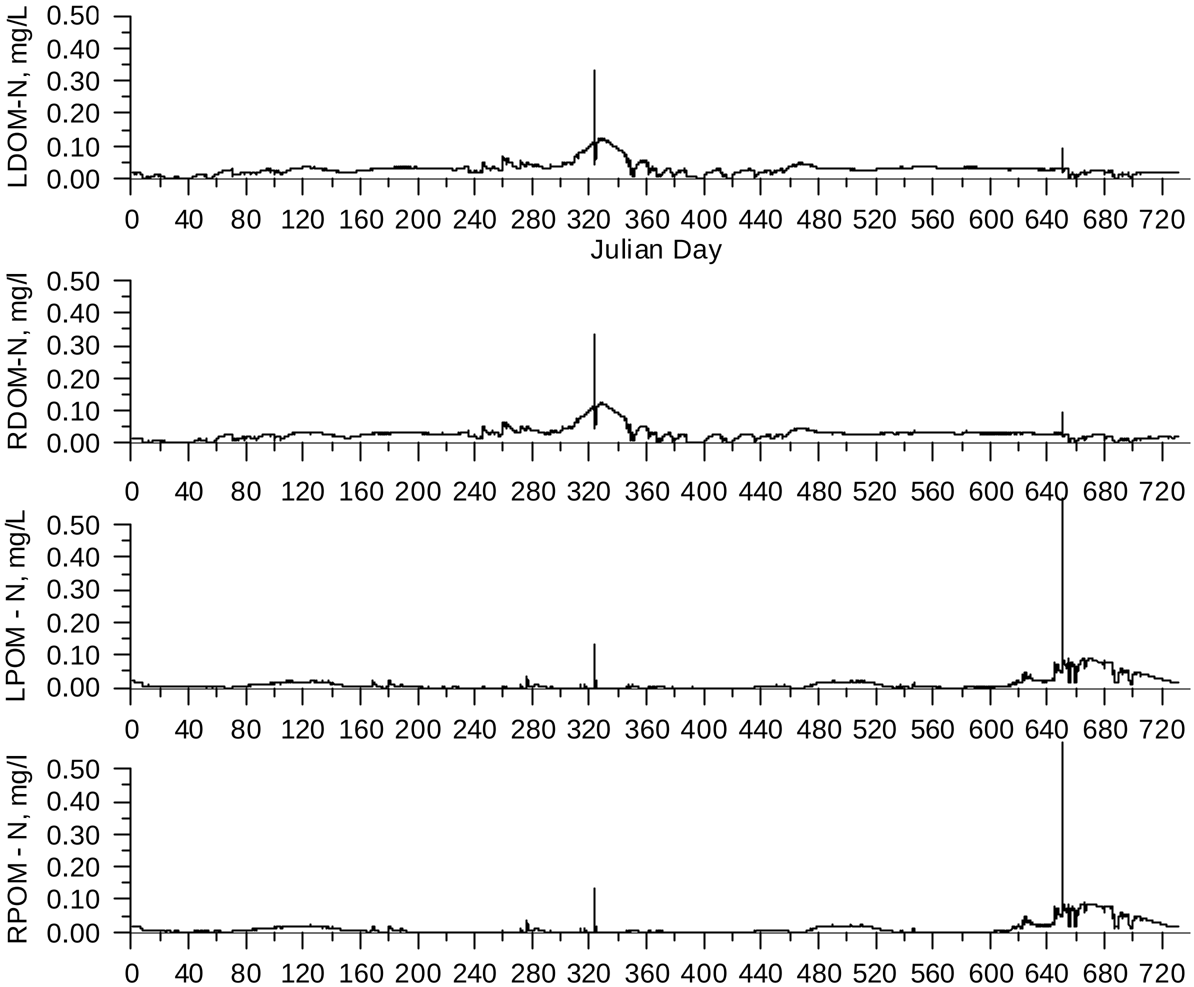

Figure 26. Constituent Concentrations used for Austin Creek.

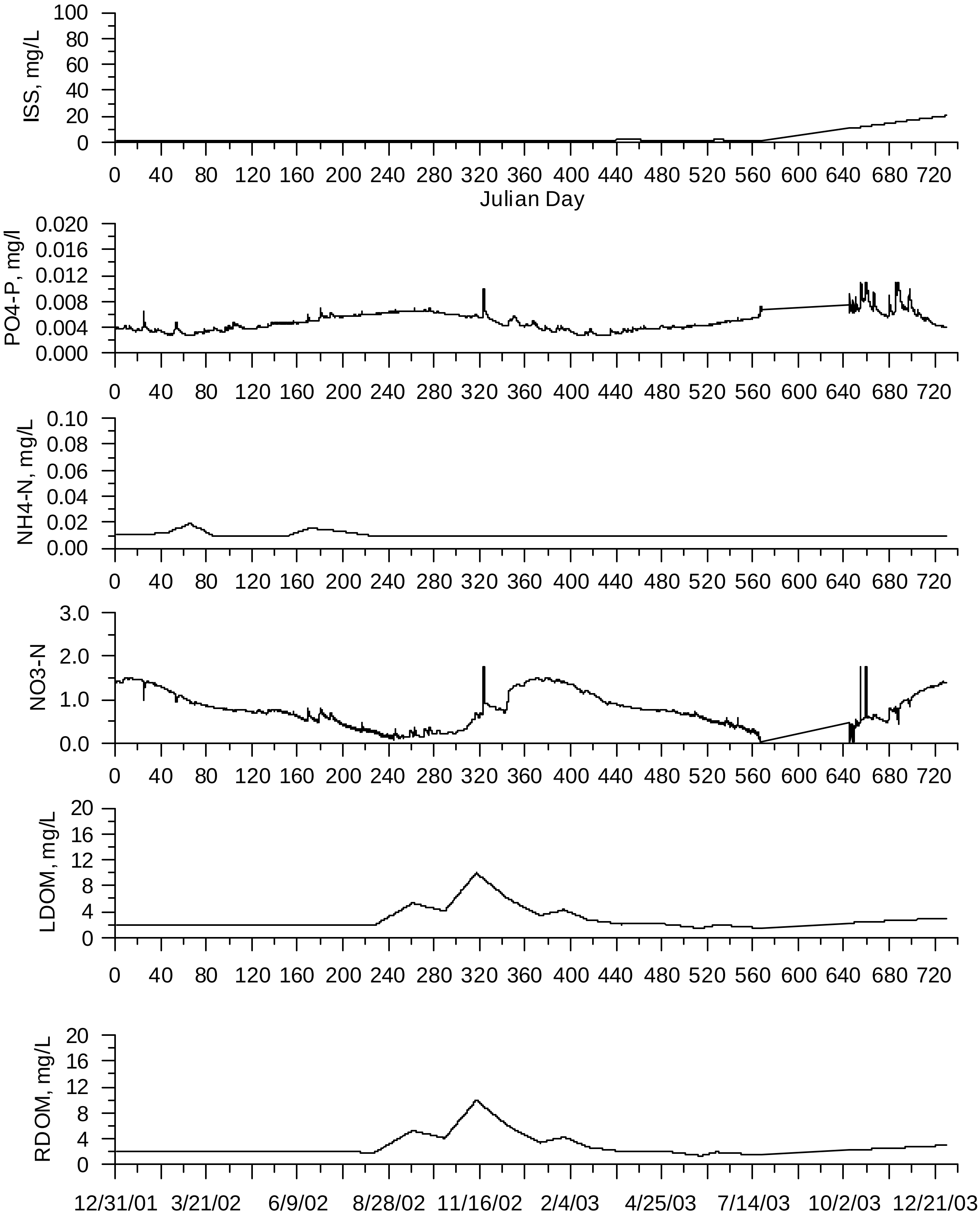

Figure 27. Constituent Concentrations used for Brannian Creek.

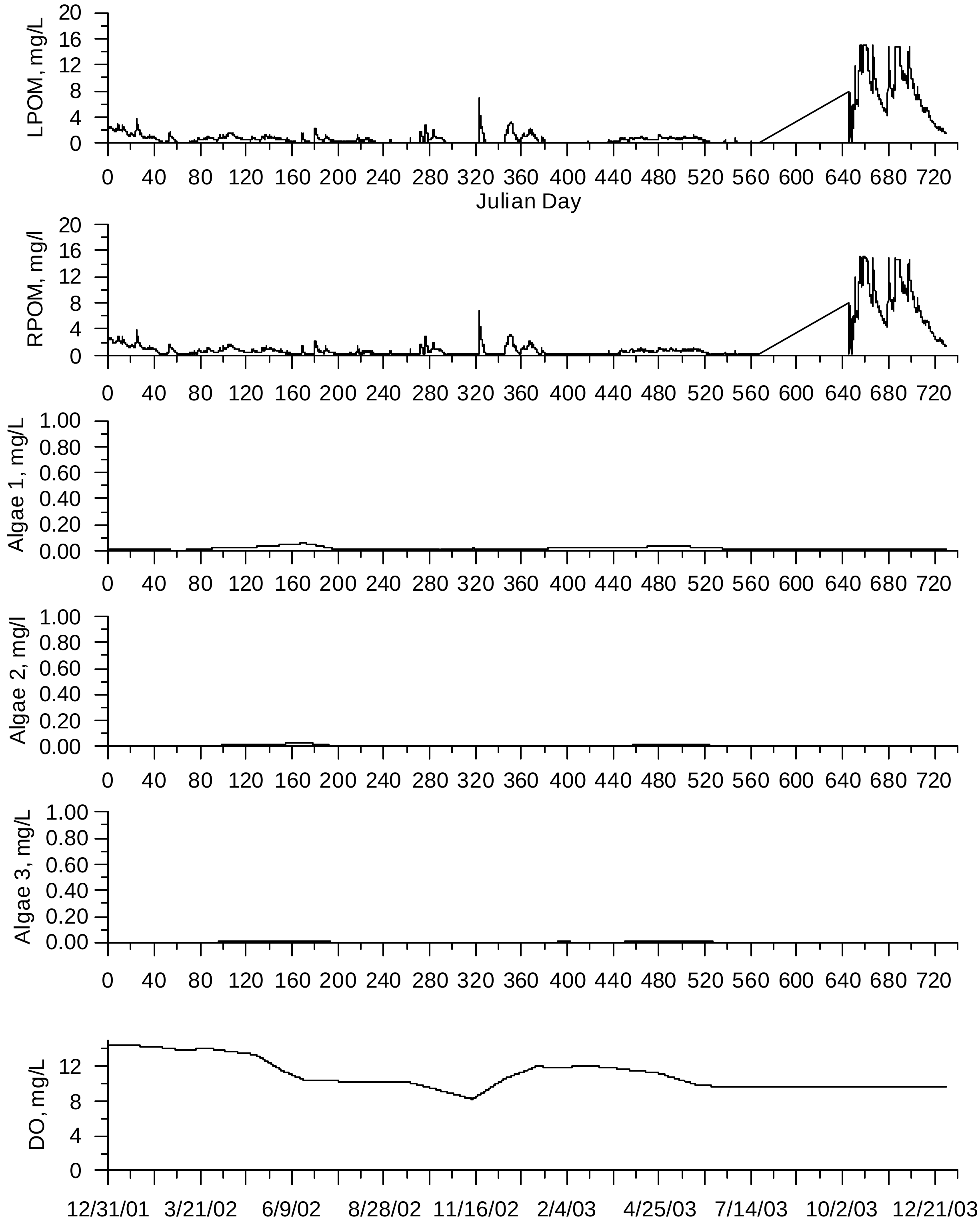

Figure 28. Constituent Concentrations used for Brannian Creek.

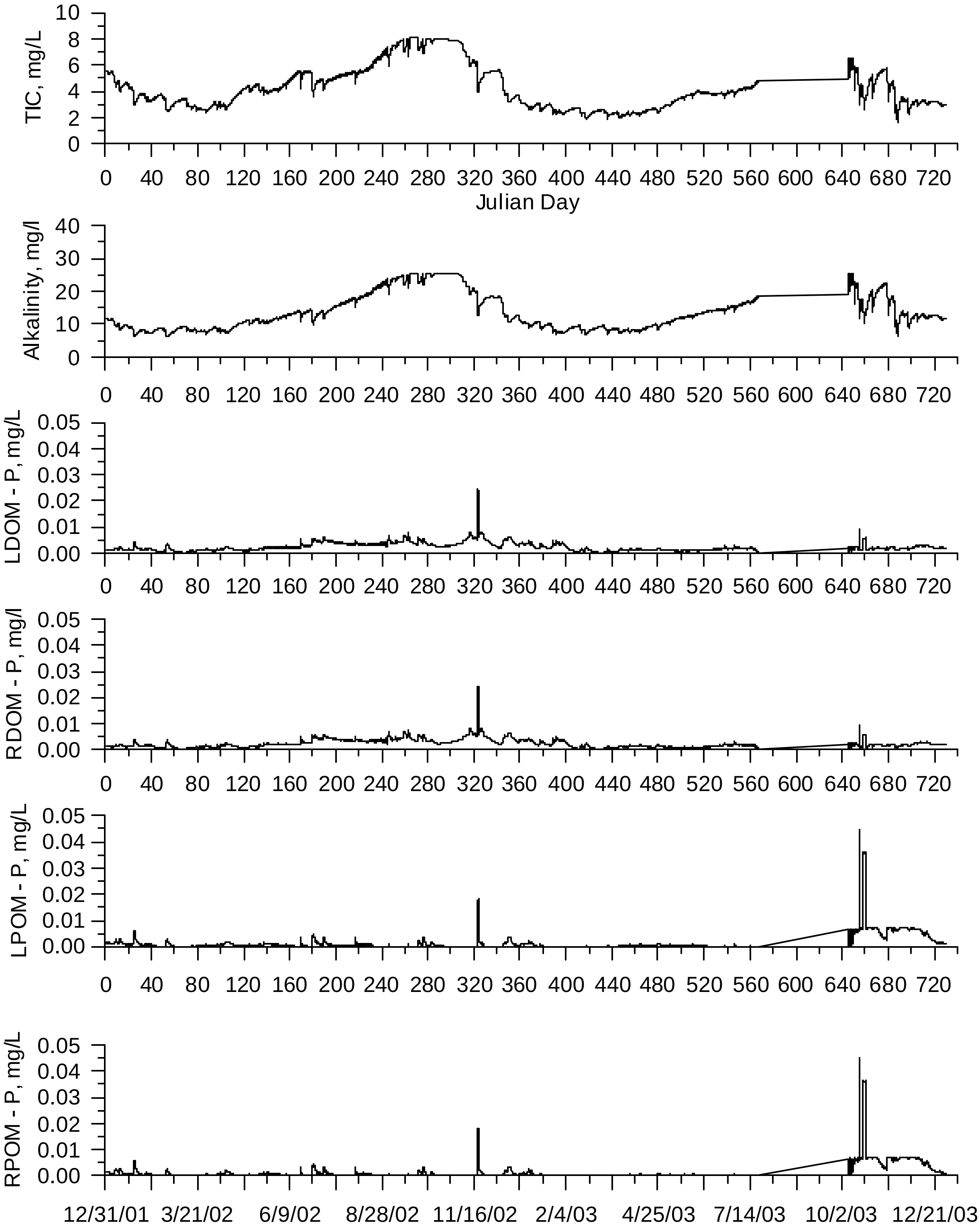

Figure 29. Constituent Concentrations used for Brannian Creek.

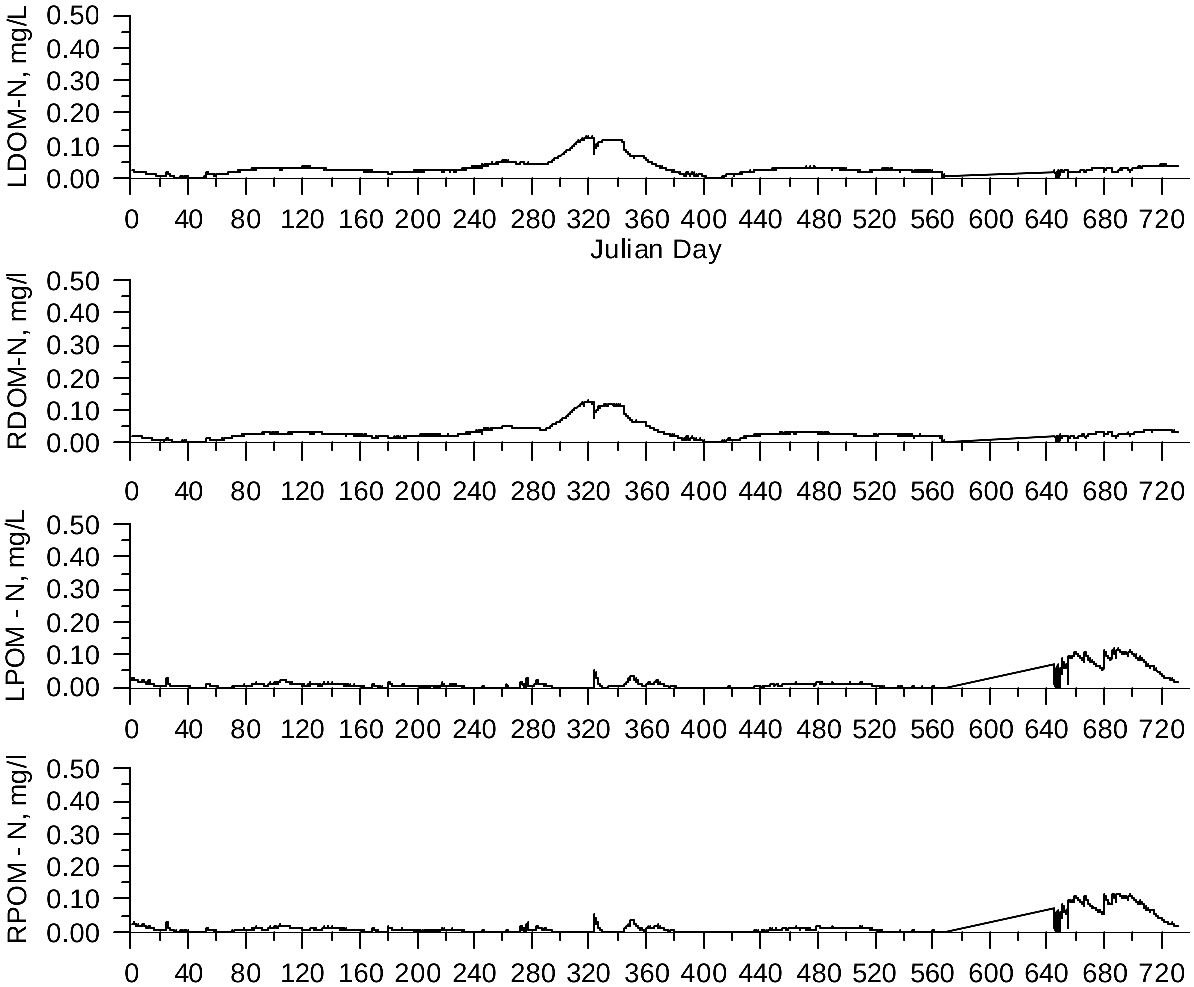

Figure 30. Constituent concentrations used for Brannian Creek.

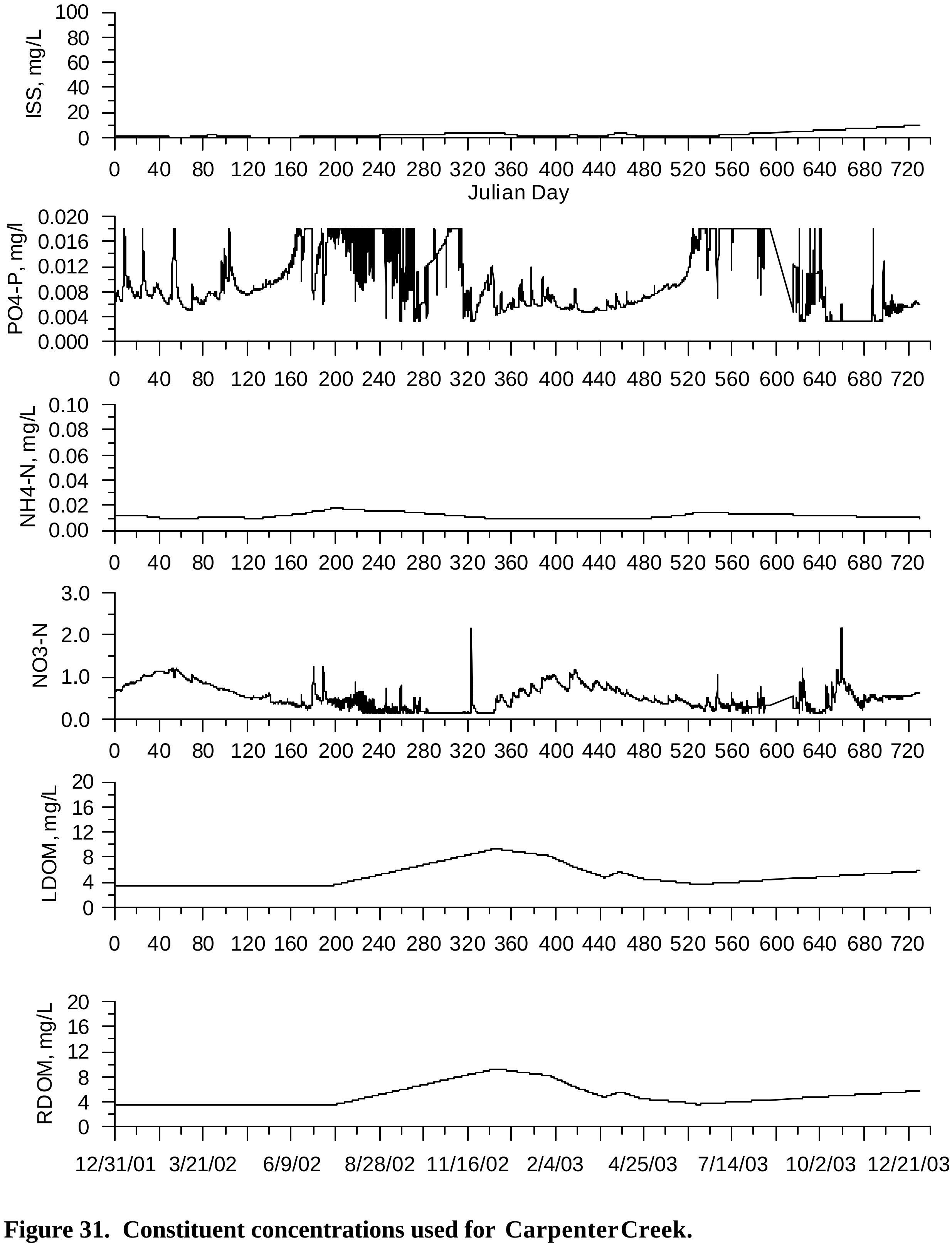

Figure 31. Constituent concentrations used for Carpenter Creek.

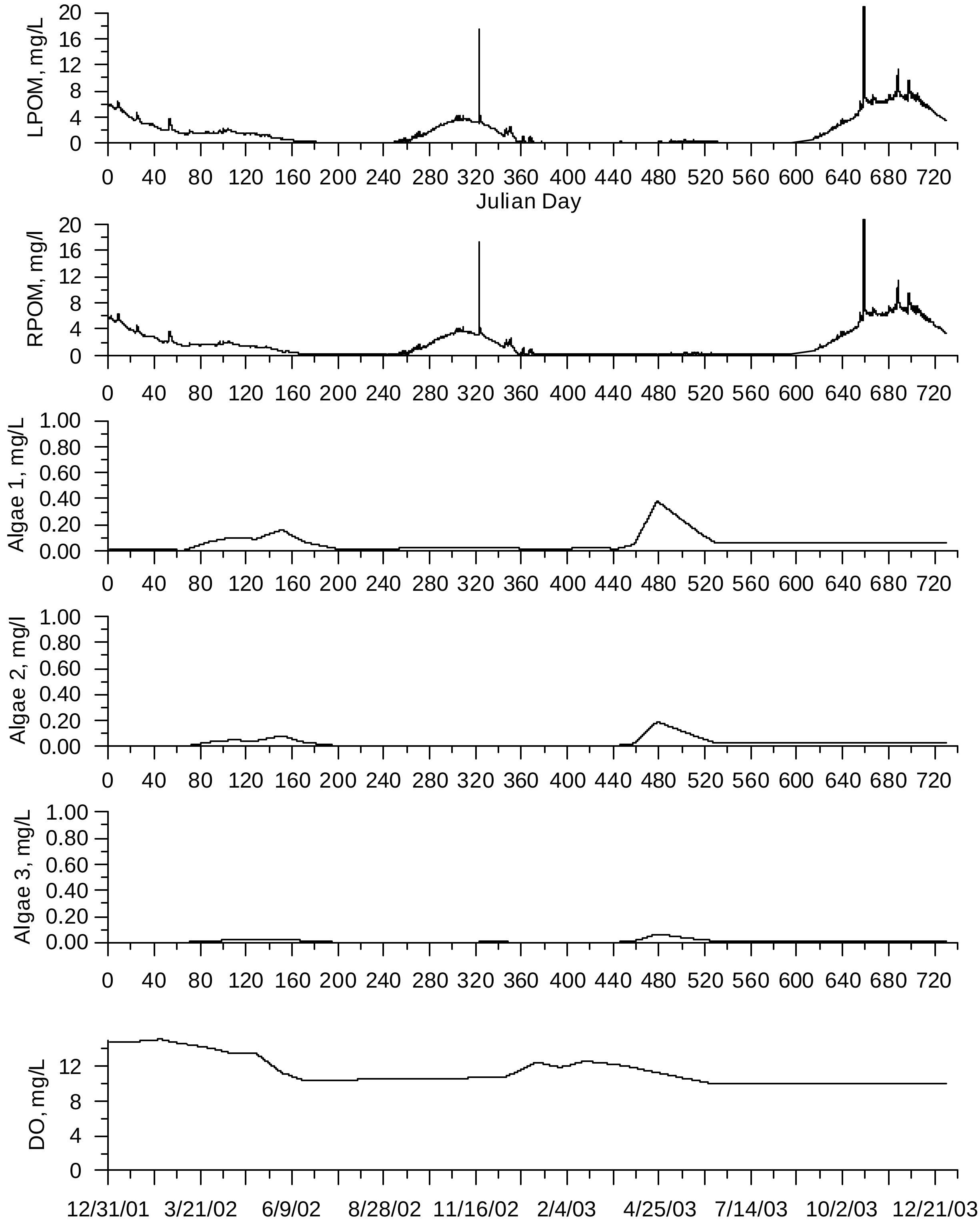

Figure 32. Constituent concentrations used for Carpenter Creek.

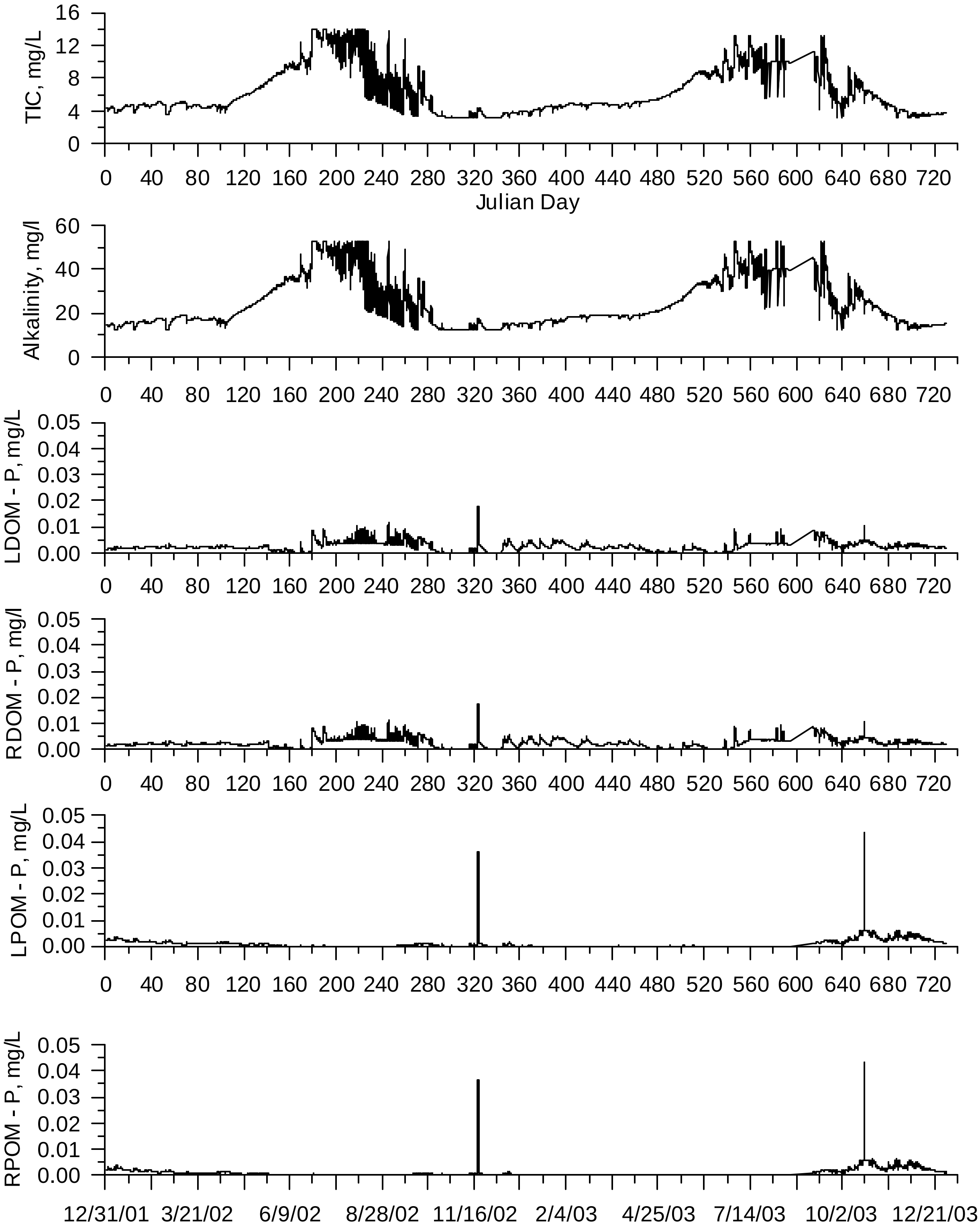

Figure 33. Constituent concentrations used for Carpenter Creek.

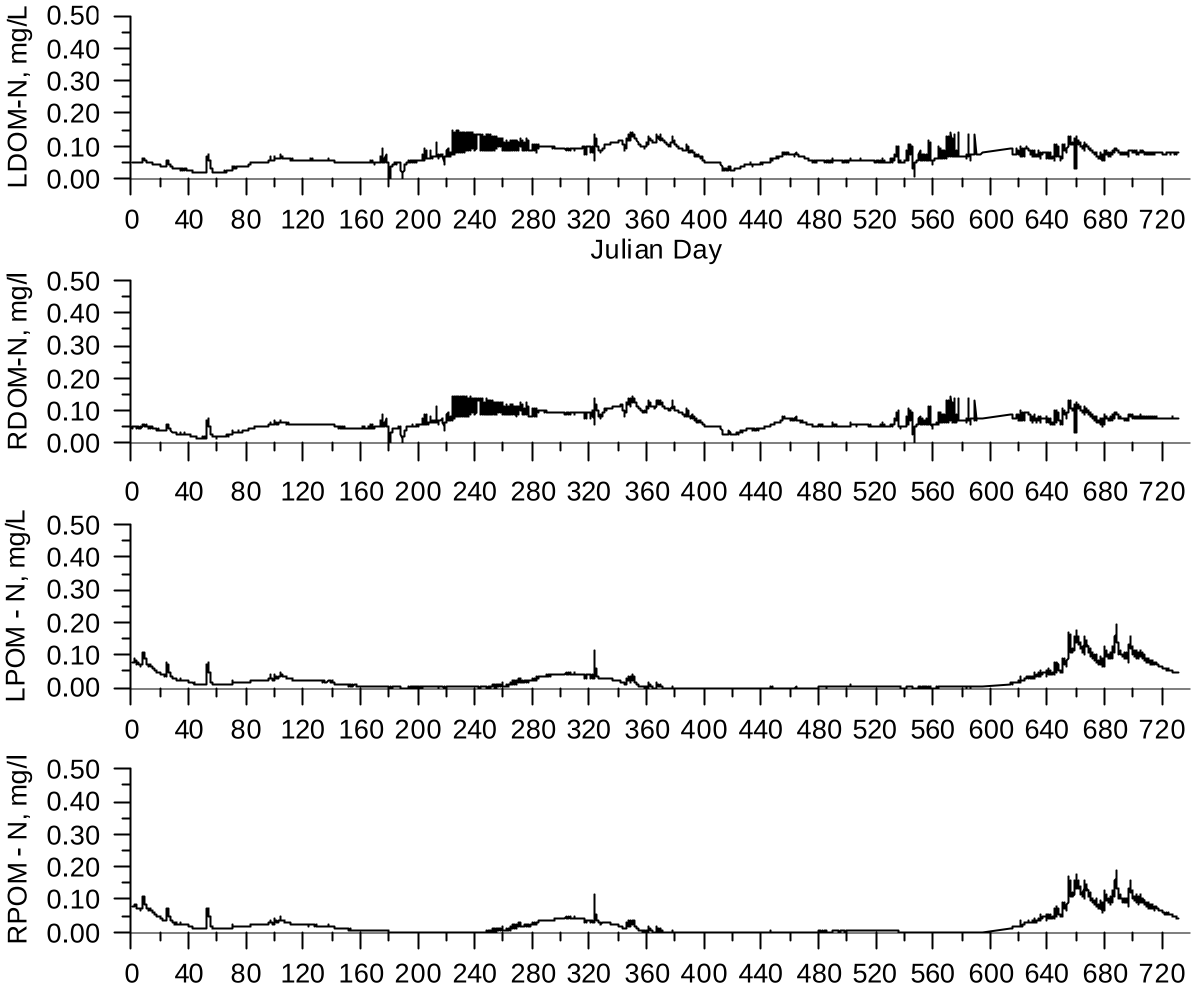

Figure 34. Constituent concentrations used for Carpenter Creek.

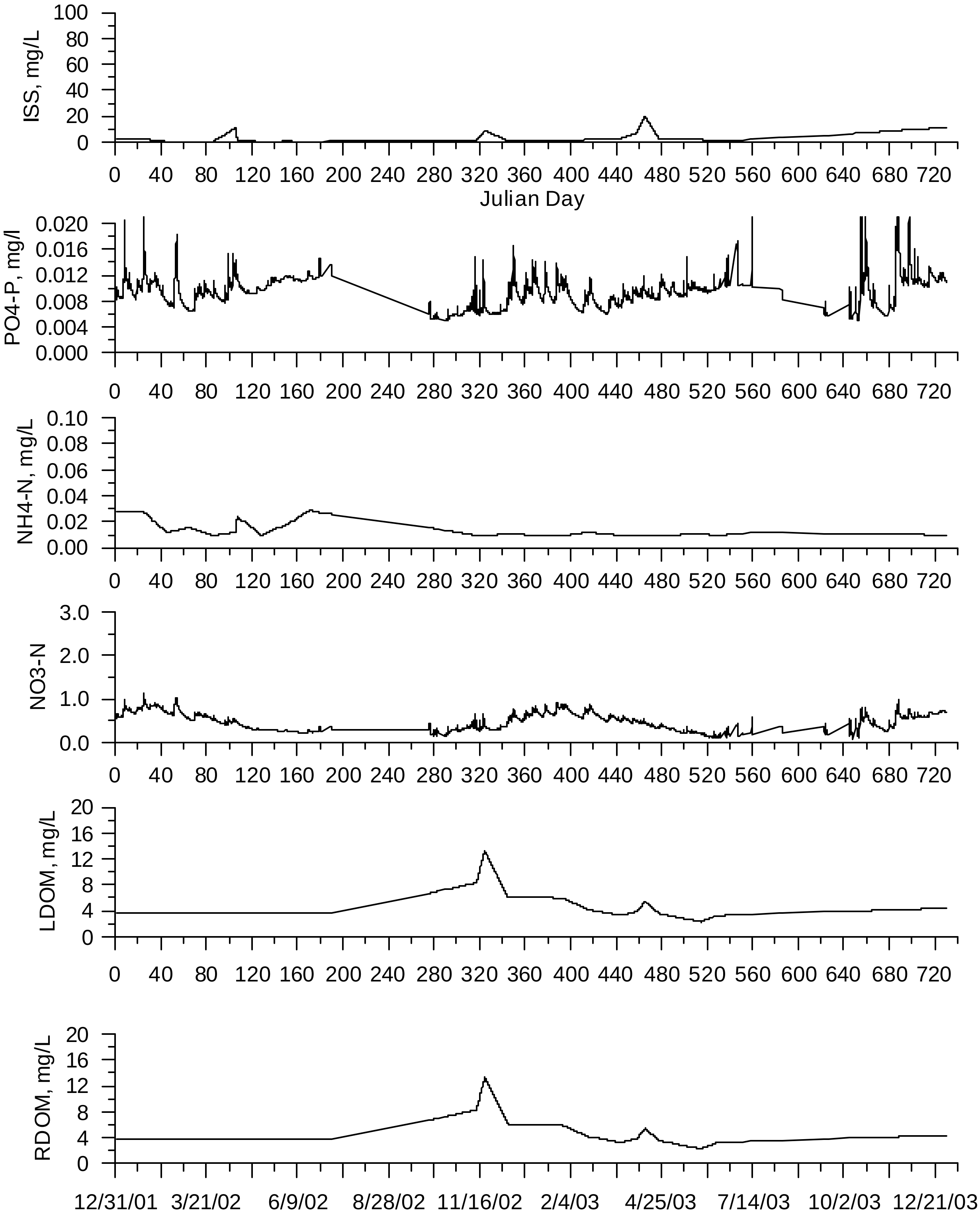

Figure 35. Constituent concentrations used for Euclid Creek.

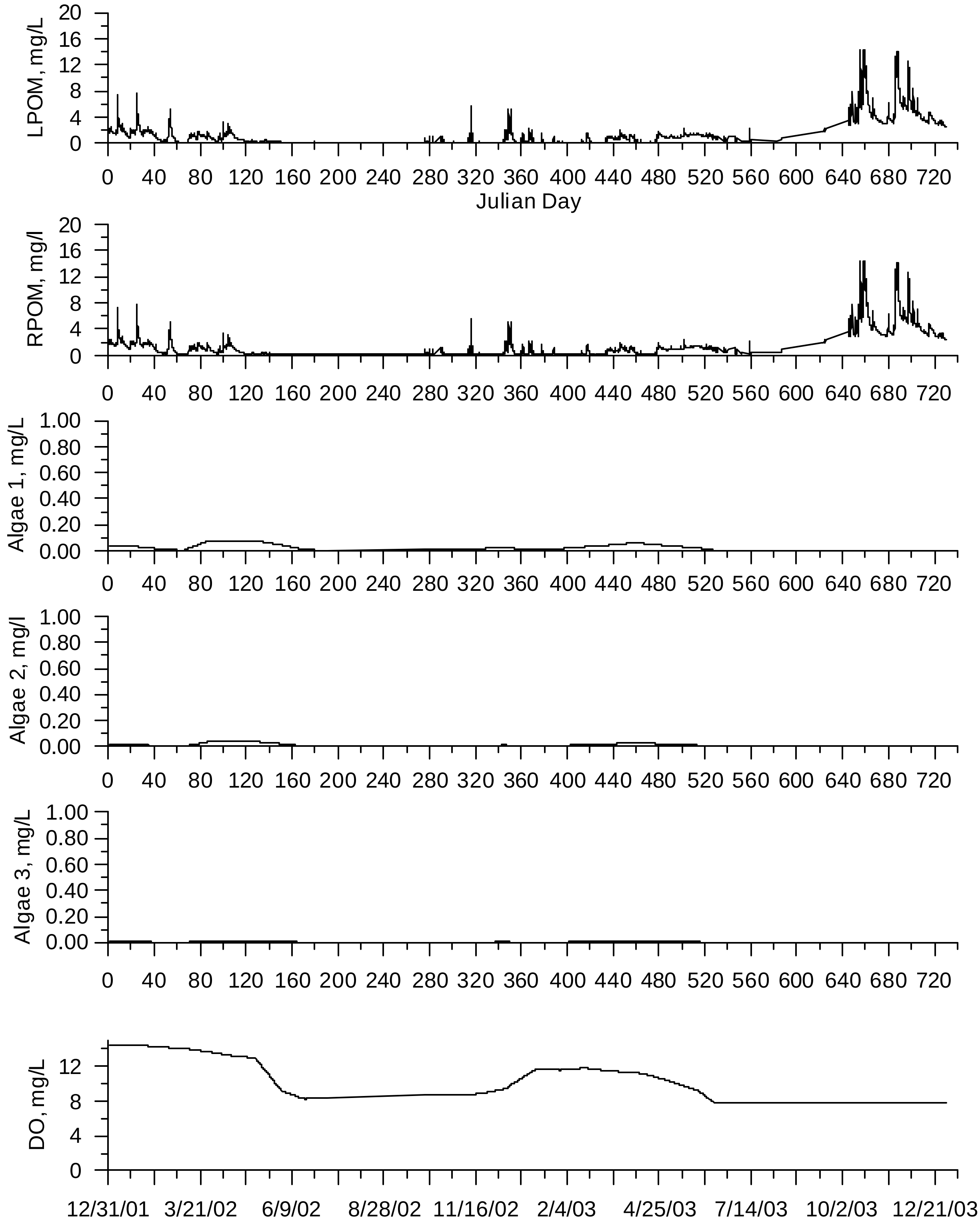

Figure 36. Constituent concentrations used for Euclid Creek.

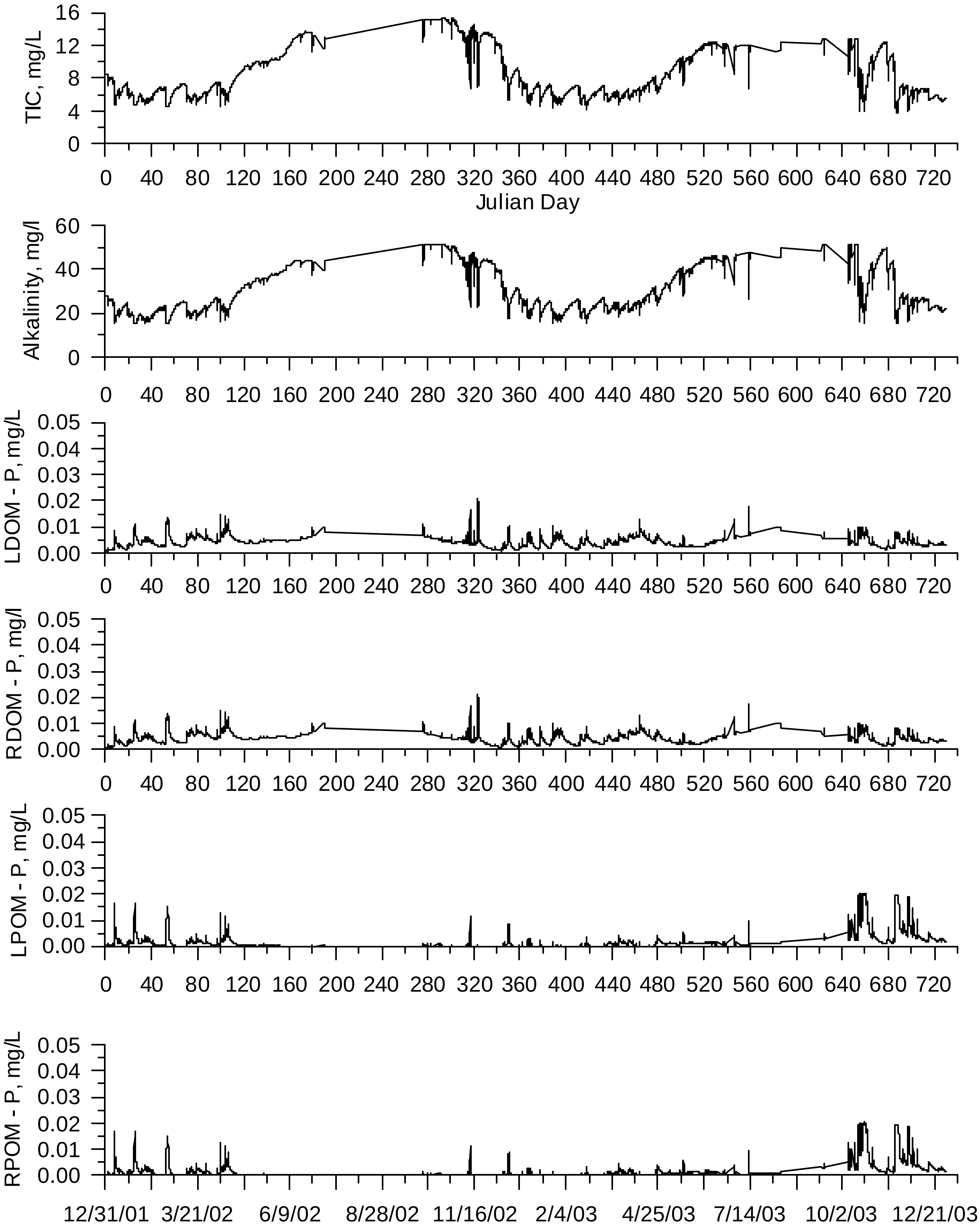

Figure 37. Constituent concentrations used for Euclid Creek.

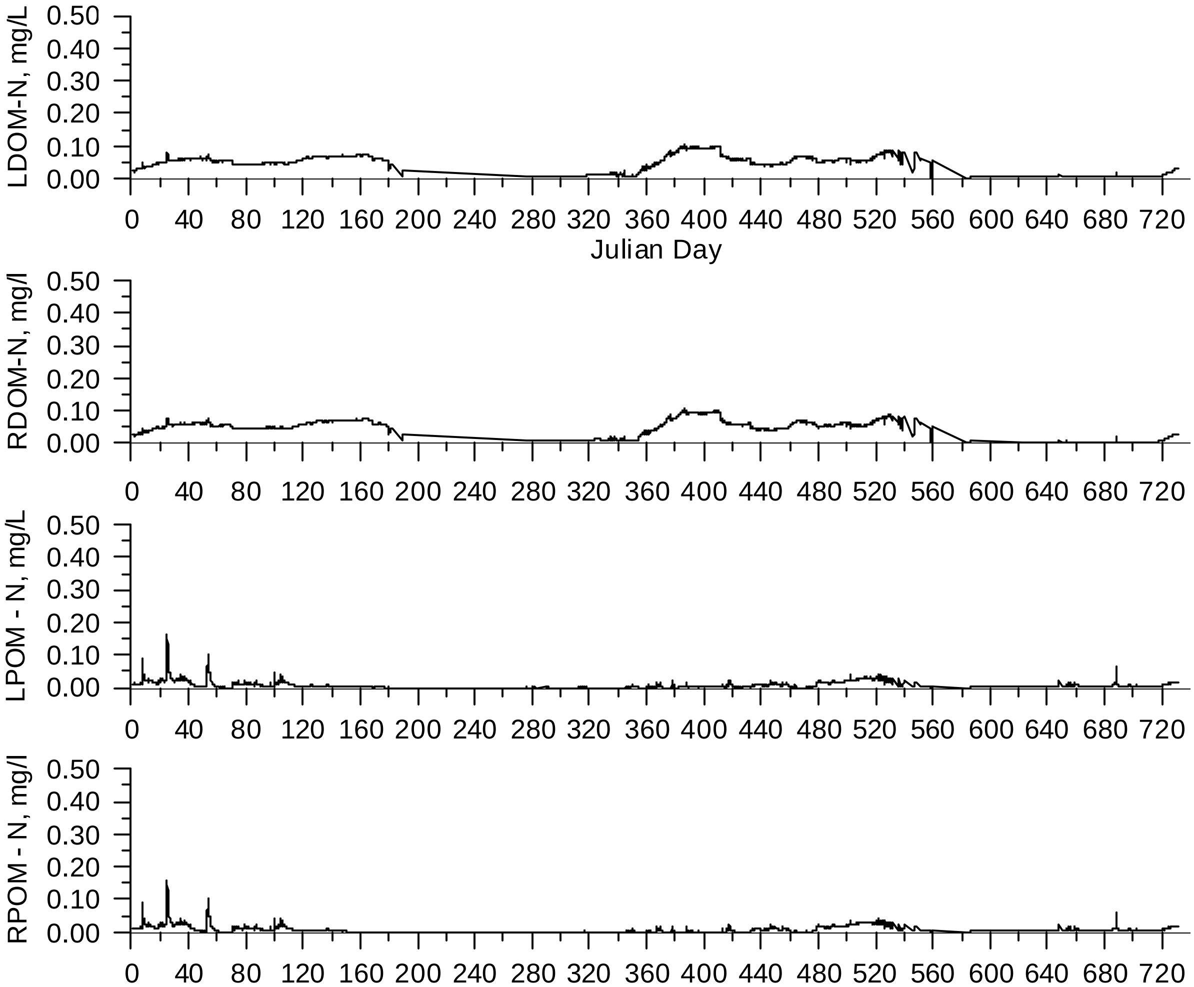

Figure 38. Constituent concentrations used for Euclid Creek.

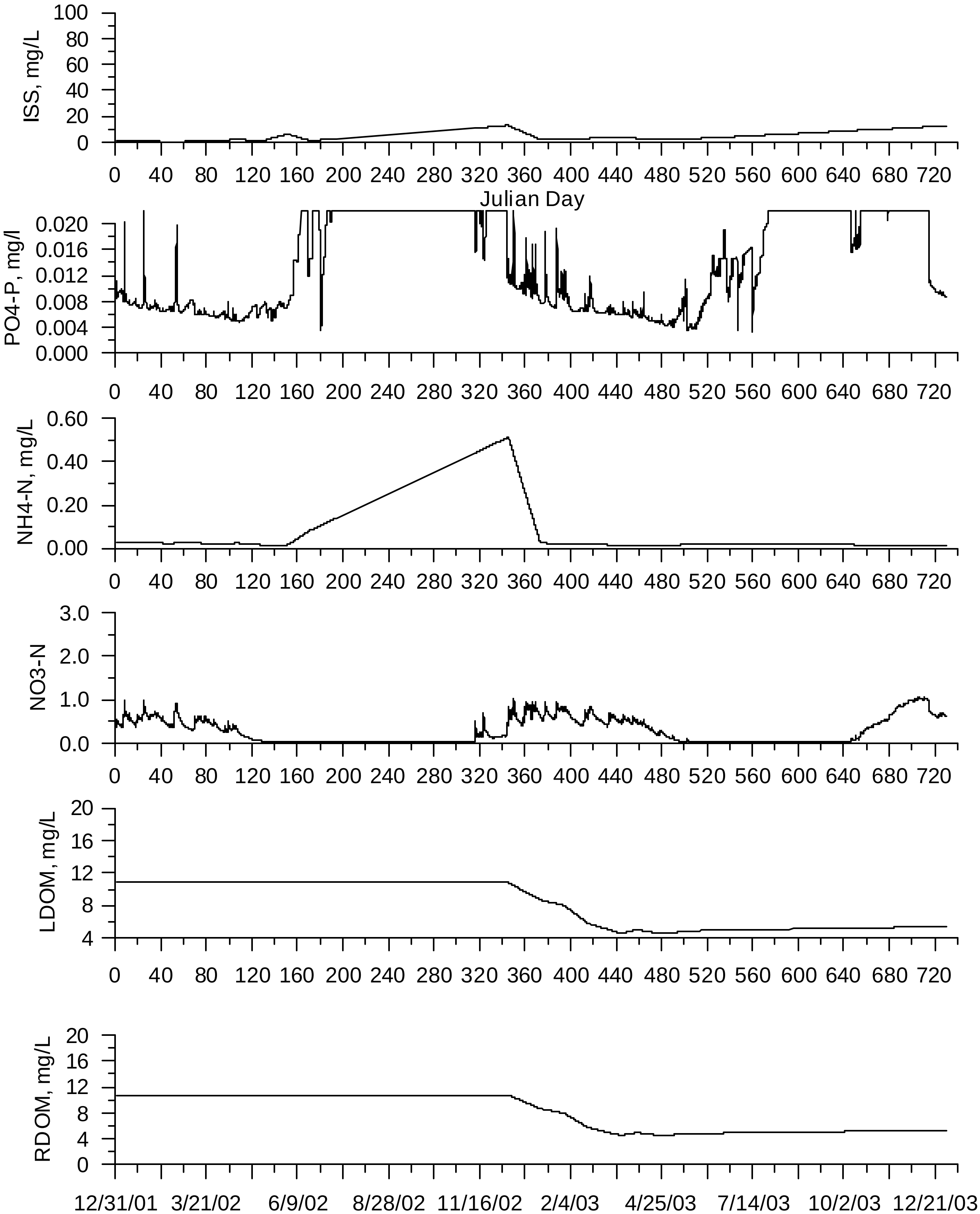

Figure 39. Constituent concentrations used for Mill Wheel Creek.

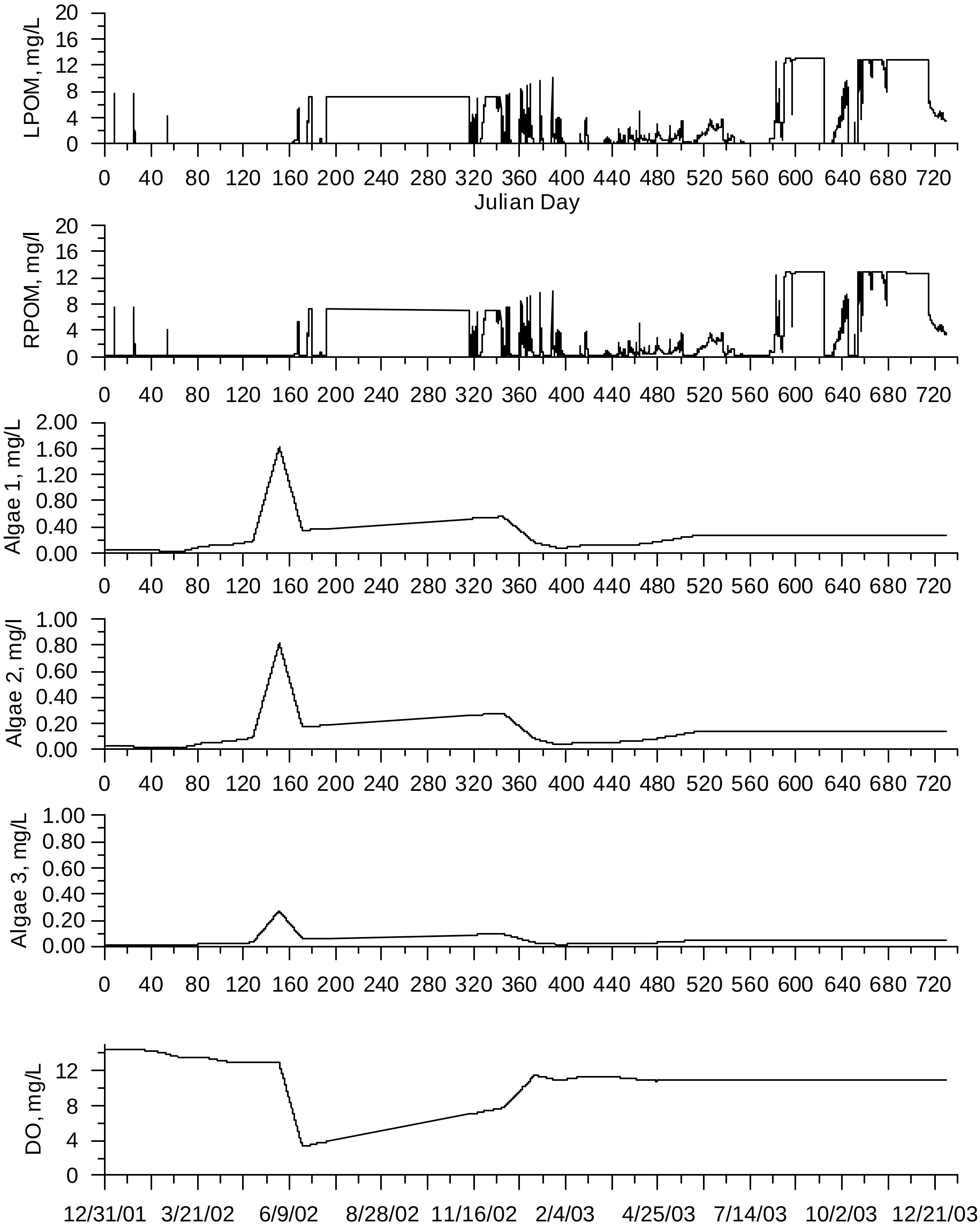

Figure 40. Constituent concentrations used for Mill Wheel Creek.

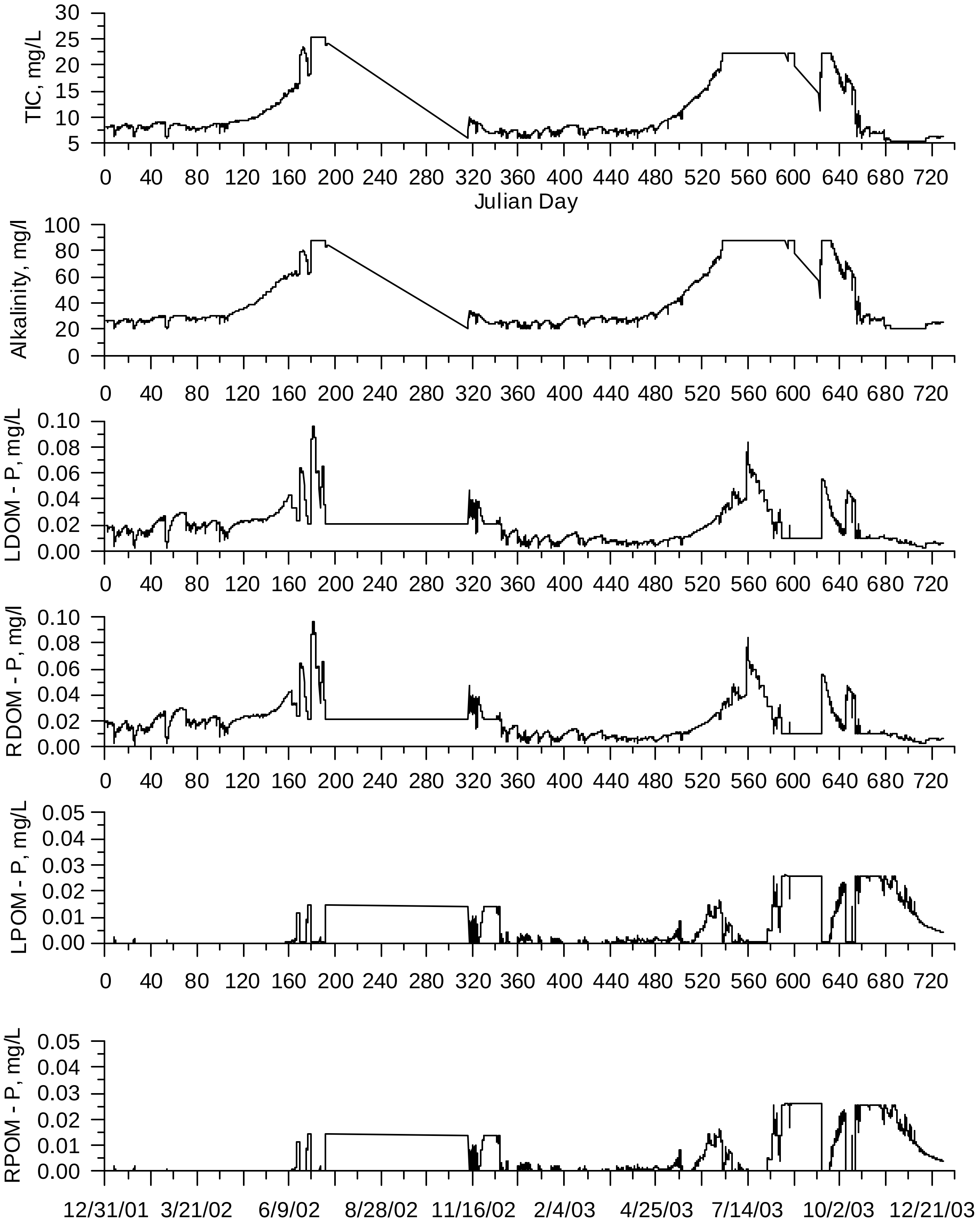

Figure 41. Constituent concentrations used for Mill Wheel Creek.

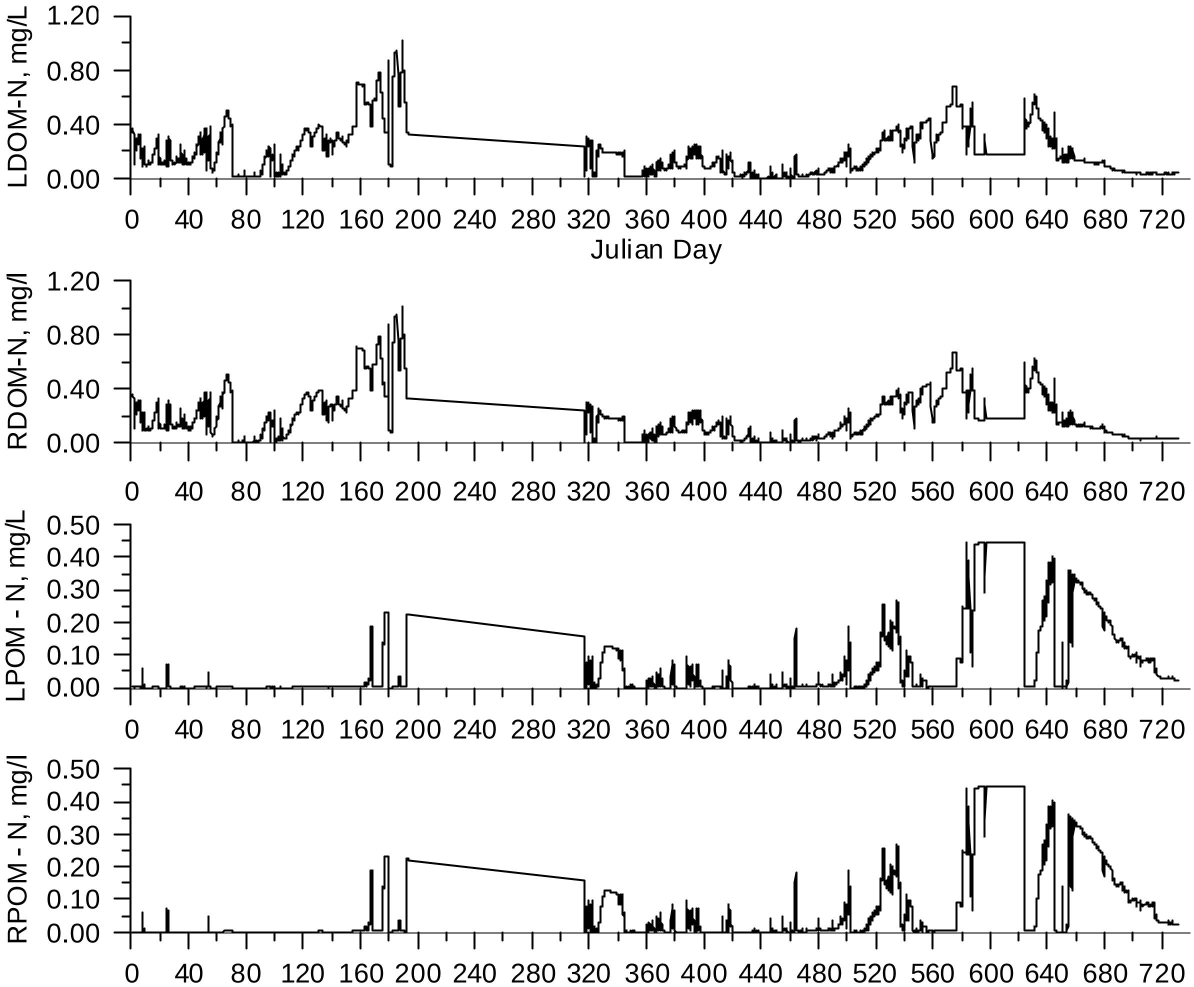

Figure 42. Constituent concentrations used for Mill Wheel Creek.

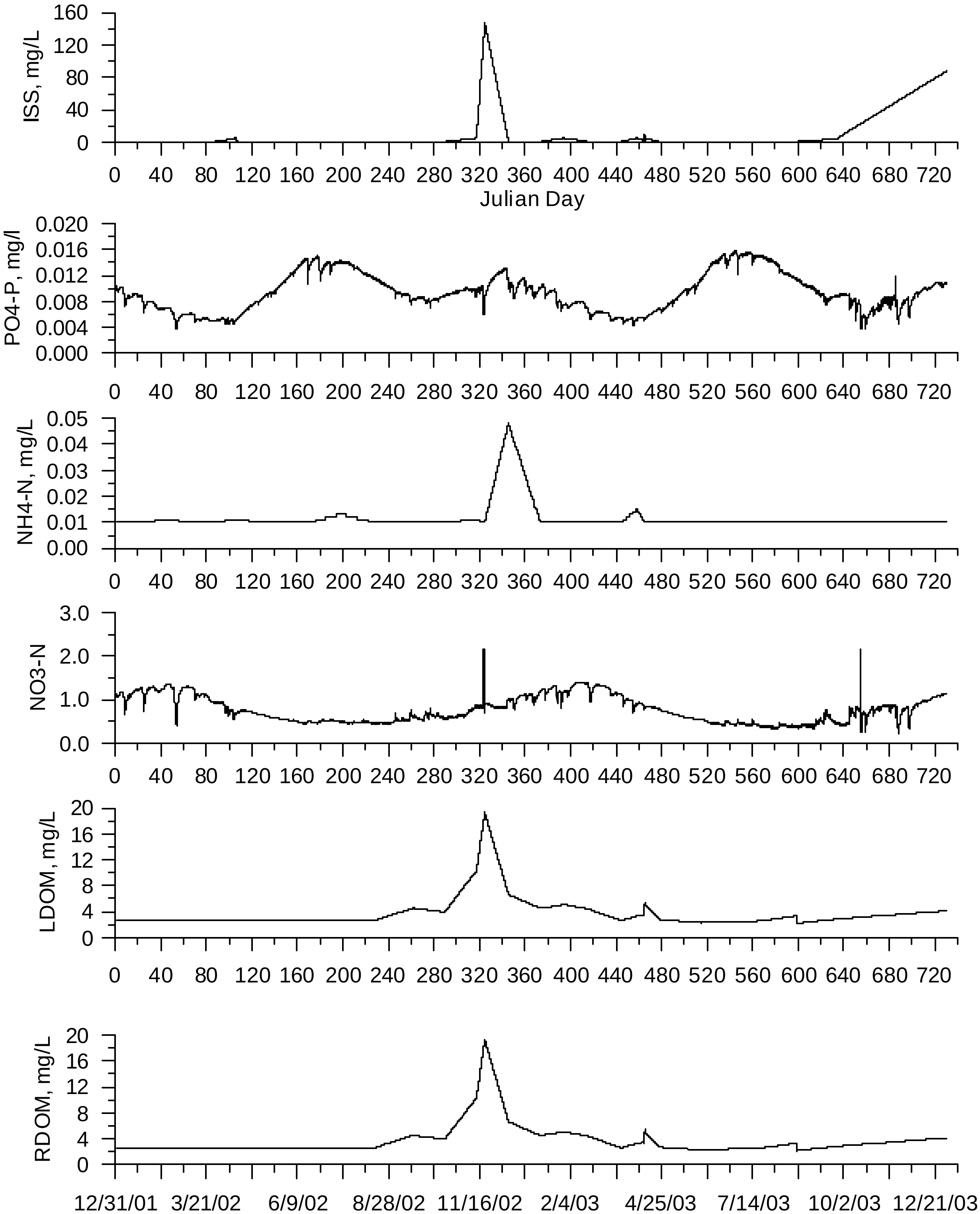

Figure 43. Constituent concentrations used for Olsen Creek.

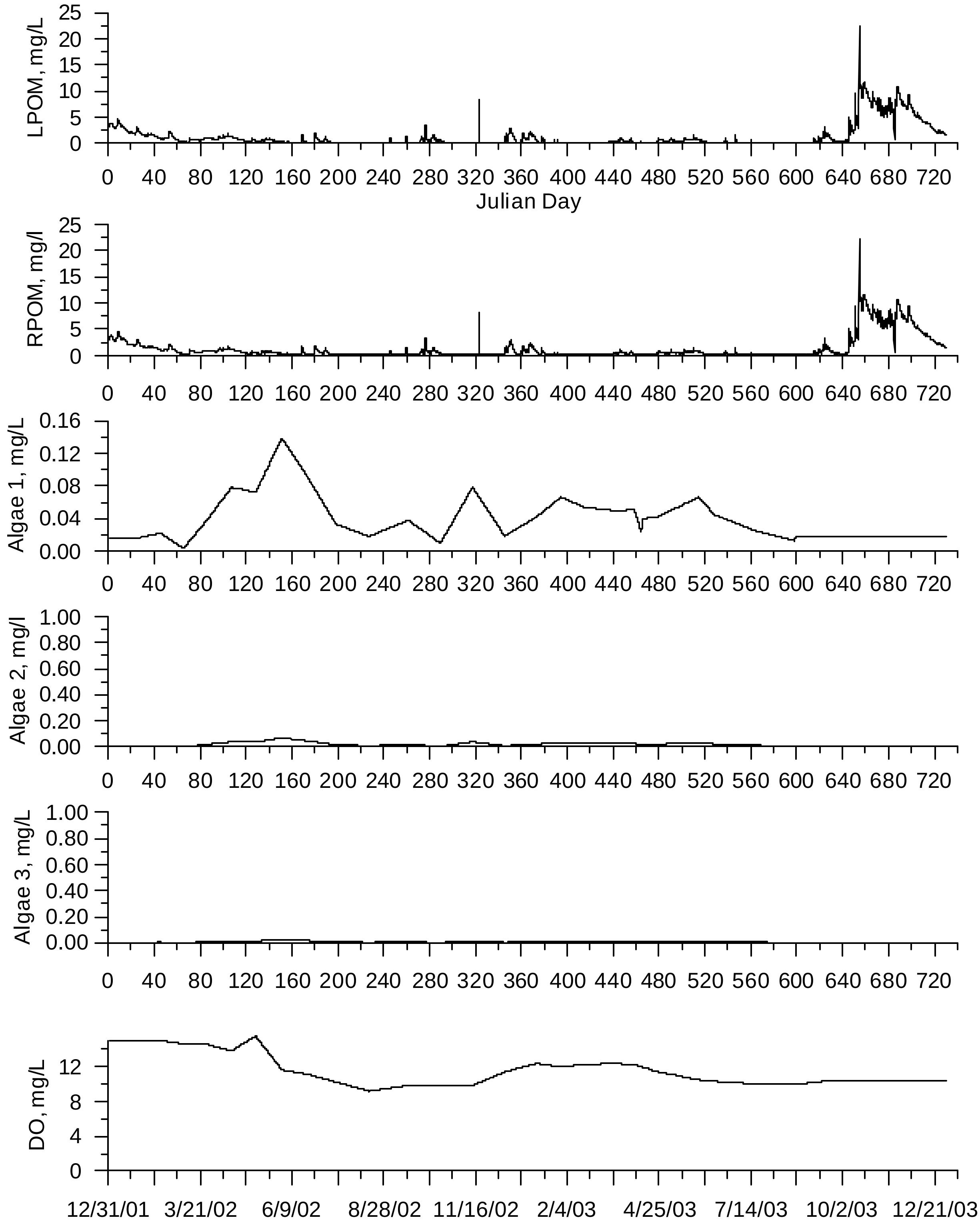

Figure 44. Constituent concentrations used for Olsen Creek.

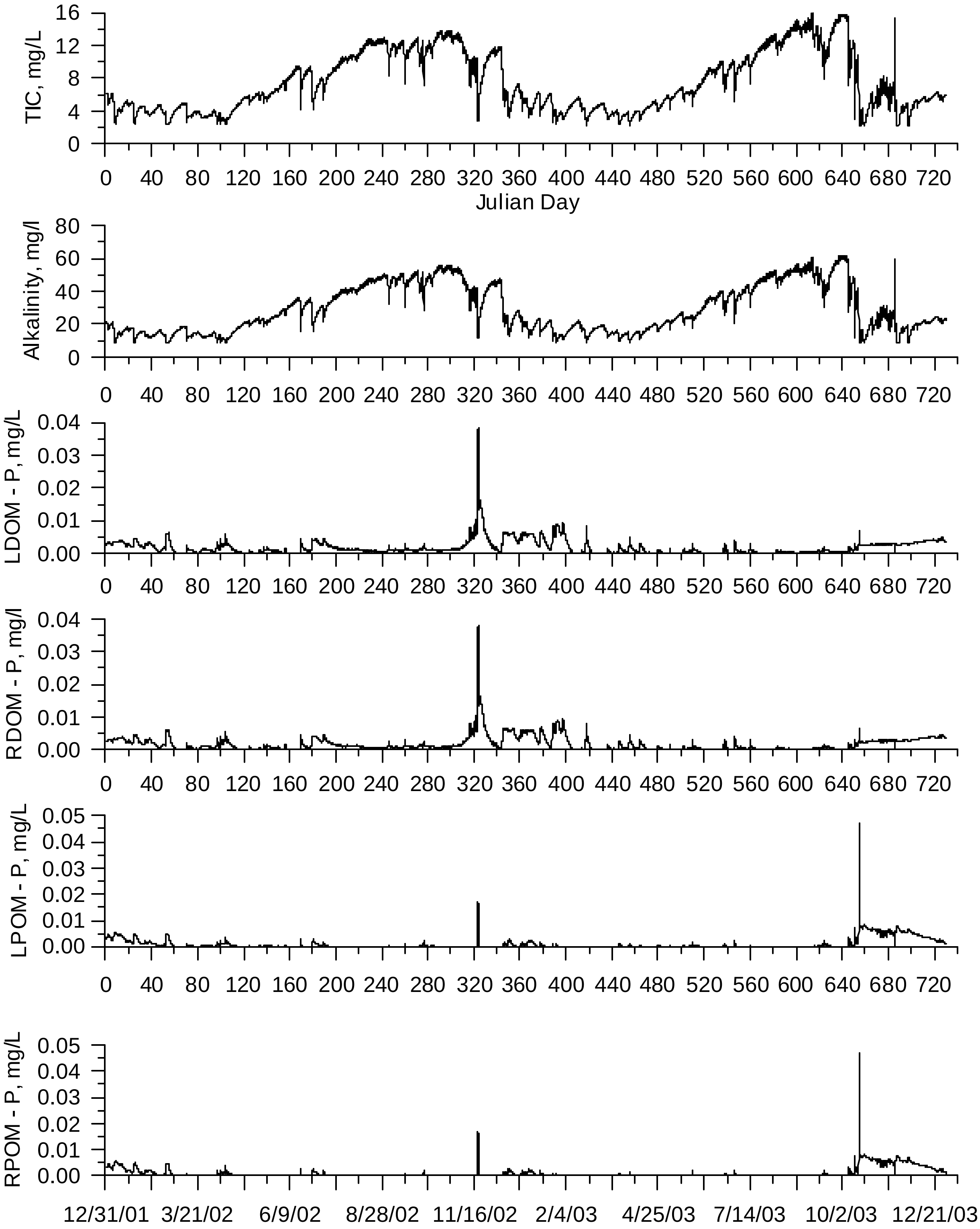

Figure 45. Constituent concentrations used for Olsen Creek.

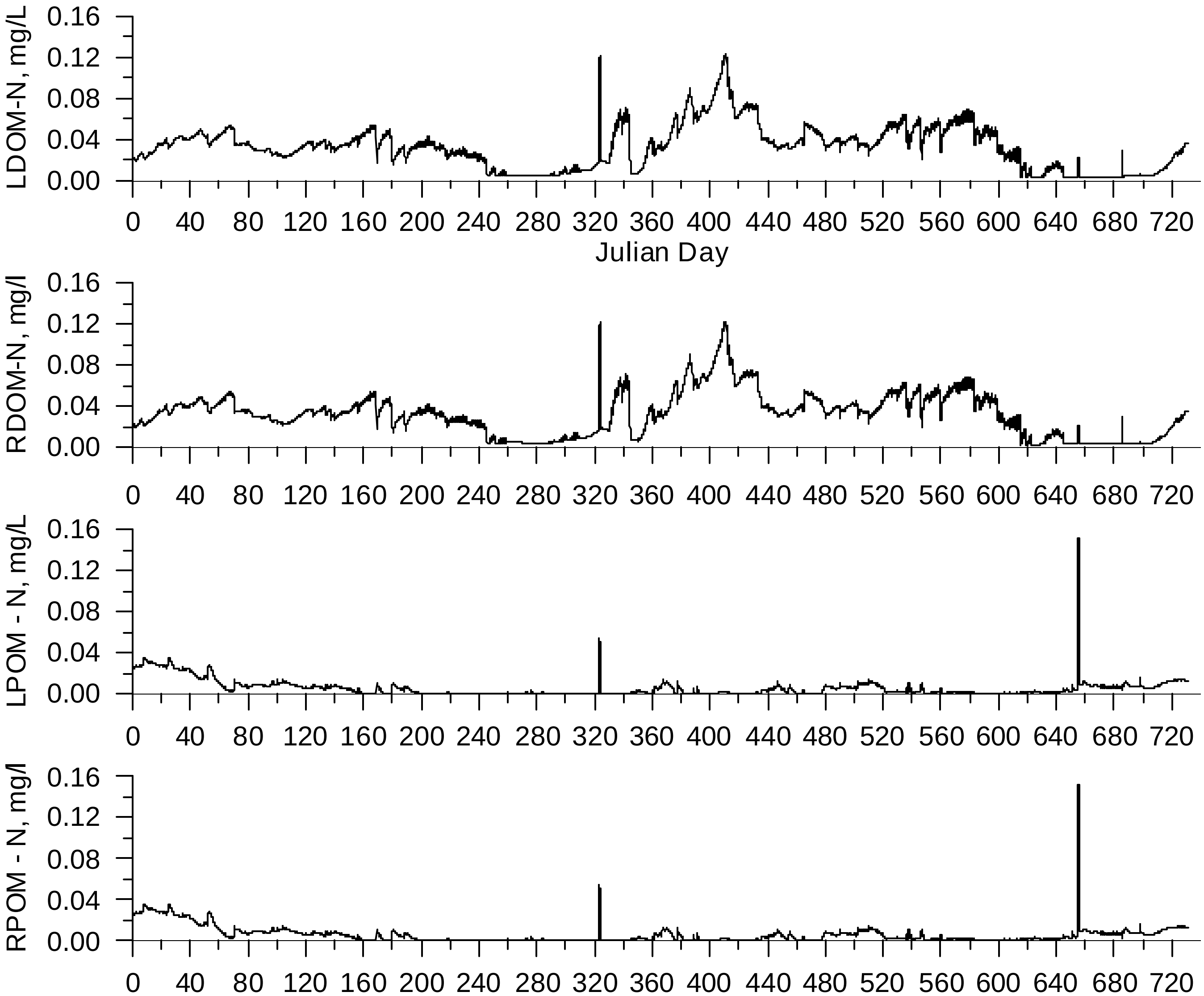

Figure 46. Constituent concentrations used for Olsen Creek.

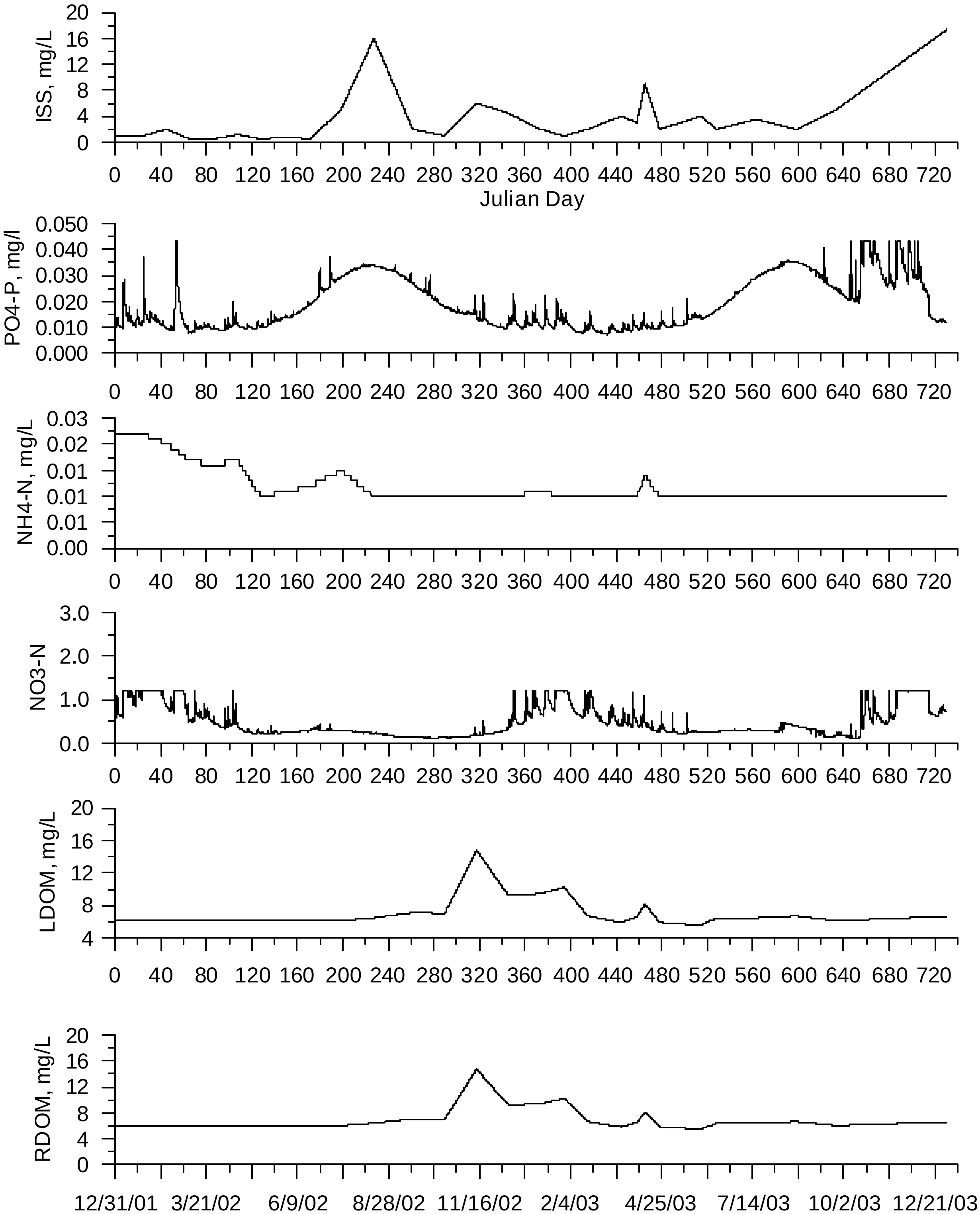

Figure 47. Constituent concentrations used for Silver Creek.

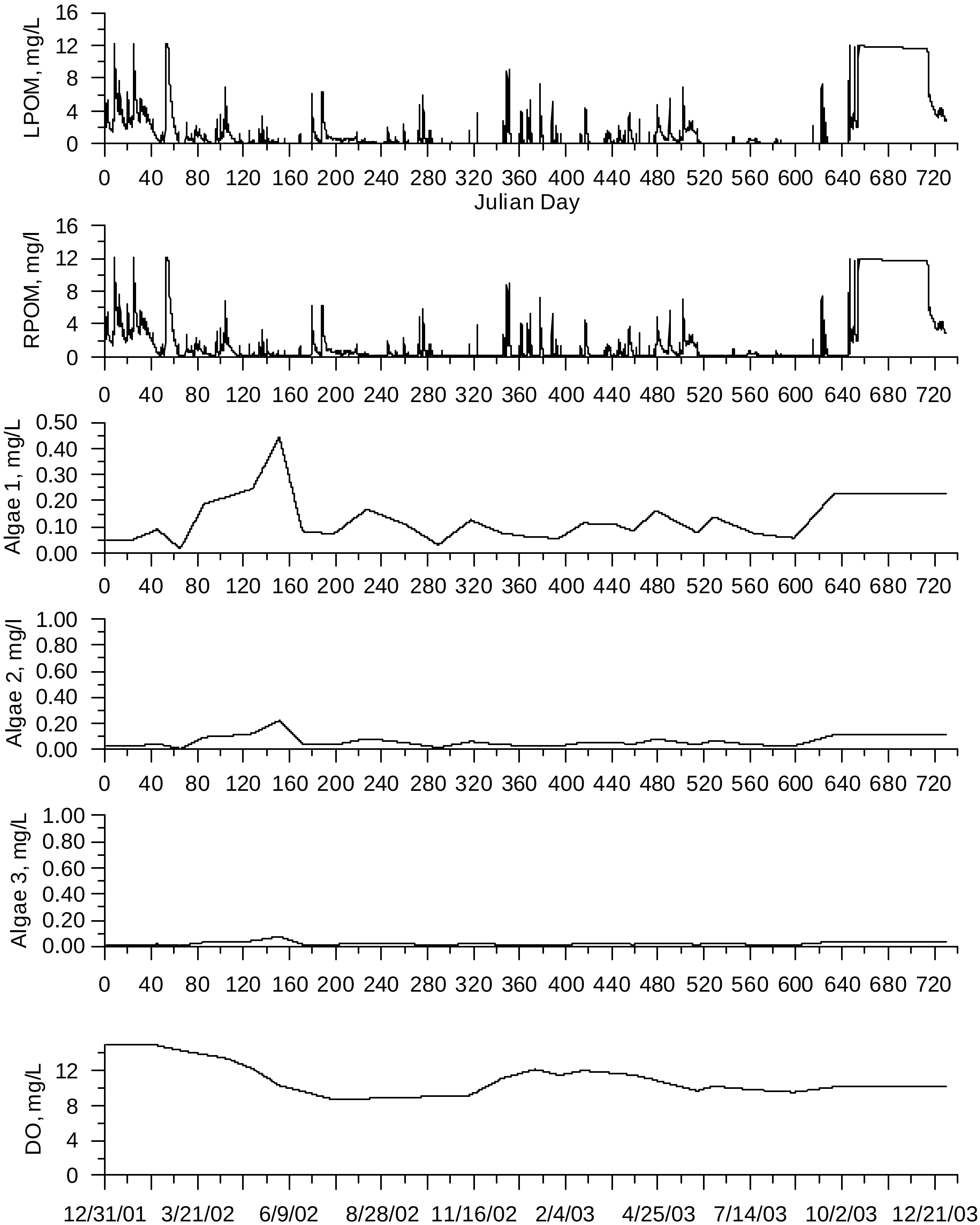

Figure 48. Constituent concentrations used for Silver Creek.

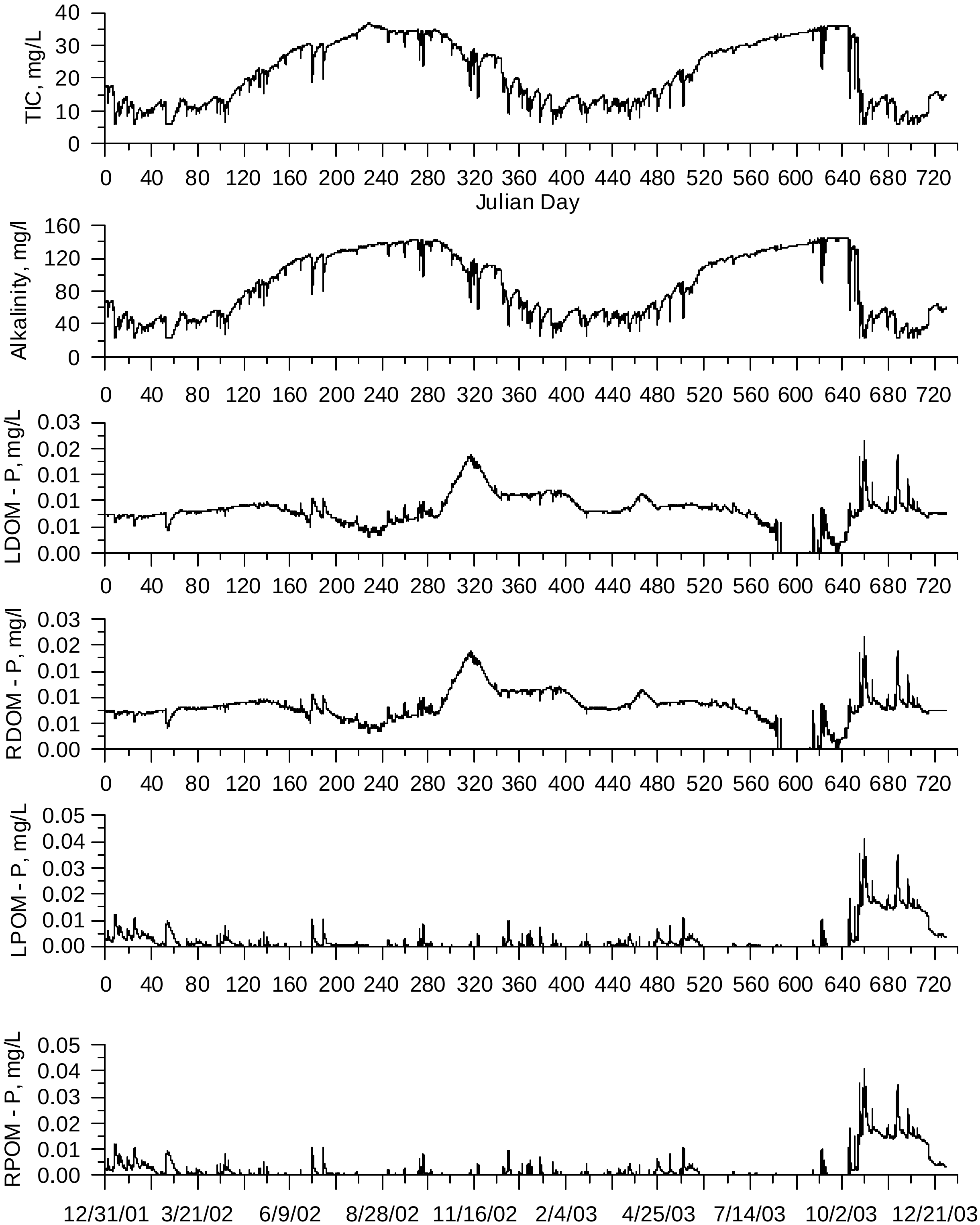

Figure 49. Constituent concentrations used for Silver Creek.

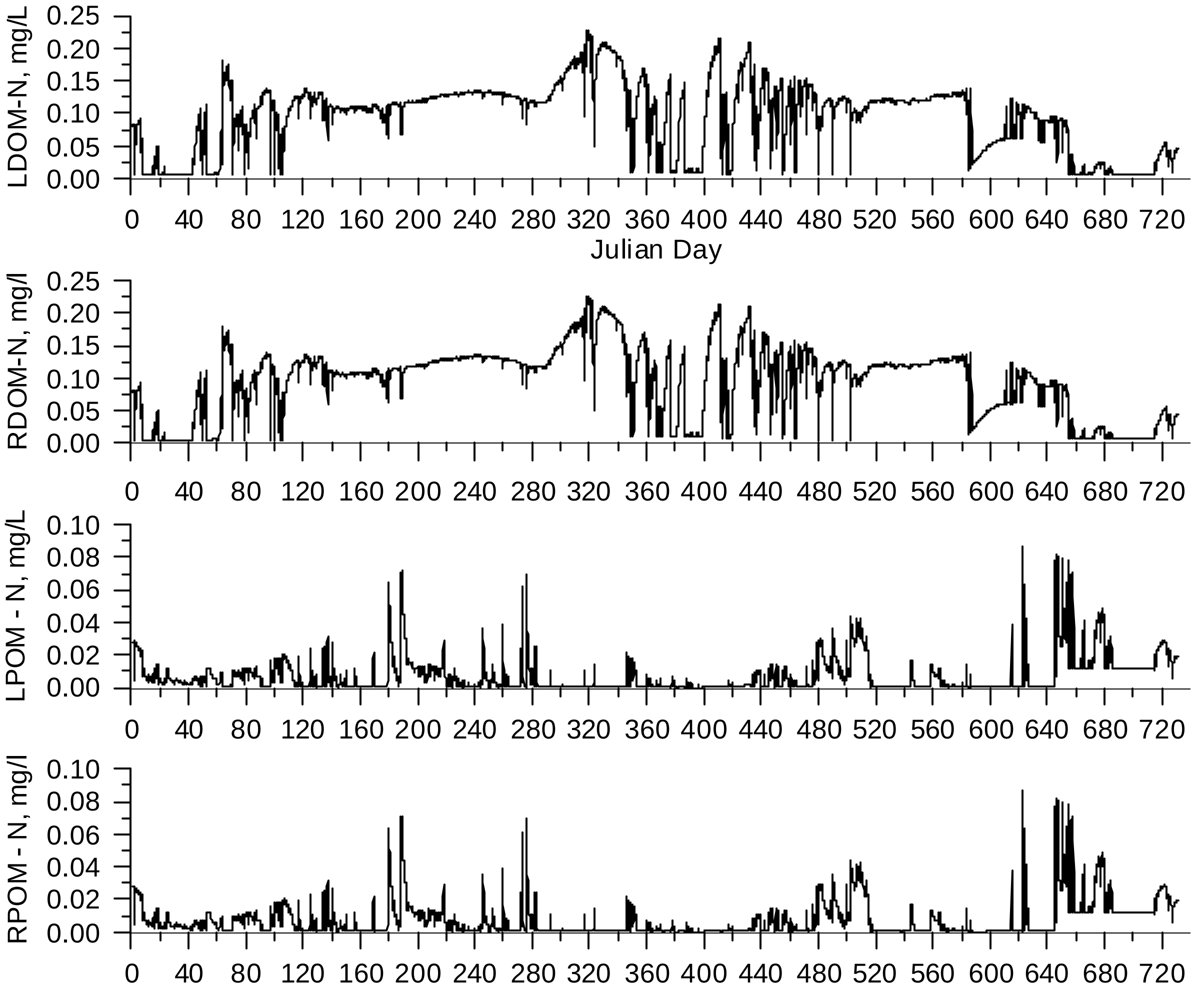

Figure 50. Constituent concentrations used for Silver Creek.

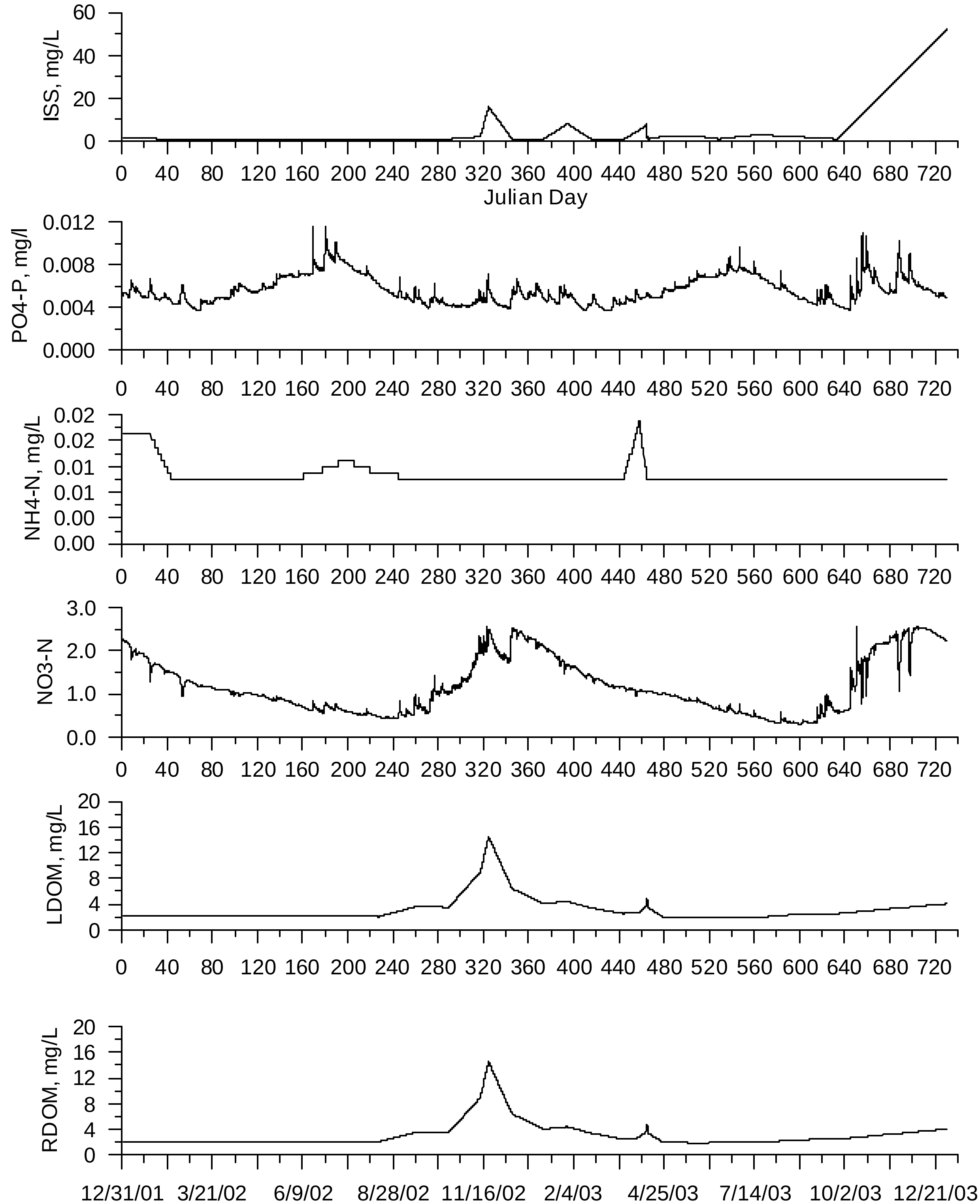

Figure 51. Constituent concentrations used for Smith Creek.

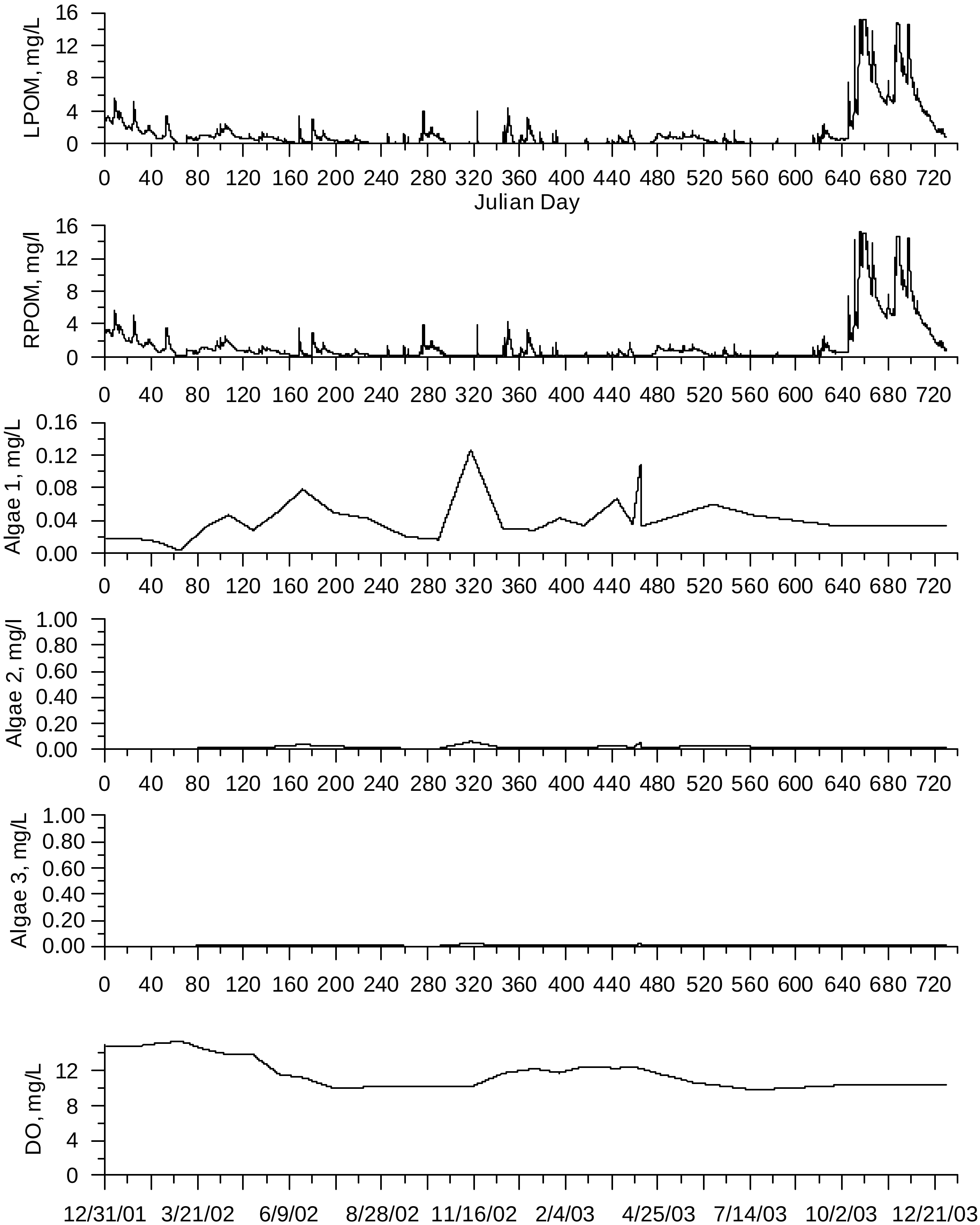

Figure 52. Constituent concentrations used for Smith Creek.

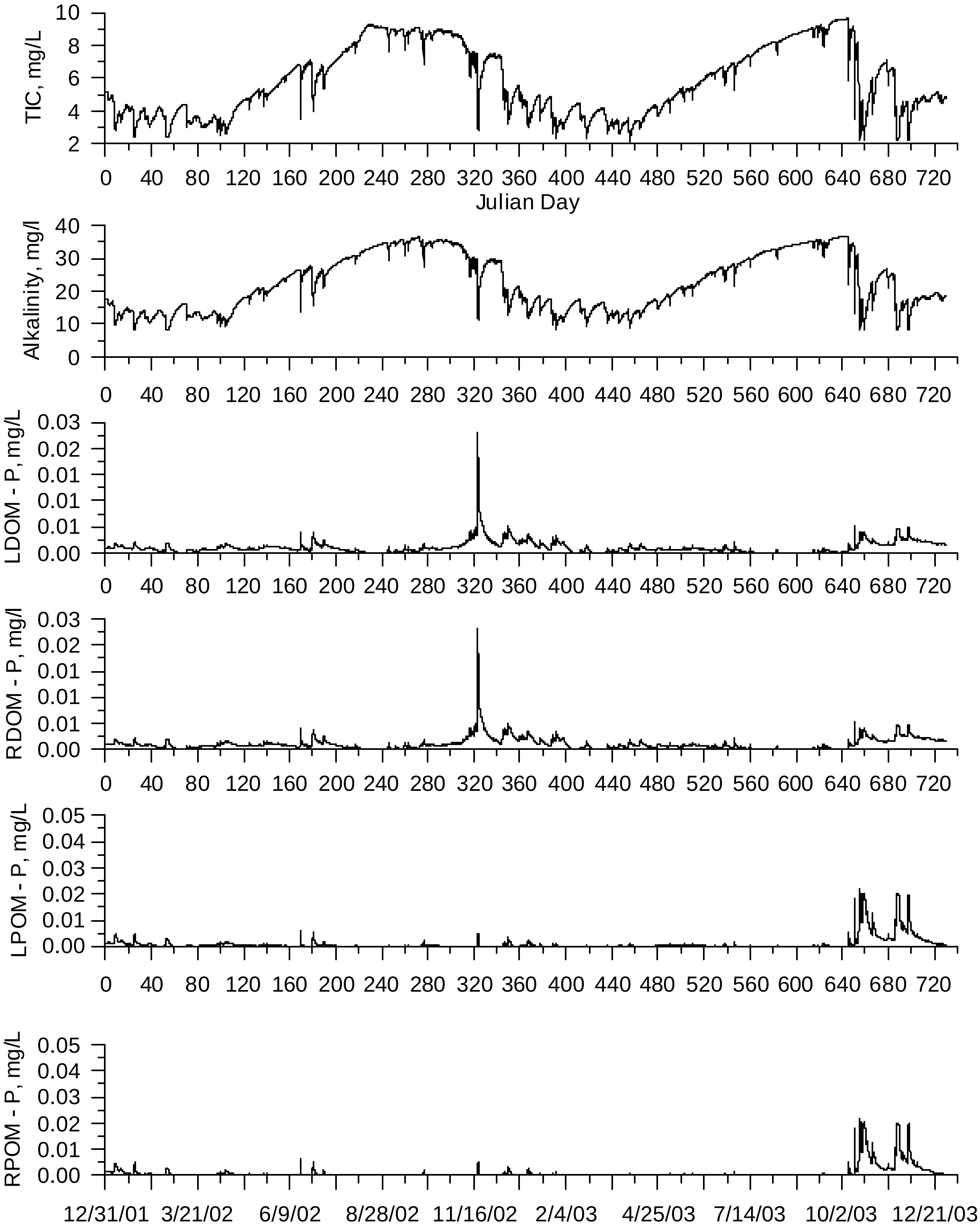

Figure 53. Constituent concentrations used for Smith Creek.

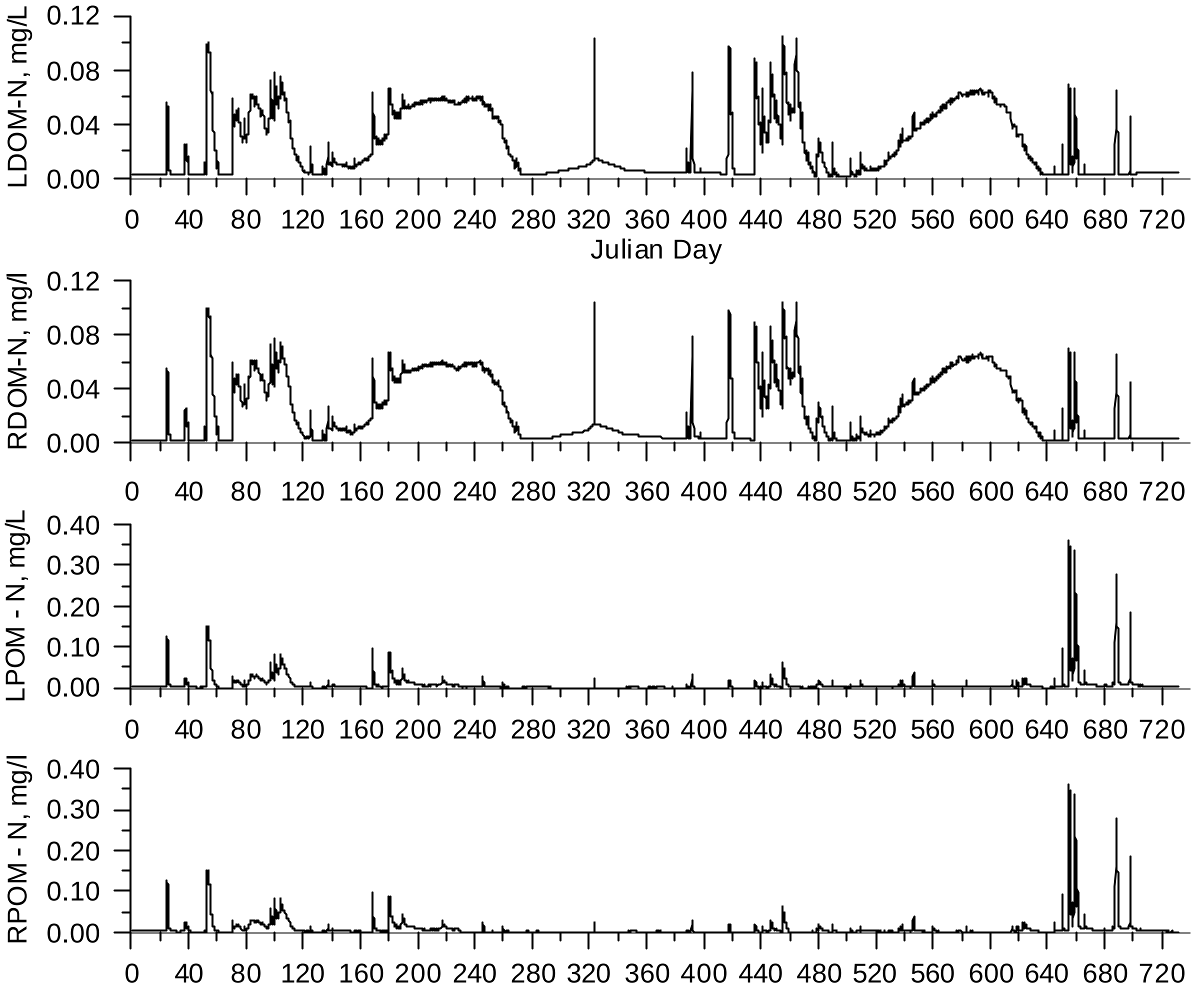

Figure 54. Constituent concentrations used for Smith Creek.

Meteorological Data

Meteorological data for the CE-QUAL-W2 model were measured near Smith Creek and near Brannian Creek. The model utilizes air and dew point temperature, wind speed and direction, and cloud cover and/or solar radiation. The Washington Department of Ecology developed the meteorological data. Meteorological input files were created for water body 1 (basin 3) and water body 2 (basins 1 and 2). Table 4 summarizes the data sources of the meteorological inputs.

Table 4. Data sources for meteorological input files.

Meteorological Input	Water Body 1 (file 'met_1.npt')	Water Body 2 (file 'met_2.npt')
Air Temperature	used the average of the two stations*	Used data at Smith
Dew Point Temperature	used the average of the two stations*	Used data at Smith
Wind direction	Used data at Smith	Used data at Smith
Wind speed	Used data at Smith	Used data at Smith
Cloud Cover	Cloud cover data are from State Climatologist	Cloud cover data are from State Climatologist
Short Wave Solar Radiation	used the bigger value of the two stations*	used the bigger value of the two stations*

*For the time period 10/1/2002 -- 11/10/2002 there was no data at Brannian, so data at Smith were used.

A time series model input of air temperature, dew point temperature, wind speed, wind direction, cloud cover and short wave solar radiation were necessary for each water body and these are shown in Figure 55 to Figure 66. Air temperature for water body 1 and water body 2 are shown in Figure 55 and Figure 56, respectively. Dew point temperatures are shown in Figure 57 and Figure 58. Figure 59 and Figure 60 show wind speed for these 2 waterbodies, respectively. Figure 61 shows wind direction data. Cloud cover data are shown in Figure 63 and Figure 64, and short wave radiation are shown in Figure 65 and Figure 66 for water body 1 and 2, respectively.

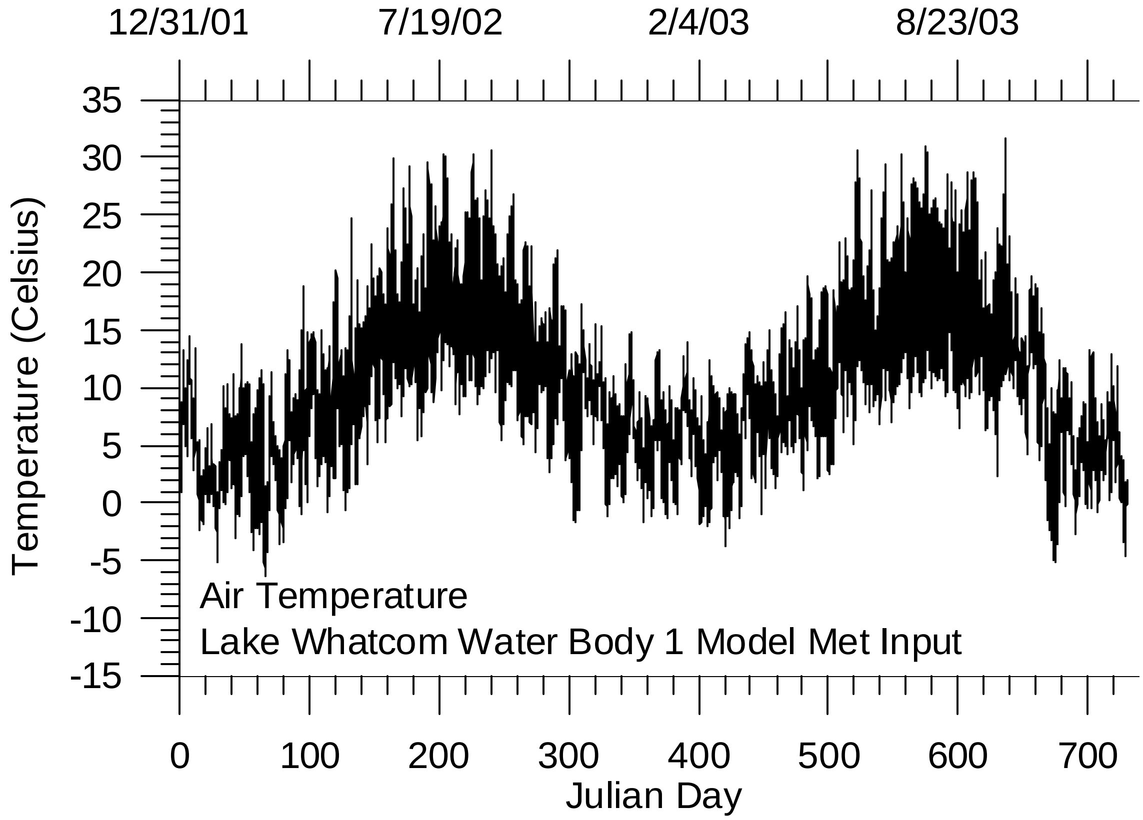

Figure 55. Air temperature for water body 1.

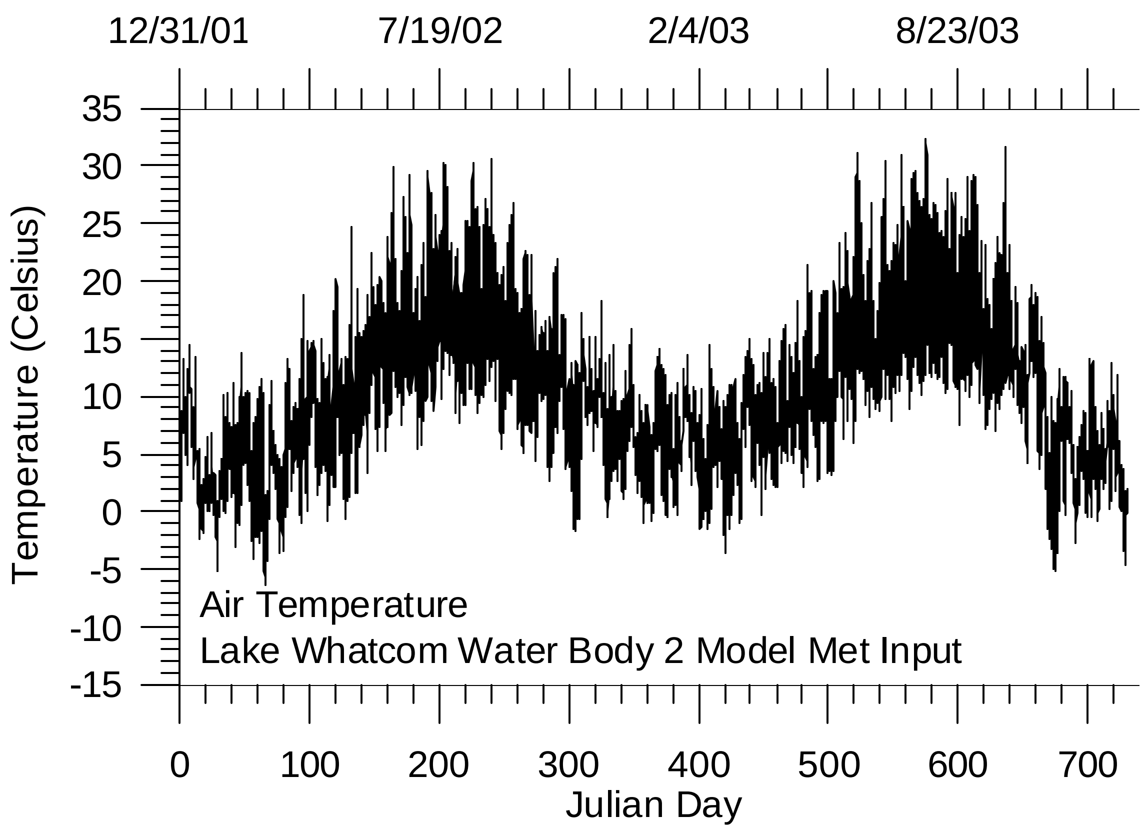

Figure 56. Air temperature for water body 2.

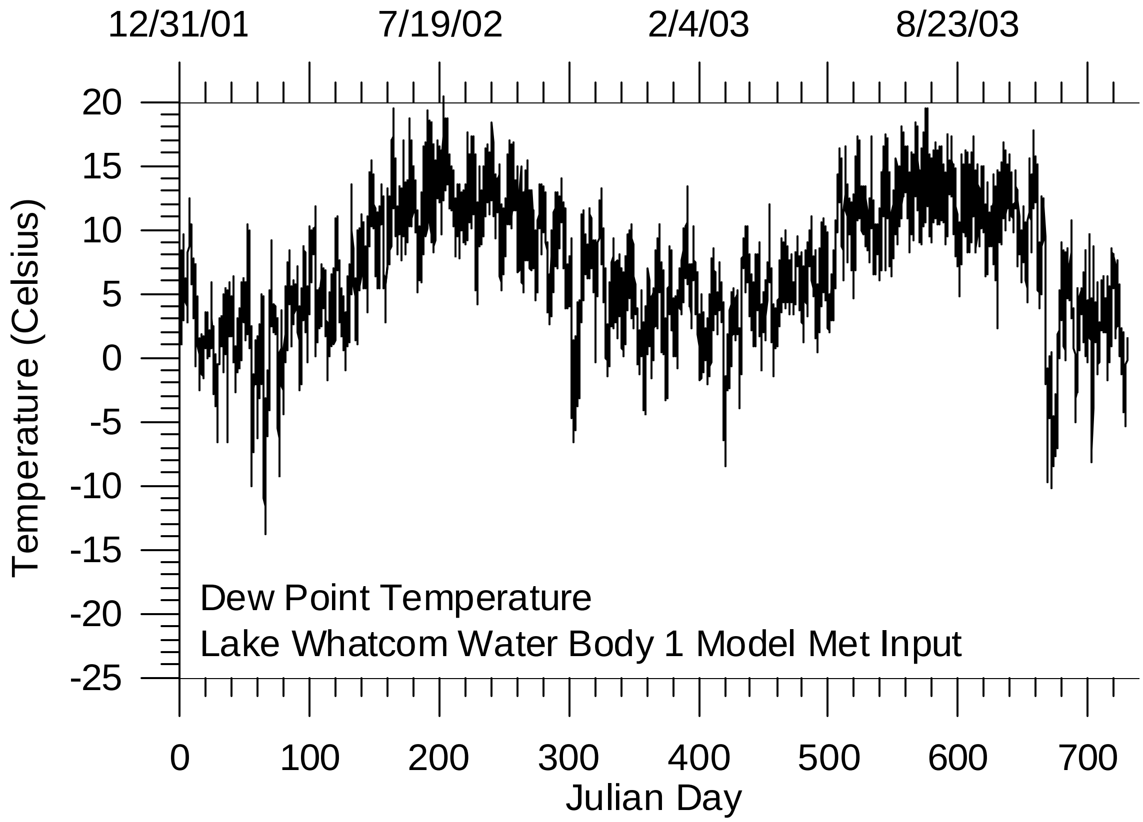

Figure 57. Dew point temperature for water body 1.

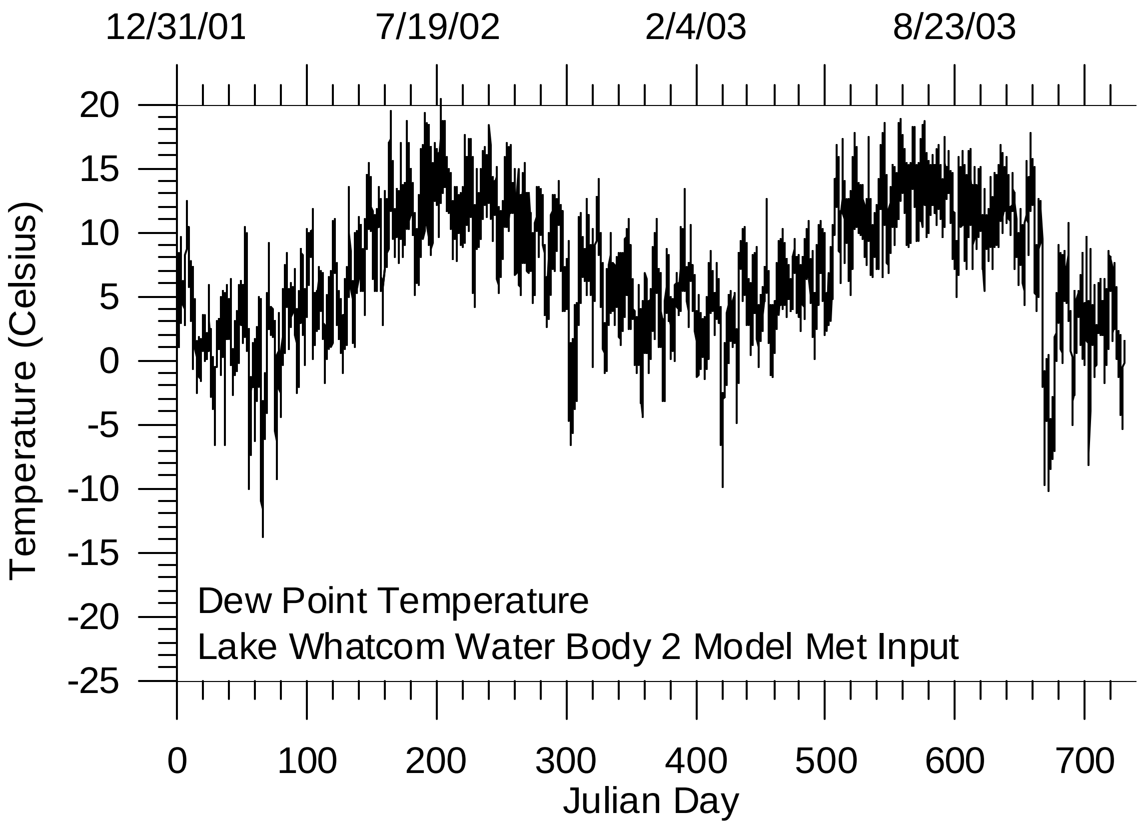

Figure 58. Dew point temperature for water body 2.

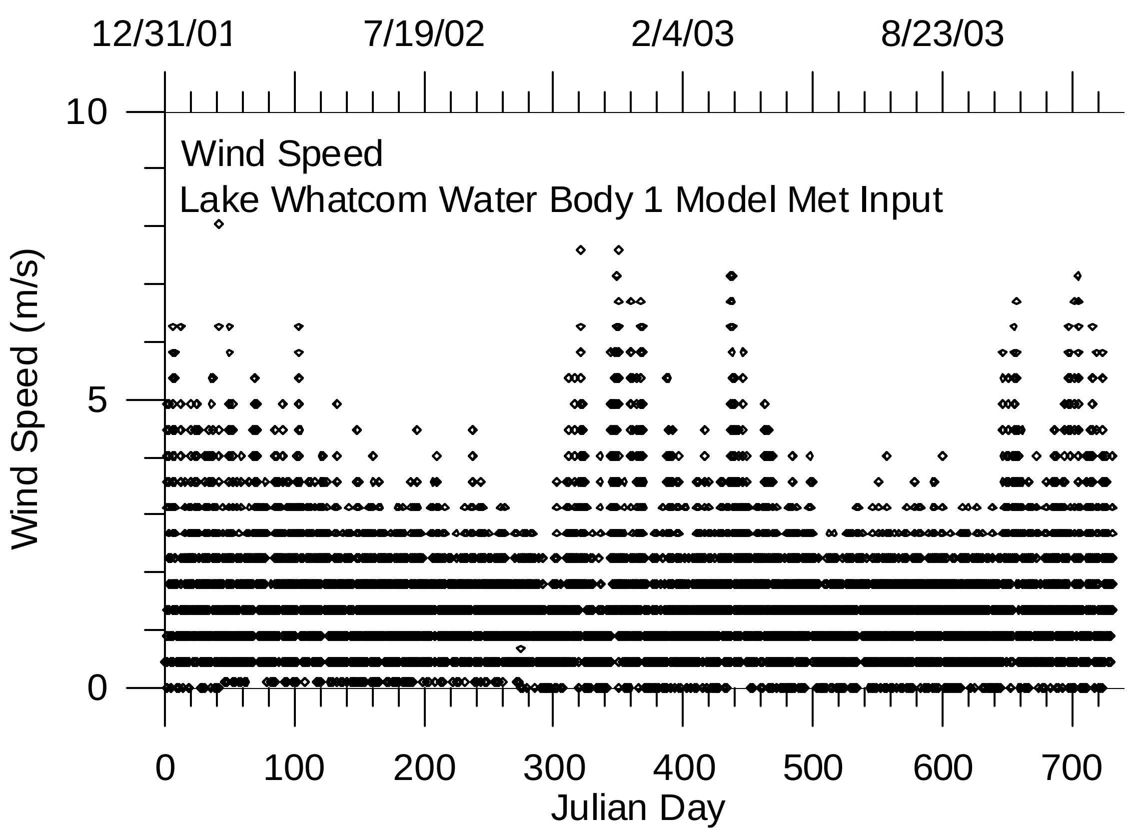

Figure 59. Wind Speed for water body 1.

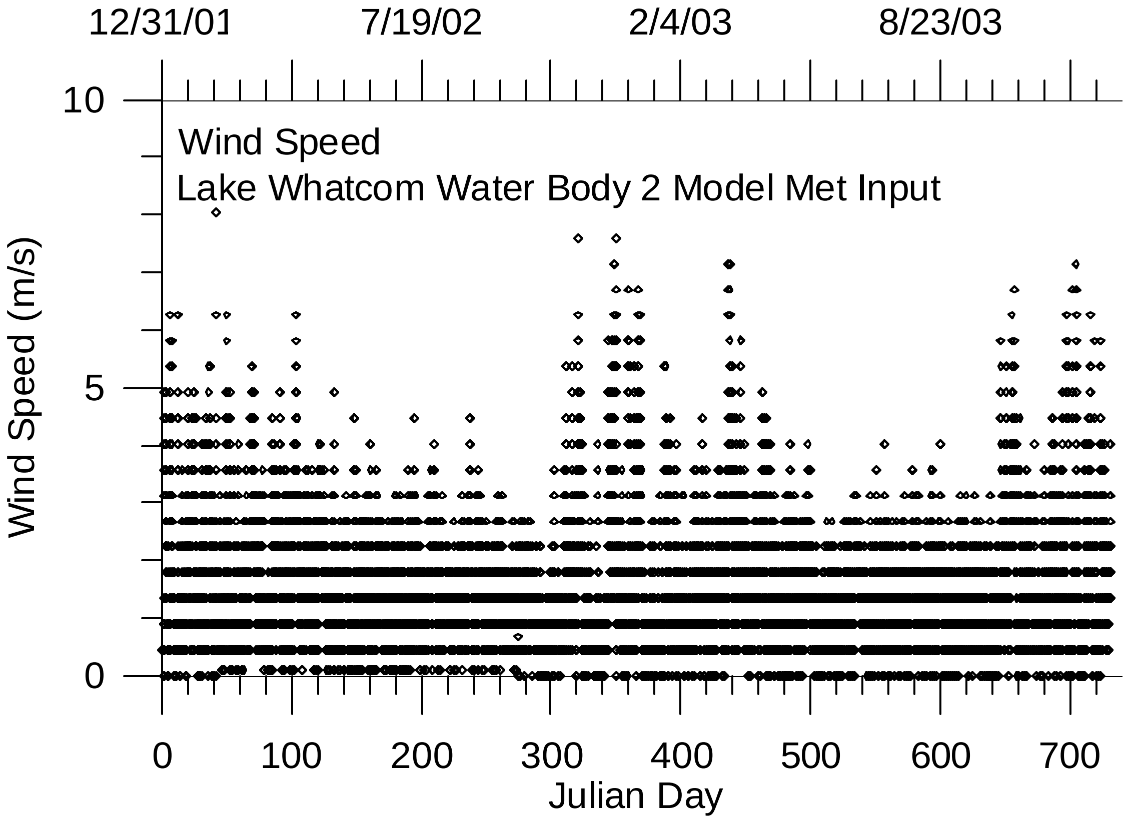

Figure 60. Wind Speed for water body 2.

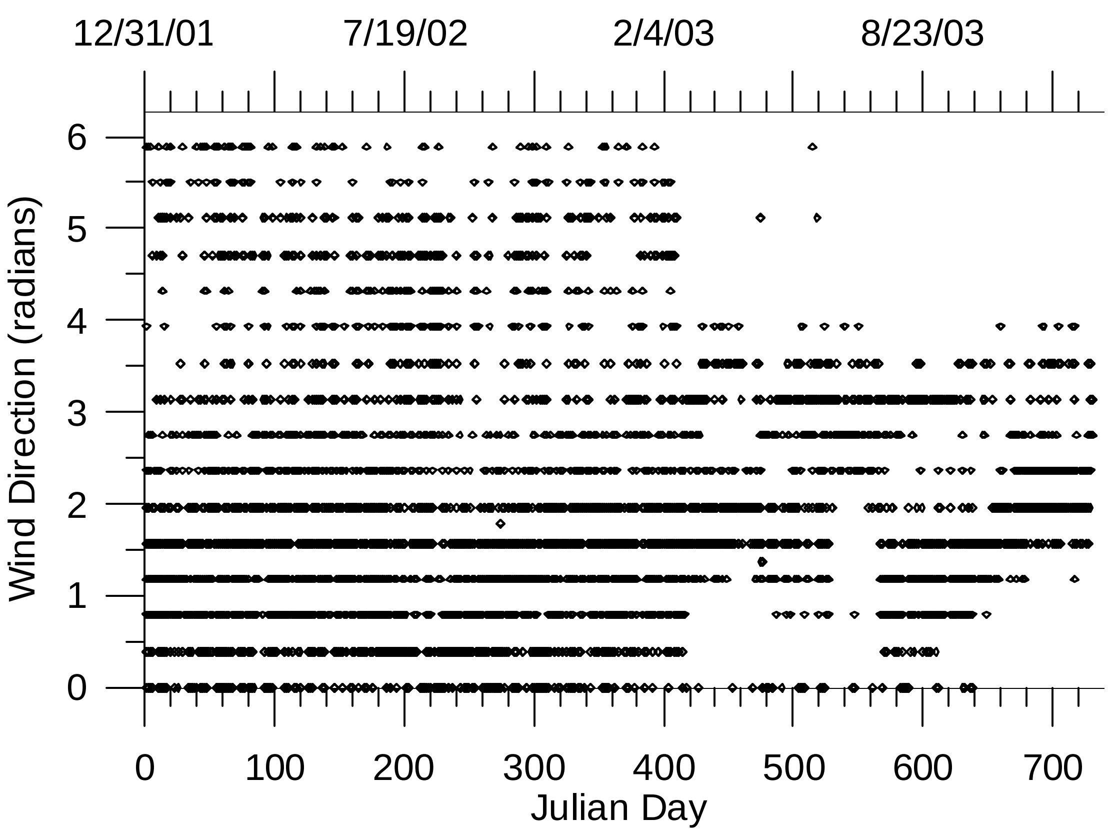

Figure 61. Wind direction used water body 1.

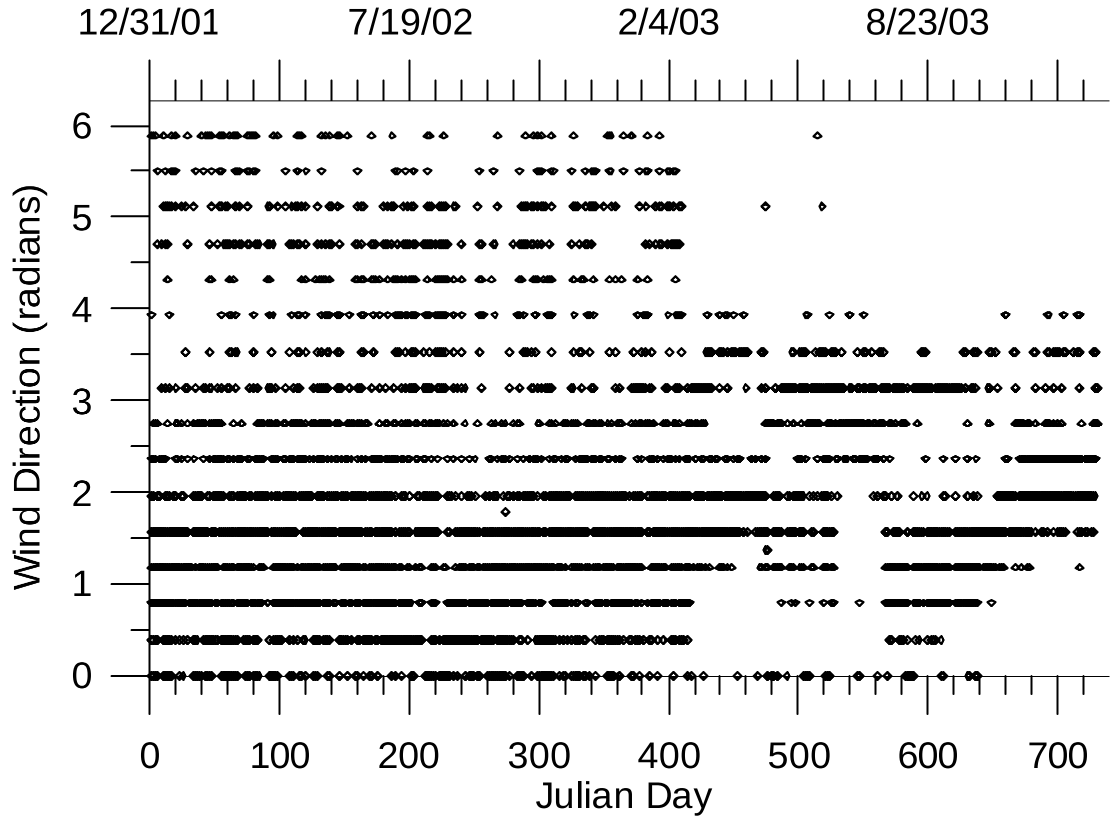

Figure 62. Wind direction used water body 2.

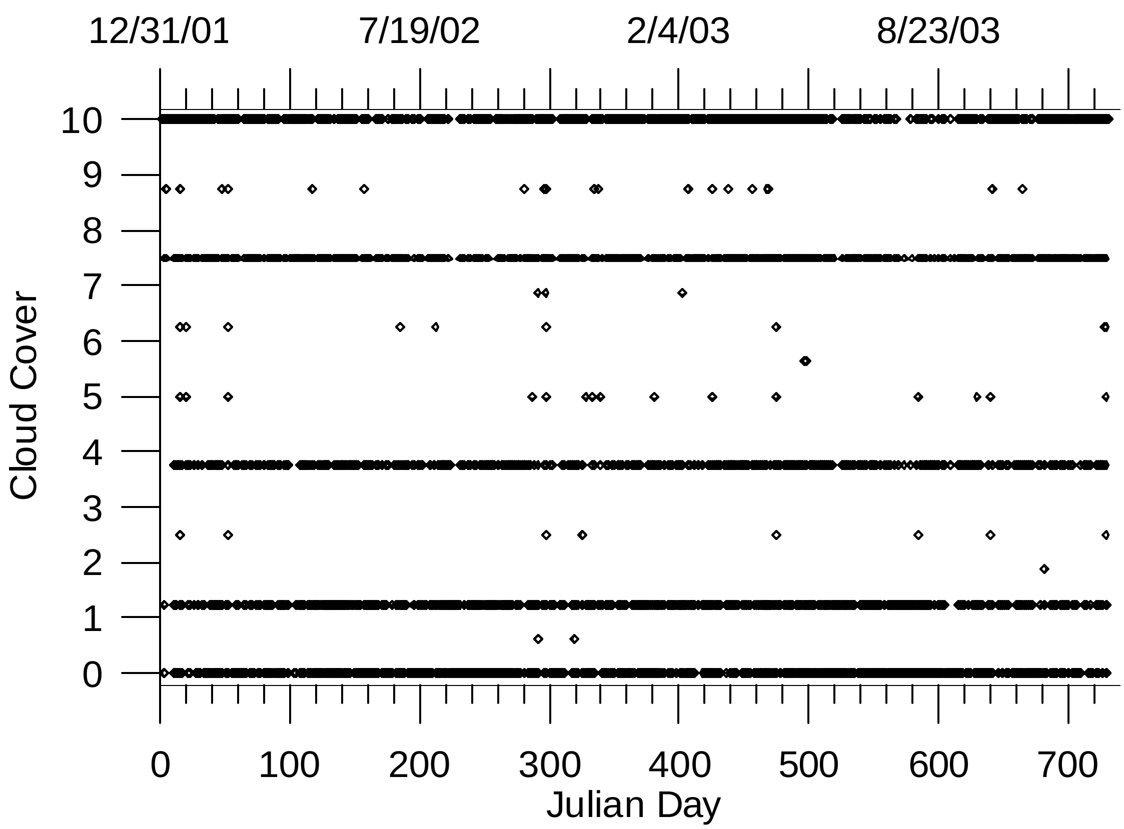

Figure 63. Cloud Cover for water body 1.

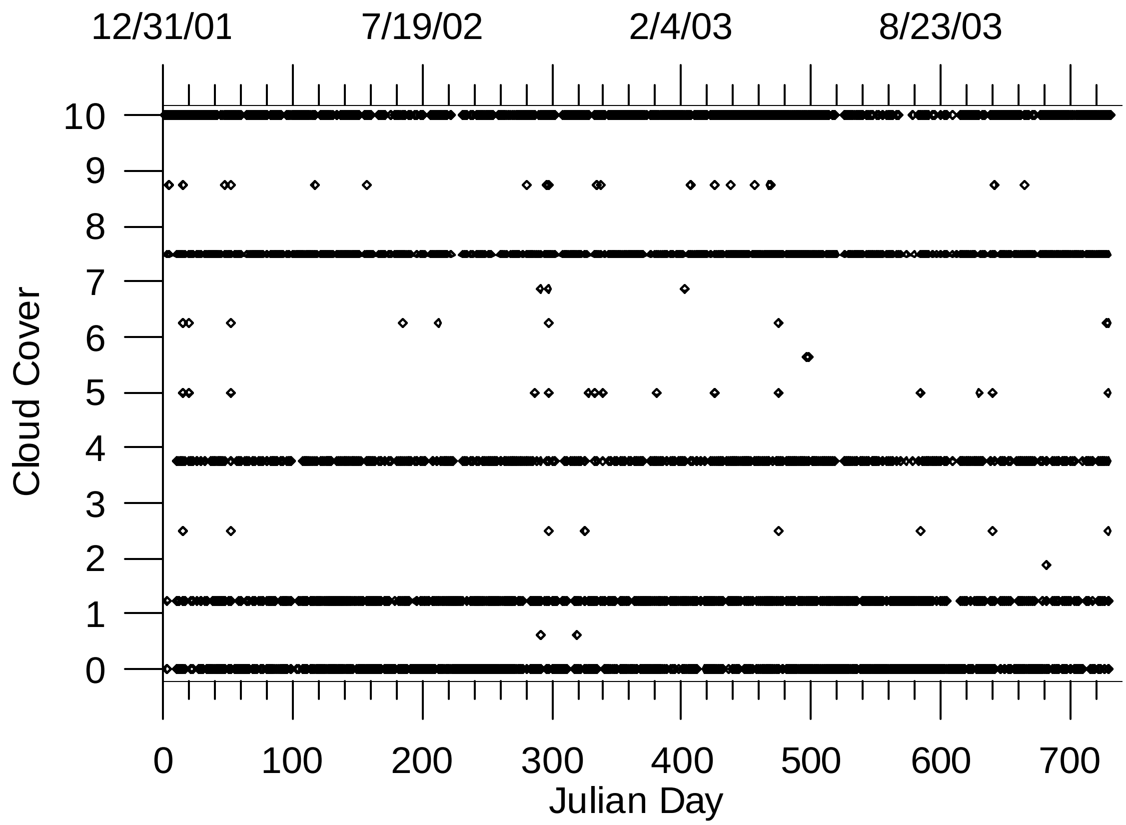

Figure 64. Cloud Cover for water body 2.

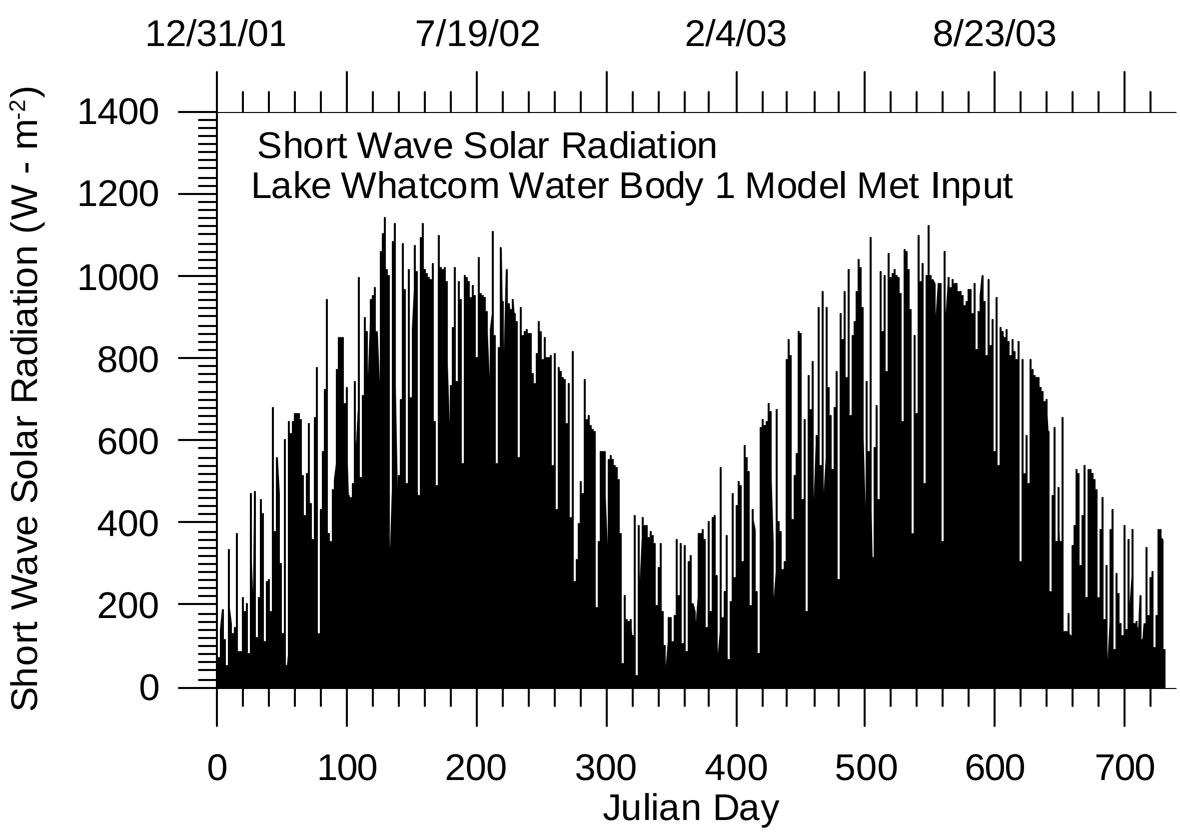

Figure 65. Short wave solar radiation for water body 1.

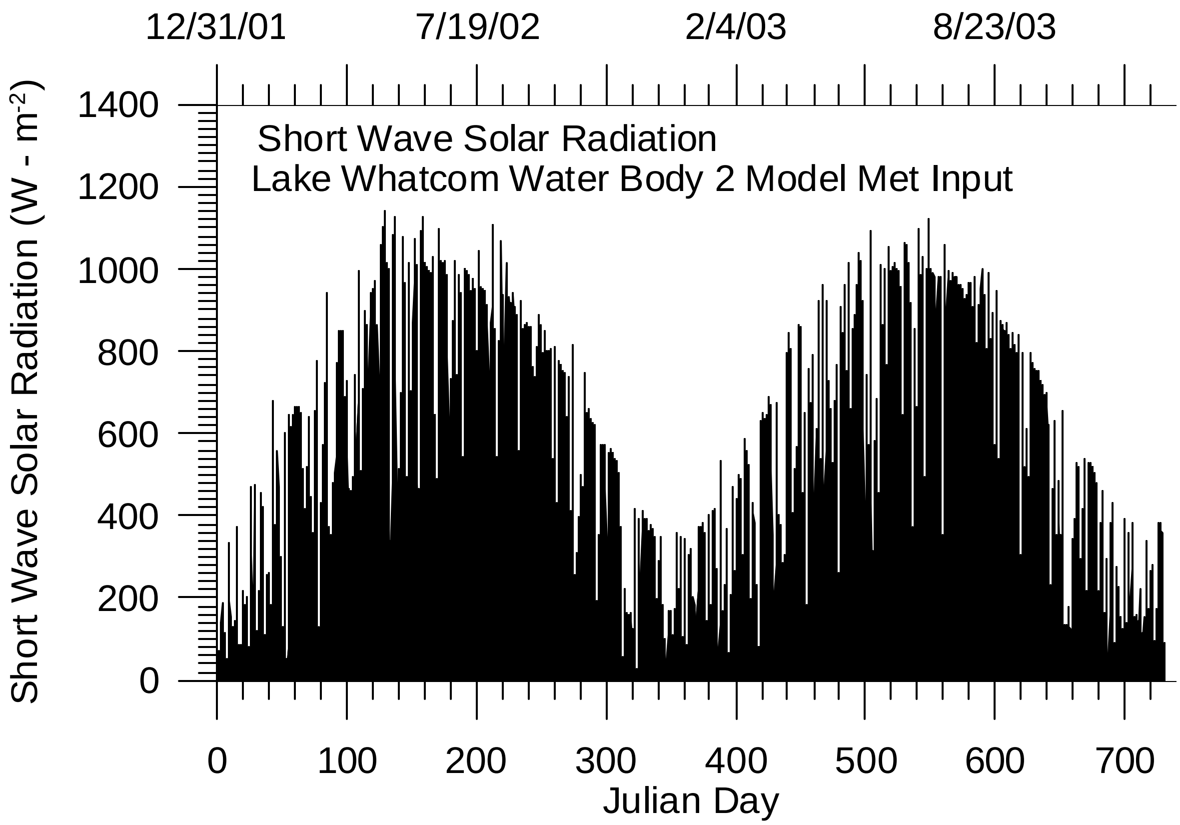

Figure 66. Short wave solar radiation for water body 2.

Groundwater

Groundwater flow rates and water quality were based on the Department of Ecology report "Lake Whatcom Total Maximum Daily Load Groundwater Study" (Pitz, 2005). Groundwater inflows were characterized in 3 shoreline sections: Agate Bay shoreline, South Bay/Anderson Creek shoreline, and the bedrock terrain shoreline which represented all the remaining shoreline area (Figure 67). The groundwater flow rates of these shoreline areas were listed in Table 5.

Table 5. Groundwater flow rates of shoreline areas.

Shoreline Area	Flow Rate (m^3/s)
Agate Bay Shoreline	0.073
South Bay/Anderson Creek Shoreline	0.169
Bedrock Terrane (remain shoreline)	0.147
Total	0.388

The groundwater inflows were characterized using point source tributaries and distributed tributaries in the model. For the Agate Bay shoreline area, a distributed tributary in branch 3 was applied. A distributed tributary in branch 2 and a single tributary into segment 2 were used for the South Bay/Anderson groundwater inflow. The bedrock terrane inflows were described using a distributed inflow into branch 4 and 7 point source tributaries in branch 1. Point source tributaries in branch 1 were used to describe the bedrock terrane inflows because the distributed tributary had been used for the water balance flow. Table 6 lists the point source tributaries and distributed tributaries which were used to characterize the groundwater inflows.

Table 6. Point source tributaries and distributed tributaries used to characterize groundwater inflows.

Type	Shoreline	Segment or Branch #	Flow rate (m^3/s)
Distributed Tributary	Agate Bay	Branch 3	0.0729
Distributed Tributary	South Bay/Anderson	Branch 2	0.0843
Point Source Tributary	South Bay/Anderson	Segment 2	0.0843
Point Source Tributary	Bedrock Terrane	Segment 4	0.0153
Point Source Tributary	Bedrock Terrane	Segment 8	0.0153
Point Source Tributary	Bedrock Terrane	Segment 12	0.0153
Point Source Tributary	Bedrock Terrane	Segment 16	0.0153
Point Source Tributary	Bedrock Terrane	Segment 20	0.0153
Point Source Tributary	Bedrock Terrane	Segment 24	0.0153
Point Source Tributary	Bedrock Terrane	Segment 28	0.0153
Distributed Tributary	Bedrock Terrane	Branch 4	0.0396

Groundwater constituent concentrations were based on geomeans of data measured in each shoreline area (Pitz, 2005). Table 7 list the constituent concentrations used for each shoreline area.

Table 7. Constituent concentrations used for groundwater inflows

Constituent	Unit of Measure	Agate Bay	South Bay/Anderson	Bedrock Terrane
DO	mg/L	0.9	0.9	0.9
TDS	mg/L	149	86	214
Chloride	mg/L	2.89	1.95	7.56
Conductivity	uS/cm	204	116	328
Ammonia-N	mg/L	0.347	0.259	0.183
Nitrate-N	mg/L	0.005	0.005	0.005
OP	mg/L	0.082	0.095	0.038
Alkalinity	mg/L	20	20	20
Inorganic C	mg/L	6.63	6.63	5.72
LDOM P	mg/L	0.0465	0.031	0.05
RDOM P	mg/L	0.0465	0.031	0.05
LDOM	mg/L	9.3	6.2	10
RDOM	mg/L	9.3	6.2	10

Groundwater temperatures were estimated using Whatcom remediation site temperatures (Figure 68).

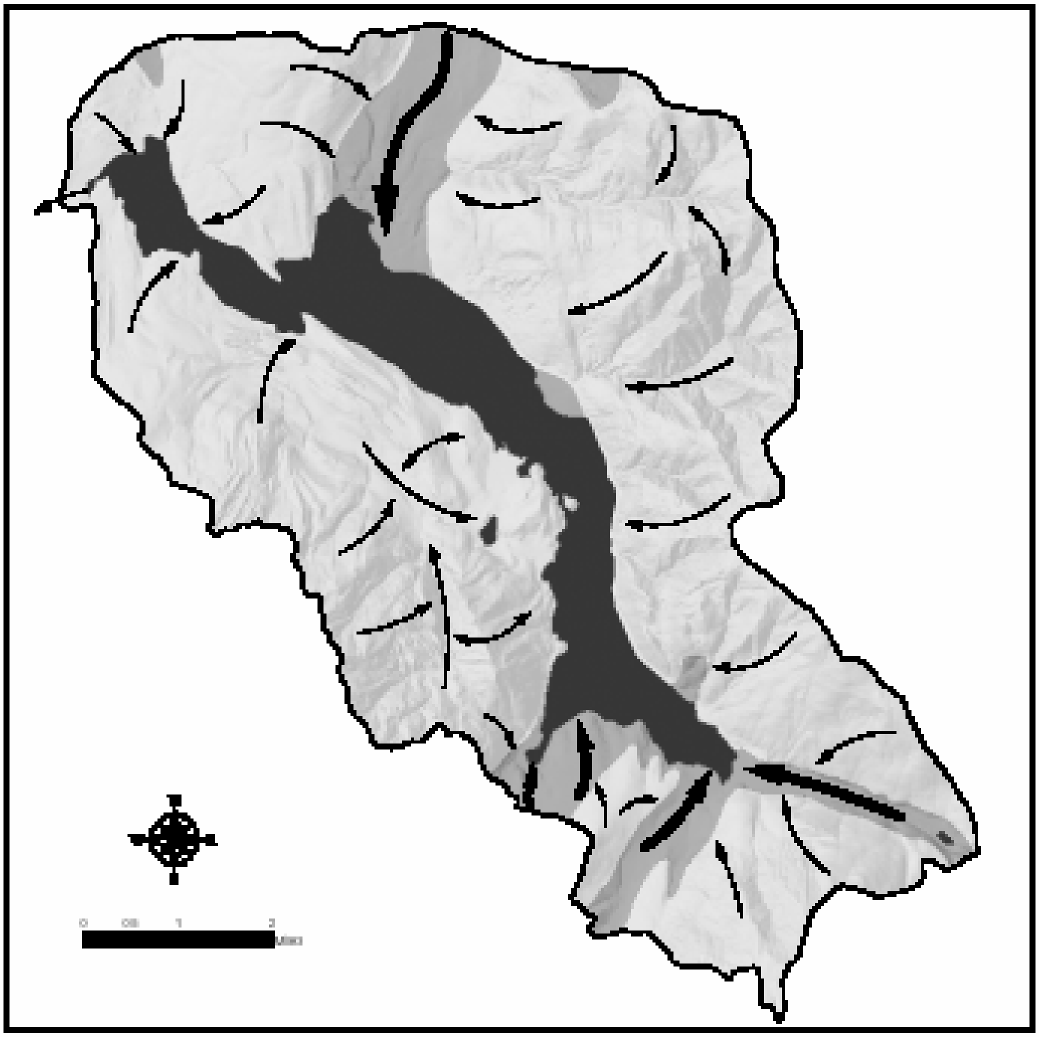

Figure 67. Flows and Water Quality Based on Ecology's "Lake Whatcom TMDL Groundwater Study", (Pitz, 2005)

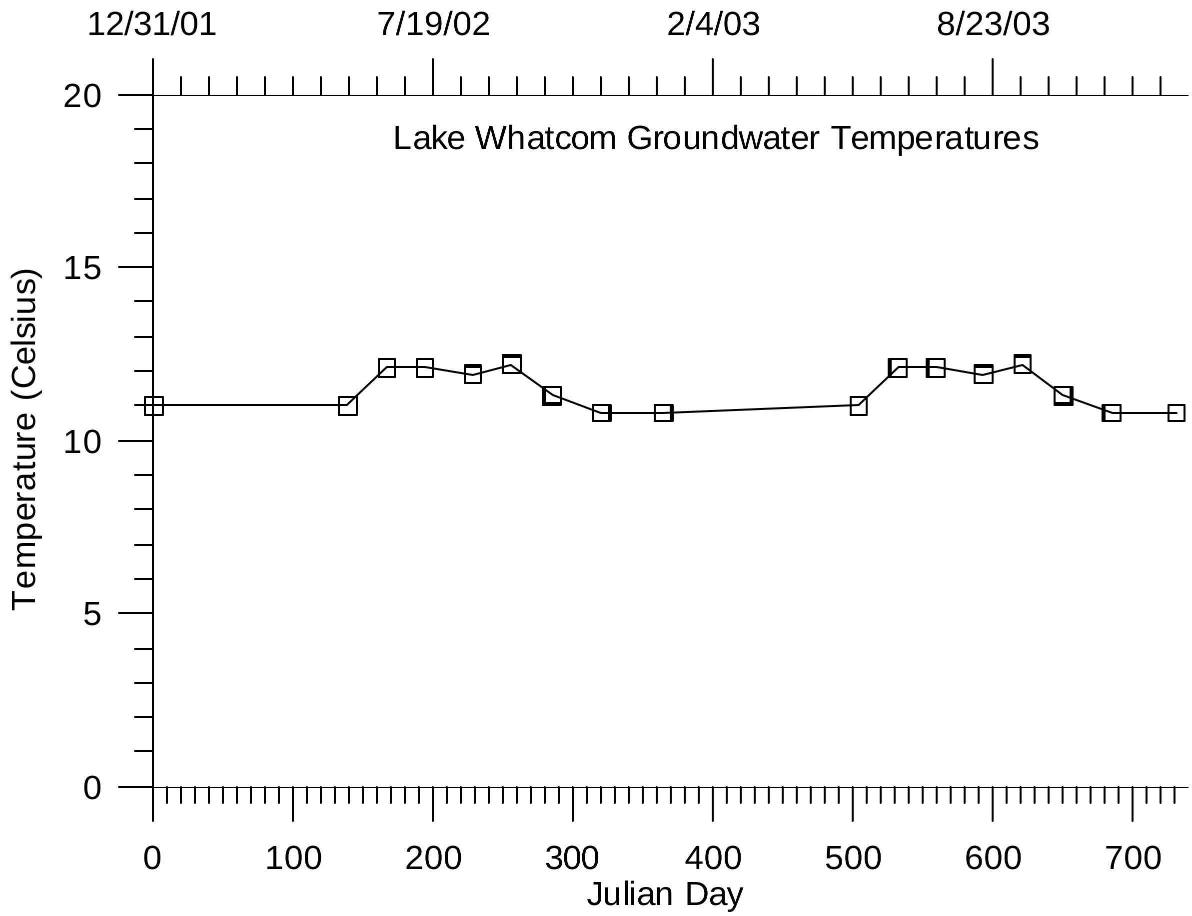

Figure 68. Groundwater temperatures.

Precipitation

Precipitation rates were developed from data collected at the Geneva Gate House, Smith, and Brannian gauges. Although the precipitation rate files were created for each water body, CE-QUAL-W2 requires precipitation files for every branch. Table 8 summarizes the steps taken in creating a precipitation rate file for each water body. The precipitation rates for each water body were shown in Figure 69.

Table 8. Steps taken in creating precipitation rate files.

Water Body	Inflow file
1 (branches 1, 2, and 3)	Used the following weighting factors provided by Western Washington University to calculate precipitation: Smith gage: 0.4610 Brannian gage: 0.3146
2 (branches 4 and 5)	Used data collected at Geneva Gate House, except for period from 5/2/02 to 5/8/02 when data at Geneva were missing and a regression between Geneva and Smith was used to fill in the data

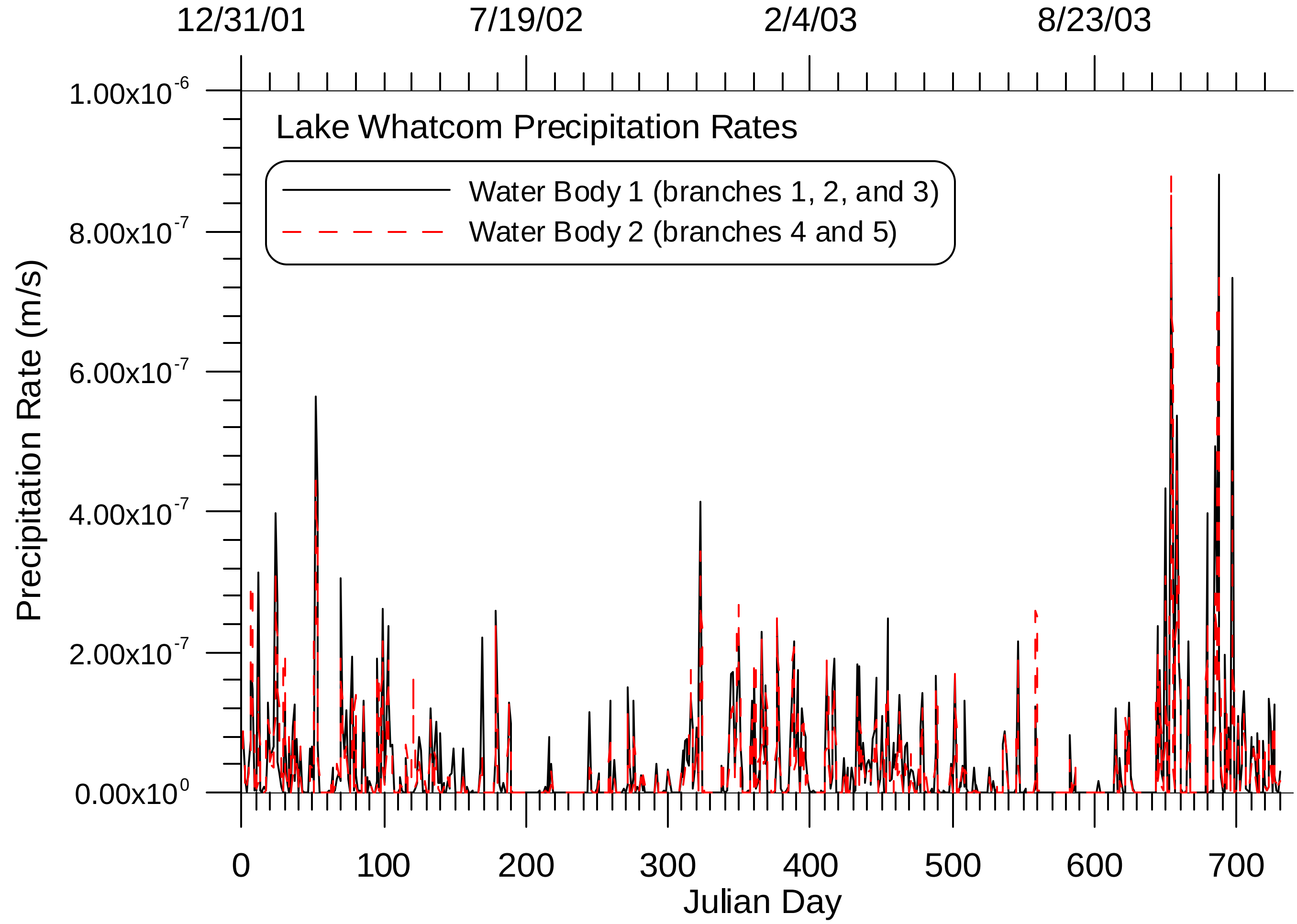

Figure 69. Precipitation rates for water body 1 and water body 2.

The precipitation temperature was assumed to be equal to air temperature. The precipitation temperature for branches 1, 3, 4 and 5 was assumed to be the average of the air temperatures at the Smith and Brannian meteorological stations. For branch 2 the precipitation was assumed to be equal to the air temperature measured at Brannian.

Precipitation constituent concentrations varied seasonally and data collected by the USGS National Atmospheric Deposition Program were used to create the time series input file. Figure 70 through Figure 73 show the constituent concentrations for precipitation.

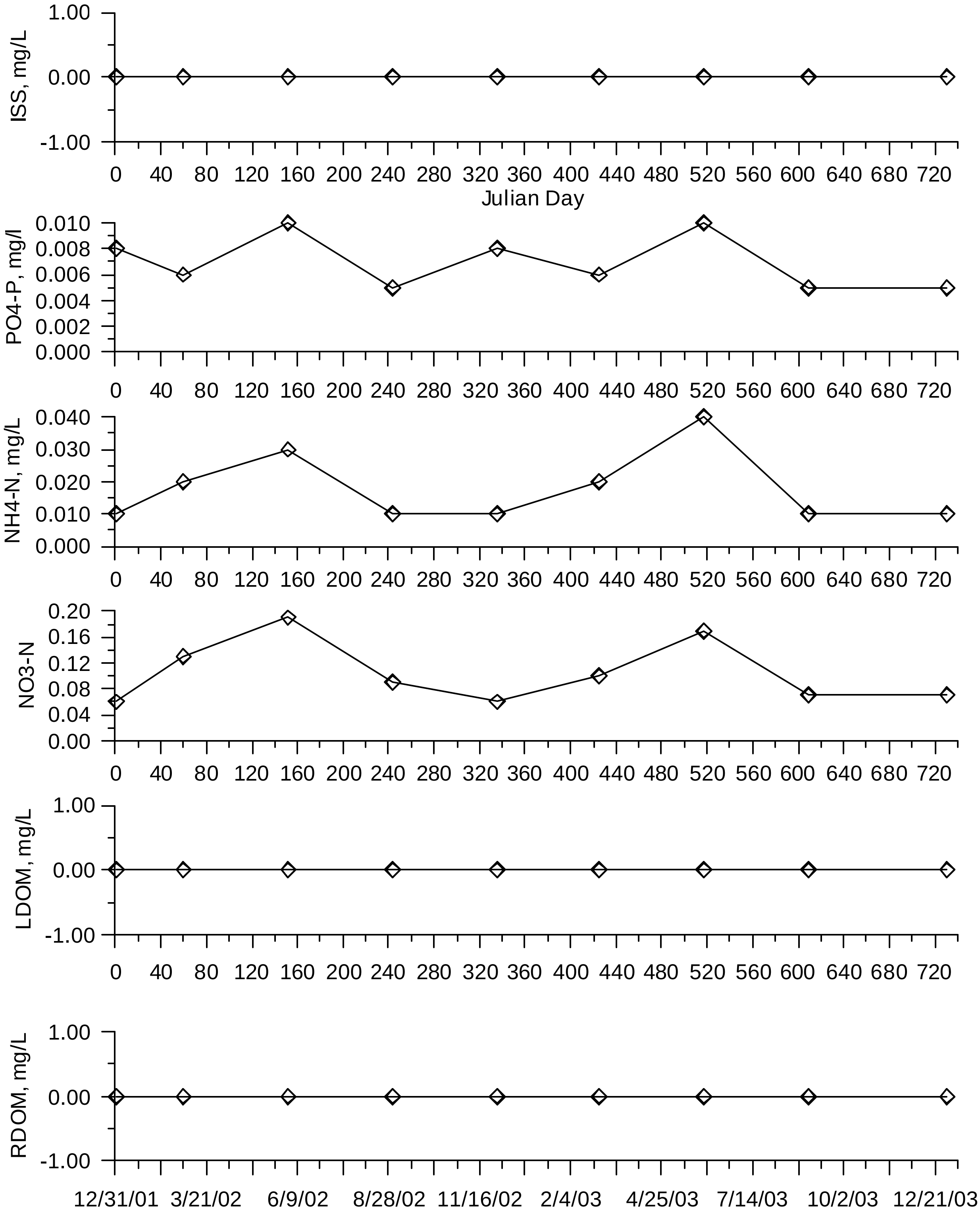

Figure 70. Constituent concentrations for precipitation.

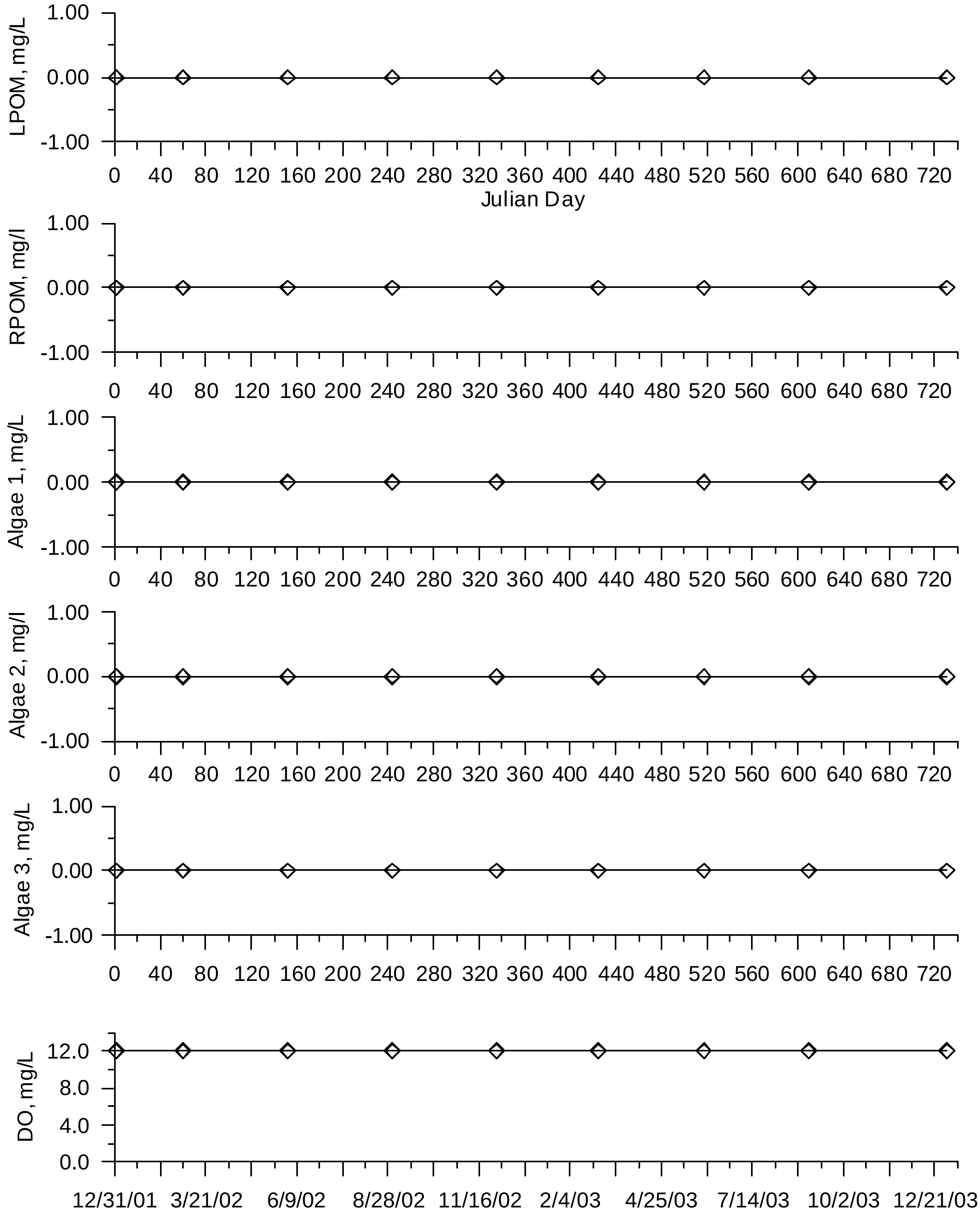

Figure 71. Constituent concentrations for precipitation (continued).

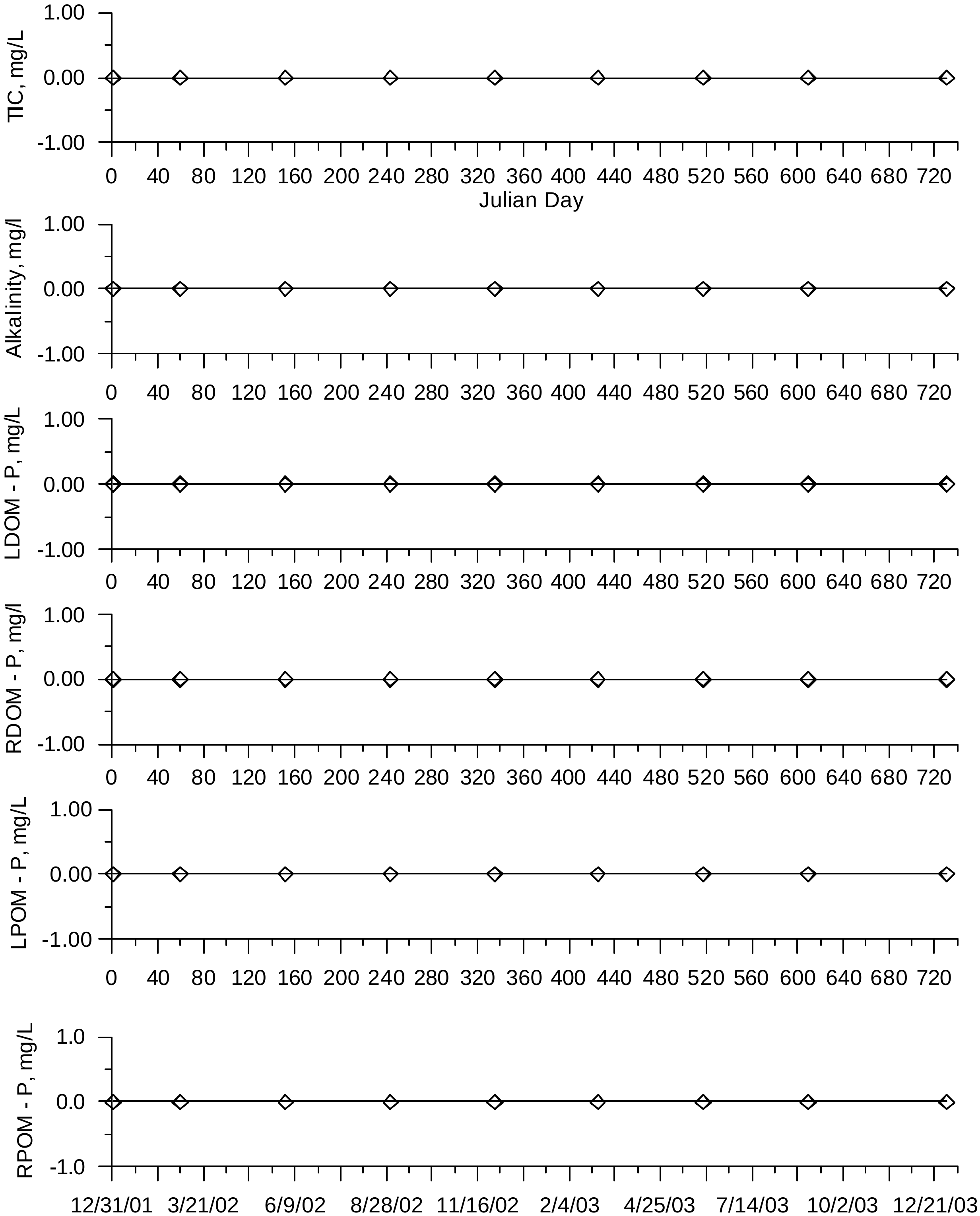

Figure 72. Constituent concentrations for precipitation (continued).

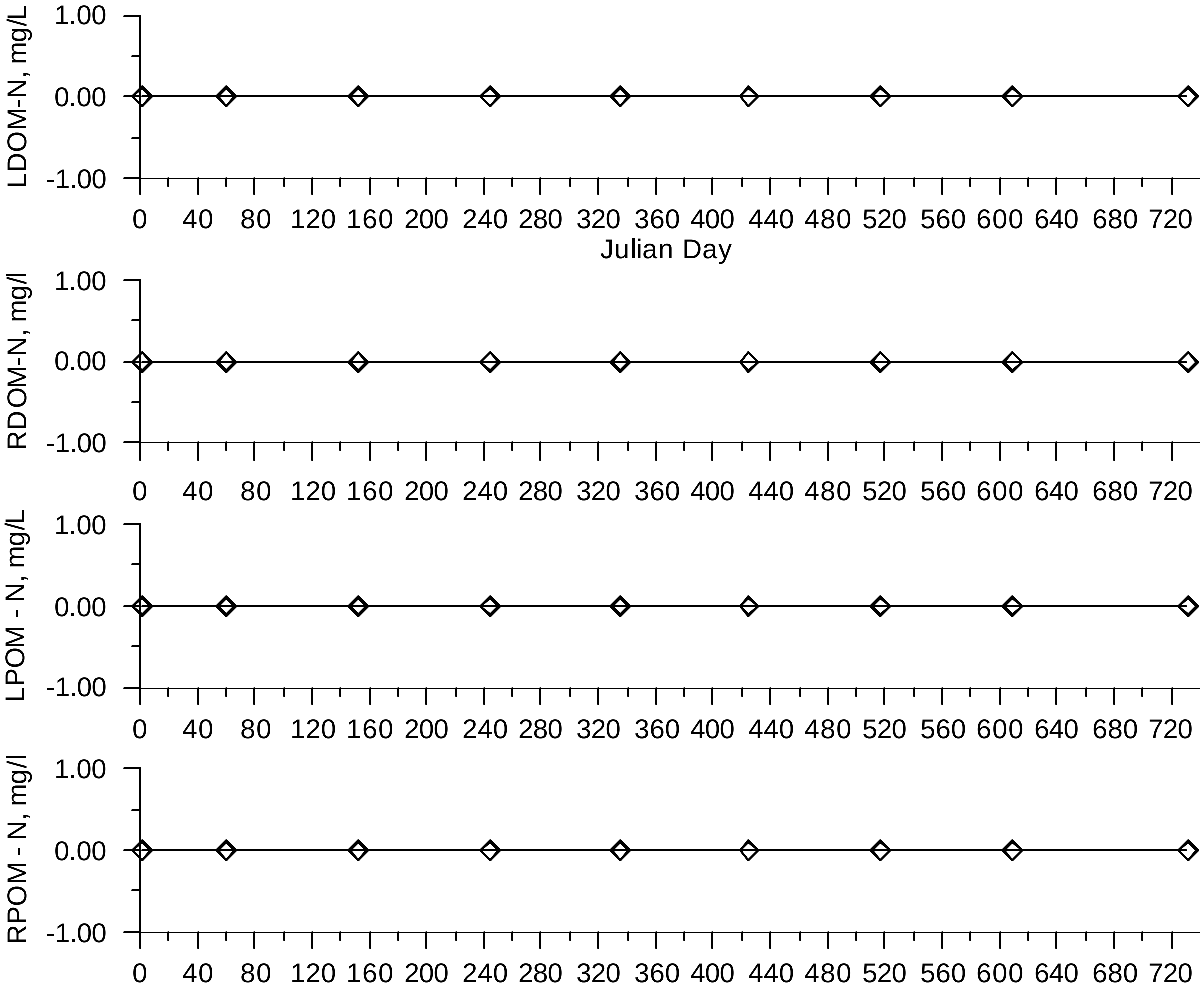

Figure 73. Constituent concentrations for precipitation (continued).

Withdrawals

Withdrawals simulating the water district 10 intake, the combined City and Georgia Pacific intake, and the fish hatchery intake were simulated. These withdrawals are listed in Table 9 and their flow rates were plotted in Figure 74. Flow rate data were obtained from the City of Bellingham.

Table 9. List of Lake Whatcom withdrawals.

Withdrawal #	Description	Model Segment	Intake elevation (m)
1	Water District 10	17	74.5
2	City and Georgia Pacific	54	83.5
3	Fish Hatchery	63	94.5

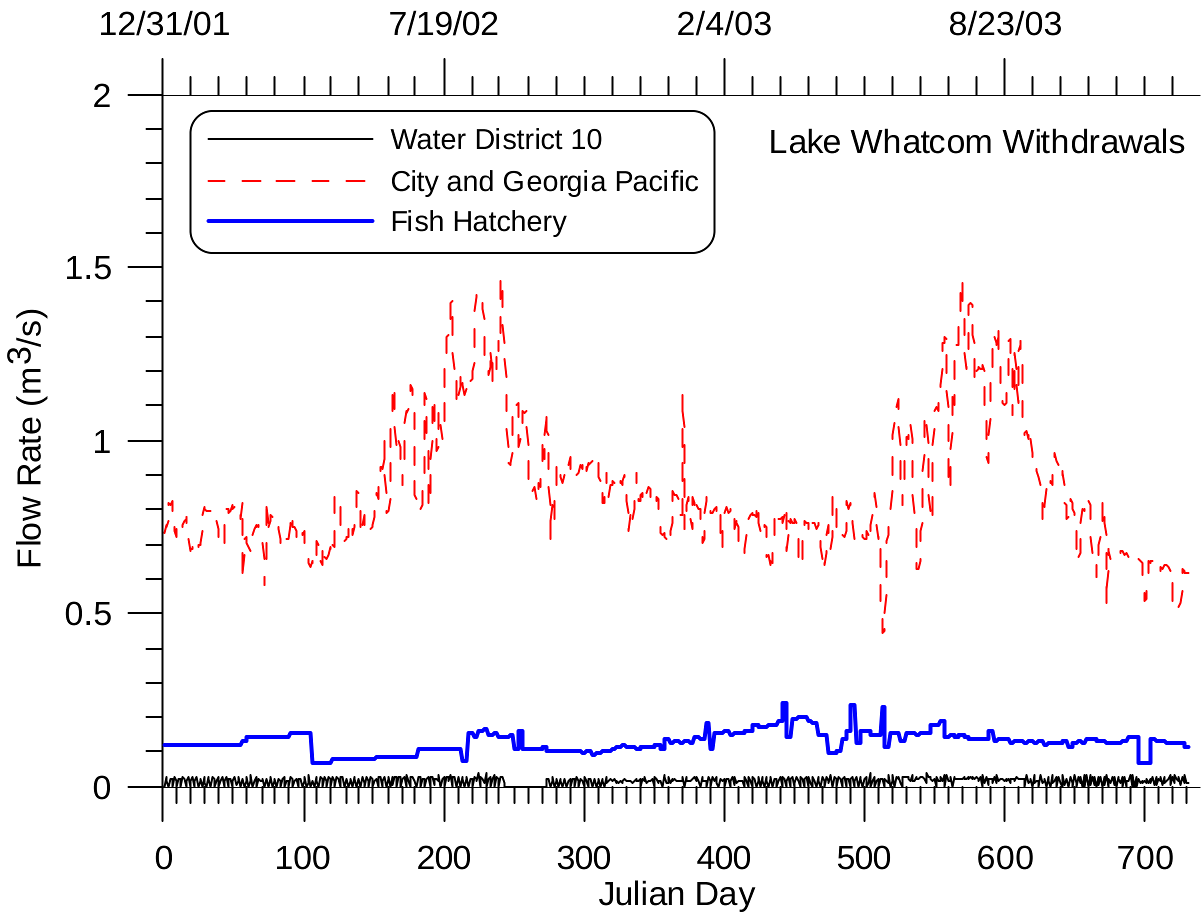

Figure 74. Lake Whatcom withdrawals.

Hydrodynamic Calibration

Water level data provided by the City of Bellingham were compared with model results were shown in Figure 75. Table 10 shows water level statistics. Water levels were calibrated by adding a distributed flow file for branch 1 to compensate for the error in inflow/outflow measurements and to also account for inflows and/or losses directly into the lake.

Table 10. Water level error statistics.

n, # of data comparisons	Mean Error M	Absolute Mean Error m	Root Mean Square Error m
685	-0.014	0.017	0.021

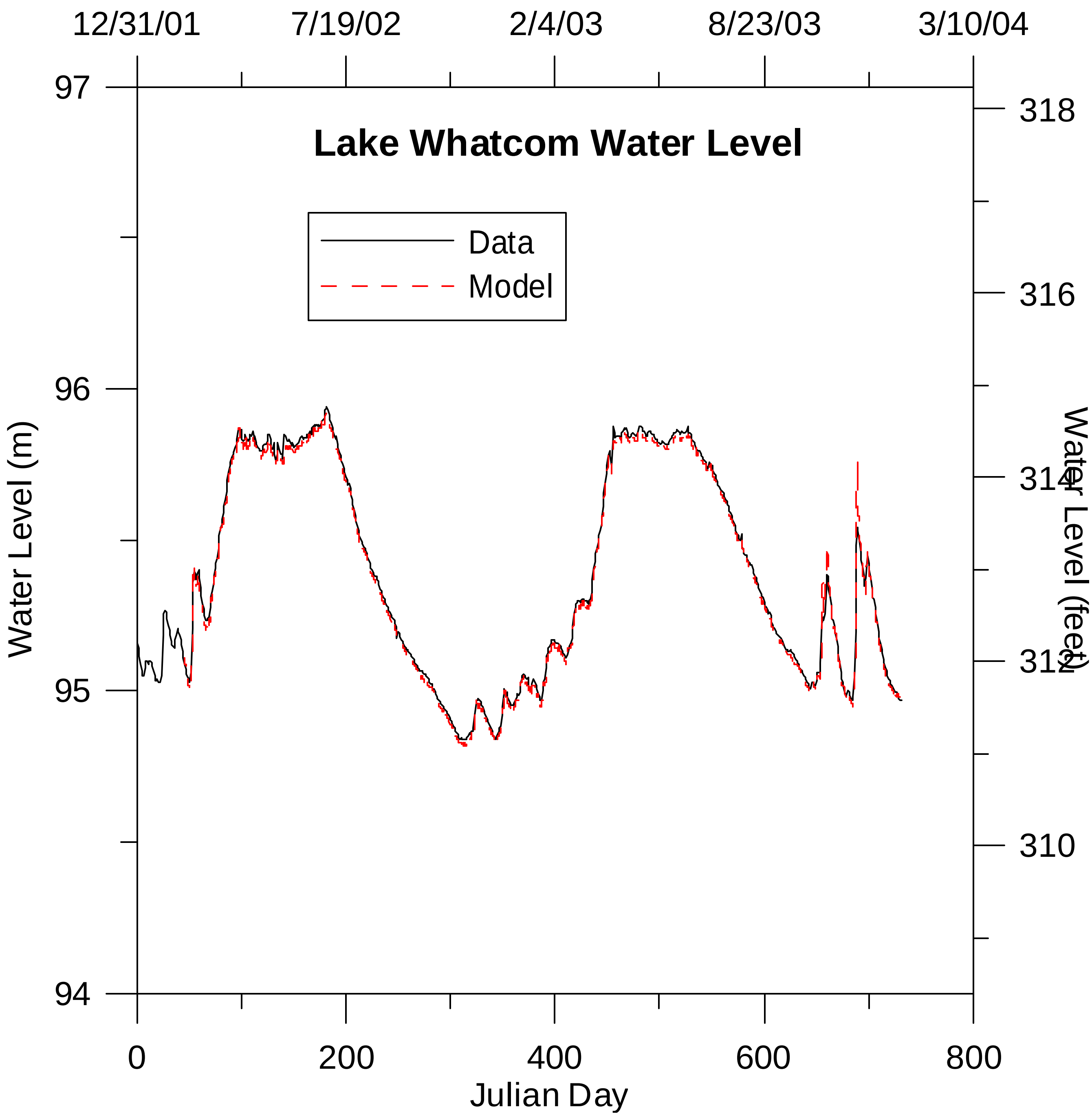

Figure 75. Water level prediction compared with data for Lake Whatcom.

Temperature Calibration

The primary model parameters affecting temperature calibration was wind sheltering coefficients. Comparisons between model predictions and temperatures were shown in Appendix B. Table 11 list error statistics between model predictions and data for all the sampling locations in the lake. The root mean square error average was less than 1 degrees Celsius for all sites. Figure 76 shows the correlation between model predictions and data. The r-squared value for model versus data was 0.995.

Table 11. Temperature profile error statistics.

Site	Mean Error (Celsius)	Absolute Mean Error (Celsius)	Root Mean Square Error (Celsius)
LW1	-0.10	0.67	0.78
LW2	0.03	0.55	0.67
LW3	-0.20	0.47	0.60
LW4	-0.22	0.58	0.69
Intake	-0.19	0.44	0.49
Average	-0.14	0.54	0.64

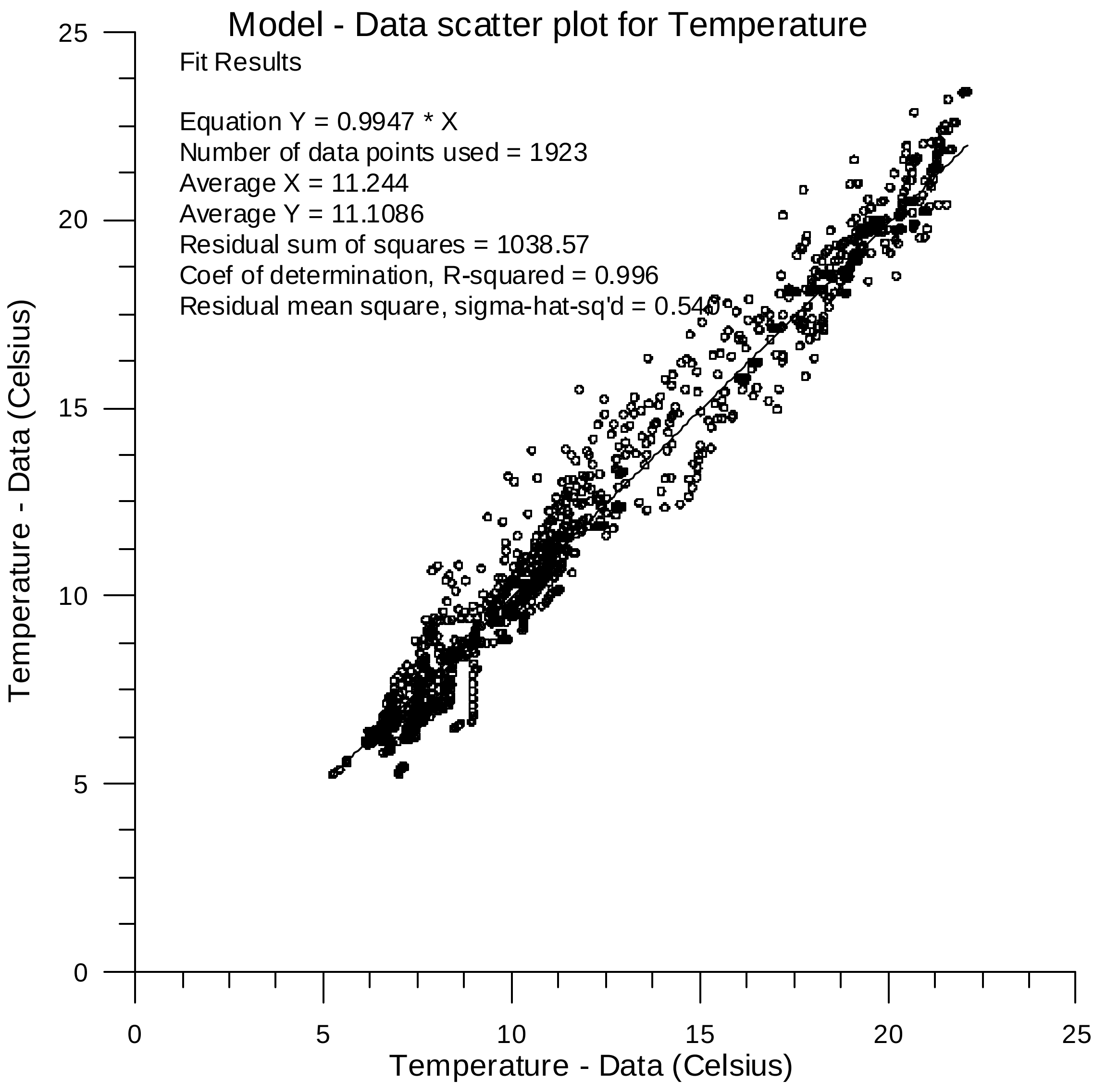

Figure 76. Model versus data scatter plot for temperature.

Water Quality Calibration

The calibrated water quality coefficients were shown in Table 12.

Table 12. W2 Model Water Quality Parameters

Variable	Description	Units	Typical values*	Initial Calibrati on Values
Hydrodynamics and Longitudinal Transport				
AX	Longitudinal eddy viscosity (for momentum dispersion)	m^2/sec	1	1
DX	Longitudinal eddy diffusivity (for dispersion of heat and constituents)	m^2/sec	1	1
Temperature				
CBHE	Coefficient of bottom heat exchange	Wm^2/sec	0.30	0.30
TSED	Sediment (ground) temperature	^oC	12.8	11.5
WSC	Wind sheltering coefficient		0.85	0.8-3.3
BETA	Fraction of incident solar radiation absorbed at the water surface		0.45	0.45
Water Quality				
EXH20	Extinction for water	/m	0.25	0.25
EXSS	Extinction due to inorganic suspended solids	m^3/m/g	0.01	0.1
EXOM	Extinction due to organic suspended solids	m^3/m/g	0.17	0.1
EXA	Extinction due to organic algal type 1	m^3/m/g	0.1	0.1
SSS	Suspended solids settling rate	m/day	2	1.5
AG1	Algal growth rate for algal type 1	/day	1.1	1.65
AM1	Algal mortality rate for algal type 1	/day	0.01	0.04
AE1	Algal excretion rate for algal type 1	/day	0.01	0.04
AR1	Algal dark respiration rate for algal type 1	/day	0.02	0.04
AS1	Algal settling rate for algal type 1	/day	0.14	0.1
ASAT1	Saturation intensity at	W/m^2	150	50

Variable	Description	Units	Typical values*	Initial Calibration Values
	maximum photosynthetic rate for algal type 1			
APOM1	Fraction of algal biomass lost by mortality to detritus for algal type 1		0.8	0.8
AT11	Lower temperature for algal growth for algal type 1	^oC	10	1
AT21	Lower temperature for maximum algal growth for algal type 1	^oC	30	3
AT31	Upper temperature for maximum algal growth for algal type 1	^oC	35	12
AT41	Upper temperature for algal growth for algal type 1	^oC	40	25
AK11	Fraction of algal growth rate at ALGT1 for algal type 1		0.1	0.5
AK21	Fraction of maximum algal growth rate at ALGT2 for algal type 1		0.99	0.99
AK31	Fraction of maximum algal growth rate at ALGT3 for algal type 1		0.99	0.99
AK41	Fraction of algal growth rate at ALGT4 for algal type 1		0.1	0.1
ALGP-A1	Stoichiometric equivalent between organic matter and phosphorus for algal type 1		0.011	0.003
ALGN-A1	Stoichiometric equivalent between organic matter and nitrogen for algal type 1		0.08	0.06
ALGC-A1	Stoichiometric equivalent between organic matter and carbon for algal type 1		0.45	0.60
AG2	Algal growth rate for algal type 2	/day	1.1	1.9
AM2	Algal mortality rate for algal type 2	/day	0.01	0.04
AE2	Algal excretion rate for algal type 2	/day	0.01	0.04
AR2	Algal dark respiration rate for algal type 2	/day	0.02	0.04

Variable	Description	Units	Typical values*	Initial Calibration Values
AS2	Algal settling rate for algal type 2	/day	0.14	0.1
ASAT2	Saturation intensity at maximum photosynthetic rate for algal type 2	W/m^2	150	75
APOM2	Fraction of algal biomass lost by mortality to detritus for algal type 2		0.8	0.8
AT12	Lower temperature for algal growth for algal type 2	^oC	10	8
AT22	Lower temperature for maximum algal growth for algal type 2	^oC	30	12
AT32	Upper temperature for maximum algal growth for algal type 2	^oC	35	16
AT42	Upper temperature for algal growth for algal type 2	^oC	40	30
AK12	Fraction of algal growth rate at ALGT1 for algal type 2		0.1	0.1
AK22	Fraction of maximum algal growth rate at ALGT2 for algal type 2		0.99	0.6
AK32	Fraction of maximum algal growth rate at ALGT3 for algal type 2		0.99	0.99
AK42	Fraction of algal growth rate at ALGT4 for algal type 2		0.1	0.1
ALGP-A2	Stoichiometric equivalent between organic matter and phosphorus for algal type 2		0.011	0.0025
ALGN-A2	Stoichiometric equivalent between organic matter and nitrogen for algal type 2		0.08	0.06
ALGC-A2	Stoichiometric equivalent between organic matter and carbon for algal type 2		0.45	0.60
AG3	Algal growth rate for algal type 2	/day	1.1	2.0
AM3	Algal mortality rate for algal type 2	/day	0.01	0.04
AE3	Algal excretion rate for	/day	0.01	0.04

Variable	Description	Units	Typical values*	Initial Calibration Values
	algal type 2			
AR3	Algal dark respiration rate for algal type 2	/day	0.02	0.04
AS3	Algal settling rate for algal type 2	/day	0.14	0.01
ASAT3	Saturation intensity at maximum photosynthetic rate for algal type 2	W/m^2	150	130
APOM3	Fraction of algal biomass lost by mortality to detritus for algal type 2		0.8	0.8
AT13	Lower temperature for algal growth for algal type 2	^oC	10	8
AT23	Lower temperature for maximum algal growth for algal type 2	^oC	30	16
AT33	Upper temperature for maximum algal growth for algal type 2	^oC	35	20
AT43	Upper temperature for algal growth for algal type 2	^oC	40	30
AK13	Fraction of algal growth rate at ALGT1 for algal type 2		0.1	0.1
AK23	Fraction of maximum algal growth rate at ALGT2 for algal type 2		0.99	0.60
AK33	Fraction of maximum algal growth rate at ALGT3 for algal type 2		0.99	0.99
AK43	Fraction of algal growth rate at ALGT4 for algal type 2		0.1	0.1
ALGP-A3	Stoichiometric equivalent between organic matter and phosphorus for algal type 2		0.011	0.002
ALGN-A3	Stoichiometric equivalent between organic matter and nitrogen for algal type 2		0.08	0.06
ALGC-A2	Stoichiometric equivalent between organic matter and carbon for algal type 2		0.45	0.60
LDOMDK	Labile DOM decay rate	/day	0.12	WB1:0.060 WB2:0.120

Variable	Description	Units	Typical values*	Initial Calibration Values
LRDDK	Labile to refractory decay rate	/day	0.001	0.01
RDOMDK	Maximum refractory decay rate	/day	0.001	0.001
LPOMDK	Labile Detritus decay rate	/day	0.06	WB1:0.020 WB2:0.040
POMS	Detritus settling rate	m/day	0.35	WB1:1.0 WB2:0.5
RPOMDK	Refractory Detritus decay rate	/day		0.001
OMT1	Lower temperature for organic matter decay	^oC	4	2
OMT2	Lower temperature for maximum organic matter decay	^oC	20	20
OMK1	Fraction of organic matter decay rate at OMT1		0.1	0.4
OMK2	Fraction of organic matter decay rate at OMT2		0.99	0.99
SEDK	Sediment decay rate	/day	0.06	WB1:0.001 WB2:0.004
PARTP	Phosphorous partitioning coefficient for suspended solids		1.2	0
AHSP1	Algal half-saturation constant for phosphorous – algae 1	g/m	0.009	0.002
AHSP2	Algal half-saturation constant for phosphorous – algae 2	g/m	0.009	0.0025
AHSP3	Algal half-saturation constant for phosphorous – algae 3	g/m	0.009	0.002
NH4DK	Ammonia decay rate (nitrification rate)	/day	0.12	0.3
AHSN	Algal half-saturation constant for ammonia	g/m^3	0.014	0.014
NH4T1	Lower temperature for ammonia decay	^oC	5	5
NH4T2	Lower temperature for maximum ammonia decay	^oC	20	25
NH4K1	Fraction of nitrification rate at NH4T1		0.1	0.1
NH4K2	Fraction of nitrification rate at NH4T2		0.99	0.99

Variable	Description	Units	Typical values*	Initial Calibration Values
NO3DK	Nitrate decay rate (denitrification rate)	/day	0.102	0.05
NO3T1	Lower temperature for nitrate decay	^oC	5	5
NO3T2	Lower temperature for maximum nitrate decay	^oC	20	25
NO3K1	Fraction of denitrification rate at NO3T1		0.1	0.1
NO3K2	Fraction of denitrification rate at NO3T2		0.99	0.99
O2NH4	Oxygen stoichiometric equivalent for ammonia decay		4.57	4.57
O2OM	Oxygen stoichiometric equivalent for organic matter decay		1.4	1.4
O2AR	Oxygen stoichiometric equivalent for dark respiration		1.4	1.1
O2AG	Oxygen stoichiometric equivalent for algal growth		1.4	1.8
ORGP	Stoichiometric equivalent between organic matter and phosphorus		0.011	WB1:0.0002 WB2:0.004
ORGN	Stoichiometric equivalent between organic matter and nitrogen		0.08	0.08
ORGC	Stoichiometric equivalent between organic matter and carbon		0.45	0.45
O2LIM	Dissolved oxygen concentration at which anaerobic processes begin	g/m^3	0.05	0.1
* Cole and Wells (2000)				

The constituent model-error statistics for all sites were included in Table 13 through Table 17. Statistics calculated include mean error (ME), absolute mean error (AME), and root mean square error (RMS). The statistics for all the sites were summarized in Table 18. Appendix B contains all the vertical profile model versus data comparisons. Scatter plots showing the model versus data comparisons were shown for dissolved oxygen and chlorophyll a in Figure 77 and Figure 78.

The percentage bio-volumes of the 3 algae groups were also compared with vertical profile data. **Error! Reference source not found.** through **Error! Reference source not found.** in Appendix B show the model predicted bio-volumes and data. The algae 1 compartment simulates Chrysophyta (mostly diatoms), the algae 2 compartment simulates Chlorophyta (greens), and the algae 3 compartment represents cyanobacteria (blue-greens). Algae data were obtained from the Washington Department of Ecology and Western Washington University (Deluna, 2004).

Table 13. Constituent error statistics for site LW1.

parameter	LW1 Mean Error (segment 61)	LW1 Absolute Mean Error (segment 61)	LW1 Root Mean Square Error (segment 61)
PO4-P (mg/l)	-0.0001	0.0027	0.0032
NH4-N (mg/l)	-0.0066	0.0253	0.0314
NOx-N (mg/l)	0.009	0.045	0.048
D. O. (mg/l)	0.267	0.813	1.02
Alkalinity (mg/l)	-1.86	1.86	2
TPN (mg/l)	-0.056	0.060	0.065
TP (mg/l)	-0.0035	0.0054	0.0065
Chlorophyll a	0.54	1.11	1.26
pH__	-0.03	0.26	0.32

Table 14. Constituent error statistics for site LW2.

parameter	LW2 ME (segment 52)	LW2 AME (segment 52)	LW2 RMS (segment 52)
PO4-P (mg/l)	-0.0009	0.0022	0.0024
NH4-N (mg/l)	-0.0069	0.0163	0.0242
NOx-N (mg/l)	-0.025	0.049	0.053
D. O. (mg/l)	0.203	0.538	0.624
Alkalinity (mg/l)	-1.02	1.09	1.29
TPN (mg/l)	-0.085	0.085	0.098
TP (mg/l)	-0.0020	0.0037	0.0047
Chlorophyll a	0.21	0.86	1.01
pH__	-0.01	0.18	0.21

Table 15. Constituent model-error statistics for site LW3.

Parameter	LW3 ME (segment 25)	LW3 AME (segment 25)	LW3 RMS (segment 25)
PO4-P (mg/l)	-0.0012	0.0016	0.0018
NH4-N (mg/l)	0.0003	0.0044	0.0055
NOx-N (mg/l)	-0.017	0.044	0.050
D. O. (mg/l)	0.409	0.602	0.706
Alkalinity (mg/l)	-0.451	0.545	0.616
TPN (mg/l)	-0.054	0.063	0.068
TP (mg/l)	-0.0016	0.0036	0.0041
Chlorophyll a	-0.16	0.91	0.99
pH__	0.03	0.14	0.17

Table 16. Constituent model-error statistics for site LW4.

Parameter	LW4 ME (segment 11)	LW4 AME (segment 11)	LW4 RMS (segment 11)
PO4-P (mg/l)	-0.0009	0.0015	0.0017
NH4-N (mg/l)	0.0003	0.0035	0.0044
NOx-N (mg/l)	-0.014	0.039	0.045
D. O. (mg/l)	0.44	0.703	0.783
Alkalinity (mg/l)	-0.39	0.506	0.597

Parameter	LW4 ME (segment 11)	LW4 AME (segment 11)	LW4 RMS (segment 11)
TPN (mg/l)	-0.051	0.059	0.063
TP (mg/l)	-0.0005	0.0033	0.0037
hlorophyll a	0.15	0.85	0.92
pH__	0.06	0.12	0.14

Table 17. Constituent model-error statistics for the intake site.

Parameter	INTAKE (segment 54)	INTAKE AME (segment 54)	INTAKE RMS (segment 54)
PO4-P (mg/l)	-0.0019	0.0019	0.0019
NH4-N (mg/l)	0.0036	0.0056	0.0058
NOx-N (mg/l)	-0.013	0.040	0.041
D. O. (mg/l)	0.203	0.57	0.598
Alkalinity (mg/l)	-0.7	0.788	0.794
TPN (mg/l)	-0.061	0.061	0.061
TP (mg/l)	-0.0007	0.0028	0.0028
Chlorophyll a	0.73	1.04	1.06
pH__	-0.09	0.25	0.26

Table 18. Constituent model-error statistics for all sites.

Parameter	Average ME	Average AME	average RMS
PO4-P (mg/l)	-0.0009	0.0015	0.0017
NH4-N (mg/l)	0.0003	0.0035	0.0044
NOx-N (mg/l)	-0.014	0.039	0.045
D. O. (mg/l)	0.44	0.703	0.783
Alkalinity (mg/l)	-0.39	0.506	0.597
TPN (mg/l)	-0.051	0.059	0.063
TP (mg/l)	-0.0005	0.0033	0.0037
Chlorophyll a	0.15	0.85	0.92
pH__	0.06	0.12	0.14

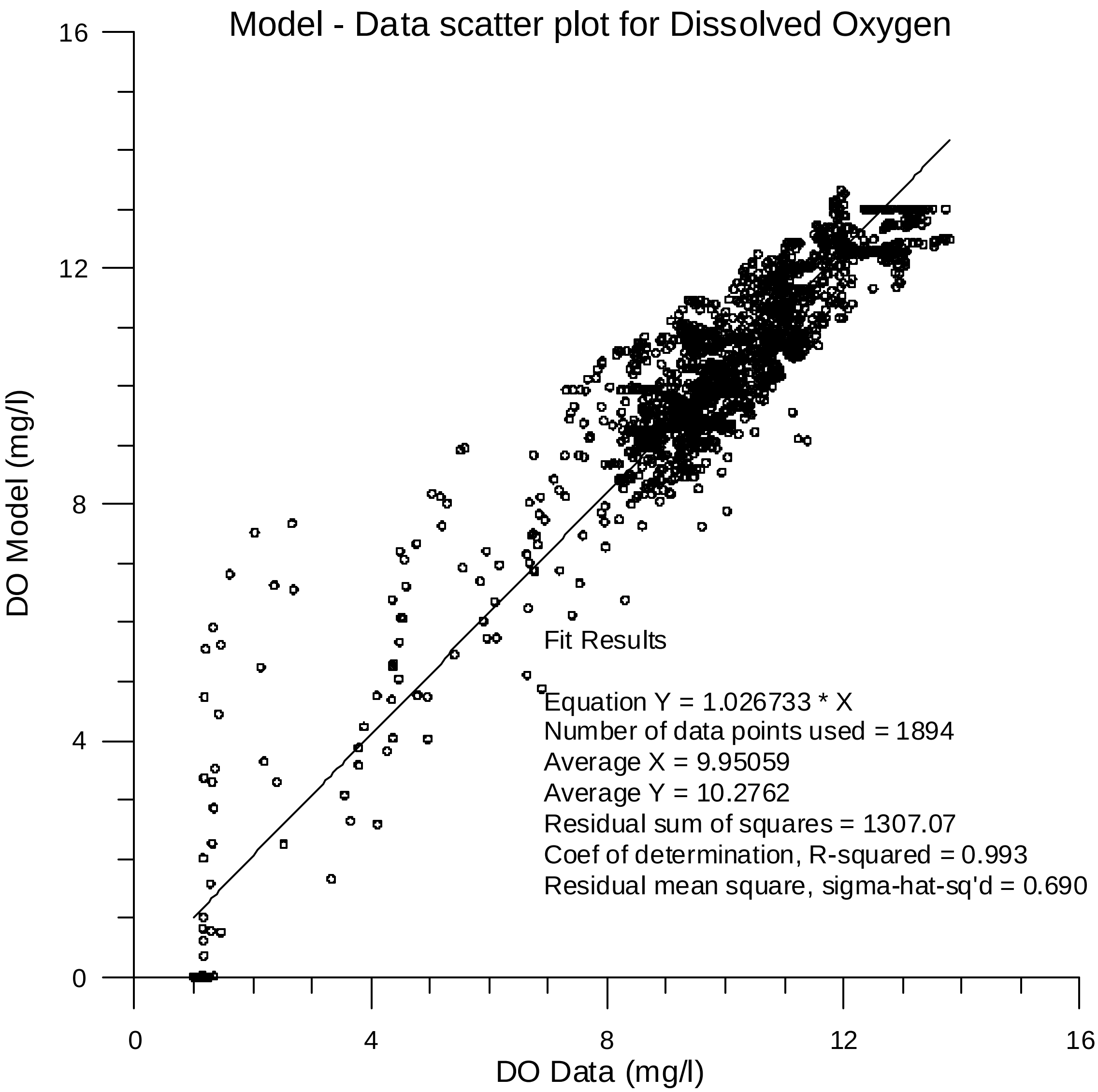

Figure 77. Model versus data scatter plot for dissolved oxygen.

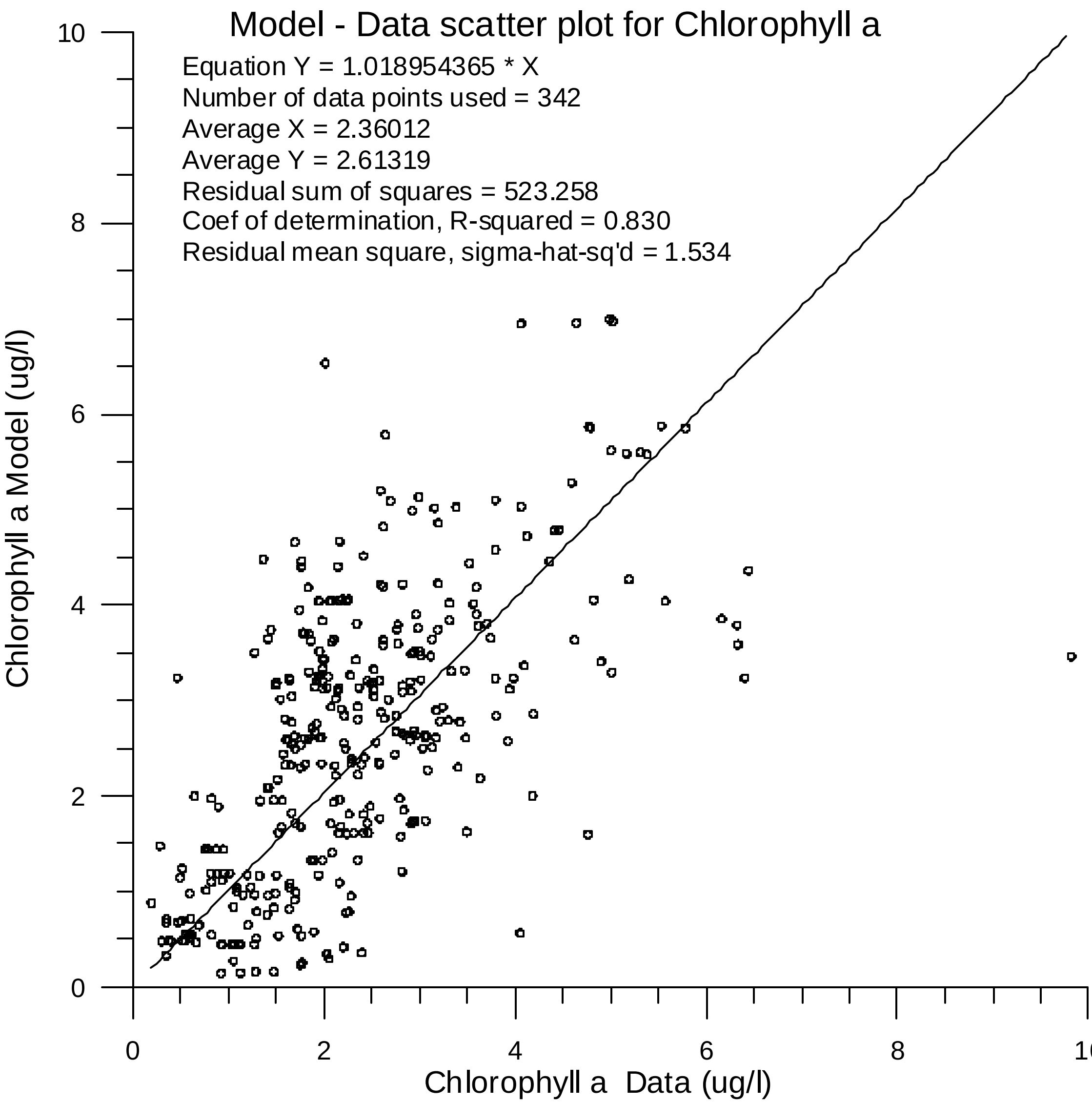

Figure 78. Model versus data scatter plot for chlorophyll a.

Scenarios

Model scenarios were simulated to determine the phosphorus loading needed to impact dissolved oxygen by 0.2 mg/l relative to natural conditions. The model scenarios were listed in Table 19. Tributary inputs for water quality, temperature, and flow were developed by the Washington Department of Ecology. The simulated time period was approximately 5 years from October 1, 1998 to December 31, 2003. The rollback scenario represented natural conditions and the buildout scenario corresponded to the loading that would occur if the Lake Whatcom watershed was developed. Partial rollback scenarios were simulated to determine the phosphorus loading necessary to reduce dissolved oxygen concentration by 0.2 mg/l at a critical time and point in the reservoir.

The bottom of basin 1 (segment 60) on 7/22/02 was selected as being the critical point or the time and location when dissolved oxygen concentration was decreased by a maximum amount relative to the rollback scenario. This time and location was selected by plotting the difference in dissolved oxygen concentrations between the rollback scenario and the base case and determine the time and location where this difference was greatest.

The phosphorus loading due to tributaries, groundwater inflows, and precipitation for the scenarios were shown in Table 20. Groundwater and precipitation phosphorus loading was the same for all scenarios. The tributary loadings were varied to help determine the phosphorus load at which dissolved oxygen concentration was affected by 0.2 mg/l at the bottom of basin 1 on 7/22/02.

Figure 79 shows the absolute value of dissolved oxygen difference plotted versus phosphorus loading of the scenarios. At a phosphorus loading of approximately 19000 kg, the dissolved oxygen concentration at the bottom of basin 1 will be affected by 0.2 mg/l. Table 21 shows the dissolved oxygen difference at the bottom of basin 1 for all the scenarios. A plot of the dissolved oxygen profile in basin 1 (segment 60) on 7/22/02 for the base case, rollback, buildout, and partial rollback run D was shown in Figure 80.

Table 19. Lake Whatcom scenario descriptions.

Scenario #	Name	Description	Phosphorus Load over simulation period (kg)
1	Base Case	5 year model simulation from October 1, 1998 to December 31, 2003.	22966
2	Rollback	Tributary loads “rolled back” to natural conditions	17719
3	Buildout	Tributary loads increased to build out conditions	26350
4	Partial Rollback A	P Load reduced to 18381 kg	18381
5	Partial Rollback B	P Load reduced to 19652 kg	19652
6	Partial Rollback C	P Load reduced to 19930 kg	19330
7	Partial Rollback D	P Load reduced to 19001 kg	19001

Table 20. Phosphorus loading from tributaries, groundwater, and precipitation for the scenarios.

Scenario	Tributaries (kg)	Groundwater (kg)	Precipitation (kg)	Total (kg)
Rollback	6730.6	9699.4	1288.7	17719
Partial Rollback A	7392.4	9699.4	1288.7	17719
Partial Rollback B	8663.6	9699.4	1288.7	17719
Partial Rollback C	8342.1	9699.4	1288.7	17719
Partial Rollback D	8013.2	9699.4	1288.7	17719
Base	11978.1	9699.4	1288.7	17719
Buildout	15361.7	9699.4	1288.7	17719

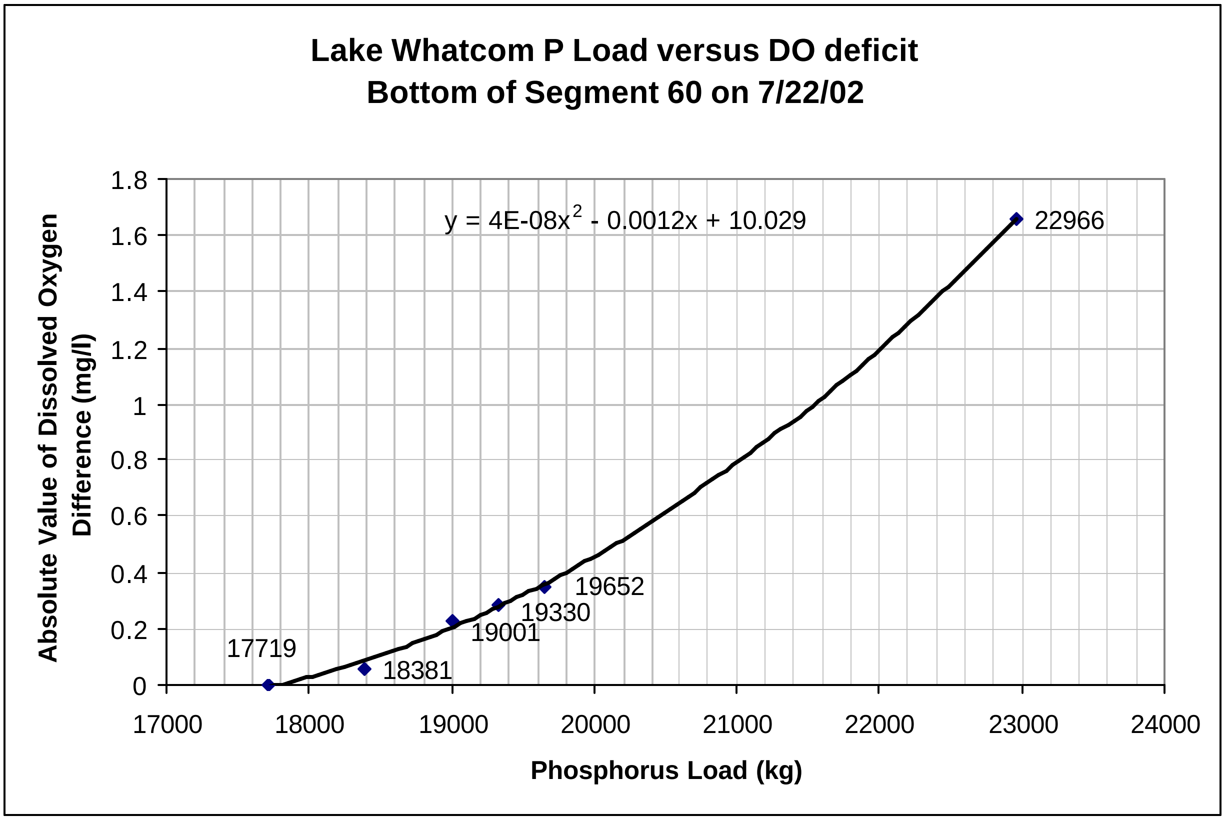

Figure 79. Graph showing DO deficit at bottom layer of Segment 60 (segment in basin 1) relative to roll back case for different phosphorus loads.

Table 21. Dissolved oxygen difference (relative to rollback scenario) at bottom of basin 1 (7/22/02) for scenarios.

Alternative	Phosphorus load (kg)	Dissolved Oxygen Difference (mg/l)
Rollback	17719	0
Partial Rollback A	18381	-0.06
Partial Rollback D	19001	-0.23
Partial Rollback C	19330	-0.28
Partial Rollback B	19652	-0.35
Base	22966	-1.66

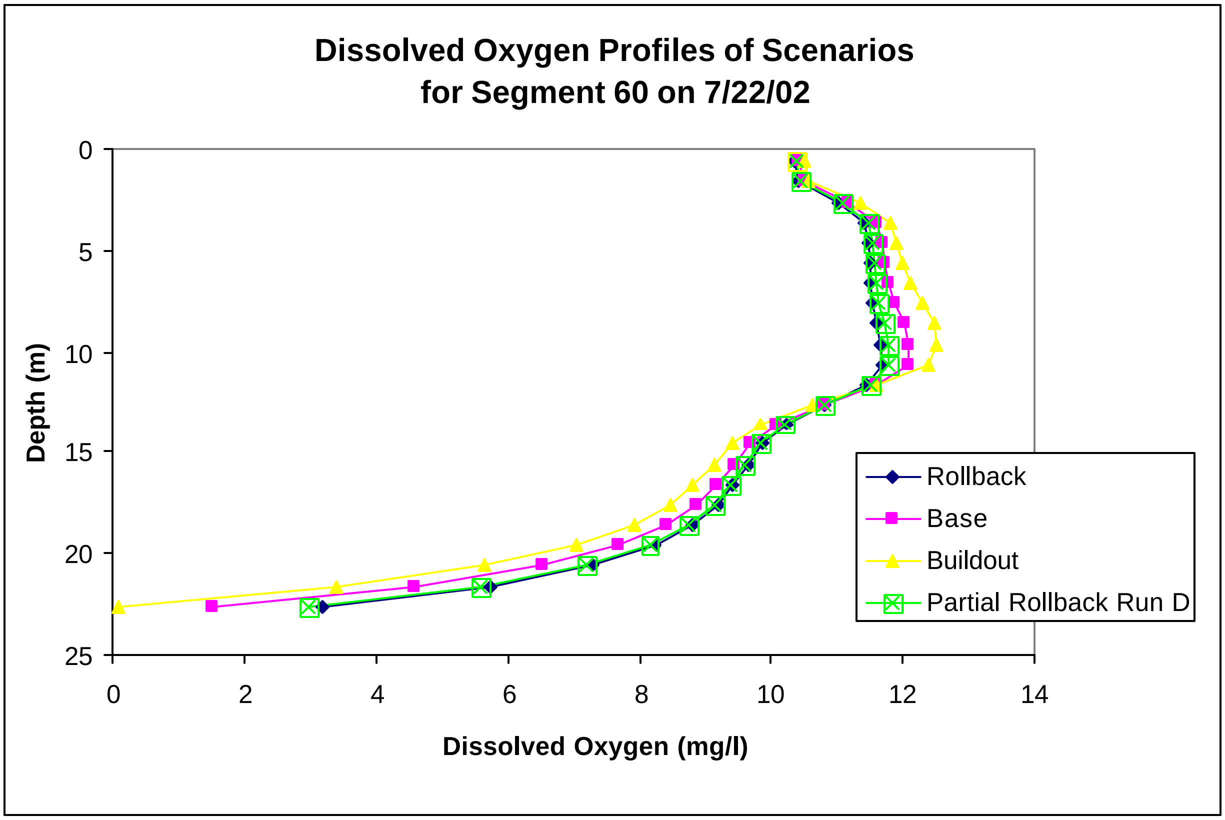

Figure 80. Dissolved Oxygen profiles of rollback, base, buildout, and partial rollback run D scenarios in basin 1 (segment 60) on 7/22/02.

Summary

A water quality and hydrodynamic model, CE-QUAL-W2 Version 3.2 (Cole and Wells, 2001; http://www.cee.pdx.edu/w2), was applied to Lake Whatcom Oregon. This report summarizes model development and calibration for the CE-QUAL-W2 Version 3.2 model of Lake Whatcom.

The system model required that boundary conditions and the topography be determined. Data in support of this modeling effort were shown in this report. This includes data such as:

- Dynamic inflow/discharge rates
- Dynamic inflow/discharge temperatures
- Dynamic inflow/discharge water quality constituents
- Dynamic meteorological data (air temperature, dew point temperature, wind speed, wind direction and cloud cover or short wave solar radiation)
- Model bathymetry

In general, the model reproduces the lake responses to the known boundary conditions. The average absolute mean error of model predictions was 0.64 degrees Celsius for temperature, 0.70 mg/l for dissolved oxygen, 0.85 ug/l for chlorophyll a, 0.12 for pH and 0.003 mg/l for total phosphorus.

Model scenarios were performed in order to understand the dissolved oxygen response of the lake. There were 5 scenarios simulated including the following:

- Base case
- Roll back
- Build out
- Partial Roll back A
- Partial Roll back B
- Partial Roll back C
- Partial Roll back D

The phosphorus loading necessary to reduce dissolved oxygen concentration by 0.2 mg/l at a critical location and time was determined.

References

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Appendix A: Model Control File

```
  W2 Model Version 3.2

TITLE C ...............................TITLE..................................
        Version 3.2 Whatcom L. Model
        WB 1 : Basin III
        WB 2 : Basin I & II




        Jing Liu & Bob Cusinamo, Department of Ecology
        Chris Berger and Scott Wells, Portland State University


GRID          NWB     NBR     IMX     KMX
                2       5      68     105

IN/OUTFL      NTR     NST     NIW     NWD     NGT     NSP     NPI     NPU
               30       1       0       3       0       0       0       0

CONSTITU      NGC     NSS     NAL     NEP    NBOD   VSTCH
                5       1       4       1       1      ON

MISCELL      NDAY
              100

TIME CON   TMSTRT   TMEND    YEAR
          45.6000 730.600    2002

DLT CON       NDT  DLTMIN
                3 0.10000

DLT DATE     DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD
          45.6000   370.0   390.0

DLT MAX    DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX
          300.000  300.00  300.00

DLT FRN      DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF
          0.20000     0.2     0.2

DLT LIMI     VISC    CELC
WB 1           ON      ON
WB 2           ON      ON

BRANCH G       US      DS     UHS     DHS     UQB     DQB   NLMIN   SLOPE
BR1             2      31       0      48       0       0       1 0.00000
BR2            34      40       0      11       0       0       1 0.00000
BR3            43      45       0      29       0       0       1 0.00000
BR4            48      63      31       0       0       0       1 0.00000
BR5            66      67       0      61       0       0       1 0.00000

LOCATION      LAT    LONG    EBOT      BS      BE    JBDN
WB 1      48.6921 122.300 -6.0000       1       3       1
WB 2      48.6921 122.300 -6.0000       4       5       4
```

```
INIT CND      T2I    ICEI  WTYPEC
WB 1      6.60000 0.00000   FRESH
WB 2      -2.0000 0.00000   FRESH

CALCULAT      VBC     EBC     MBC     PQC     EVC     PRC
WB 1           ON      ON      ON      ON      ON      ON
WB 2           ON      ON      ON      ON      ON      ON

DEAD SEA    WINDC    QINC   QOUTC   HEATC
WB 1           ON      ON      ON      ON
WB 2           ON      ON      ON      ON

INTERPOL    QINIC   DTRIC    HDIC
BR1            ON     OFF      ON
BR2            ON     OFF      ON
BR3            ON     OFF      ON
BR4            ON     OFF      ON
BR5            ON     OFF      ON

HEAT EXCH  SLHTC    SROC  RHEVAP   METIC  FETCHC     AFW     BFW     CFW   WINDH
WB 1         TERM      ON     OFF      ON     OFF 9.20000 0.46000 2.00000 2.27000
WB 2         TERM      ON     OFF      ON     OFF 9.20000 0.46000 2.00000 2.27000

ICE COVE     ICEC  SLICEC  ALBEDO   HWICE    BICE    GICE  ICEMIN   ICET2
WB 1          OFF  DETAIL 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000
WB 2          OFF  DETAIL 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000

TRANSPOR    SLTRC   THETA
WB 1     ULTIMATE 0.55000
WB 2     ULTIMATE 0.55000

HYD COEF       AX      DX    CBHE    TSED      FI   TSEDF   FRICC
WB 1      1.00000 1.00000   7E-08 11.5000 0.01000 1.00000    MANN
WB 2      1.00000 1.00000   7E-08 11.5000 0.01000 1.00000    MANN

EDDY VISC     AZC   AZSLC   AZMAX  PHISET
WB 1          W2N     IMP 1.00000     0.0
WB 2          W2N     IMP 1.00000     0.0

N STRUC      NSTR
BR1             0
BR2             0
BR3             0
BR4             1
BR5             0

STR INT     STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC
BR 1
BR 2
BR 3
BR 4           ON
BR 5

STR TOP     KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR
BR1
BR2
BR3
BR4             2
BR5
```

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STR BOT    KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR
BR1
BR2
BR3
BR4           55
BR5

STR SINK   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC
BR1
BR2
BR3
BR4        POINT
BR5

STR ELEV    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR
BR1
BR2
BR3
BR4      94.5000
BR5

STR WIDT    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR
BR1
BR2
BR3
BR4      0.00000
BR5

PIPES       IUPI    IDPI    EUPI    EDPI     WPI   DLXPI     FPI  FMINPI   WTHLC


PIPE UP    PUPIC   ETUPI   EBUPI   KTUPI   KBUPI


PIPE DOWN  PDPIC   ETDPI   EBDPI   KTDPI   KBDPI


SPILLWAY    IUSP    IDSP     ESP    A1SP    B1SP    A2SP    B2SP   WTHLC


SPILL UP   PUSPC   ETUSP   EBUSP   KTUSP   KBUSP


SPILL DOWN PDSPC   ETUSP   EBUSP   KTDSP   KBDSP


SPILL GAS GASSPC    EQSP  AGASSP  BGASSP  CGASSP


GATES       IUGT    IDGT     EGT    A1GT    B1GT    G1GT    A2GT    B2GT    G2GT
WTHLC


GATE WEIR   GTA1    GTB1    GTA2    GTB2  DYNVAR


GATE UP    PUGTC   ETUGT   EBUGT   KTUGT   KBUGT
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GATE DOWN  PDGTC   ETDGT   EBDGT   KTDGT   KBDGT

GATE GAS  GASGTC    EQGT  AGASGT  BGASGT  CGASGT

PUMPS 1     IUPU    IDPU     EPU  STRTPU   ENDPU   EONPU  EOFFPU     QPU   WTHLC

PUMPS 2     PPUC    ETPU    EBPU    KTPU    KBPU

WEIR SEG     IWR     IWR     IWR     IWR     IWR     IWR     IWR     IWR     IWR

WEIR TOP    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR

WEIR BOT    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR

WD INT      WDIC    WDIC    WDIC    WDIC    WDIC    WDIC    WDIC    WDIC    WDIC
              ON      ON      ON

WD SEG       IWD     IWD     IWD     IWD     IWD     IWD     IWD     IWD     IWD
              17      54      63

WD ELEV      EWD     EWD     EWD     EWD     EWD     EWD     EWD     EWD     EWD
         74.5000 83.5000 94.5000

WD TOP      KTWD    KTWD    KTWD    KTWD    KTWD    KTWD    KTWD    KTWD    KTWD
               2       2       2

WD BOT      KBWD    KBWD    KBWD    KBWD    KBWD    KBWD    KBWD    KBWD    KBWD
              74      67      61

TRIB PLA    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC
           DISTR DENSITY   DISTR   DISTR   DISTR   DISTR   DISTR   DISTR   DISTR
           DISTR   DISTR   DISTR   DISTR   DISTR   DISTR   DISTR   DISTR   DISTR
           DISTR   DISTR   DISTR   DISTR   DISTR   DISTR   DISTR   DISTR   DISTR
           DISTR   DISTR   DISTR

TRIB INT    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC
             OFF     OFF     OFF     OFF     OFF     OFF     OFF     OFF     OFF
             OFF     OFF     OFF     OFF     OFF     OFF     OFF     OFF     OFF
             OFF     OFF     OFF     OFF     OFF     OFF     OFF     OFF     OFF
             OFF     OFF     OFF

TRIB SEG     ITR     ITR     ITR     ITR     ITR     ITR     ITR     ITR     ITR
              29      45      66      60      66      28      63      55      25
              20      60      62      57      49      59      23      19       5
              11       2       2       4       2       4       8      12      16
              20      24      28

TRIB TOP   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
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         0.00000 0.00000 0.00000

TRIB BOT   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000

DST TRIB    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC
BR 1          ON
BR 2          ON
BR 3          ON
BR 4          ON
BR 5          ON

PUMPBACK     JBG     KTG     KBG     JBP     KTP     KBP
               0       0       0       0       0       0

PRINTER      LJC
              IV

HYD PRIN  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC
NVIOL         ON      ON
U             ON      ON
W             ON      ON
T             ON      ON
RHO          OFF     OFF
AZ           OFF     OFF
SHEAR        OFF     OFF
ST           OFF     OFF
SB           OFF     OFF
ADMX         OFF     OFF
DM           OFF     OFF
HDG          OFF     OFF
ADMZ         OFF     OFF
HPG          OFF     OFF
GRAV         OFF     OFF

SNP PRINT   SNPC    NSNP   NISNP
WB 1          ON       3       9
WB 2          ON       3      15

SNP DATE    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD
WB 1     45.6000 53.6000 54.6000
WB 2     45.6000 53.6000 54.6000

SNP FREQ    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF
WB 1     1.00000 0.10000 3.00000
WB 2     1.00000 0.10000 3.00000

SNP SEG     ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP
WB 1           2       5      11      15      20      24      25      26      31
WB 2          48      49      50      51      52      53      54      55      56
              60      61      62      63      66      67

SCR PRINT   SCRC    NSCR
WB 1         OFF       1
WB 2          ON       1
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SCR DATE    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD
WB 1     1.00000
WB 2     1.00000

SCR FREQ    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF
WB 1     0.50000
WB 2     0.50000

PRF PLOT    PRFC    NPRF   NIPRF
WB 1          ON      55       5
WB 2          ON      55       7

PRF DATE    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD
WB 1     43.4000 45.4000 92.4000 94.4000 127.400 129.400 155.400 165.400 183.400
         191.400 196.400 218.400 220.400 222.400 225.400 246.400 248.400 259.400
         281.400 283.400 309.400 311.400 317.400 337.400 339.400 400.400 402.400
         456.400 458.400 491.400 493.400 512.400 519.400 521.400 526.400 554.400
         556.400 561.400 575.600 582.400 584.400 591.400 596.400 603.600 610.400
         612.400 617.600 631.400 645.400 647.400 673.400 675.400 703.400 708.400
         711.400
WB 2     43.4000 45.4000 92.4000 94.4000 127.400 129.400 155.400 165.400 183.400
         191.400 196.400 218.400 220.400 222.400 225.400 246.400 248.400 259.400
         281.400 283.400 309.400 311.400 317.400 337.400 339.400 400.400 402.400
         456.400 458.400 491.400 493.400 512.400 519.400 521.400 526.400 554.400
         556.400 561.400 575.600 582.400 584.400 591.400 596.400 603.600 610.400
         612.400 617.600 631.400 645.400 647.400 673.400 675.400 703.400 708.400
         711.400

PRF FREQ    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF
WB 1     900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000
WB 2     900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
         900.000

PRF SEG     IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF
WB 1          11      24      25      26      31
WB 2          48      52      54      56      60      61      62

SPR PLOT    SPRC    NSPR   NISPR
WB 1         OFF      59       5
WB 2         OFF      59       6

SPR DATE    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD
WB 1     43.6000 45.6000 92.6000 94.6000 127.600 129.600 155.600 165.600 183.600
         191.600 196.540 196.660 218.600 220.600 222.600 225.490 225.580 246.600
         248.600 259.470 259.530 281.600 283.600 309.600 311.600 317.600 337.600
         339.600 400.600 402.600 456.600 458.600 491.600 493.600 512.490 512.550
         519.600 521.600 526.470 526.540 554.600 556.600 561.470 561.530 582.600
         584.600 596.460 596.600 610.600 612.600 631.470 631.540 645.600 647.600
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          673.600 675.600 703.600 708.600 711.600
WB 2      43.6000 45.6000 92.6000 94.6000 127.600 129.600 155.600 165.600 183.600
          191.600 196.540 196.660 218.600 220.600 222.600 225.490 225.580 246.600
          248.600 259.470 259.530 281.600 283.600 309.600 311.600 317.600 337.600
          339.600 400.600 402.600 456.600 458.600 491.600 493.600 512.490 512.550
          519.600 521.600 526.470 526.540 554.600 556.600 561.470 561.530 582.600
          584.600 596.460 596.600 610.600 612.600 631.470 631.540 645.600 647.600
          673.600 675.600 703.600 708.600 711.600

SPR FREQ     SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF
WB 1      900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000
WB 2      900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000 900.000
          900.000 900.000 900.000 900.000 900.000

SPR SEG      ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR
WB 1           11      24      25      26      31
WB 2           48      52      56      60      61      62

VPL PLOT     VPLC    NVPL
WB 1          OFF       1
WB 2          OFF       1

VPL DATE     VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD
WB 1      63.5000
WB 2      63.5000

VPL FREQ     VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF
WB 1      1.00000
WB 2      1.00000

CPL PLOT     CPLC    NCPL
WB 1           ON       1
WB 2           ON       1

CPL DATE     CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD
WB 1      45.5000
WB 2      45.5000

CPL FREQ     CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF
WB 1      1.00000
WB 2      1.00000

FLUXES       FLXC    NFLX
WB 1           ON       1
WB 2           ON       1

FLX DATE     FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD
WB 1         45.6
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WB 2        45.6

FLX FREQ    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF
WB 1        30.0
WB 2        30.0

TSR PLOT    TSRC    NTSR   NITSR
              ON       1       5

TSR DATE    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD
         45.0000

TSR FREQ    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF
         0.10000

TSR SEG     ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR
               2      54      61      63      63

TSR LAYE    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR
         1.00000 3.00000 0.00000 0.00000   0.000

WITH OUT    WDOC    NWDO   NIWDO
             OFF       1       3

WITH DAT    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD
         1.00000

WITH FRE    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF
         1.00000

WITH SEG    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO
               4       6      15

RESTART     RSOC    NRSO    RSIC
              ON       1     OFF

RSO DATE    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD
          45.600

RSO FREQ    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF
          30.000

CST COMP     CCC    LIMC     CUF
              ON      ON      10

CST ACTIVE   CAC
TDS          OFF
Gen1         OFF
Gen2         OFF
Gen3         OFF
Gen4         OFF
Gen5          ON
ISS1          ON
PO4           ON
NH4           ON
NO3           ON
DSI          OFF
PSI          OFF
FE           OFF
```

LDOM	ON
RDOM	ON
LPOM	ON
RPOM	ON
BOD1	OFF
ALG1	ON
ALG2	ON
ALG3	ON
ALG4	OFF
DO	ON
TIC	ON
ALK	ON

CST DERI	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC
DOC	ON	ON							
POC	OFF	OFF							
TOC	ON	ON							
DON	OFF	OFF							
PON	OFF	OFF							
TON	OFF	OFF							
TKN	ON	ON							
TN	ON	ON							
DOP	OFF	OFF							
POP	OFF	OFF							
TOP	OFF	OFF							
TP	ON	ON							
APR	OFF	OFF							
CHLA	ON	ON							
ATOT	OFF	OFF							
%DO	OFF	OFF							
TSS	ON	ON							
TISS	OFF	OFF							
CBOD	OFF	OFF							
pH	ON	ON							
CO2	OFF	OFF							
HCO3	OFF	OFF							
CO3	OFF	OFF							

CST FLUX	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC
TISSIN	OFF	OFF							
TISSOUT	OFF	OFF							
PO4AR	OFF	OFF							
PO4AG	OFF	OFF							
PO4AP	OFF	OFF							
PO4ER	OFF	OFF							
PO4EG	OFF	OFF							
PO4EP	OFF	OFF							
PO4POM	OFF	OFF							
PO4DOM	OFF	OFF							
PO4OM	OFF	OFF							
PO4SED	OFF	OFF							
PO4SOD	OFF	OFF							
PO4SET	OFF	OFF							
NH4NITR	OFF	OFF							
NH4AR	OFF	OFF							
NH4AG	OFF	OFF							
NH4AP	OFF	OFF							
NH4ER	OFF	OFF							
NH4EG	OFF	OFF							

```
NH4EP          OFF      OFF
NH4POM         OFF      OFF
NH4DOM         OFF      OFF
NH4OM          OFF      OFF
NH4SED         OFF      OFF
NH4SOD         OFF      OFF
NO3DEN         OFF      OFF
NO3AG          OFF      OFF
NO3EG          OFF      OFF
NO3SED         OFF      OFF
DSIAG          OFF      OFF
DSIEG          OFF      OFF
DSIPIS         OFF      OFF
DSISED         OFF      OFF
DSISOD         OFF      OFF
DSISET         OFF      OFF
PSIAM          OFF      OFF
PSINET         OFF      OFF
PSIDK          OFF      OFF
FESET          OFF      OFF
FESED          OFF      OFF
LDOMDK         OFF      OFF
LRDOM          OFF      OFF
RDOMDK         OFF      OFF
LDOMAP         OFF      OFF
LDOMEP         OFF      OFF
LPOMDK         OFF      OFF
LRPOM          OFF      OFF
RPOMDK         OFF      OFF
LPOMAP         OFF      OFF
LPOMEP         OFF      OFF
LPOMSET        OFF      OFF
RPOMSET        OFF      OFF
CBODDK         OFF      OFF
DOAP           OFF      OFF
DOAR           OFF      OFF
DOEP           OFF      OFF
DOER           OFF      OFF
DOPOM          OFF      OFF
DODOM          OFF      OFF
DOOM           OFF      OFF
DONITR         OFF      OFF
DOCBOD         OFF      OFF
DOREAR         OFF      OFF
DOSED          OFF      OFF
DOSOD          OFF      OFF
TICAG          OFF      OFF
TICEG          OFF      OFF
SEDDK          OFF      OFF
SEDAS          OFF      OFF
SEDLPOM        OFF      OFF
SEDSET         OFF      OFF
SODDK          OFF      OFF

CST ICON    C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB
TDS       0.00000 0.00000
Gen1      0.00000 0.00000
Gen2      0.00000 0.00000
Gen3      0.00000 0.00000
```

```
Gen4      0.00000 0.00000
Gen5      0.00000 0.00000
ISS1      0.00000 0.00000
PO4       0.00050 0.00150
NH4       0.00300 0.00300
NO3       0.40000 0.40000
DSI       0.00000 0.00000
PSI       0.00000 0.00000
FE        0.00000 0.00000
LDOM      0.10000 0.10000
RDOM      0.40000 0.40000
LPOM      0.20000 0.20000
RPOM      0.50000 0.50000
BOD1      0.00000 0.00000
ALG1      0.05000 0.05000
ALG2      0.01000 0.01000
ALG3      0.00000 0.00000
ALG4      0.00000 0.00000
DO        13.0000 13.0000
TIC       5.03000 4.77000
ALK       18.0000 18.5000

CST PRIN   CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC
TDS           OFF     OFF
Gen1          OFF     OFF
Gen2          OFF     OFF
Gen3          OFF     OFF
Gen4          OFF     OFF
Gen5          OFF     OFF
ISS1           ON      ON
PO4            ON      ON
NH4            ON      ON
NO3            ON      ON
DSI           OFF     OFF
PSI           OFF     OFF
FE            OFF     OFF
LDOM           ON      ON
RDOM           ON      ON
LPOM           ON      ON
RPOM           ON      ON
BOD1           ON      ON
ALG1           ON      ON
ALG2           ON      ON
ALG3           ON      ON
ALG4           ON      ON
DO             ON      ON
TIC            ON      ON
ALK            ON      ON

CIN CON    CINBRC  CINBRC  CINBRC  CINBRC  CINBRC  CINBRC  CINBRC  CINBRC  CINBRC
TDS            ON      ON      ON      ON      ON
Gen1           ON      ON      ON      ON      ON
Gen2          OFF     OFF     OFF     OFF     OFF
Gen3           ON      ON      ON      ON      ON
Gen4           ON      ON      ON      ON      ON
Gen5           ON      ON      ON      ON      ON
ISS1           ON      ON      ON      ON      ON
PO4            ON      ON      ON      ON      ON
NH4            ON      ON      ON      ON      ON
```

NO3	ON	ON	ON	ON	ON
DSI	OFF	OFF	OFF	OFF	OFF
PSI	OFF	OFF	OFF	OFF	OFF
FE	OFF	OFF	OFF	OFF	OFF
LDOM	ON	ON	ON	ON	ON
RDOM	ON	ON	ON	ON	ON
LPOM	ON	ON	ON	ON	ON
RPOM	ON	ON	ON	ON	ON
BOD1	OFF	OFF	OFF	OFF	OFF
ALG1	ON	ON	ON	ON	ON
ALG2	ON	ON	ON	ON	ON
ALG3	ON	ON	ON	ON	ON
ALG4	ON	ON	ON	ON	ON
DO	ON	ON	ON	ON	ON
TIC	ON	ON	ON	ON	ON
ALK	ON	ON	ON	ON	ON

CTR CON	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC
TDS	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
Gen1	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
Gen2	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF						
Gen3	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
Gen4	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
Gen5	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
ISS1	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
PO4	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
NH4	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
NO3	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
DSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF

	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF						
PSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF						
FE	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF						
LDOM	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
RDOM	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
LPOM	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
RPOM	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
BOD1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF						
ALG1	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
ALG2	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
ALG3	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
ALG4	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
DO	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
TIC	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						
ALK	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON						

CDT CON	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC
TDS	ON	ON	ON	ON	ON				
Gen1	ON	ON	ON	ON	ON				
Gen2	OFF	OFF	OFF	OFF	OFF				
Gen3	ON	ON	ON	ON	ON				
Gen4	ON	ON	ON	ON	ON				
Gen5	ON	ON	ON	ON	ON				
ISS1	ON	ON	ON	ON	ON				
PO4	ON	ON	ON	ON	ON				
NH4	ON	ON	ON	ON	ON				
NO3	ON	ON	ON	ON	ON				
DSI	OFF	OFF	OFF	OFF	OFF				
PSI	OFF	OFF	OFF	OFF	OFF				
FE	OFF	OFF	OFF	OFF	OFF				
LDOM	ON	ON	ON	ON	ON				
RDOM	ON	ON	ON	ON	ON				
LPOM	ON	ON	ON	ON	ON				
RPOM	ON	ON	ON	ON	ON				
BOD1	OFF	OFF	OFF	OFF	OFF				
ALG1	ON	ON	ON	ON	ON				
ALG2	ON	ON	ON	ON	ON				
ALG3	ON	ON	ON	ON	ON				
ALG4	ON	ON	ON	ON	ON				
DO	ON	ON	ON	ON	ON				
TIC	ON	ON	ON	ON	ON				
ALK	ON	ON	ON	ON	ON				

CPR CON	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC
TDS	ON	ON	ON	ON	ON				
Gen1	ON	ON	ON	ON	ON				
Gen2	OFF	OFF	OFF	OFF	OFF				
Gen3	ON	ON	ON	ON	ON				
Gen4	ON	ON	ON	ON	ON				
Gen5	ON	ON	ON	ON	ON				
ISS1	ON	ON	ON	ON	ON				
PO4	ON	ON	ON	ON	ON				
NH4	ON	ON	ON	ON	ON				
NO3	ON	ON	ON	ON	ON				
DSI	OFF	OFF	OFF	OFF	OFF				
PSI	OFF	OFF	OFF	OFF	OFF				
FE	OFF	OFF	OFF	OFF	OFF				
LDOM	ON	ON	ON	ON	ON				
RDOM	ON	ON	ON	ON	ON				
LPOM	ON	ON	ON	ON	ON				
RPOM	ON	ON	ON	ON	ON				
BOD1	OFF	OFF	OFF	OFF	OFF				
ALG1	ON	ON	ON	ON	ON				
ALG2	ON	ON	ON	ON	ON				
ALG3	ON	ON	ON	ON	ON				
ALG4	ON	ON	ON	ON	ON				
DO	ON	ON	ON	ON	ON				
TIC	ON	ON	ON	ON	ON				
ALK	ON	ON	ON	ON	ON				

EX COEF	EXH2O	EXSS	EXOM	BETA	EXC	EXIC
WB 1	0.25000	0.10000	0.10000	0.45000	OFF	OFF
WB 2	0.28000	0.10000	0.08000	0.45000	OFF	OFF

```
ALG EX        EXA     EXA     EXA     EXA     EXA     EXA
         0.10000 0.10000 0.10000 0.10000

GENERIC     CGQ10   CG0DK   CG1DK     CGS
CG 1     0.00000 0.00000 0.00000 0.00000
CG 2     0.00000 0.00000 0.00000 0.00000
CG 3     0.00000 -1.0000 0.00000 0.00000
CG 4     1.04000 0.00000 0.50000 0.00000
CG 5     0.00000 0.00000 0.00000 0.00000

S SOLIDS      SSS   SEDRC   TAUCR
SS# 1    1.50000     OFF .15E-04

ALGAL RATE    AG      AR      AE      AM      AS    AHSP    AHSN   AHSSI    ASAT
ALG1     1.65000 0.04000 0.04000 0.04000 0.10000 0.00200 0.01400 0.00000 50.0000
ALG2     1.90000 0.04000 0.04000 0.04000 0.10000 0.00250 0.01400 0.00000 75.0000
ALG3     2.00000 0.04000 0.04000 0.04000 0.01000 0.00200 0.01400 0.00000 130.000
ALG4     0.00000 0.10000 0.04000 0.10000 0.10000 0.00200 0.01400 0.00000 30.0000

ALGAL TEMP   AT1     AT2     AT3     AT4     AK1     AK2     AK3     AK4
ALG1     1.00000  3.0000 12.0000 25.0000 0.50000 0.99000 0.99000 0.10000
ALG2     8.00000 12.0000 16.0000 30.0000 0.10000 0.60000 0.99000 0.10000
ALG3     8.00000 16.0000 20.0000 30.0000 0.10000 0.60000 0.99000 0.10000
ALG1     1.00000  3.0000 12.0000 25.0000 0.50000 0.99000 0.99000 0.10000

ALG STOI     ALGP    ALGN    ALGC   ALGSI   ACHLA   ALPOM   ANEQN    ANPR
ALG1     0.00300 0.06000 0.60000 0.00000 150.000 0.80000       1 0.00100
ALG2     0.00250 0.06000 0.60000 0.00000  90.000 0.80000       1 0.00100
ALG3     0.00200 0.06000 0.60000 0.00000 120.000 0.80000       1 0.00100
ALG1     0.00500 0.08000 0.60000 0.00000 130.000 0.80000       1 0.00100

EPIPHYTE     EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC
EPI1          OFF     OFF

EPI PRIN     EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC
EPI1          OFF     OFF

EPI INIT    EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI
EPI1     20.0000 20.0000

EPI RATE       EG      ER      EE      EM      EB    EHSP    EHSN   EHSSI
EPI1     1.50000 0.04000 0.04000 0.10000 0.00100 0.00300 0.01400 0.00000

EPI HALF     ESAT     EHS   ENEQN    ENPR
EPI1     150.000 15.0000       2 0.00100

EPI TEMP      ET1     ET2     ET3     ET4     EK1     EK2     EK3     EK4
EPI1     1.00000 3.00000 20.0000 30.0000 0.10000 0.99000 0.99000 0.10000

EPI STOI       EP      EN      EC     ESI   ECHLA    EPOM
EPI1     0.00500 0.08000 0.45000 0.00000 65.0000 0.80000

DOM        LDOMDK  RDOMDK   LRDDK
WB 1     0.06000 0.00100 0.01000
WB 2     0.12000 0.00100 0.01000

POM        LPOMDK  RPOMDK   LRPDK    POMS
WB 1     0.02000 0.00100 0.01000 1.00000
WB 2     0.04000 0.00100 0.01000 0.50000
```

```
OM STOIC     ORGP    ORGN    ORGC   ORGSI
WB 1      0.00020 0.08000 0.45000 0.18000
WB 2      0.00400 0.08000 0.45000 0.18000

OM RATE      OMT1    OMT2    OMK1    OMK2
WB 1      2.00000 20.0000 0.40000 0.99000
WB 2      2.00000 20.0000 0.40000 0.99000

CBOD         KBOD    TBOD    RBOD
BOD 1     0.04180 1.01470 1.00000

CBOD STOIC  BODP    BODN    BODC
BOD 1     0.00500 0.08000 0.45000

PHOSPHOR     PO4R   PARTP
WB 1      .10E-05 0.00000
WB 2      .50E-03 0.00000

AMMONIUM     NH4R   NH4DK
WB 1      0.04000 0.30000
WB 2      0.04000 0.30000

NH4 RATE    NH4T1   NH4T2   NH4K1   NH4K2
WB 1      5.00000 25.0000 0.10000 0.99000
WB 2      5.00000 25.0000 0.10000 0.99000

NITRATE     NO3DK    NO3S
WB 1      0.05000 0.10000
WB 2      0.05000 0.10000

NO3 RATE    NO3T1   NO3T2   NO3K1   NO3K2
WB 1      5.00000 25.0000 0.10000 0.99000
WB 2      5.00000 25.0000 0.10000 0.99000

SILICA       DSIR    PSIS   PSIDK  PARTSI
WB 1      0.10000 0.00000 0.30000 0.20000
WB 2      0.10000 0.00000 0.30000 0.20000

IRON          FER     FES
WB 1      0.10000 0.00000
WB 2      0.10000 0.00000

SED CO2      CO2R
WB 1      0.70000
WB 2      0.40000

STOICH 1    O2NH4    O2OM
WB 1      4.57000 1.40000
WB 2      4.57000 1.40000

STOICH 2     O2AR    O2AG
ALG1      1.10000 1.80000
ALG2      1.10000 1.80000
ALG3      1.10000 1.80000
ALG4      1.10000 1.80000

STOICH 3     O2ER    O2EG
EPI1      1.10000 1.40000
```

```
O2 LIMIT   O2LIM
         0.10000

SEDIMENT    SEDC  SEDPRC   SEDCI    SEDK    FSOD    FSED
WB 1          ON      ON-2.00000 0.00100 1.00000 1.00000
WB 2          ON      ON-2.00000 0.00400 1.00000 1.00000

SOD RATE   SODT1   SODT2   SODK1   SODK2
WB 1     5.00000 20.0000 0.10000 0.99000
WB 2     5.00000 20.0000 0.10000 0.99000

S DEMAND     SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD
         0.80000 0.80000 0.80000 0.80000 0.80000 0.80000 0.80000 0.80000 0.80000
         0.80000 0.80000 0.80000 0.80000 0.80000 0.80000 0.80000 0.80000 0.80000
         0.80000 0.80000 0.80000 0.80000 0.80000 0.80000 0.80000 0.80000 0.80000
         0.80000 0.80000 0.80000 0.80000 0.70000 0.70000 0.70000 0.70000 0.70000
         0.70000 0.70000 0.70000 0.70000 0.70000 0.70000 0.70000 0.70000 0.70000
         0.45000 0.45000 0.45000 0.45000 0.45000 0.45000 0.45000 0.45000 0.45000
         0.45000 0.45000 0.45000 0.60000 0.60000 0.60000 0.60000 0.60000 0.60000
         0.60000 0.60000 0.60000 0.60000 0.60000

REAERATION  TYPE    EQN#   COEF1   COEF2   COEF3   COEF4
WB 1        LAKE       3 0.00000 0.00000 0.00000 0.00000
WB 2        LAKE       3 0.00000 0.00000 0.00000 0.00000

RSI FILE..................................RSIFN.................................
        rsi.npt

QWD FILE..................................QWDFN.................................
        qwd.npt

QGT FILE..................................QGTFN.................................
        qgt.npt

WSC FILE..................................WSCFN.................................
        wsc.npt

SHD FILE..................................SHDFN.................................
        shade.npt

BTH FILE..................................BTHFN.................................
WB 1    bth_1_coarse.npt
WB 2    bth_2_coarsed.npt

MET FILE..................................METFN.................................
WB 1    met_1.npt
WB 2    met_2.npt

EXT FILE..................................EXTFN.................................
WB 1    ext_1.npt
WB 2    ext_2.npt

VPR FILE..................................VPRFN.................................
WB 1    vpr_1.npt
WB 2    vpr_2.npt

LPR FILE..................................LPRFN.................................
WB 1    lpr_1.npt
```

```
WB 2    lpr_2.npt

QIN FILE.................................QINFN................................
BR1     qin_br1.npt
BR2     qin_br2.npt
BR3     qin_br3.npt
BR4     qin_br4.npt
BR5     qin_br5.npt

TIN FILE.................................TINFN................................
BR1     tin_br1.npt
BR2     tin_br2.npt
BR3     tin_br3.npt
BR4     tin_br4.npt
BR5     tin_br5.npt

CIN FILE.................................CINFN................................
BR1     cin_br1.npt
BR2     cin_br2.npt
BR3     cin_br3.npt
BR4     cin_br4.npt
BR5     cin_br5.npt

QOT FILE.................................QOTFN................................
BR1     qot_br1.npt
BR2     qot_br2.npt
BR3     qot_br3.npt
BR4     whatcom-creek-q_hourly.npt
BR5     qot_br5.npt

QTR FILE.................................QTRFN................................
TR1     qtr_aga.npt
TR2     qtr_car.npt
TR3     qtr_hil.npt
TR4     qtr_aca.npt
TR5     qtr_sil.npt
TR6     qtr_ols.npt
TR7     qtr_blo.npt
TR8     qtr_eag.npt
TR9     qtr_nsh.npt
TR10    qtr_smi.npt
TR11    qtr_don.npt
TR12    qtr_mil.npt
TR13    qtr_cab.npt
TR14    qtr_str.npt
TR15    qtr_euc.npt
TR16    qtr_sud.npt
TR17    qtr_aus.npt
TR18    qtr_blu.npt
TR19    qtr_bay.npt
TR20    qtr_and.npt
TR21    qtr_fir.npt
TR22    qtr_bra.npt
tr23    qtr_gw2.npt
tr24    qtr_gw4.npt
tr25    qtr_gw8.npt
tr26    qtr_gw12.npt
tr27    qtr_gw16.npt
tr28    qtr_gw20.npt
```

```
tr29    qtr_gw24.npt
tr30    qtr_gw28.npt

TTR FILE.................................TTRFN................................
TR1     ttr_aga.npt
TR2     ttr_car.npt
TR3     ttr_hil.npt
TR4     ttr_aca.npt
TR5     ttr_sil.npt
TR6     ttr_ols.npt
TR7     ttr_blo.npt
TR8     ttr_eag.npt
TR9     ttr_nsh.npt
TR10    ttr_smi.npt
TR11    ttr_don.npt
TR12    ttr_mil.npt
TR13    ttr_cab.npt
TR14    ttr_str.npt
TR15    ttr_euc.npt
TR16    ttr_sud.npt
TR17    ttr_aus.npt
TR18    ttr_blu.npt
TR19    ttr_bay.npt
TR20    ttr_and.npt
TR21    ttr_fir.npt
TR22    ttr_bra.npt
tr23    ttr_gw2.npt
tr24    ttr_gw4.npt
tr25    ttr_gw8.npt
tr26    ttr_gw12.npt
tr27    ttr_gw16.npt
tr28    ttr_gw20.npt
tr29    ttr_gw24.npt
tr30    ttr_gw28.npt

CTR FILE.................................CTRFN................................
TR1     ctr_aga.npt
TR2     ctr_car.npt
TR3     ctr_hil.npt
TR4     ctr_aca.npt
TR5     ctr_sil.npt
TR6     ctr_ols.npt
TR7     ctr_blo.npt
TR8     ctr_eag.npt
TR9     ctr_nsh.npt
TR10    ctr_smi.npt
TR11    ctr_don.npt
TR12    ctr_mil.npt
TR13    ctr_cab.npt
TR14    ctr_str.npt
TR15    ctr_euc.npt
TR16    ctr_sud.npt
TR17    ctr_aus.npt
TR18    ctr_blu.npt
TR19    ctr_bay.npt
TR20    ctr_and.npt
TR21    ctr_fir.npt
TR22    ctr_bra.npt
tr23    ctr_gw2.npt
```

```
tr24    ctr_gw4.npt
tr25    ctr_gw8.npt
tr26    ctr_gw12.npt
tr27    ctr_gw16.npt
tr28    ctr_gw20.npt
tr29    ctr_gw24.npt
tr30    ctr_gw28.npt

QDT FILE.................................QDTFN................................
BR1     qdt_br1.npt
BR2     qdt_br2.npt
BR3     qdt_br3.npt
BR4     qdt_br4.npt
BR5     qdt_br5.npt

TDT FILE.................................TDTFN................................
BR1     tdt_br1.npt
BR2     tdt_br2.npt
BR3     tdt_br3.npt
BR4     tdt_br4.npt
BR5     tdt_br5.npt

CDT FILE.................................CDTFN................................
BR1     cdt_br1.npt
BR2     cdt_br2.npt
BR3     cdt_br3.npt
BR4     cdt_br4.npt
BR5     cdt_br5.npt

PRE FILE.................................PREFN................................
BR1     pre_br1.npt
BR2     pre_br2.npt
BR3     pre_br3.npt
BR4     pre_br4.npt
BR5     pre_br5.npt

TPR FILE.................................TPRFN................................
BR1     tpr_br1.npt
BR2     tpr_br2.npt
BR3     tpr_br3.npt
BR4     tpr_br4.npt
BR5     tpr_br5.npt

CPR FILE.................................CPRFN................................
BR1     cpr_br1.npt
BR2     cpr_br2.npt
BR3     cpr_br3.npt
BR4     cpr_br4.npt
BR5     cpr_br5.npt

EUH FILE.................................EUHFN................................
BR1     euh_br1.npt
BR2     euh_br2.npt
BR3     euh_br3.npt
BR4     euh_br4.npt
BR5     euh_br5.npt

TUH FILE.................................TUHFN................................
BR1     tuh_br1.npt
```

```
BR2     tuh_br2.npt
BR3     tuh_br3.npt
BR4     tuh_br4.npt
BR5     tuh_br5.npt

CUH FILE.................................CUHFN................................
BR1     cuh_br1.npt
BR2     cuh_br2.npt
BR3     cuh_br3.npt
BR4     cuh_br4.npt
BR5     cuh_br5.npt

EDH FILE.................................EDHFN................................
BR1     edh_br1.npt
BR2     edh_br2.npt
BR3     edh_br3.npt
BR4     edh_br4.npt
BR5     edh_br5.npt

TDH FILE.................................TDHFN................................
BR1     tdh_br1.npt
BR2     tdh_br2.npt
BR3     tdh_br3.npt
BR4     tdh_br4.npt
BR5     tdh_br5.npt

CDH FILE.................................CDHFN................................
BR1     cdh_br1.npt
BR2     cdh_br2.npt
BR3     cdh_br3.npt
BR4     cdh_br4.npt
BR5     cdh_br5.npt

SNP FILE.................................SNPFN................................
WB 1    snp1.opt
WB 2    snp2.opt

PRF FILE.................................PRFFN................................
WB 1    prf1.opt
WB 2    prf2.opt

VPL FILE.................................VPLFN................................
WB 1    vpl1.opt
WB 2    vpl2.opt

CPL FILE.................................CPLFN................................
WB 1    cpl1.opt
WB 2    cpl2.opt

SPR FILE.................................SPRFN................................
WB 1    spr1.opt
WB 2    spr2.opt

FLX FILE.................................FLXFN................................
WB 1    flx1.opt
WB 2    flx2.opt

TSR FILE.................................TSRFN................................
        tsr.opt
```

WDO FILE.................................WDOFN...............................
wdo.opt

Appendix B: Vertical Profiles of Model Predictions and data

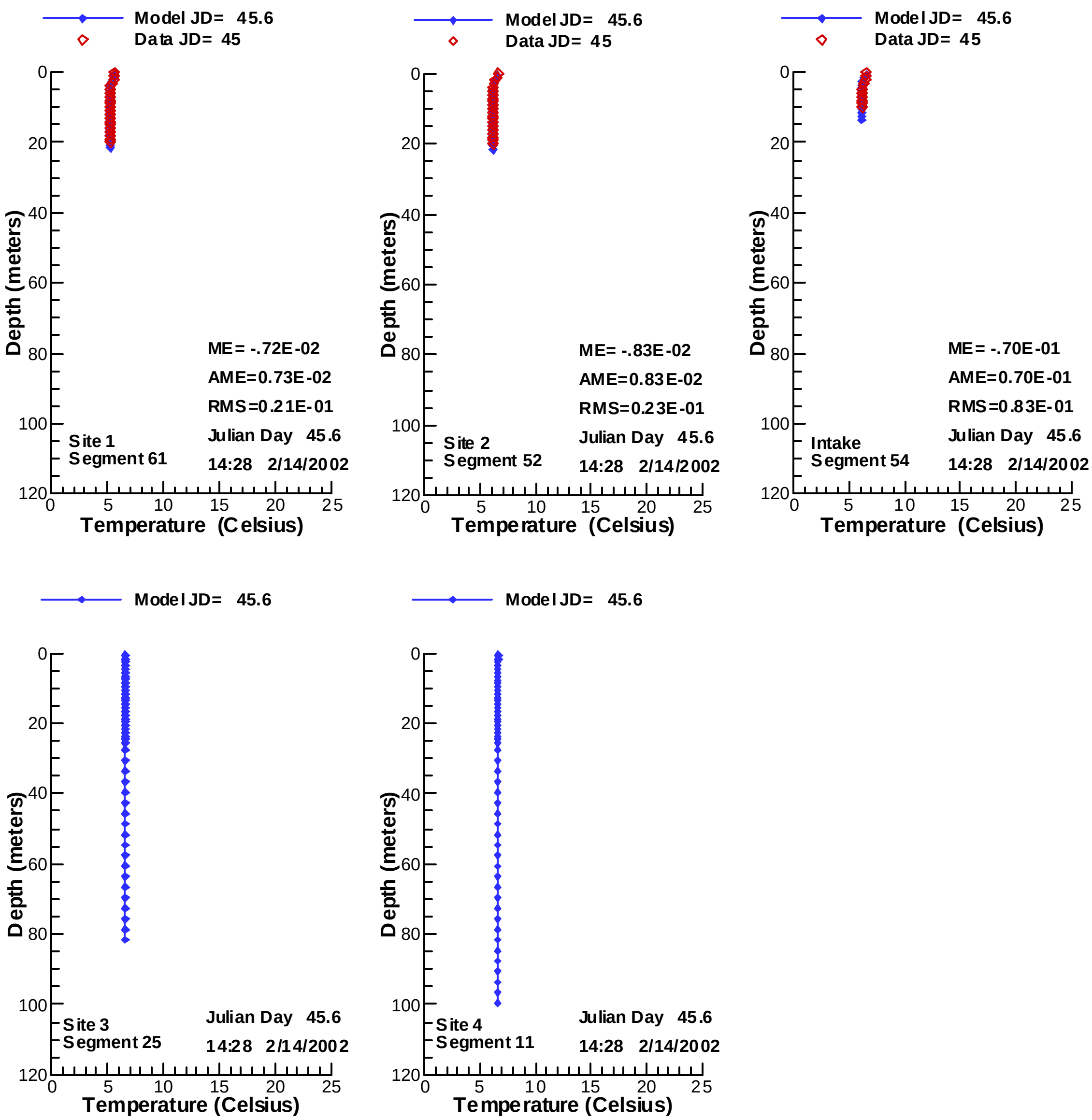

Figure 81. Vertical profiles of TEMPERATURE compared with data for 2/14/2002.

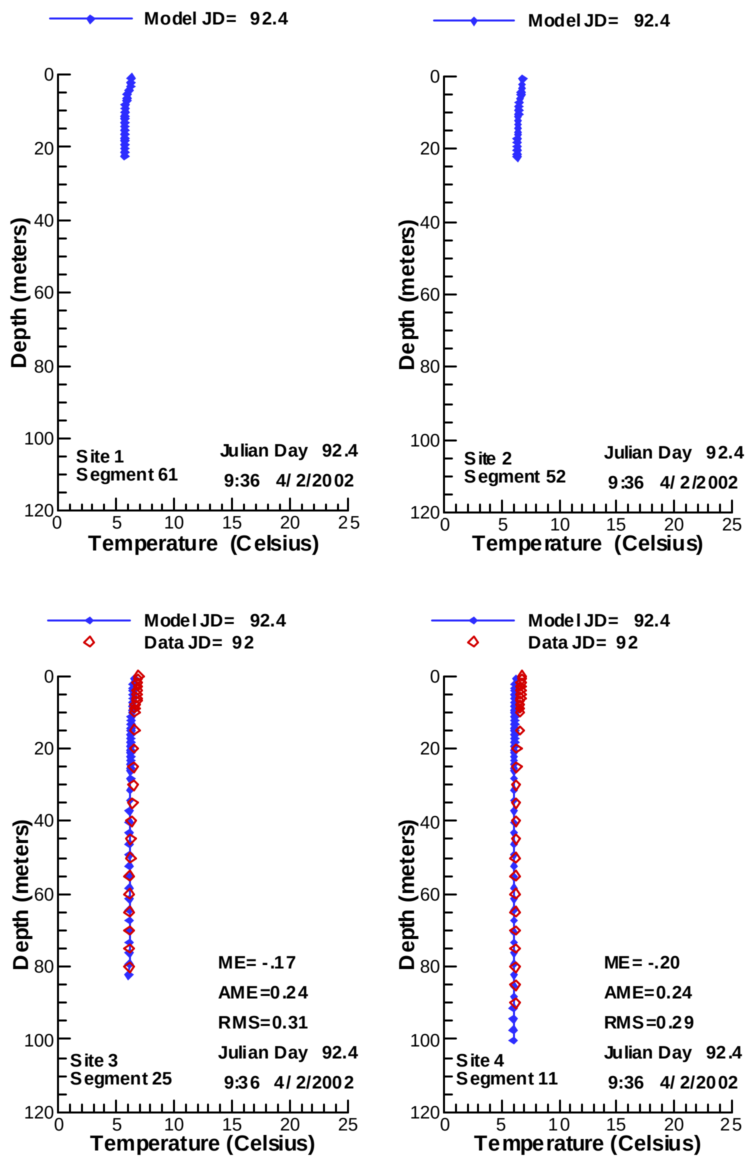

Figure 82. Vertical profiles of TEMPERATURE compared with data for 4/ 2/2002.

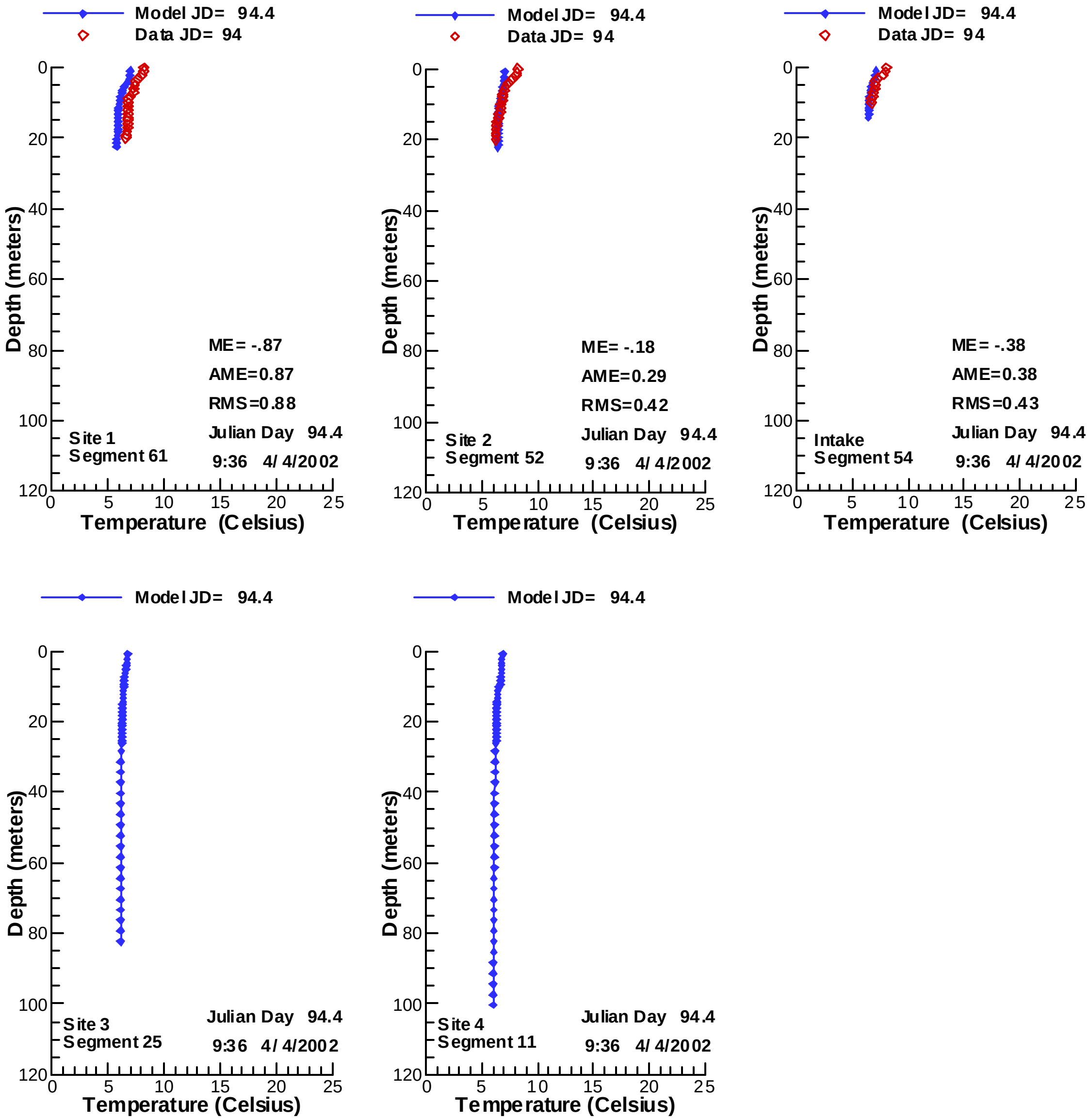

Figure 83. Vertical profiles of TEMPERATURE compared with data for 4/ 4/2002.

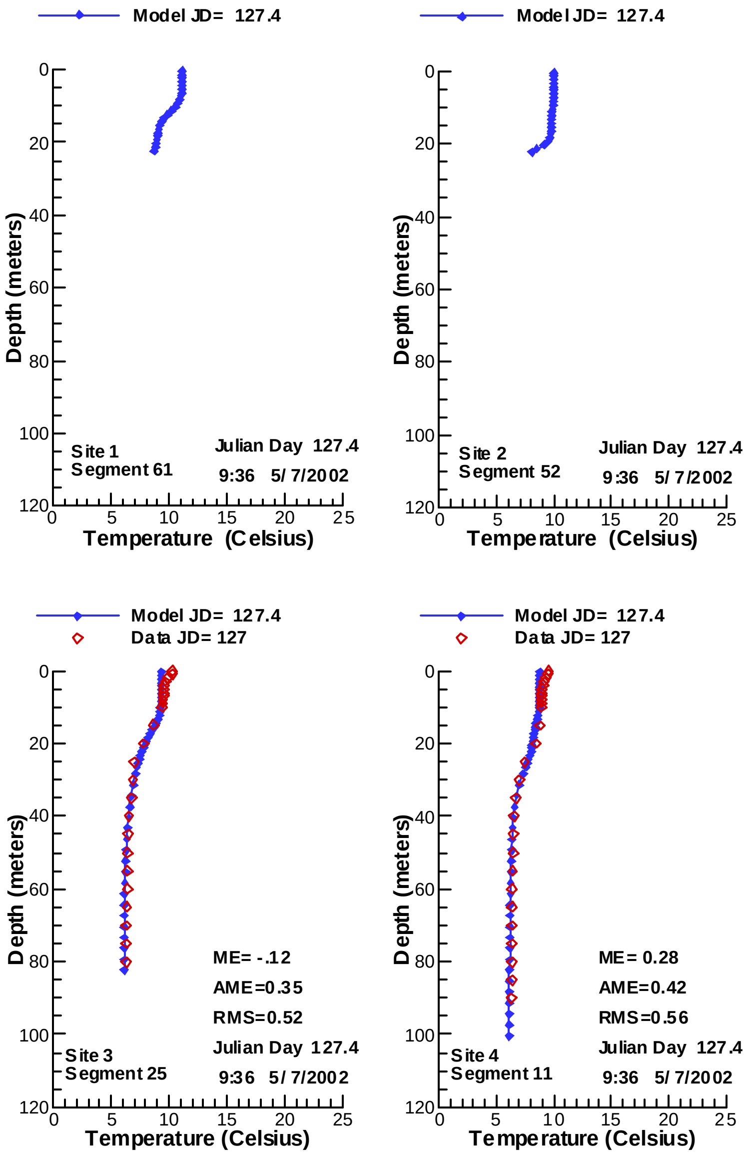

Figure 84. Vertical profiles of TEMPERATURE compared with data for 5/ 7/2002.

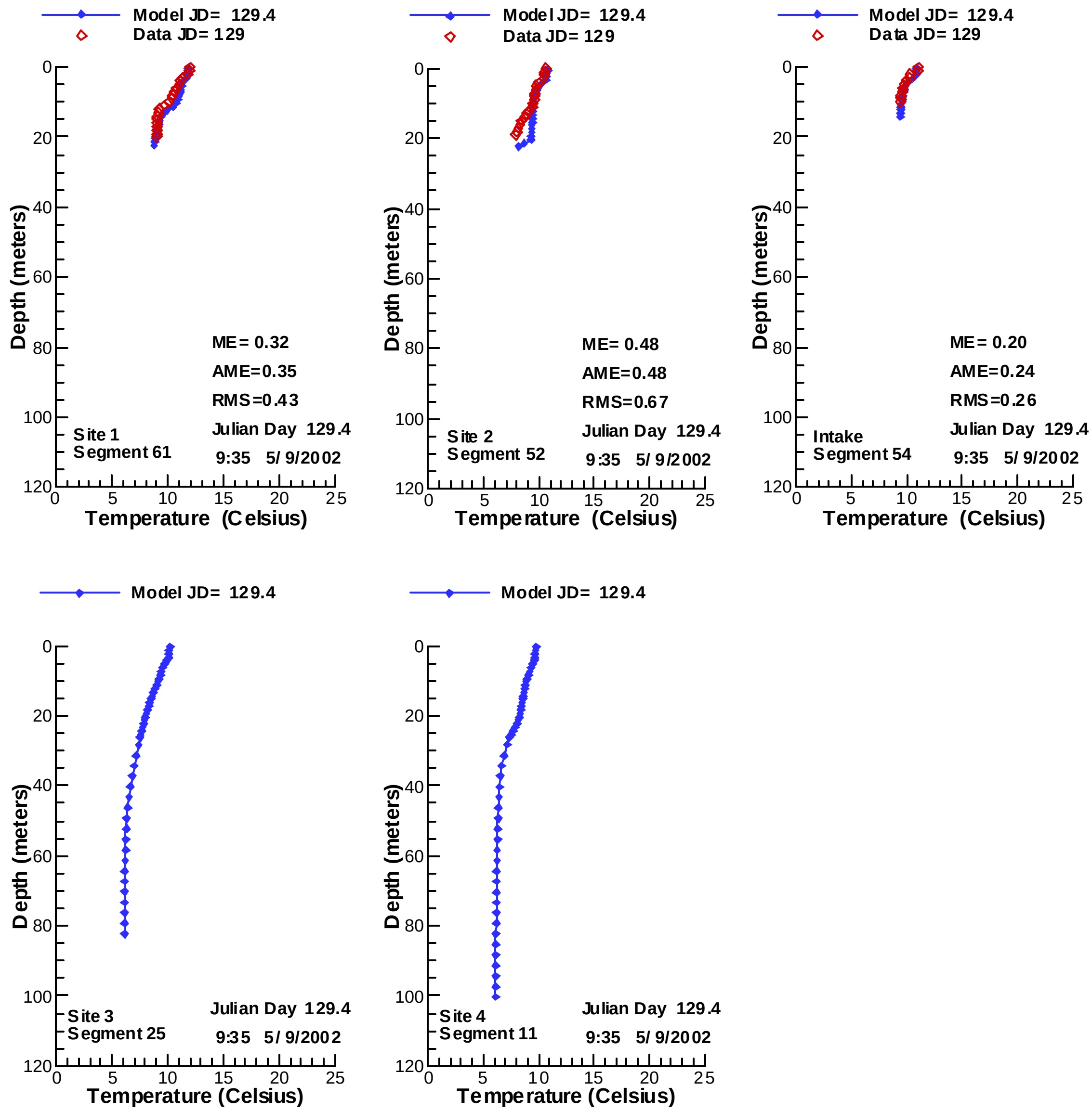

Figure 85. Vertical profiles of TEMPERATURE compared with data for 5/ 9/2002.

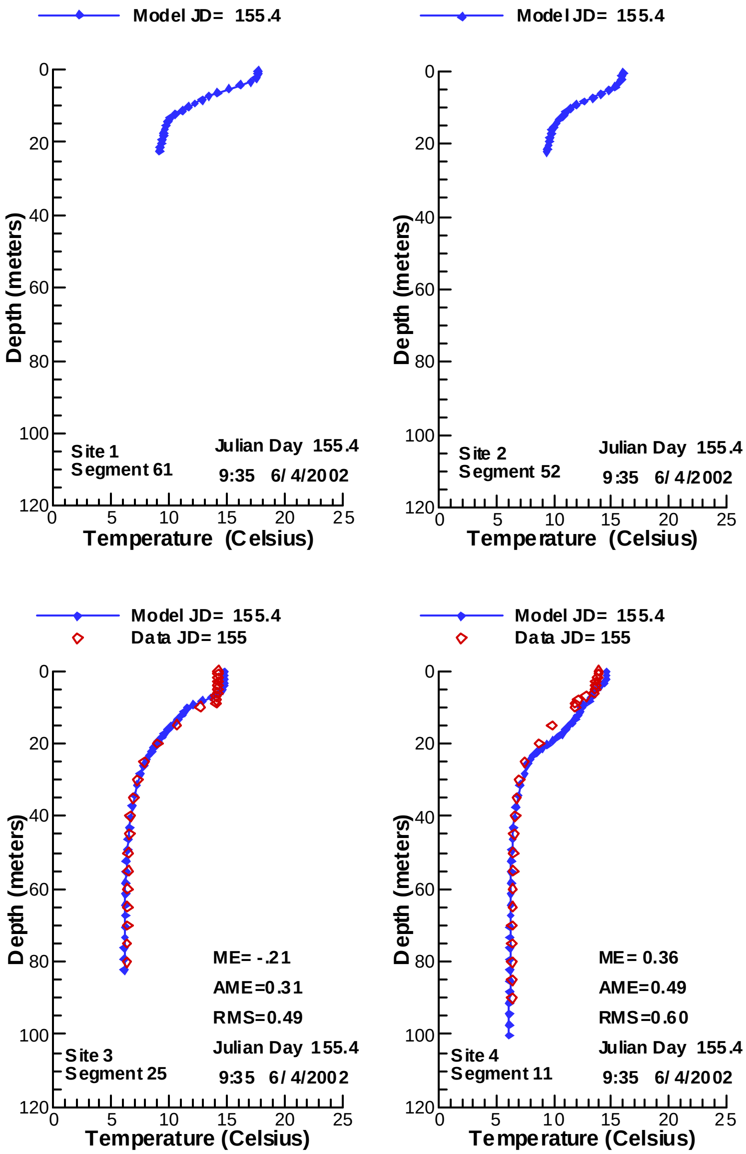

Figure 86. Vertical profiles of TEMPERATURE compared with data for 6/ 4/2002.

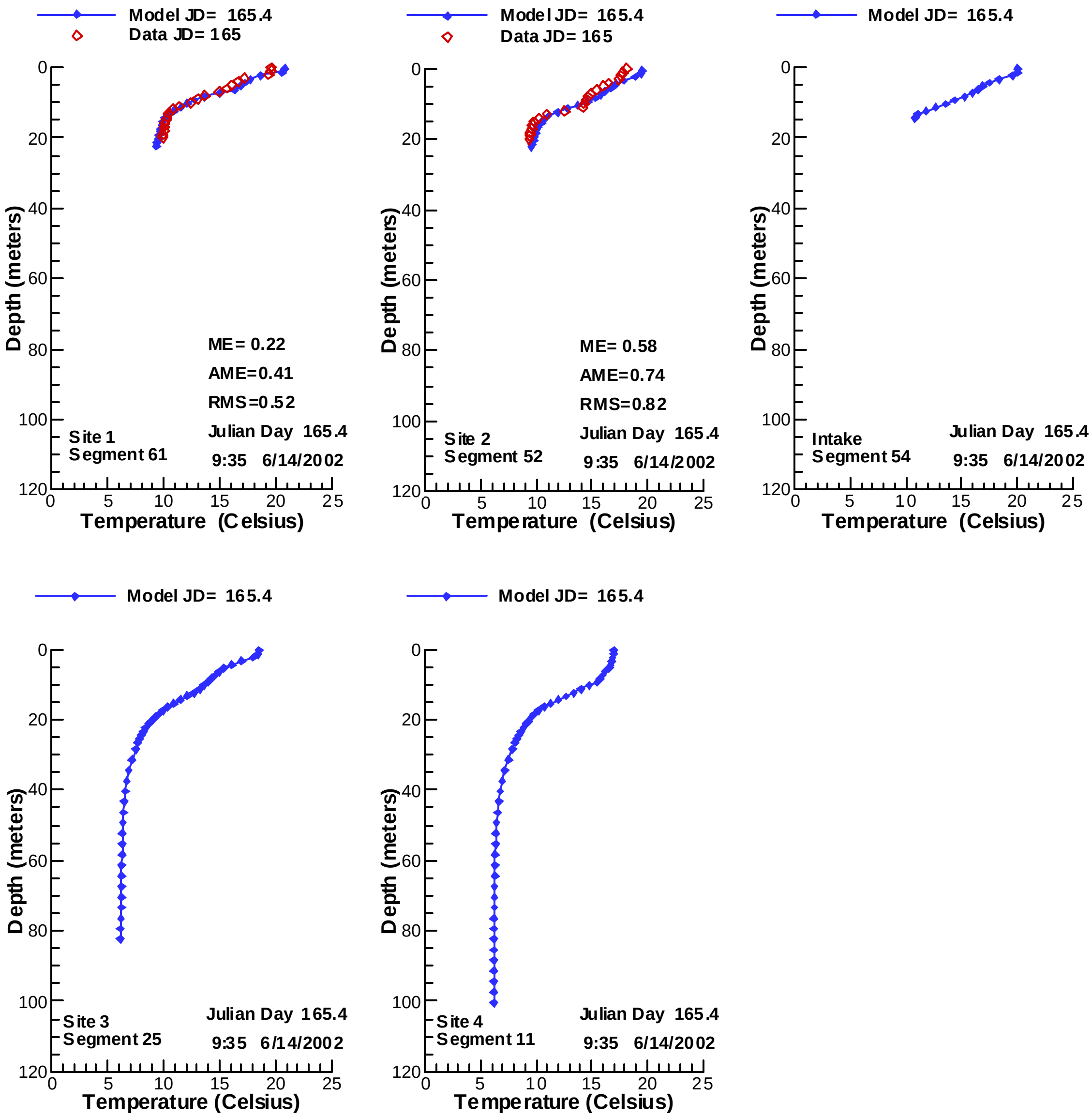

Figure 87. Vertical profiles of TEMPERATURE compared with data for 6/14/2002.

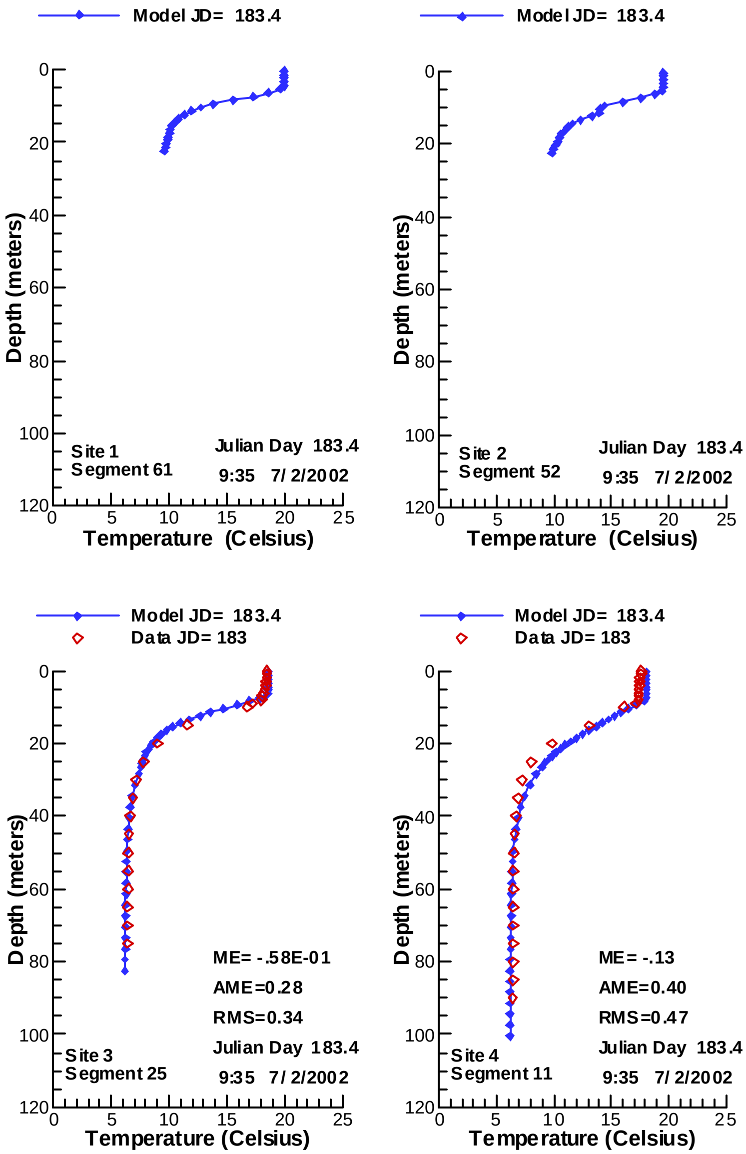

Figure 88. Vertical profiles of TEMPERATURE compared with data for 7/ 2/2002.

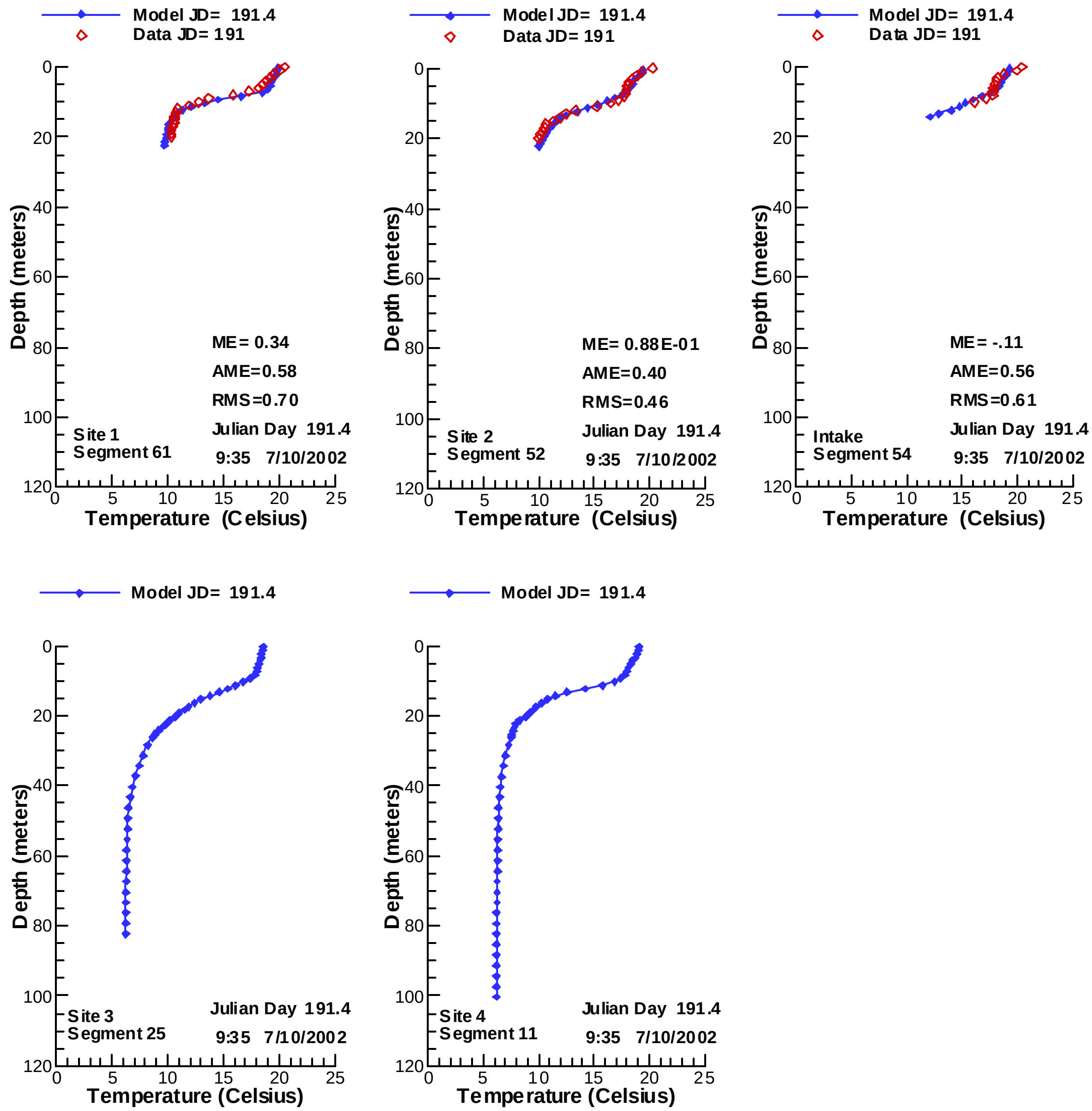

Figure 89. Vertical profiles of TEMPERATURE compared with data for 7/10/2002.

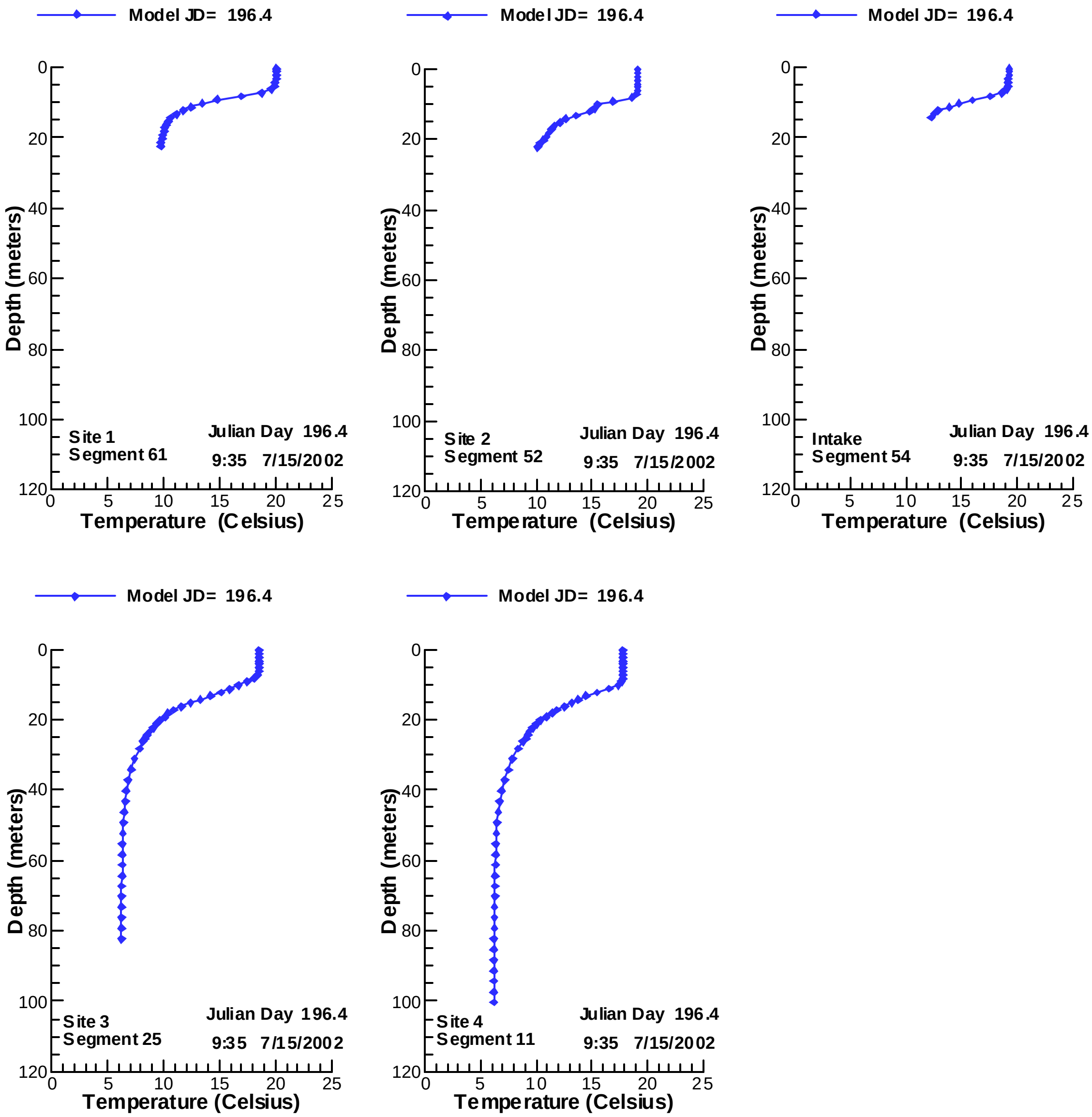

Figure 90. Vertical profiles of TEMPERATURE compared with data for 7/15/2002.

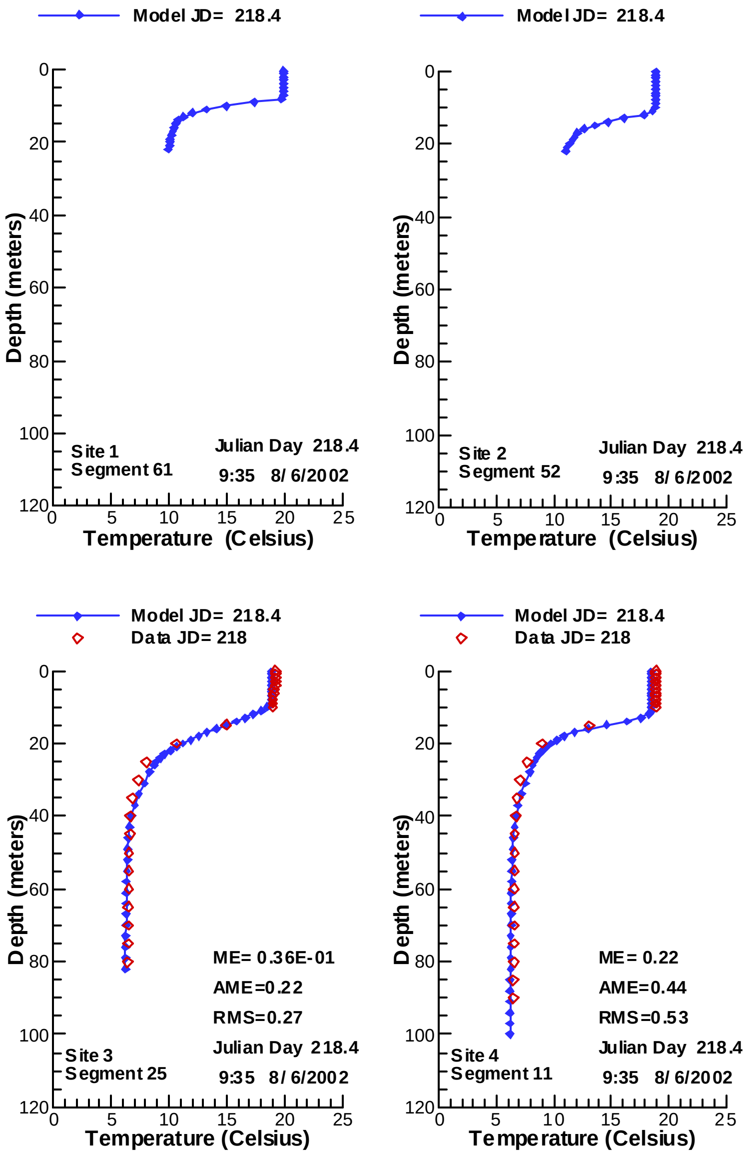

Figure 91. Vertical profiles of TEMPERATURE compared with data for 8/ 6/2002.

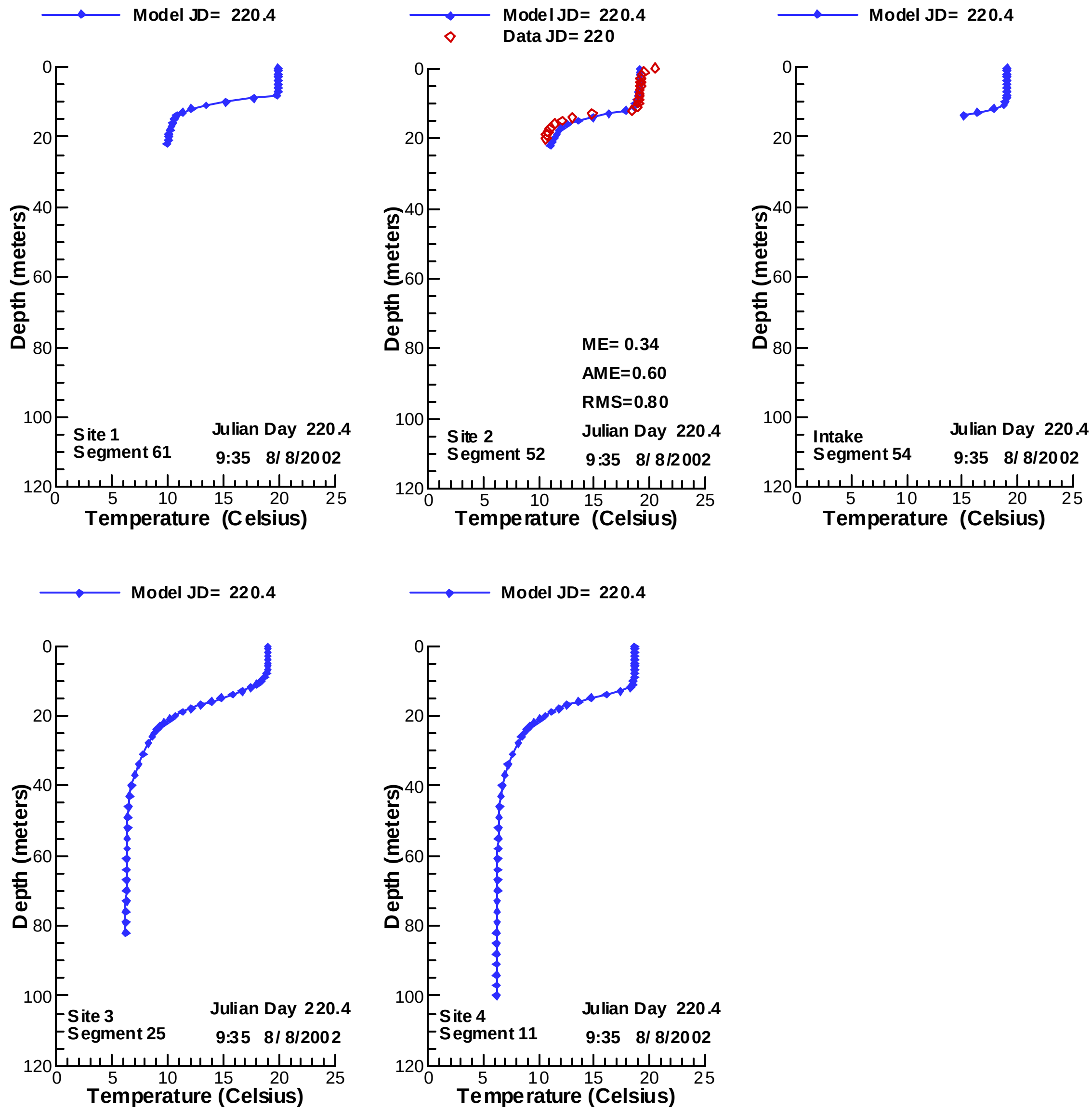

Figure 92. Vertical profiles of TEMPERATURE compared with data for 8/ 8/2002.

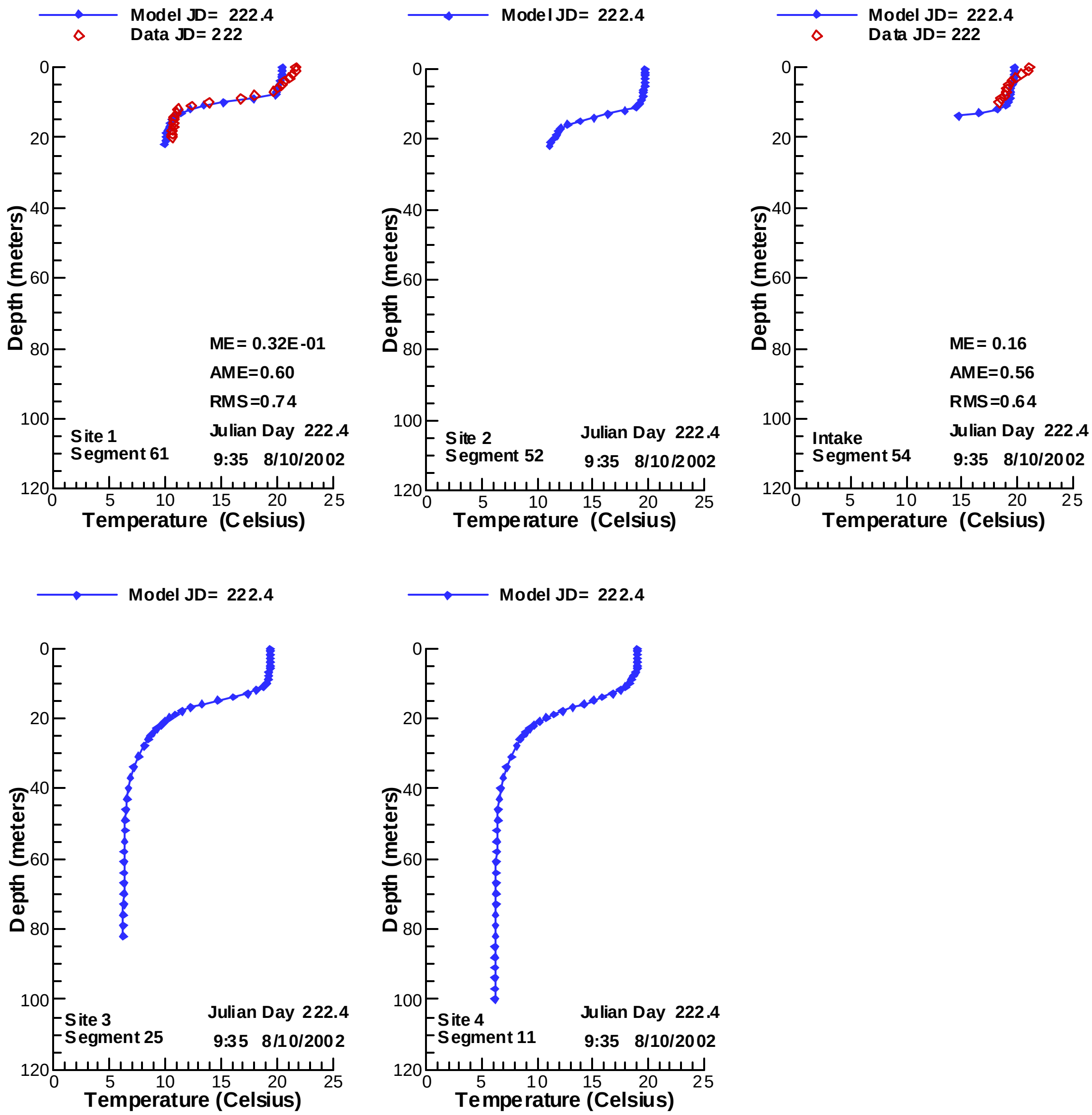

Figure 93. Vertical profiles of TEMPERATURE compared with data for 8/10/2002.

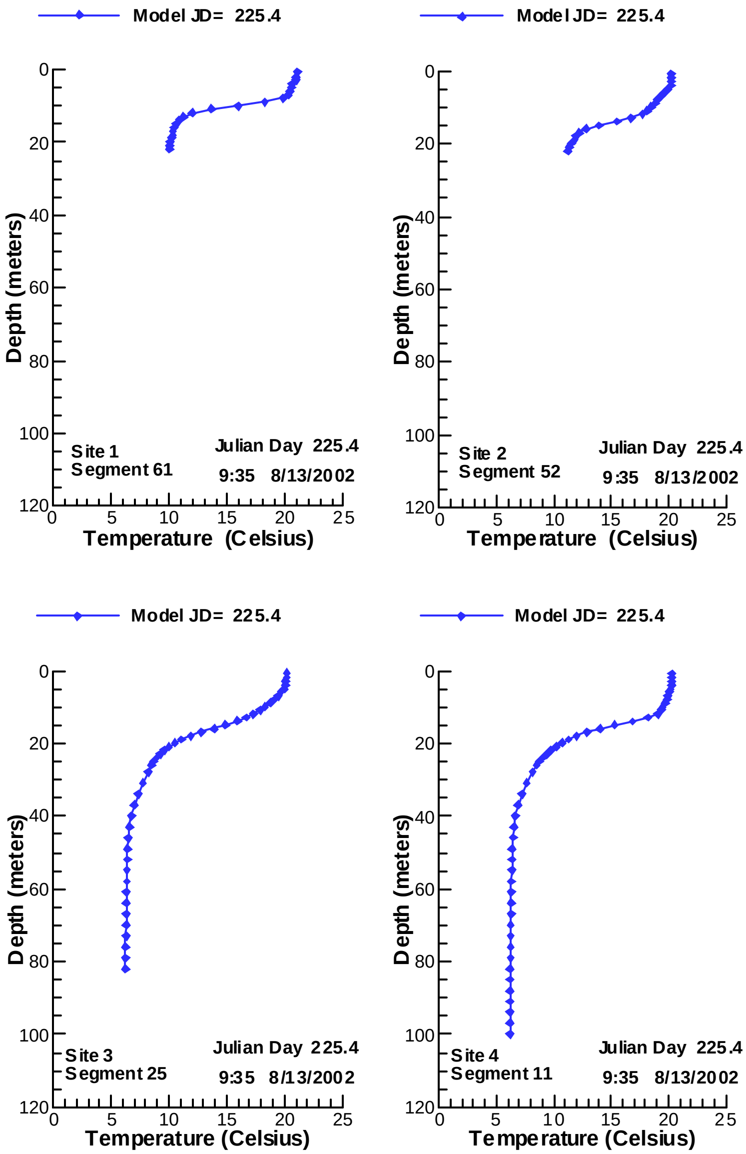

Figure 94. Vertical profiles of TEMPERATURE compared with data for 8/13/2002.

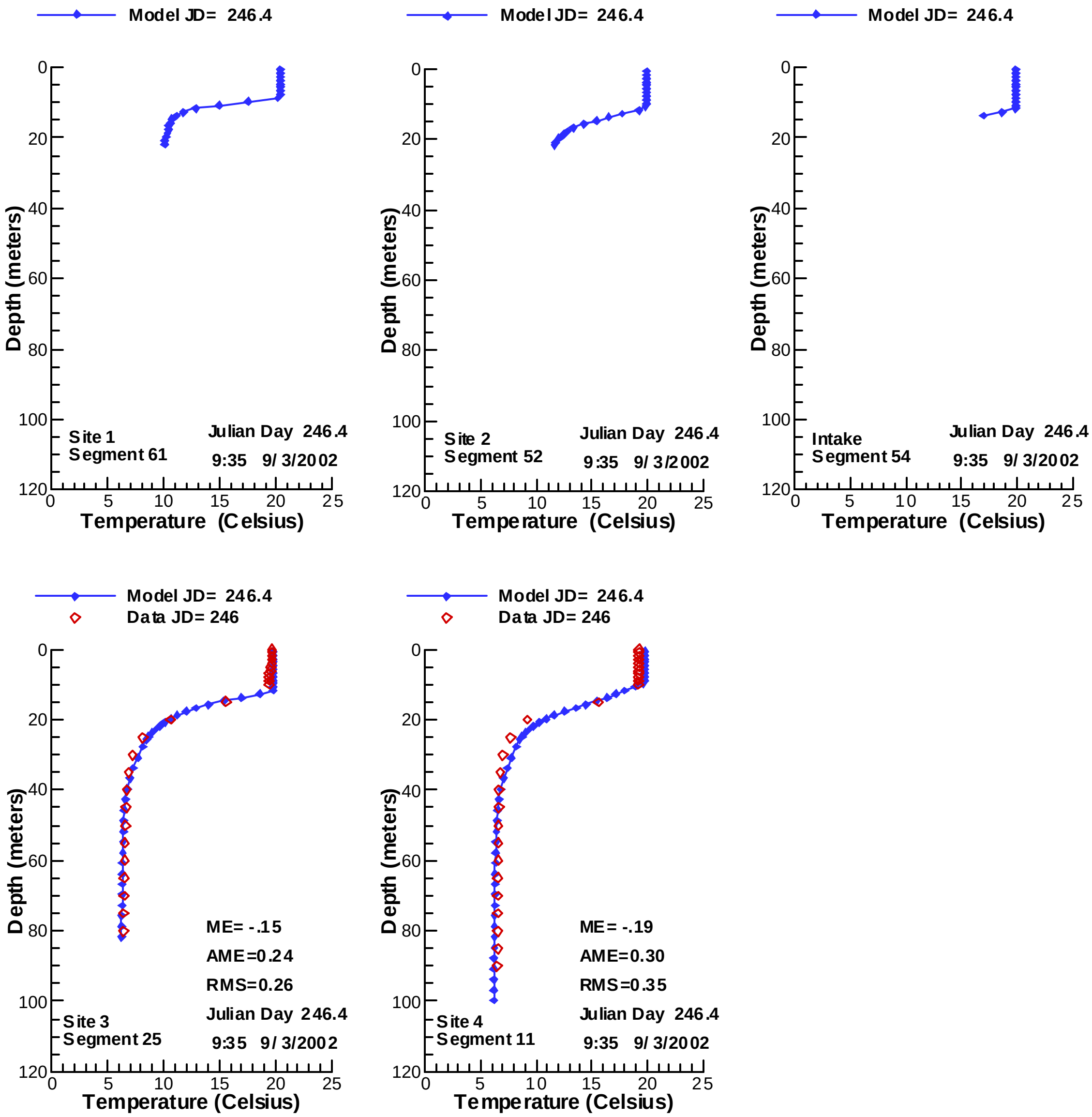

Figure 95. Vertical profiles of TEMPERATURE compared with data for 9/ 3/2002.

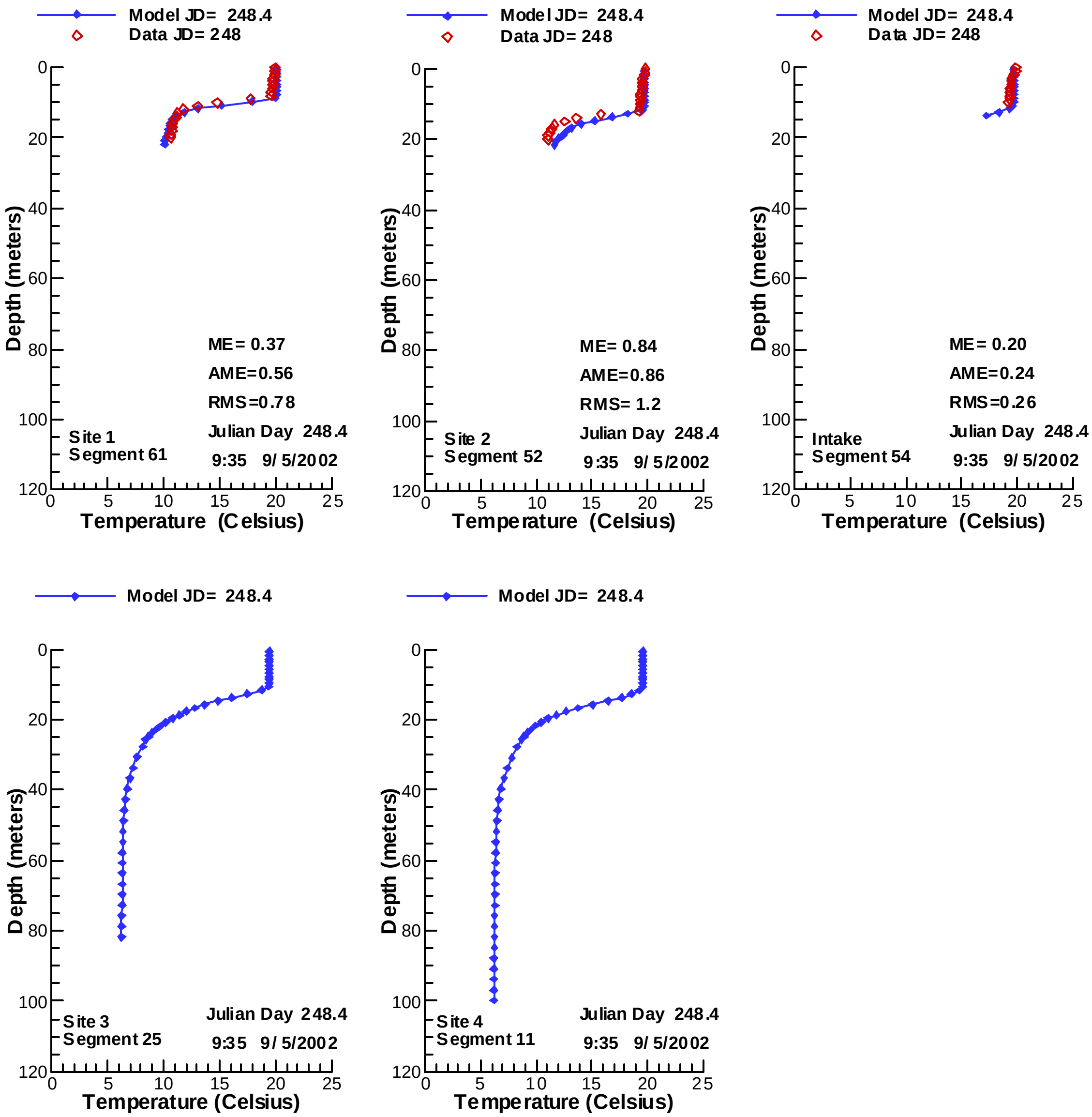

Figure 96. Vertical profiles of TEMPERATURE compared with data for 9/ 5/2002.

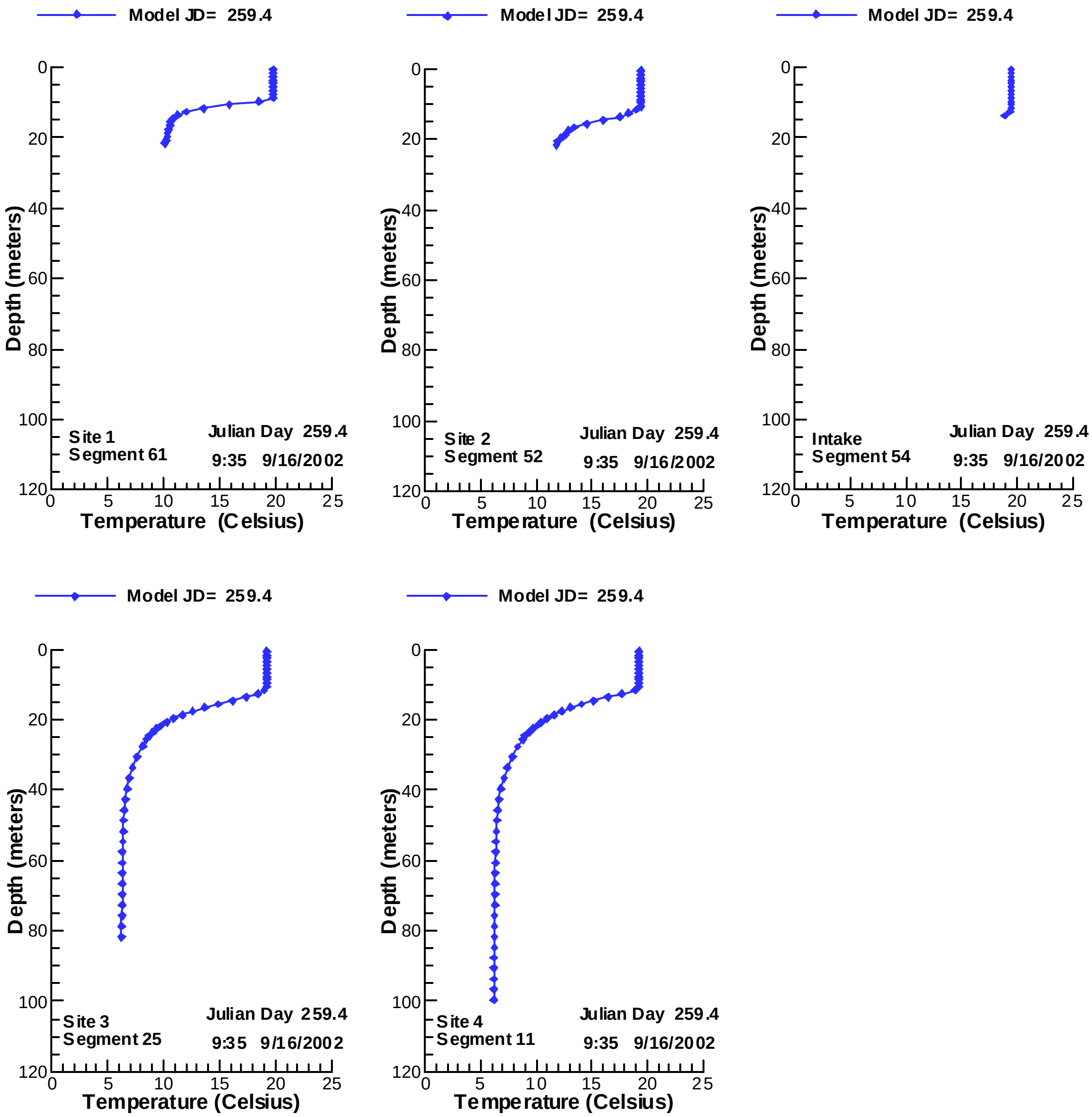

Figure 97. Vertical profiles of TEMPERATURE compared with data for 9/16/2002.

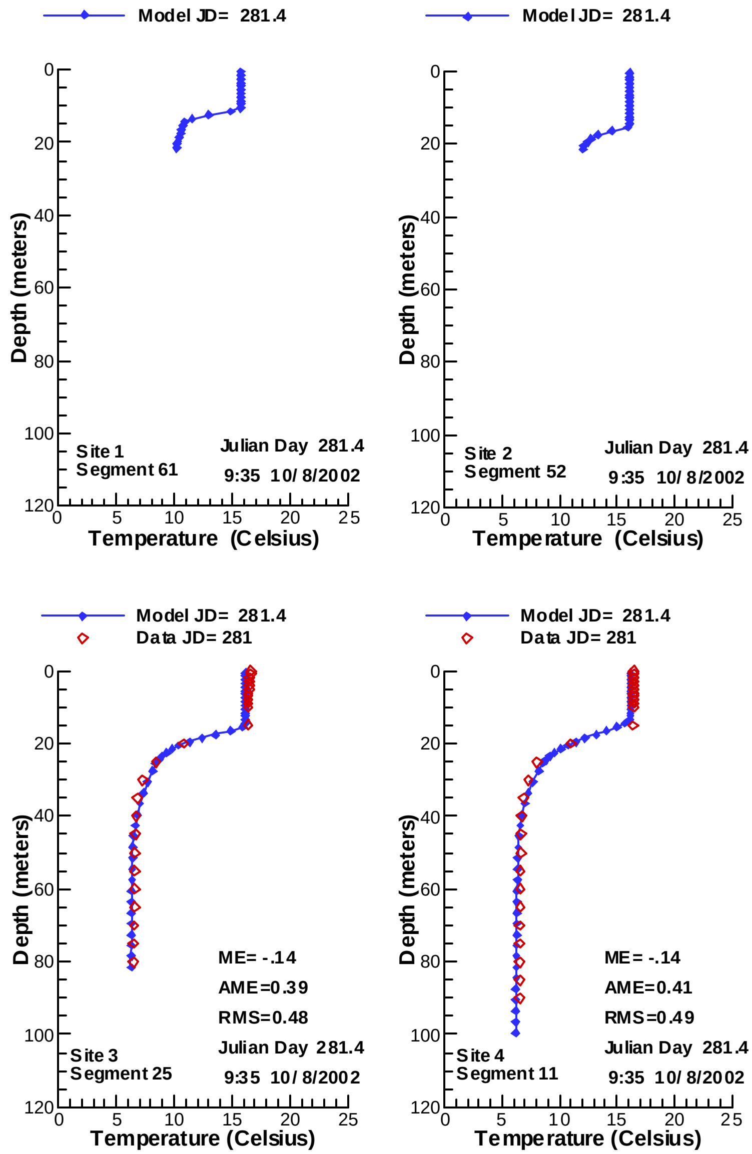

Figure 98. Vertical profiles of TEMPERATURE compared with data for 10/ 8/2002.

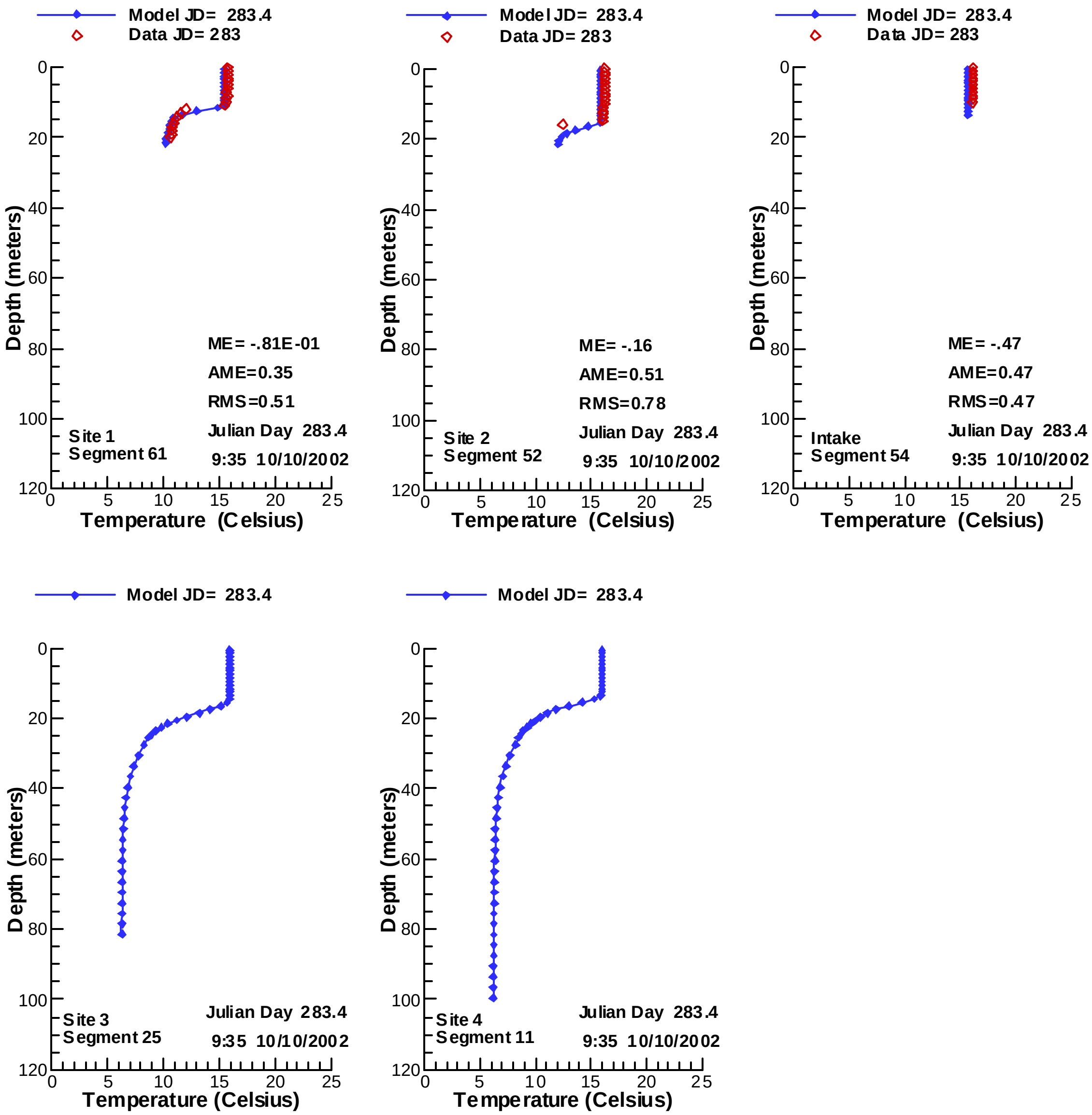

Figure 99. Vertical profiles of TEMPERATURE compared with data for 10/10/2002.

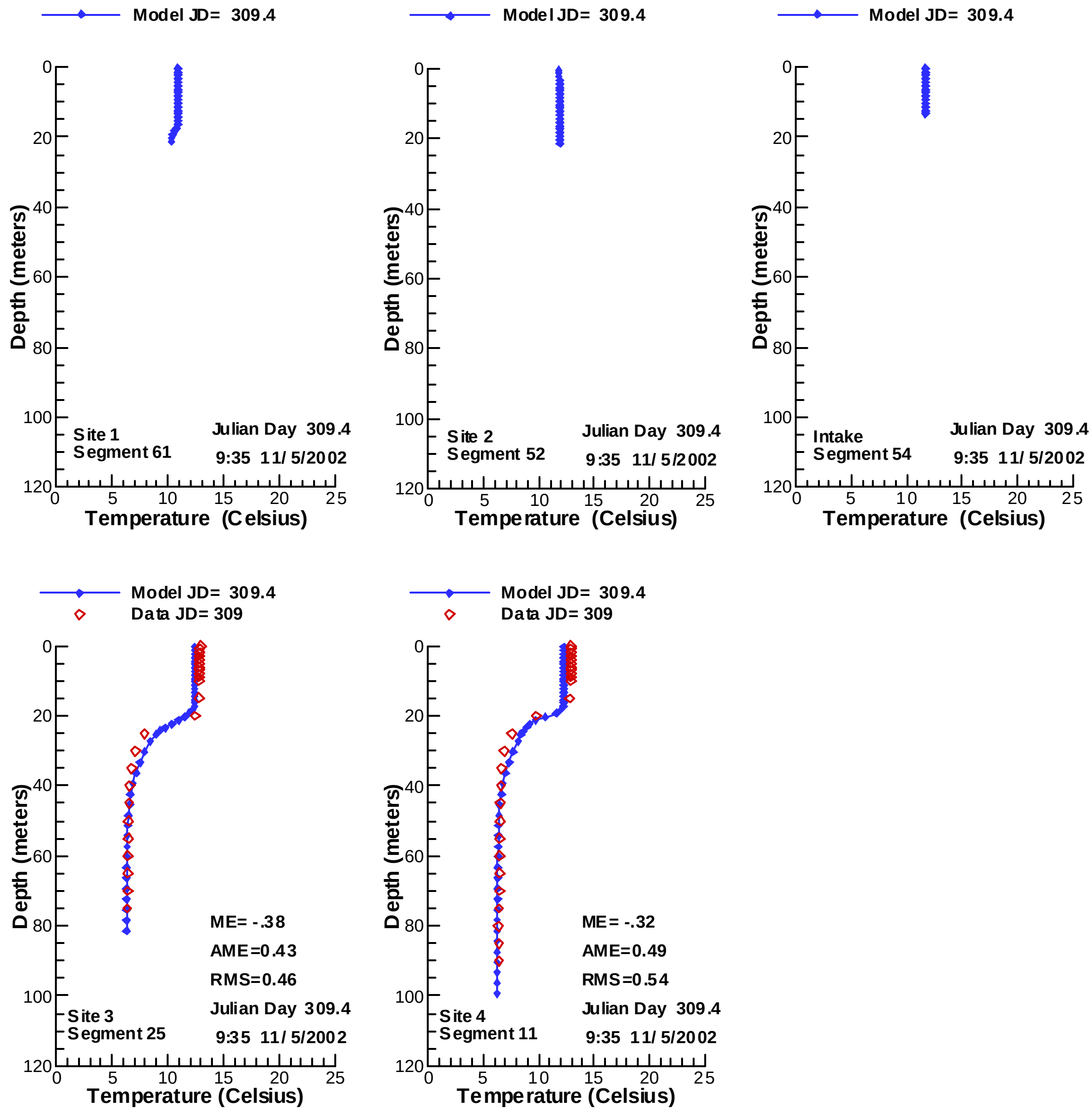

Figure 100. Vertical profiles of TEMPERATURE compared with data for 11/ 5/2002.

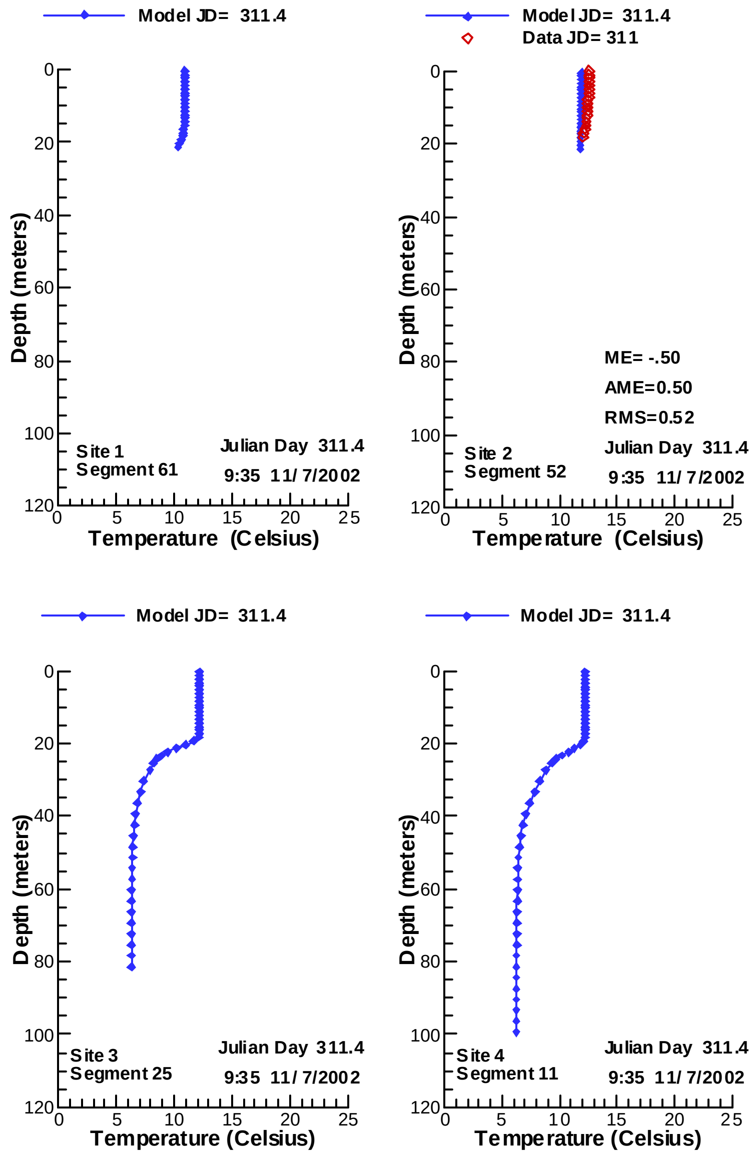

Figure 101. Vertical profiles of TEMPERATURE compared with data for 11/ 7/2002.

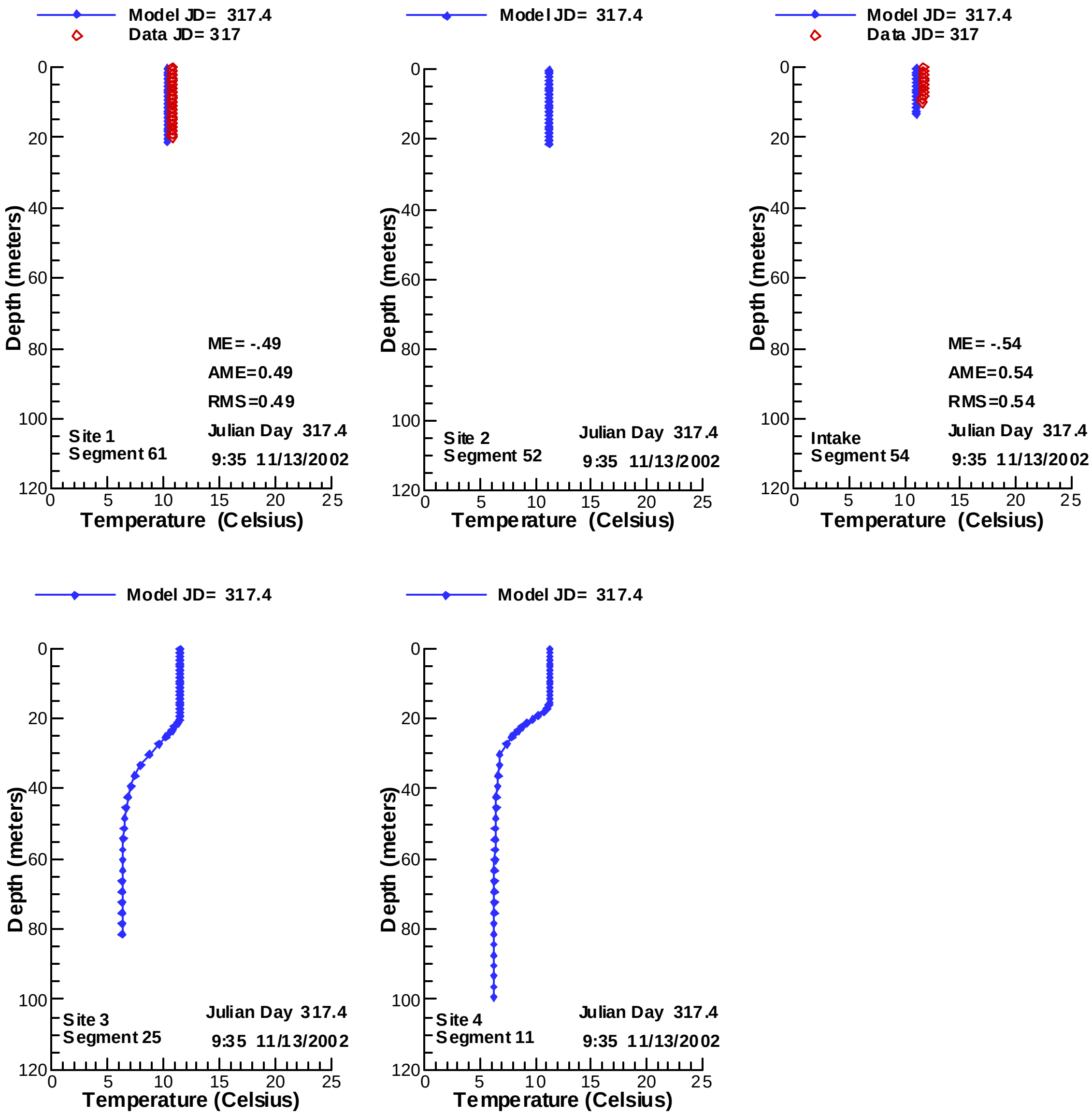

Figure 102. Vertical profiles of TEMPERATURE compared with data for 11/13/2002.

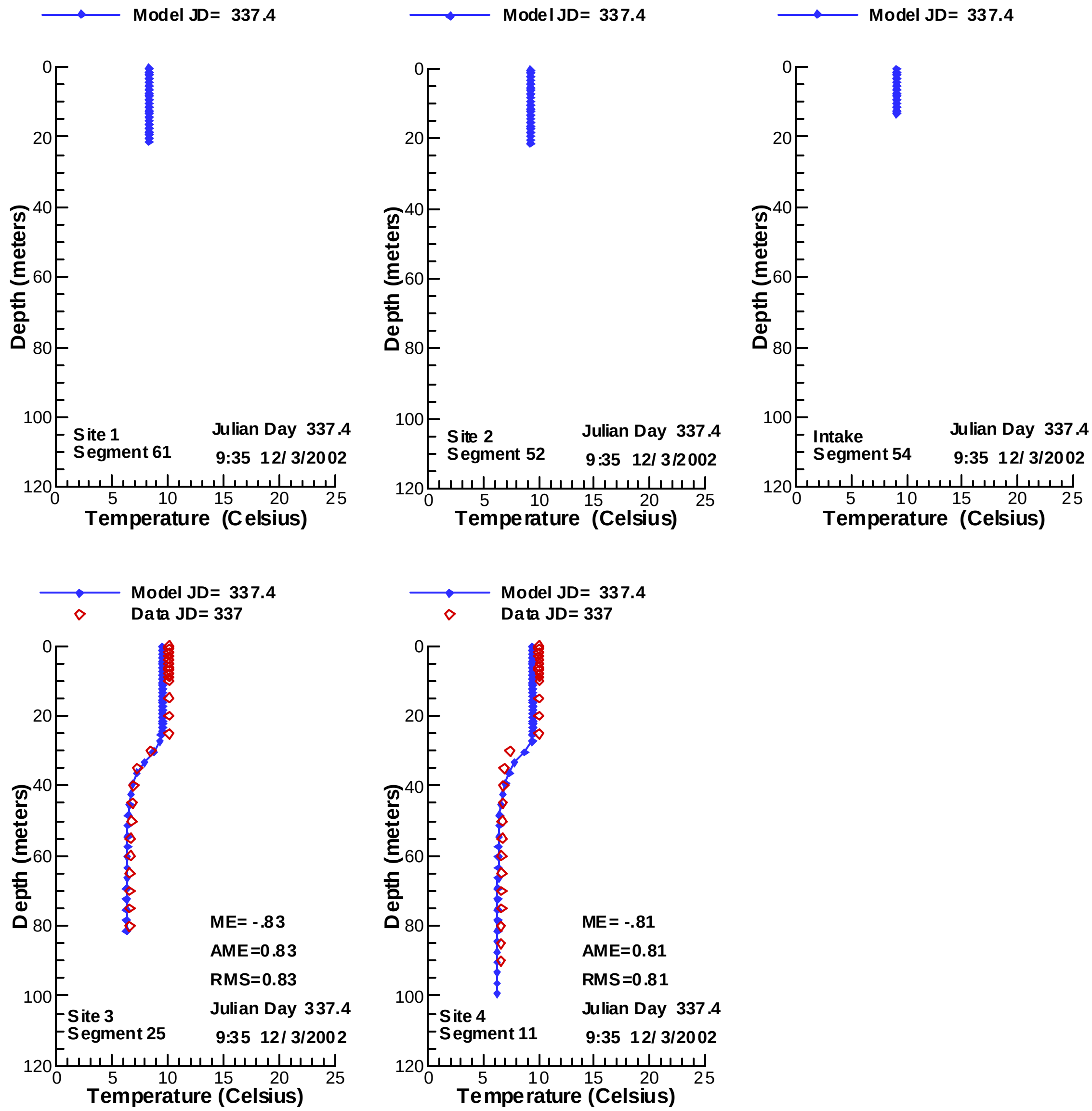

Figure 103. Vertical profiles of TEMPERATURE compared with data for 12/ 3/2002.

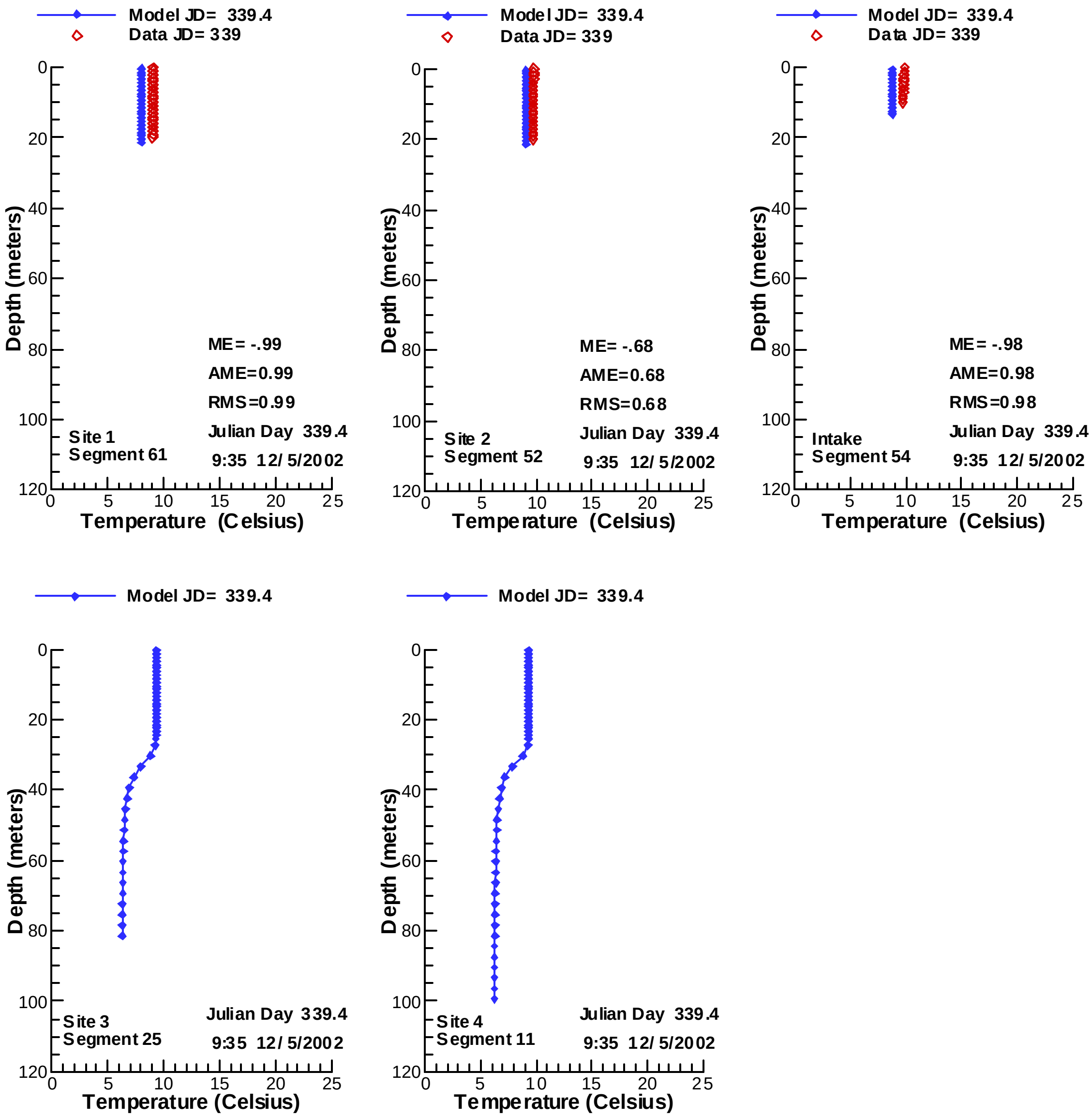

Figure 104. Vertical profiles of TEMPERATURE compared with data for 12/ 5/2002.

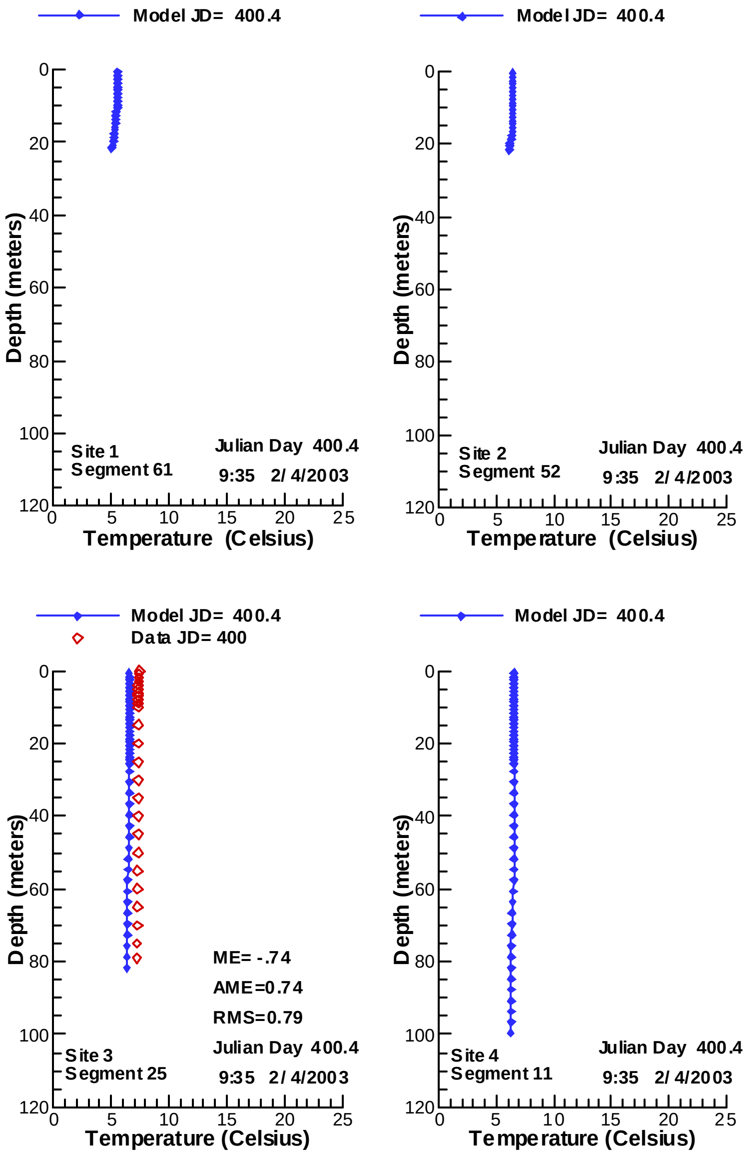

Figure 105. Vertical profiles of TEMPERATURE compared with data for 2/ 4/2003.

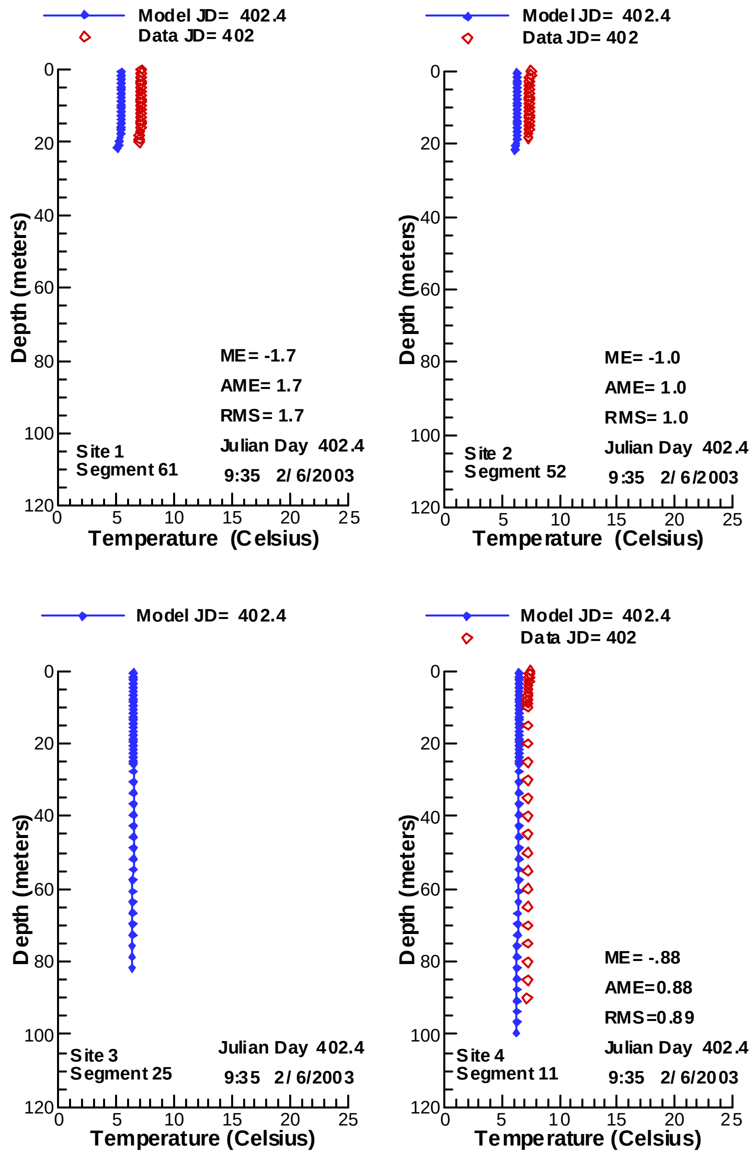

Figure 106. Vertical profiles of TEMPERATURE compared with data for 2/ 6/2003.

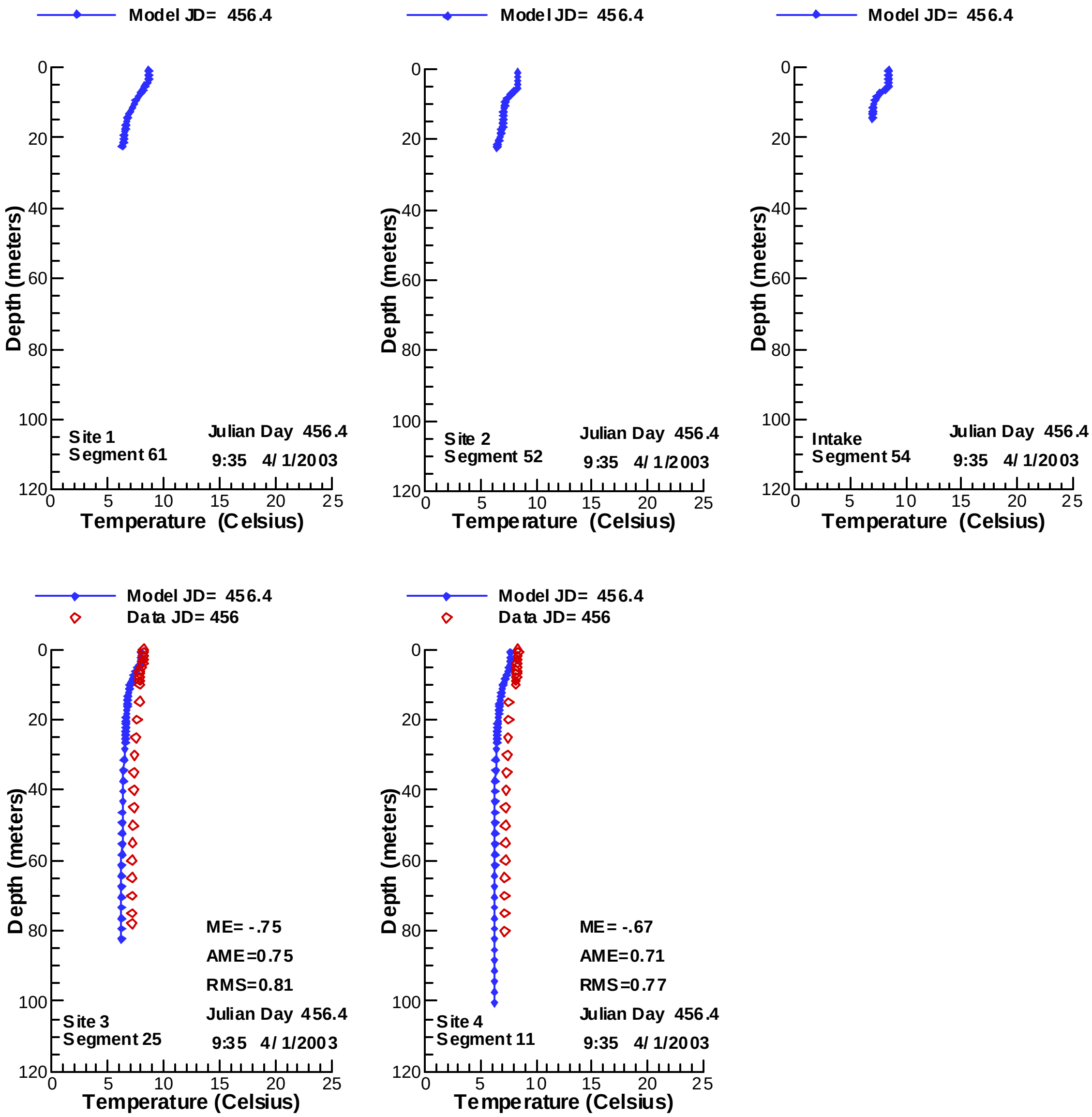

Figure 107. Vertical profiles of TEMPERATURE compared with data for 4/ 1/2003.

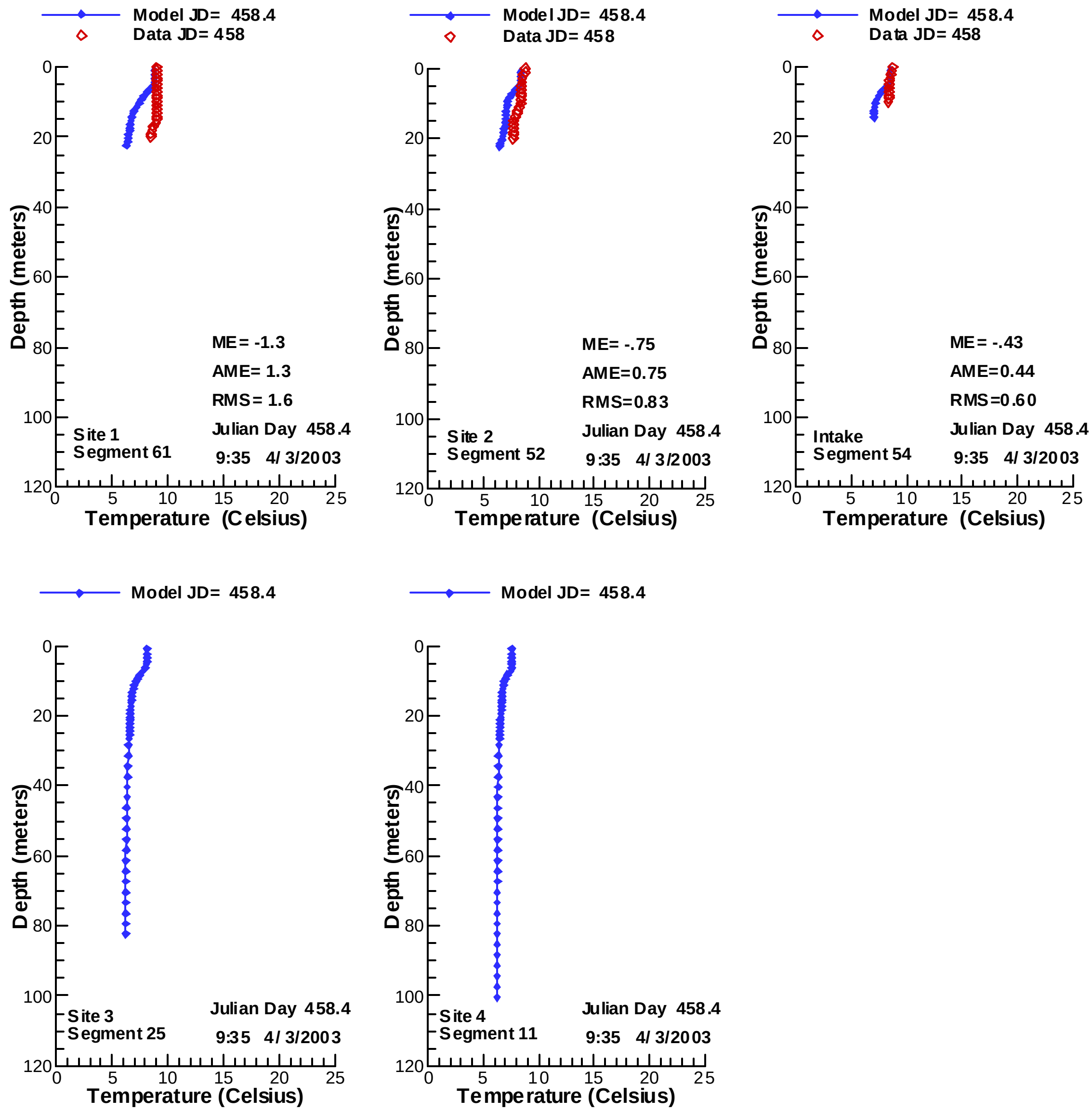

Figure 108. Vertical profiles of TEMPERATURE compared with data for 4/ 3/2003.

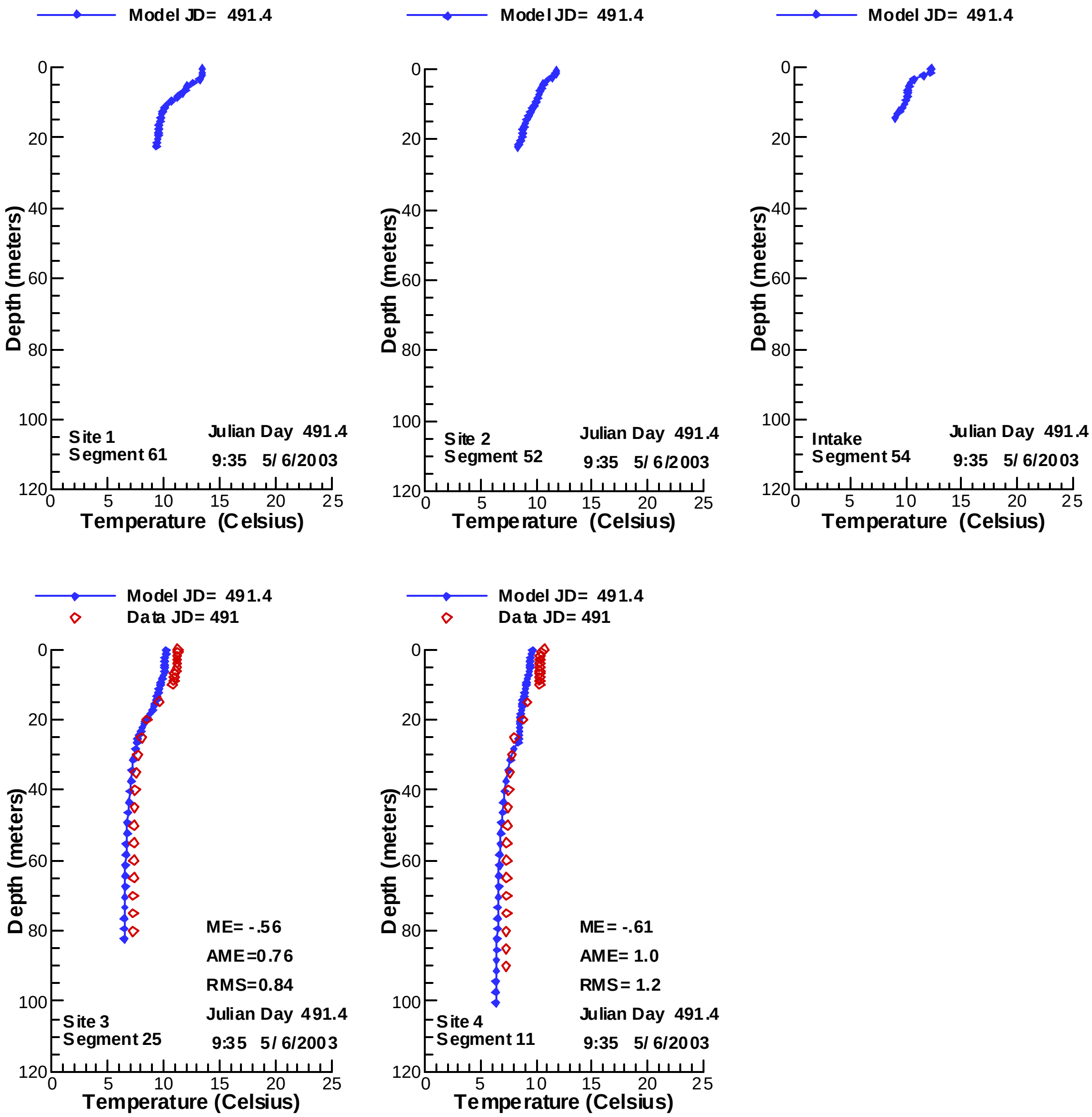

Figure 109. Vertical profiles of TEMPERATURE compared with data for 5/ 6/2003.

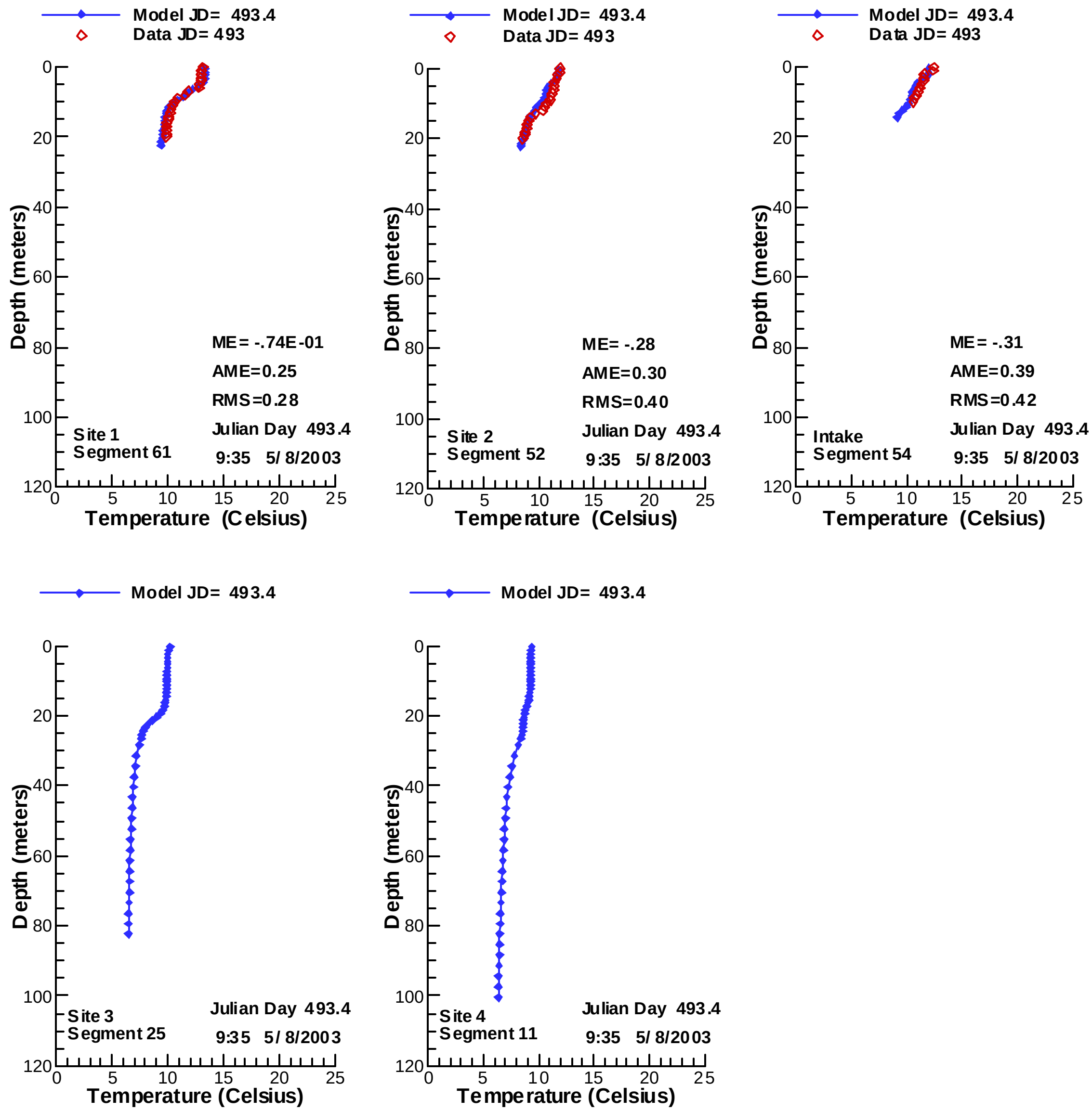

Figure 110. Vertical profiles of TEMPERATURE compared with data for 5/ 8/2003.

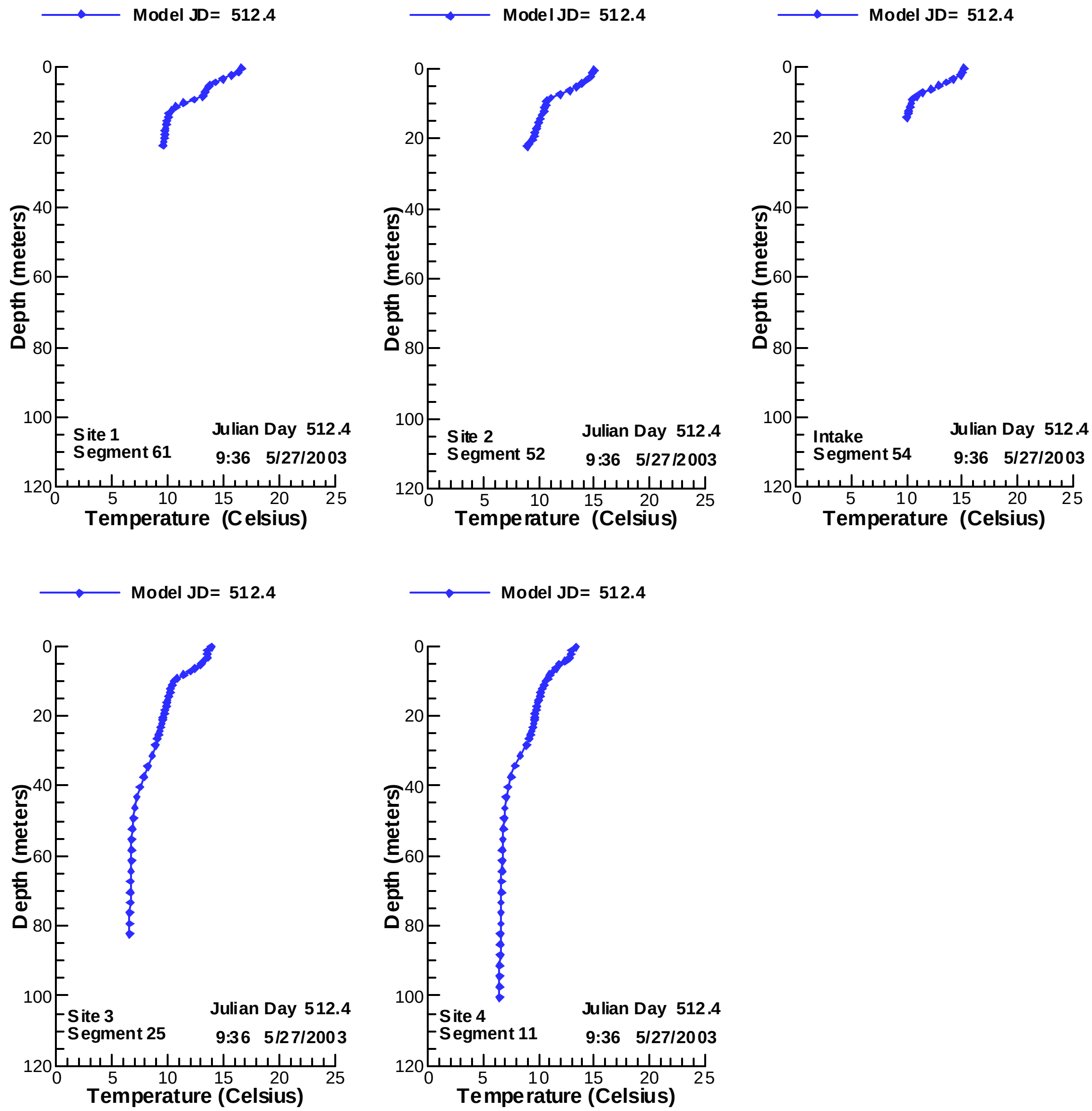

Figure 111. Vertical profiles of TEMPERATURE compared with data for 5/27/2003.

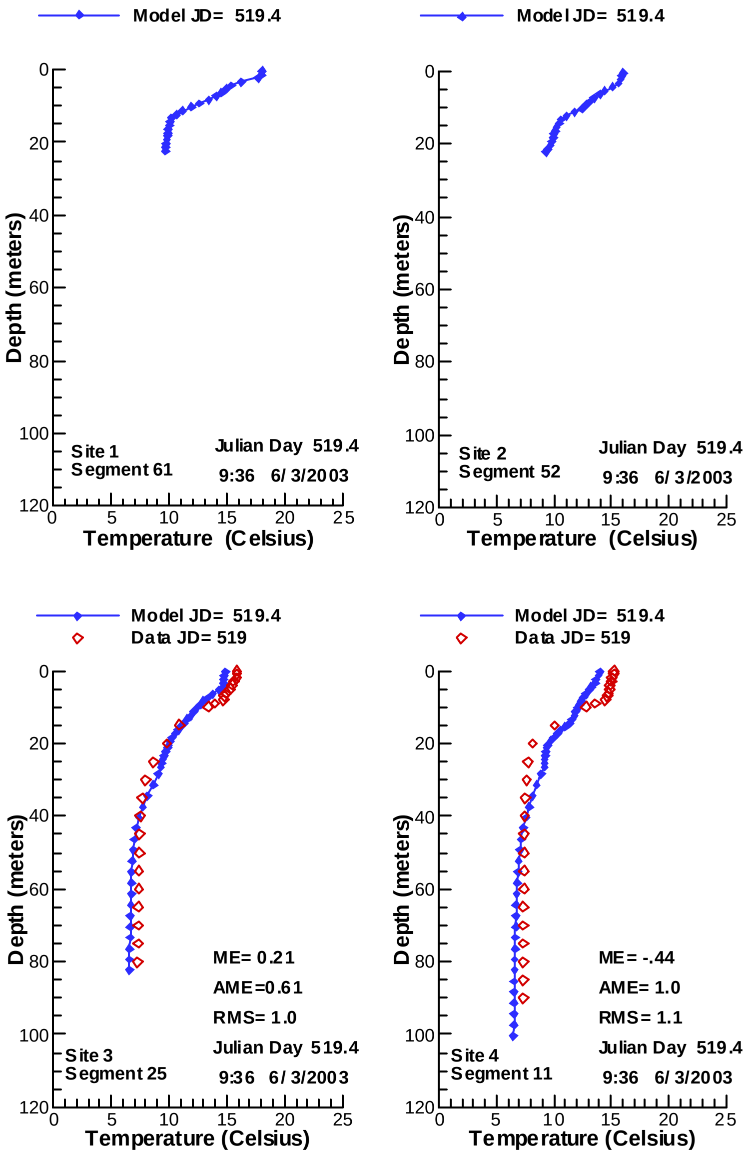

Figure 112. Vertical profiles of TEMPERATURE compared with data for 6/ 3/2003.

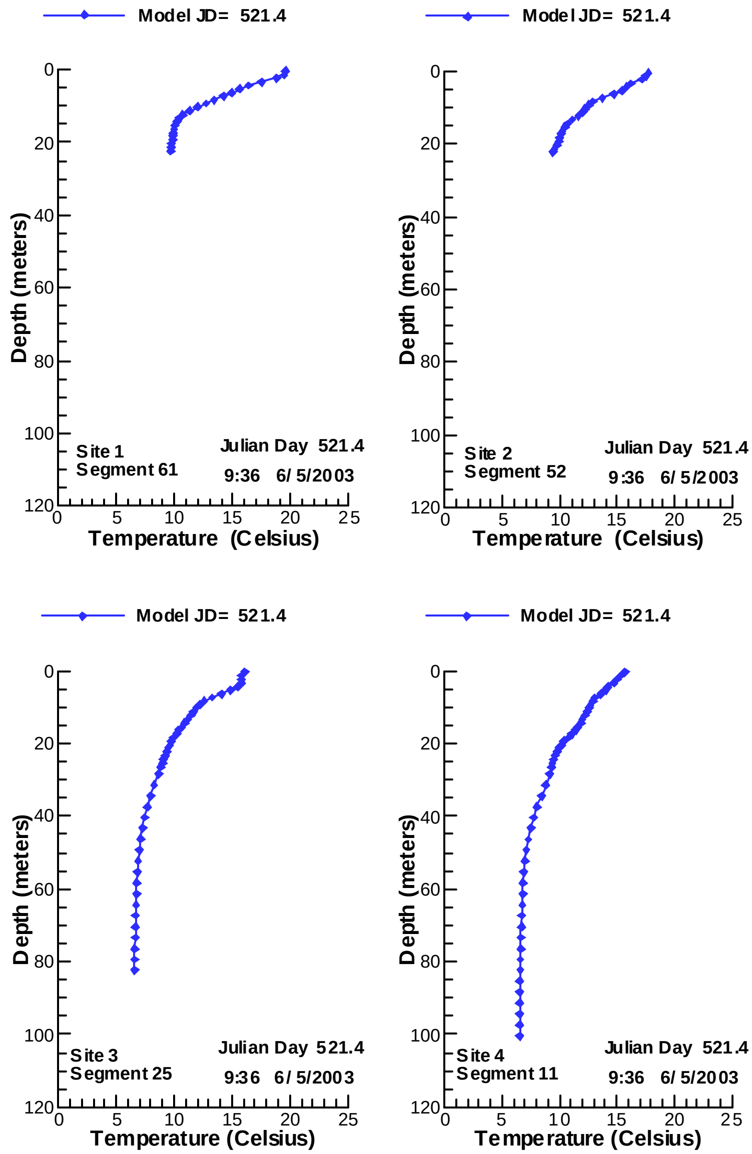

Figure 113. Vertical profiles of TEMPERATURE compared with data for 6/ 5/2003.

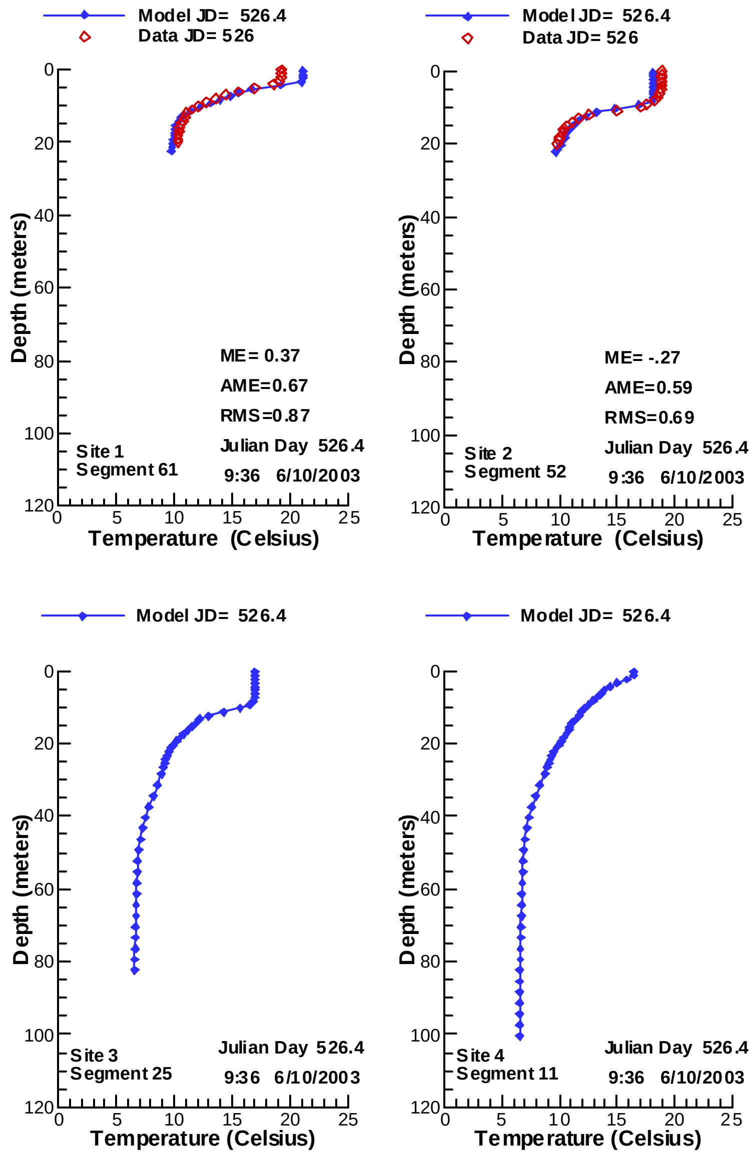

Figure 114. Vertical profiles of TEMPERATURE compared with data for 6/10/2003.

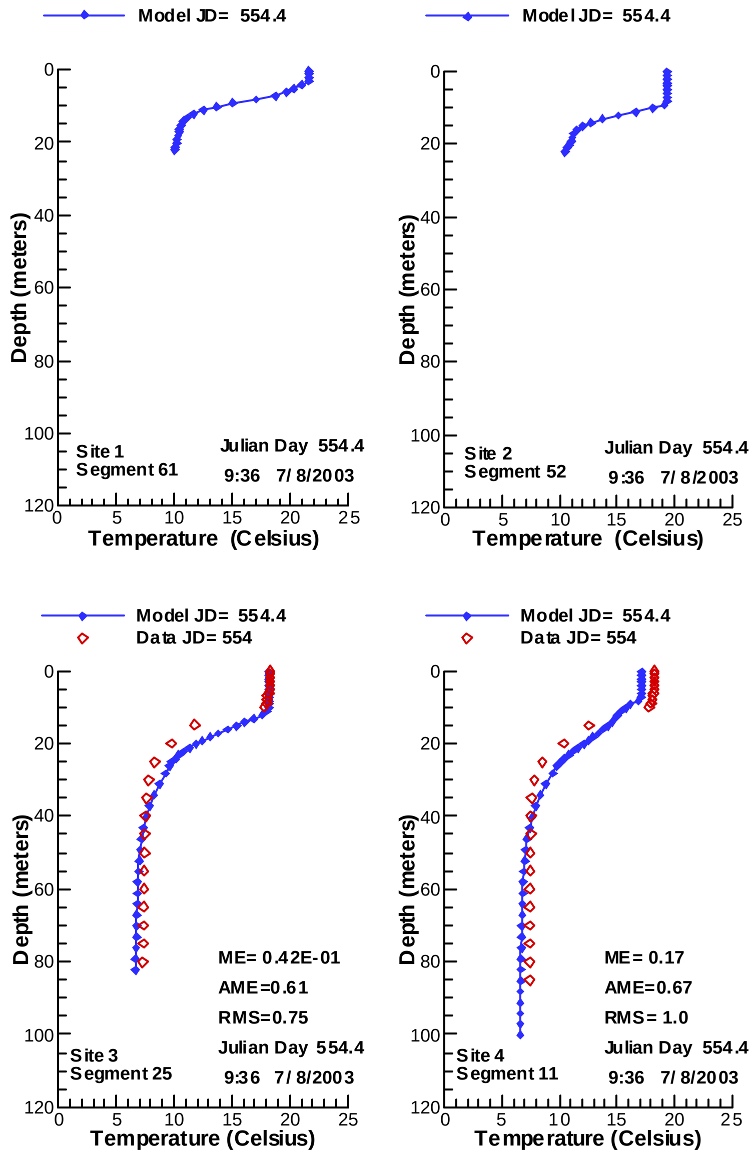

Figure 115. Vertical profiles of TEMPERATURE compared with data for 7/ 8/2003.

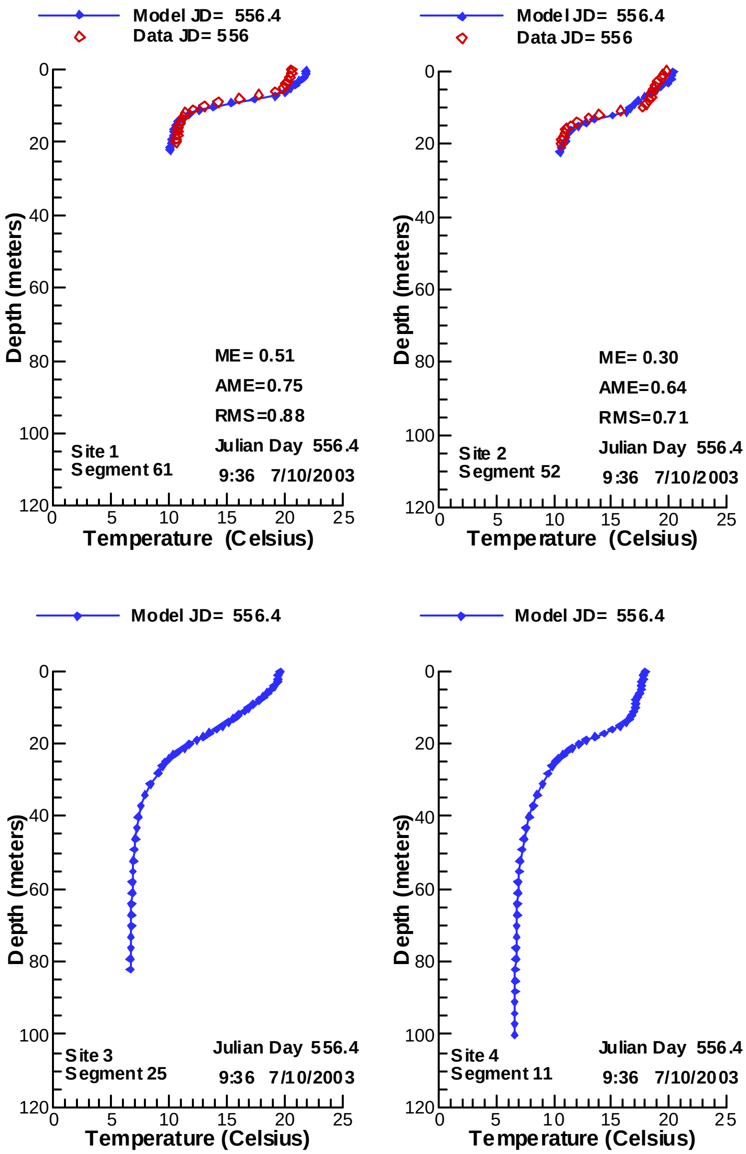

Figure 116. Vertical profiles of TEMPERATURE compared with data for 7/10/2003.

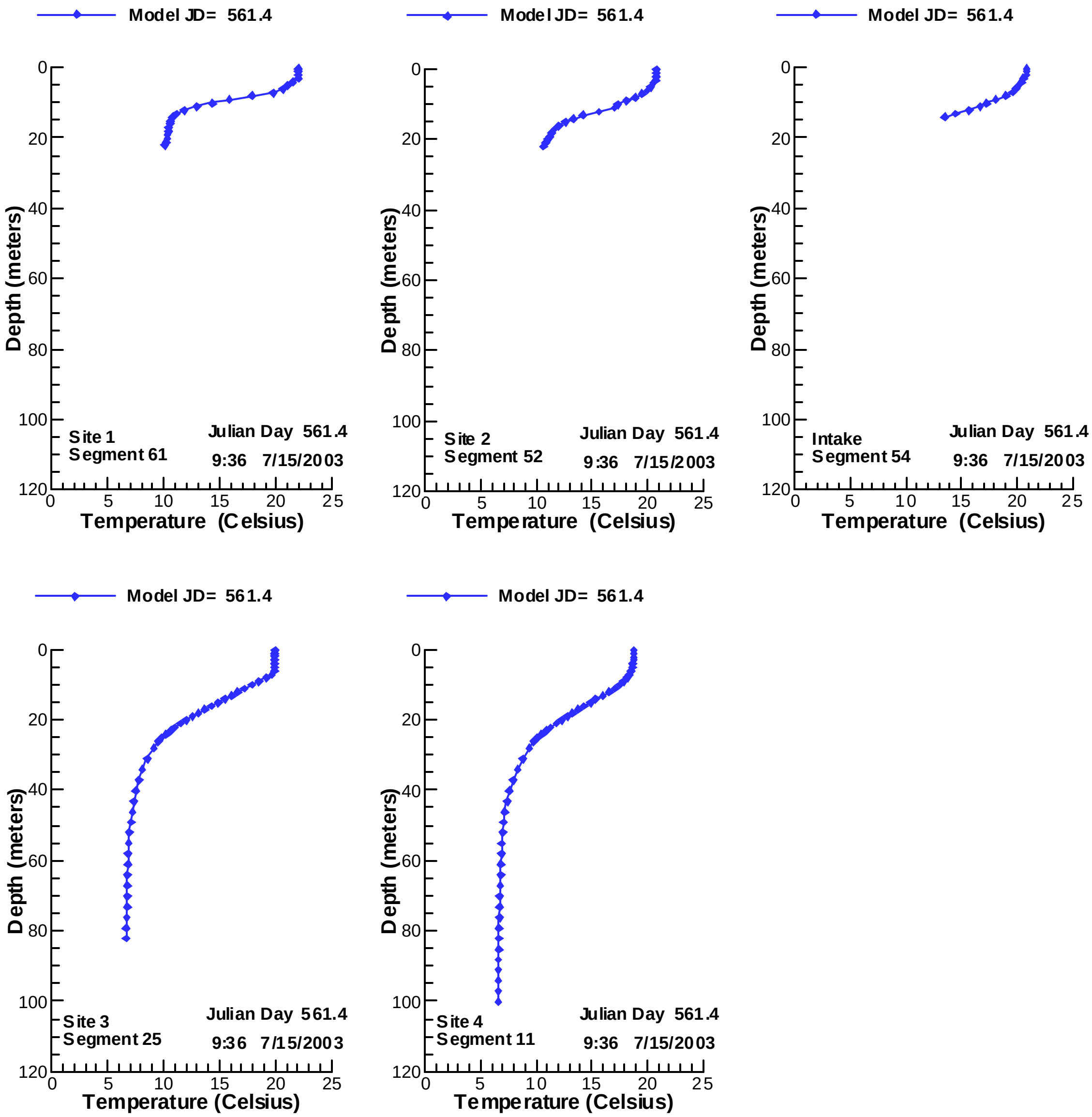

Figure 117. Vertical profiles of TEMPERATURE compared with data for 7/15/2003.

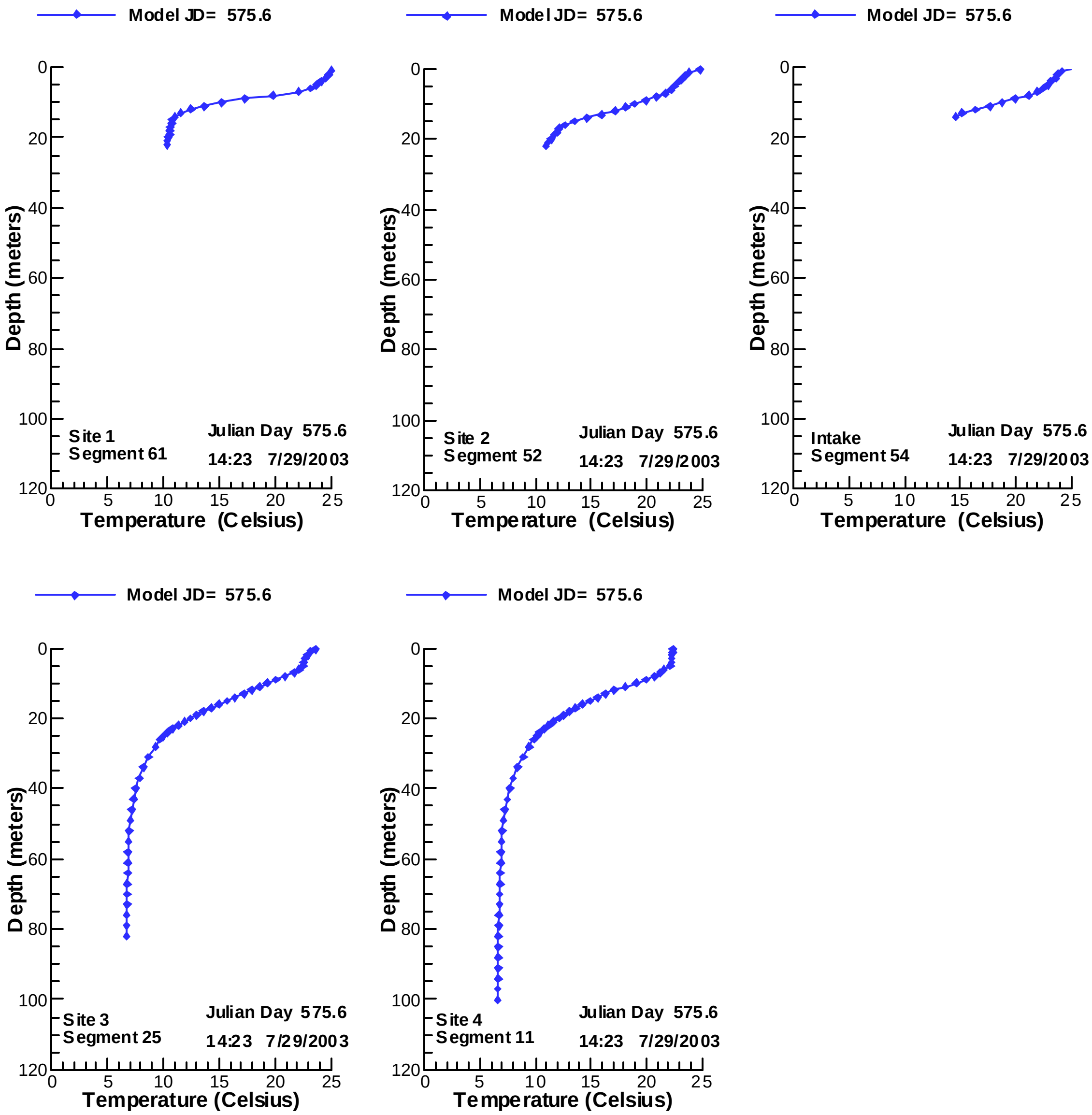

Figure 118. Vertical profiles of TEMPERATURE compared with data for 7/29/2003.

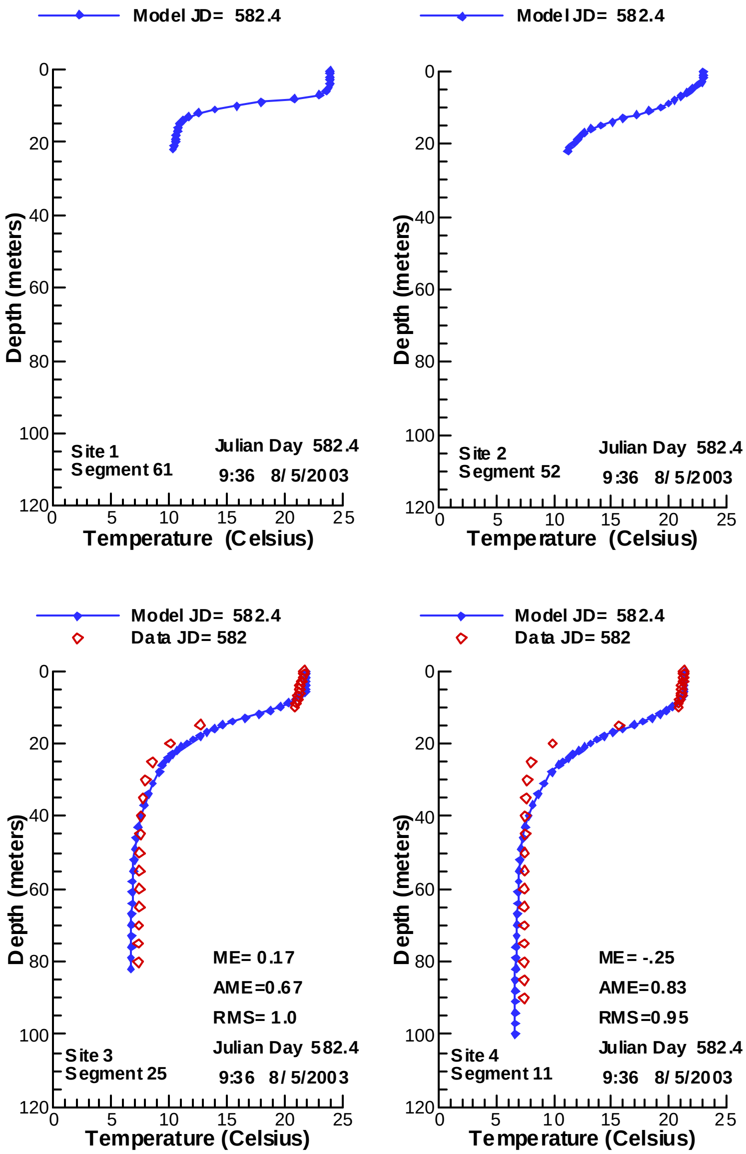

Figure 119. Vertical profiles of TEMPERATURE compared with data for 8/ 5/2003.

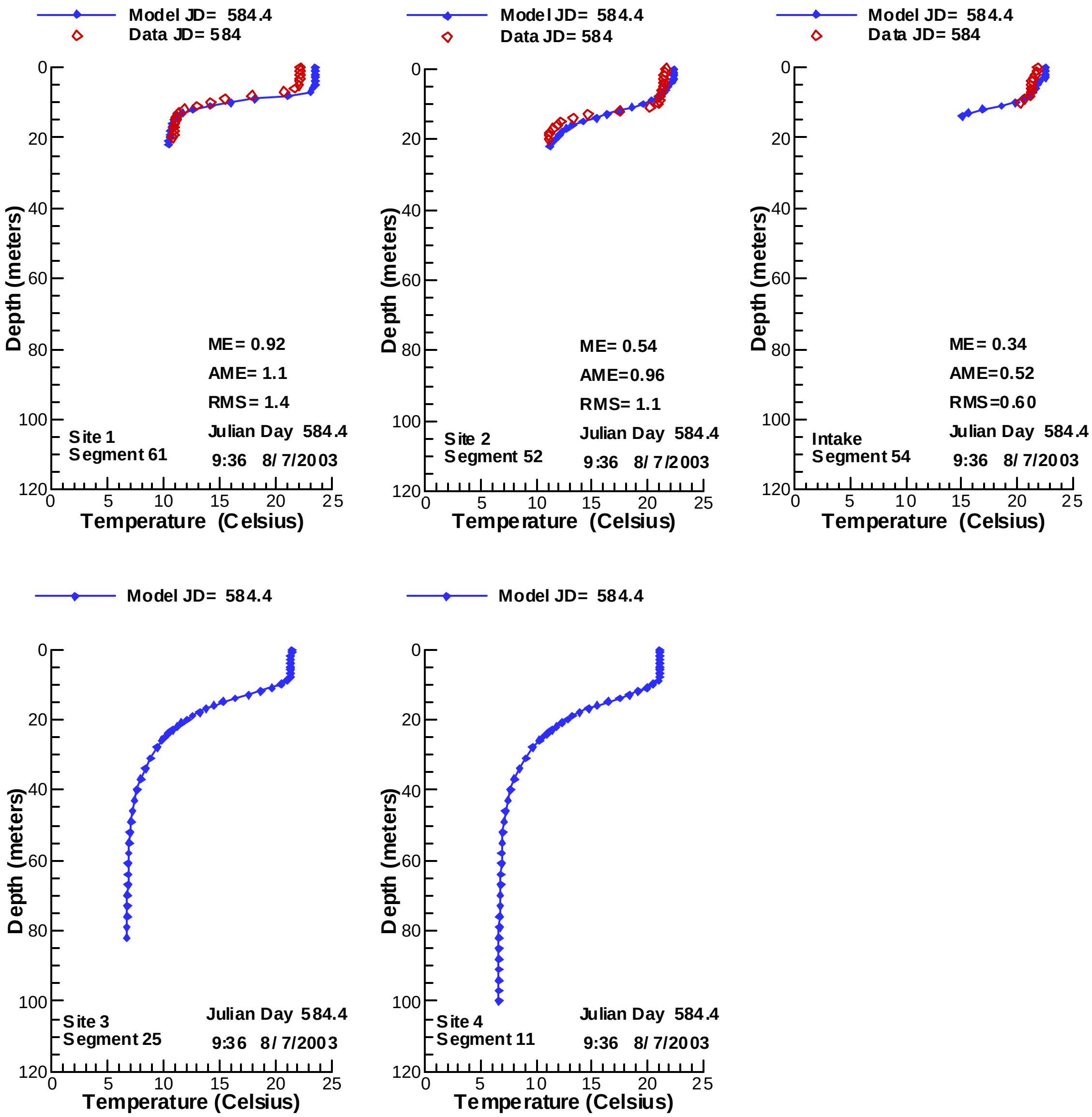

Figure 120. Vertical profiles of TEMPERATURE compared with data for 8/ 7/2003.

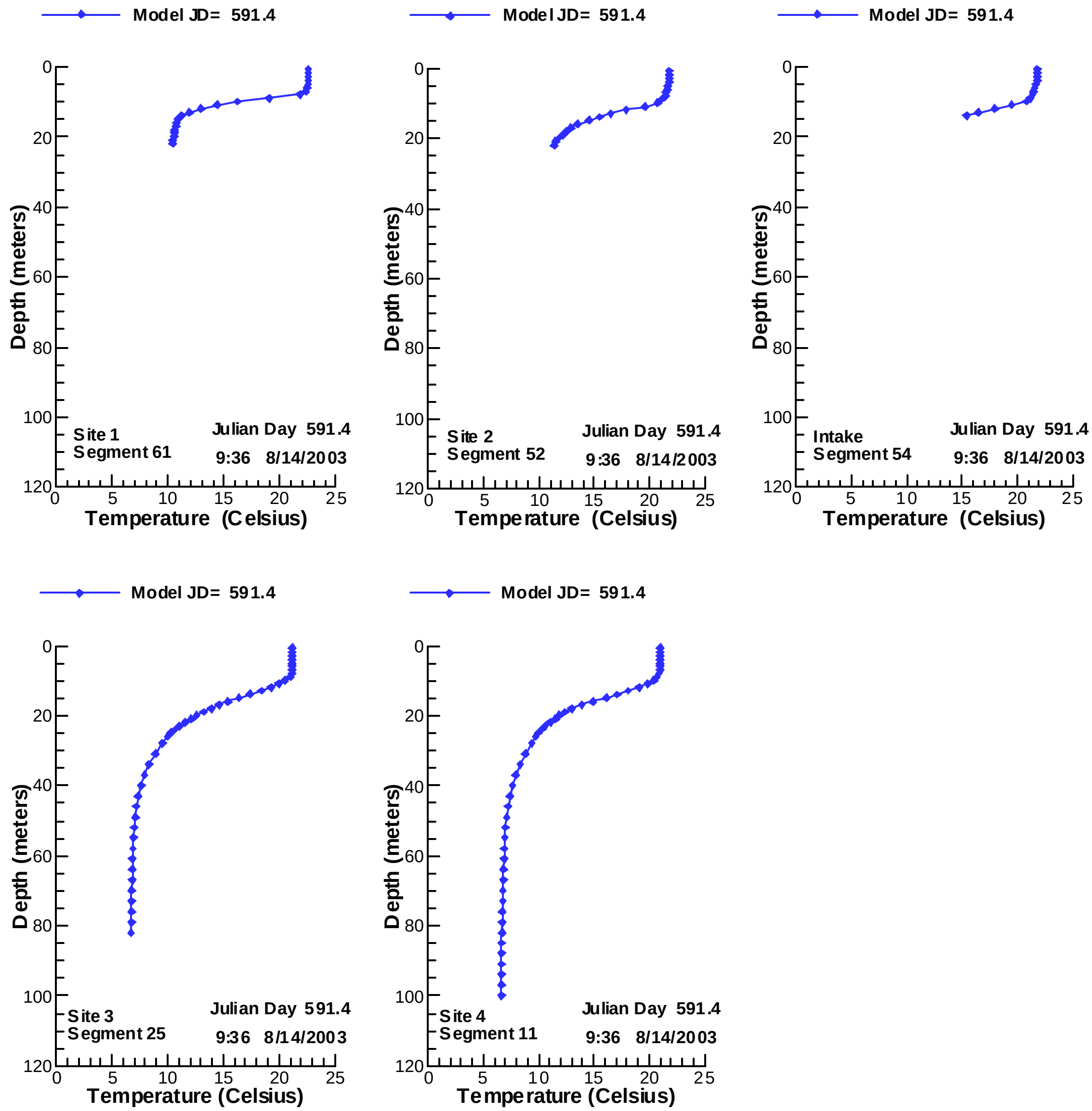

Figure 121. Vertical profiles of TEMPERATURE compared with data for 8/14/2003.

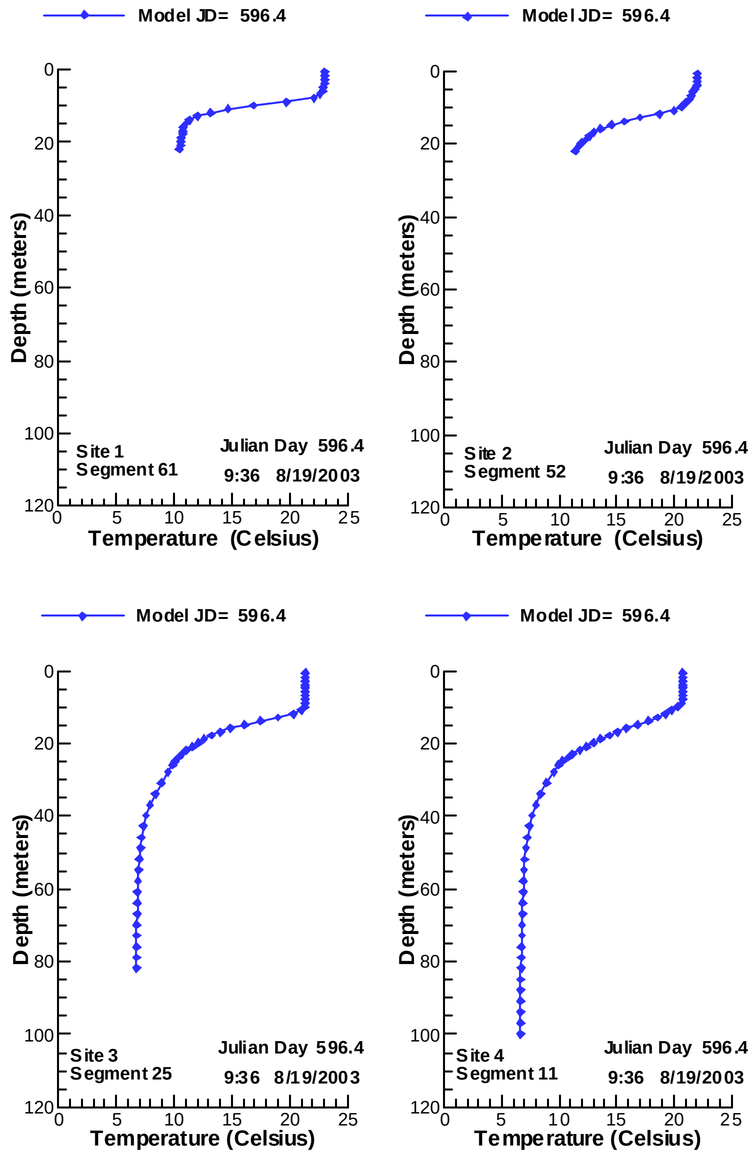

Figure 122. Vertical profiles of TEMPERATURE compared with data for 8/19/2003.

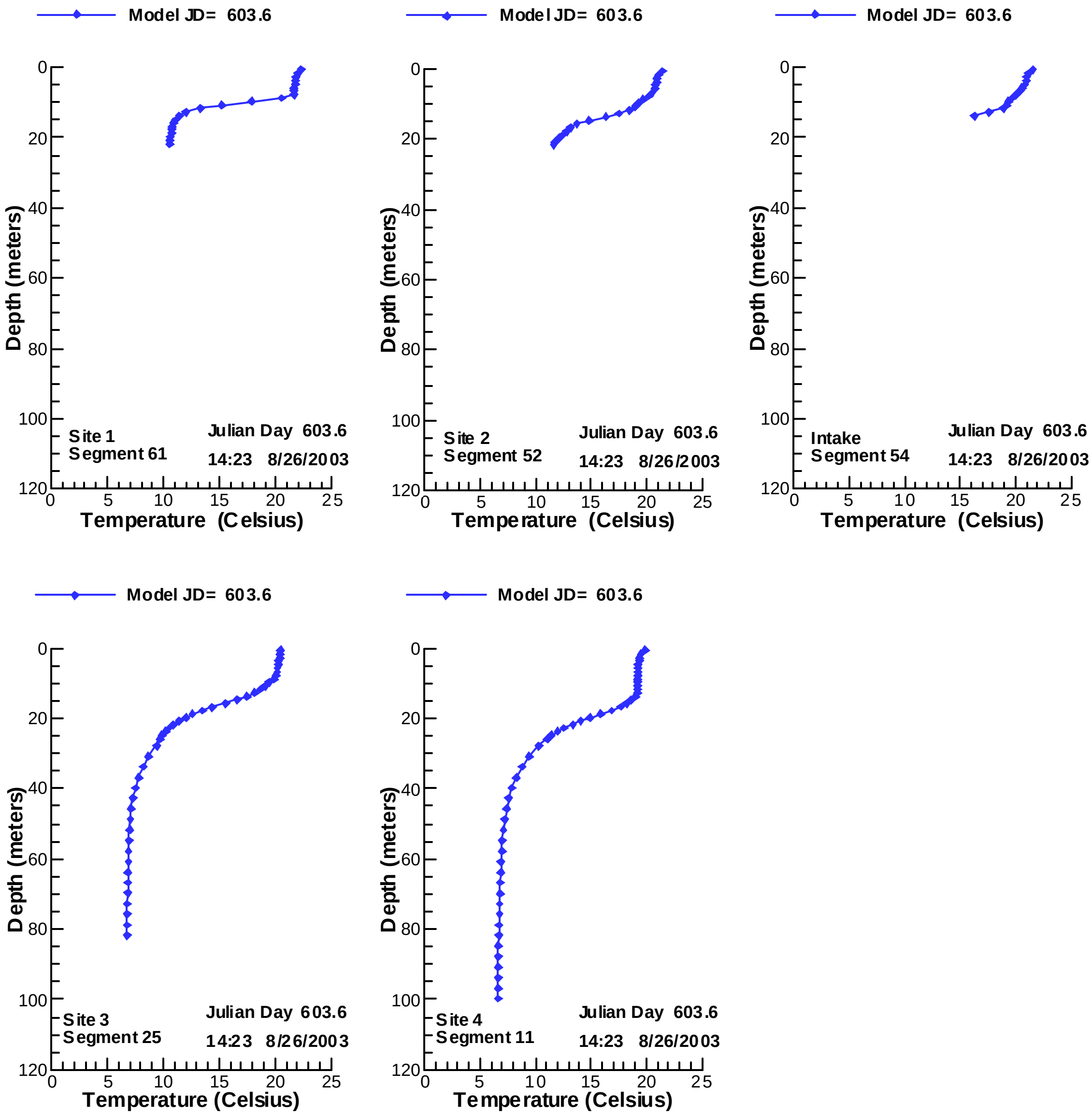

Figure 123. Vertical profiles of TEMPERATURE compared with data for 8/26/2003.

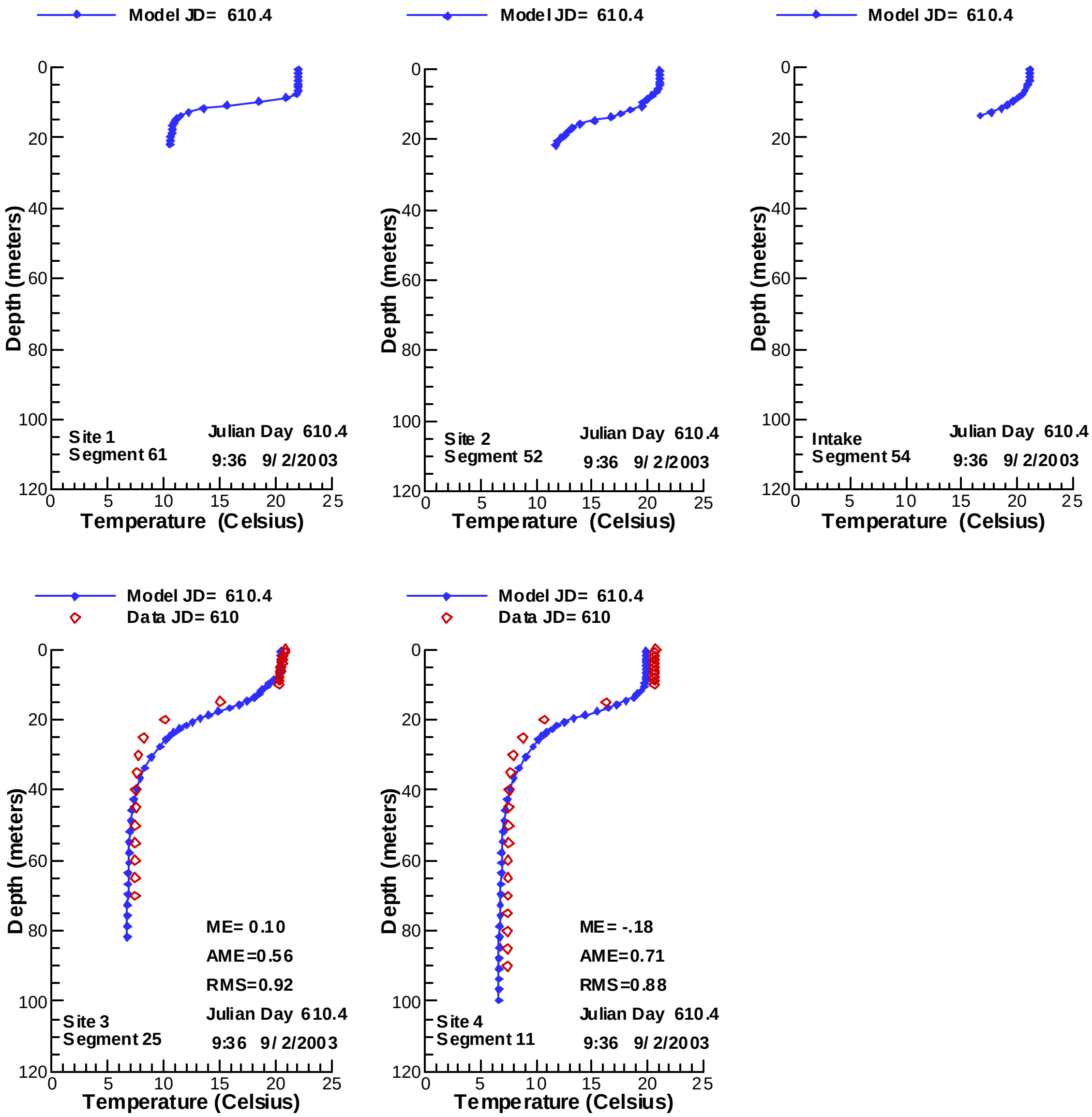

Figure 124. Vertical profiles of TEMPERATURE compared with data for 9/ 2/2003.

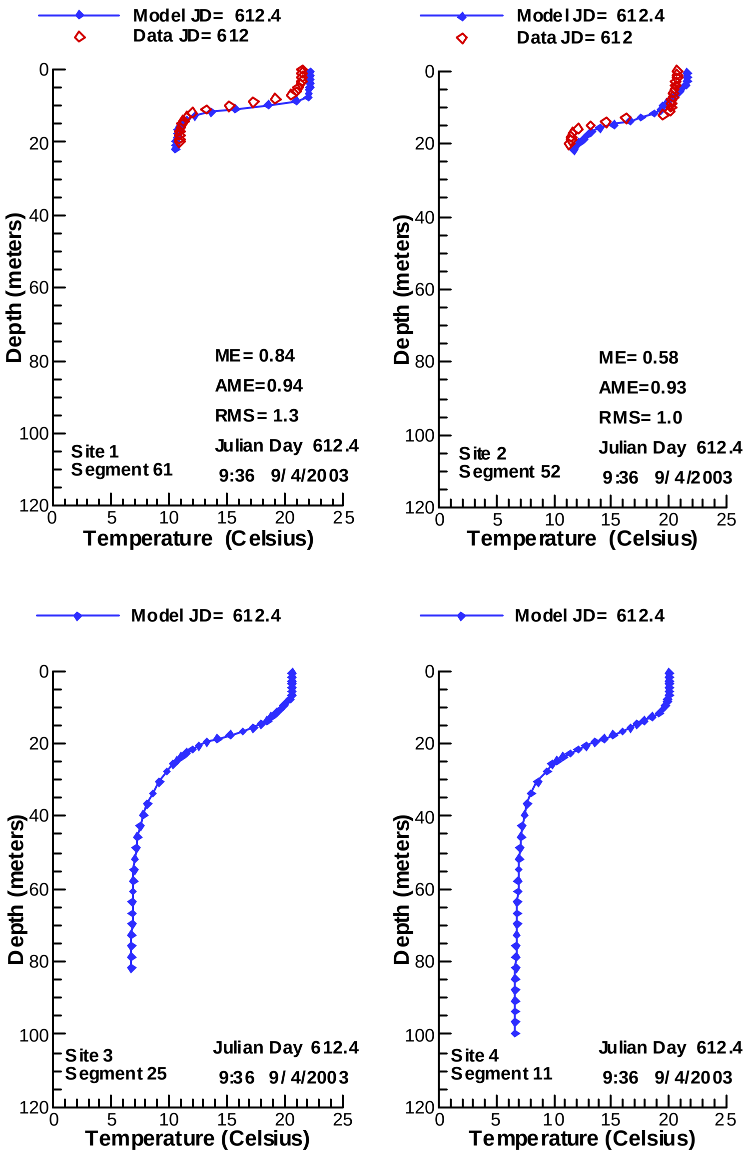

Figure 125. Vertical profiles of TEMPERATURE compared with data for 9/ 4/2003.

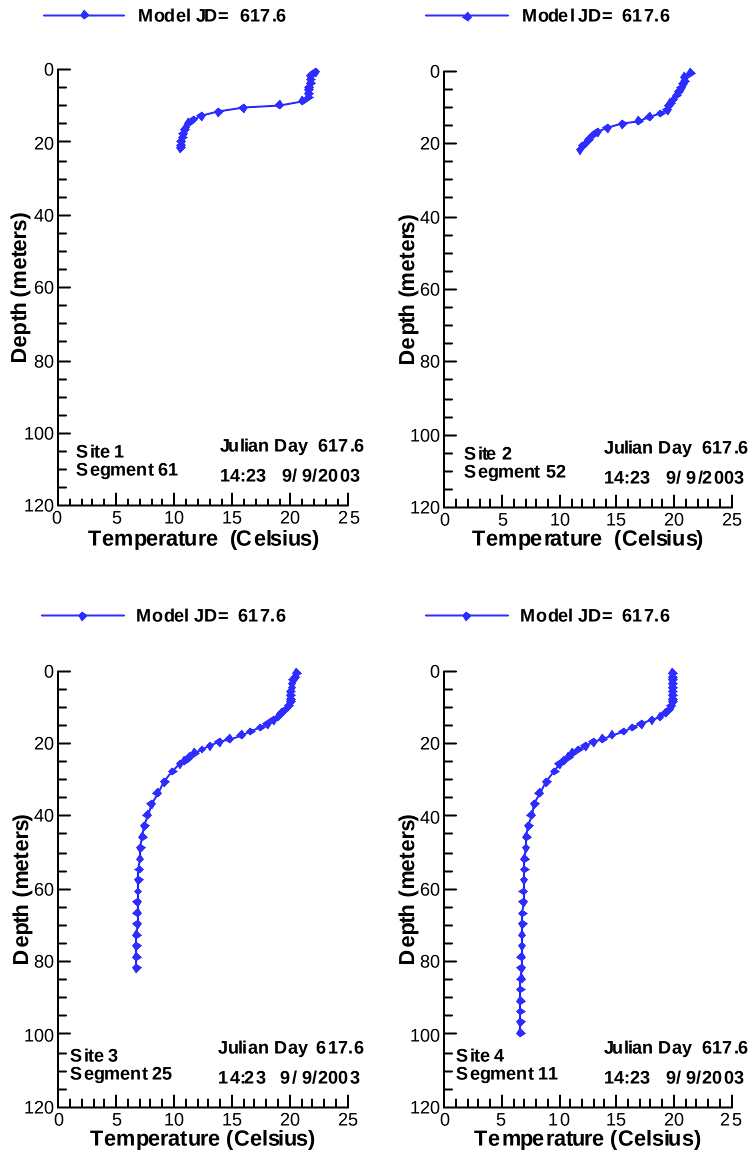

Figure 126. Vertical profiles of TEMPERATURE compared with data for 9/ 9/2003.

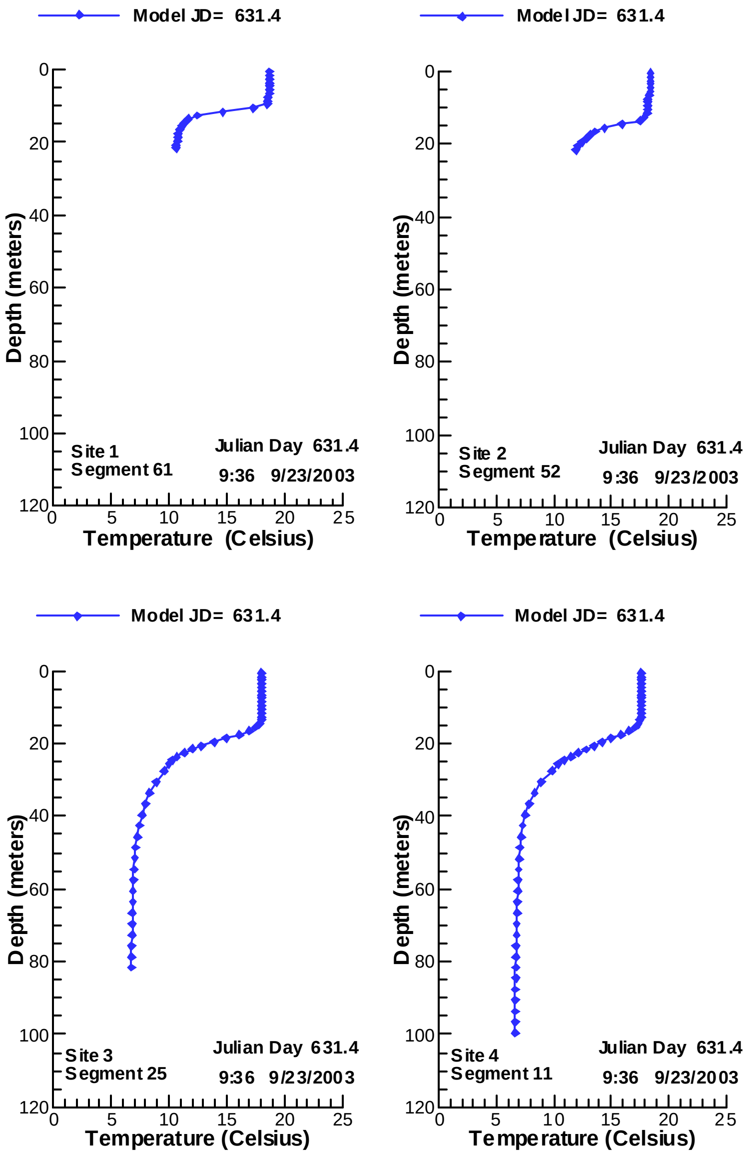

Figure 127. Vertical profiles of TEMPERATURE compared with data for 9/23/2003.

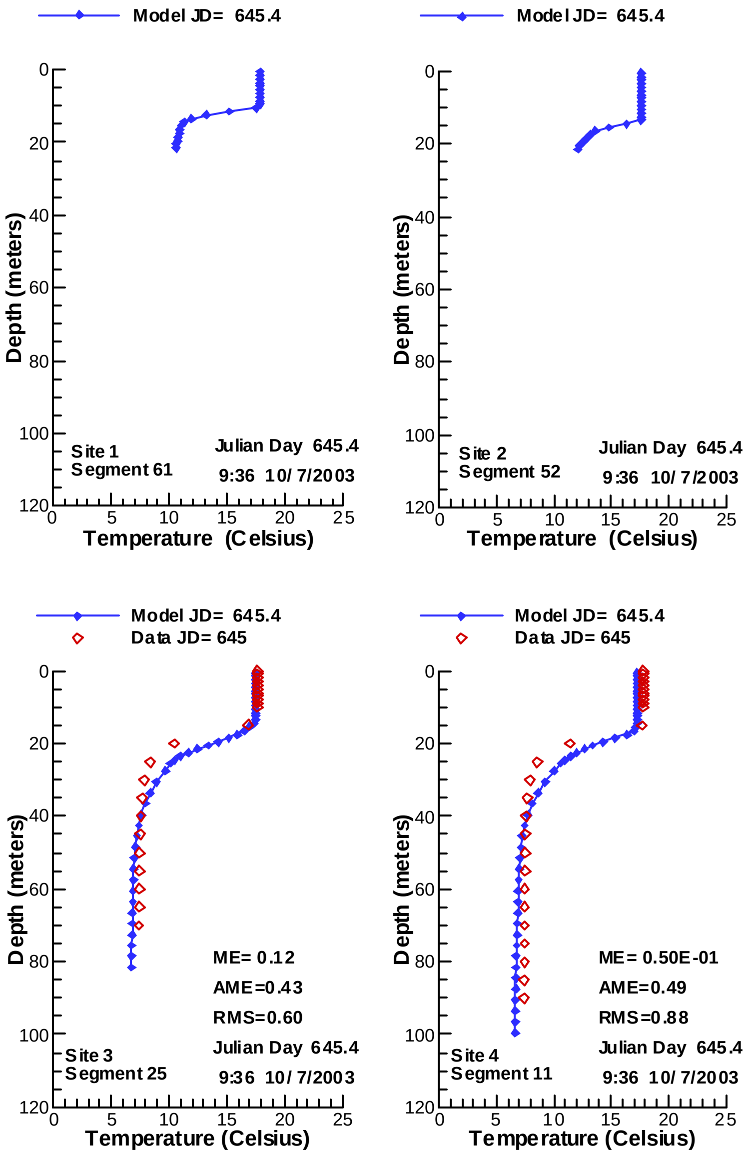

Figure 128. Vertical profiles of TEMPERATURE compared with data for 10/ 7/2003.

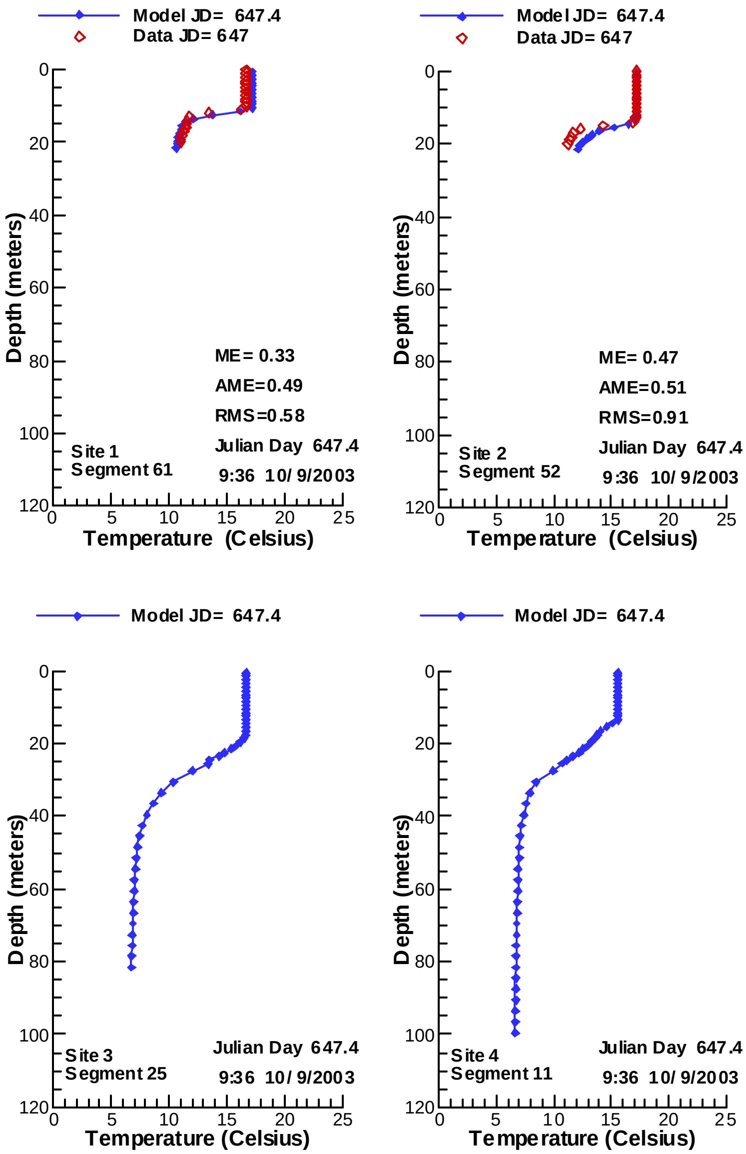

Figure 129. Vertical profiles of TEMPERATURE compared with data for 10/ 9/2003.

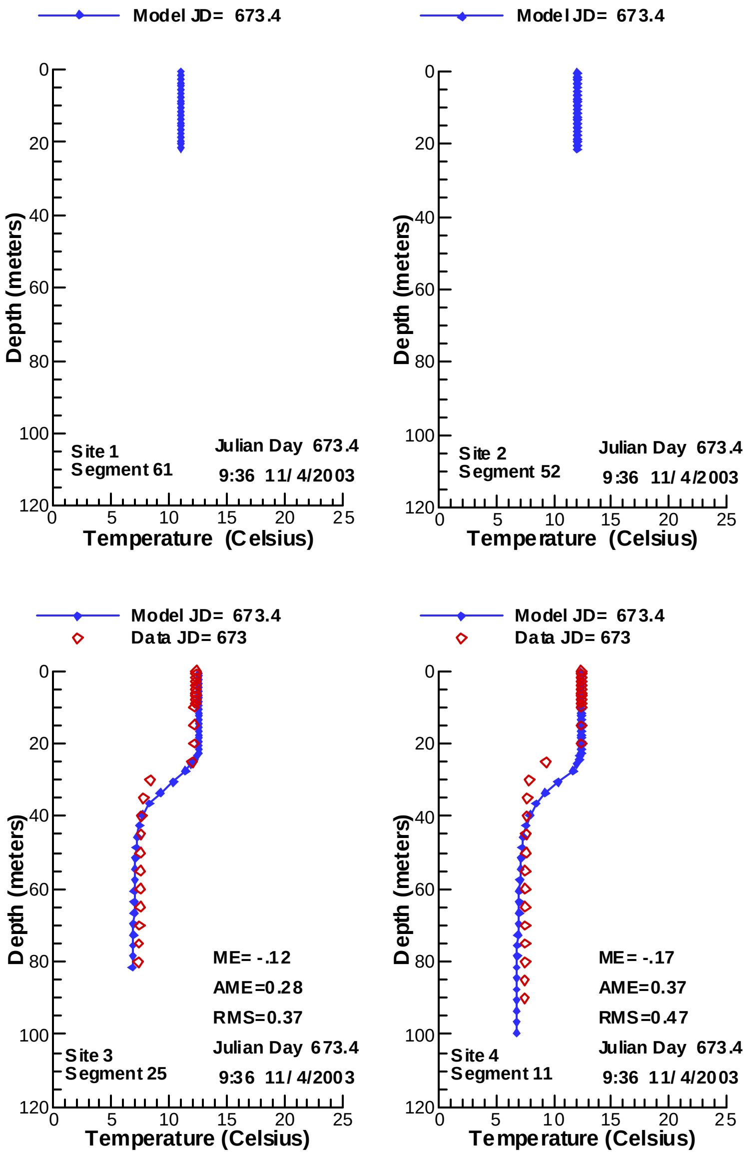

Figure 130. Vertical profiles of TEMPERATURE compared with data for 11/ 4/2003.

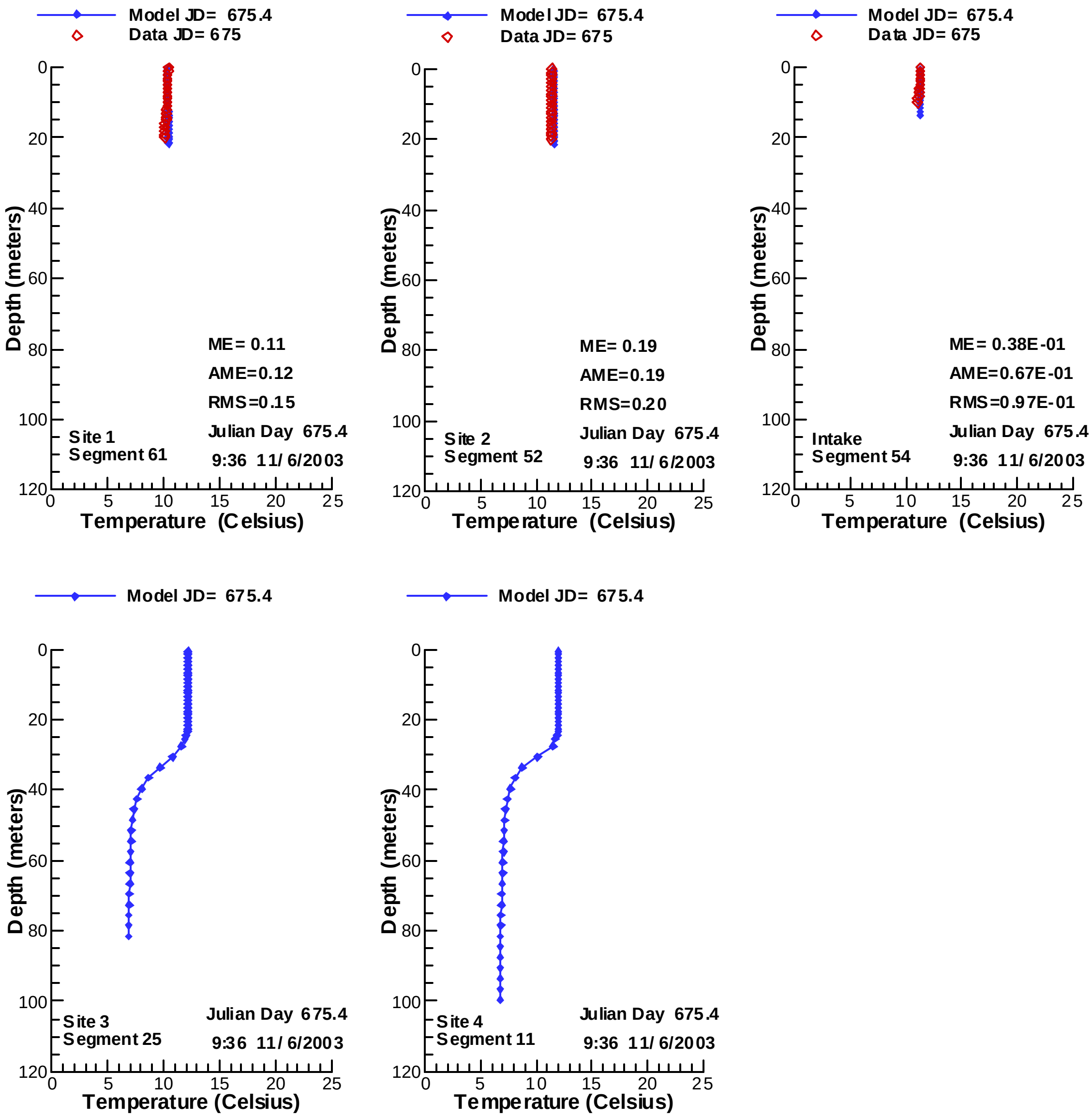

Figure 131. Vertical profiles of TEMPERATURE compared with data for 11/ 6/2003.

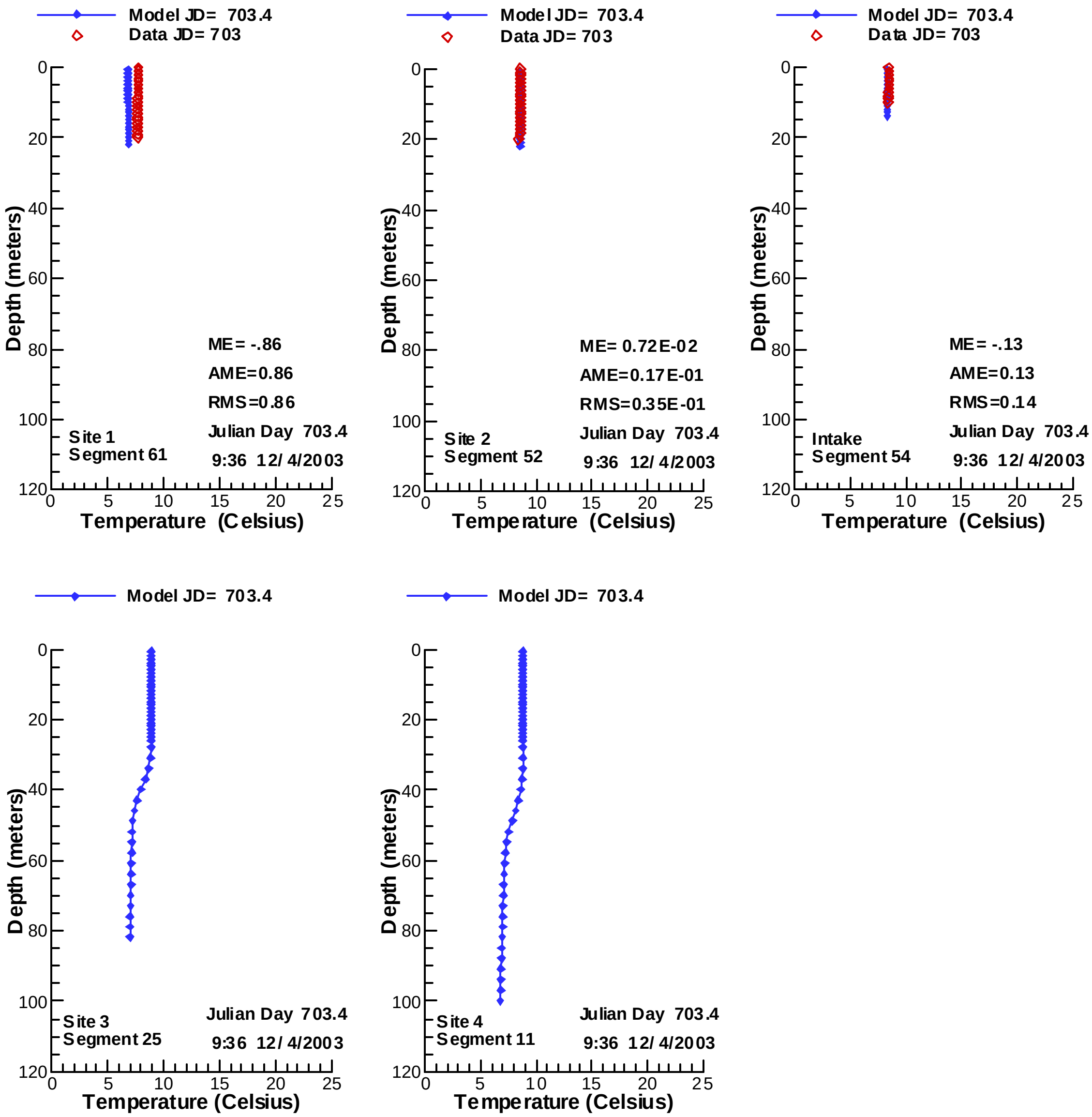

Figure 132. Vertical profiles of TEMPERATURE compared with data for 12/ 4/2003.

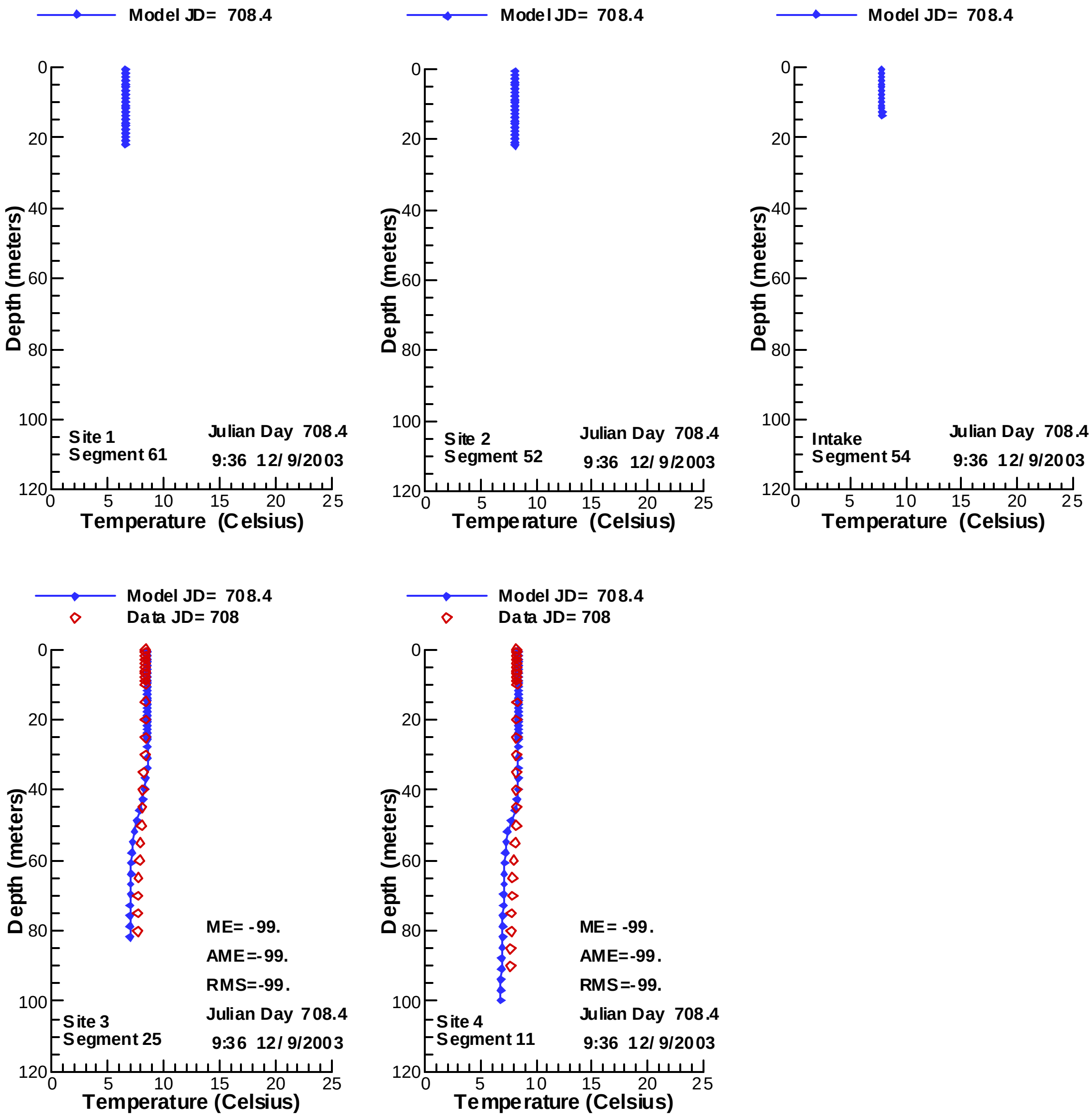

Figure 133. Vertical profiles of TEMPERATURE compared with data for 12/ 9/2003.

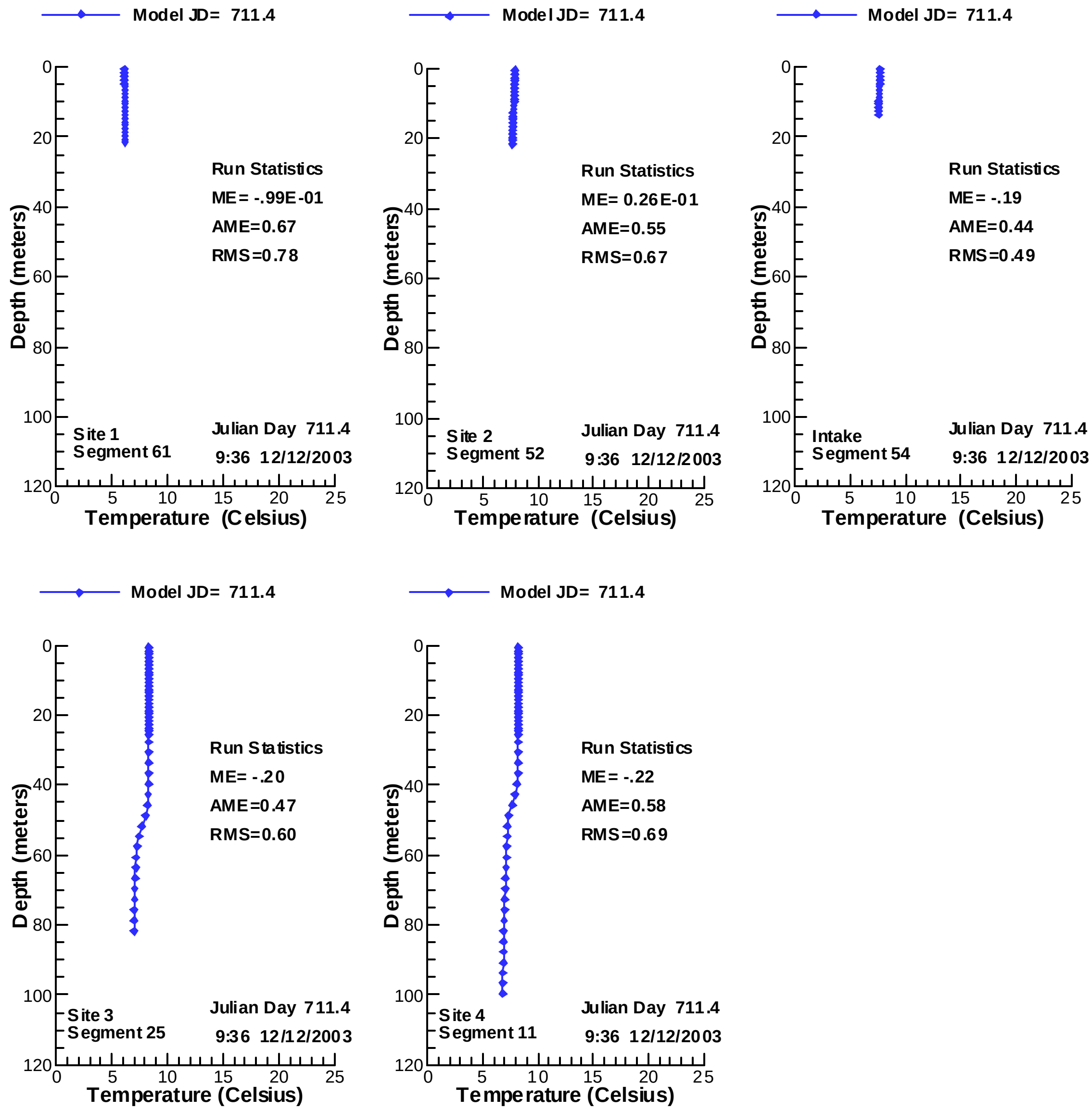

Figure 134. Vertical profiles of TEMPERATURE compared with data for 12/12/2003.

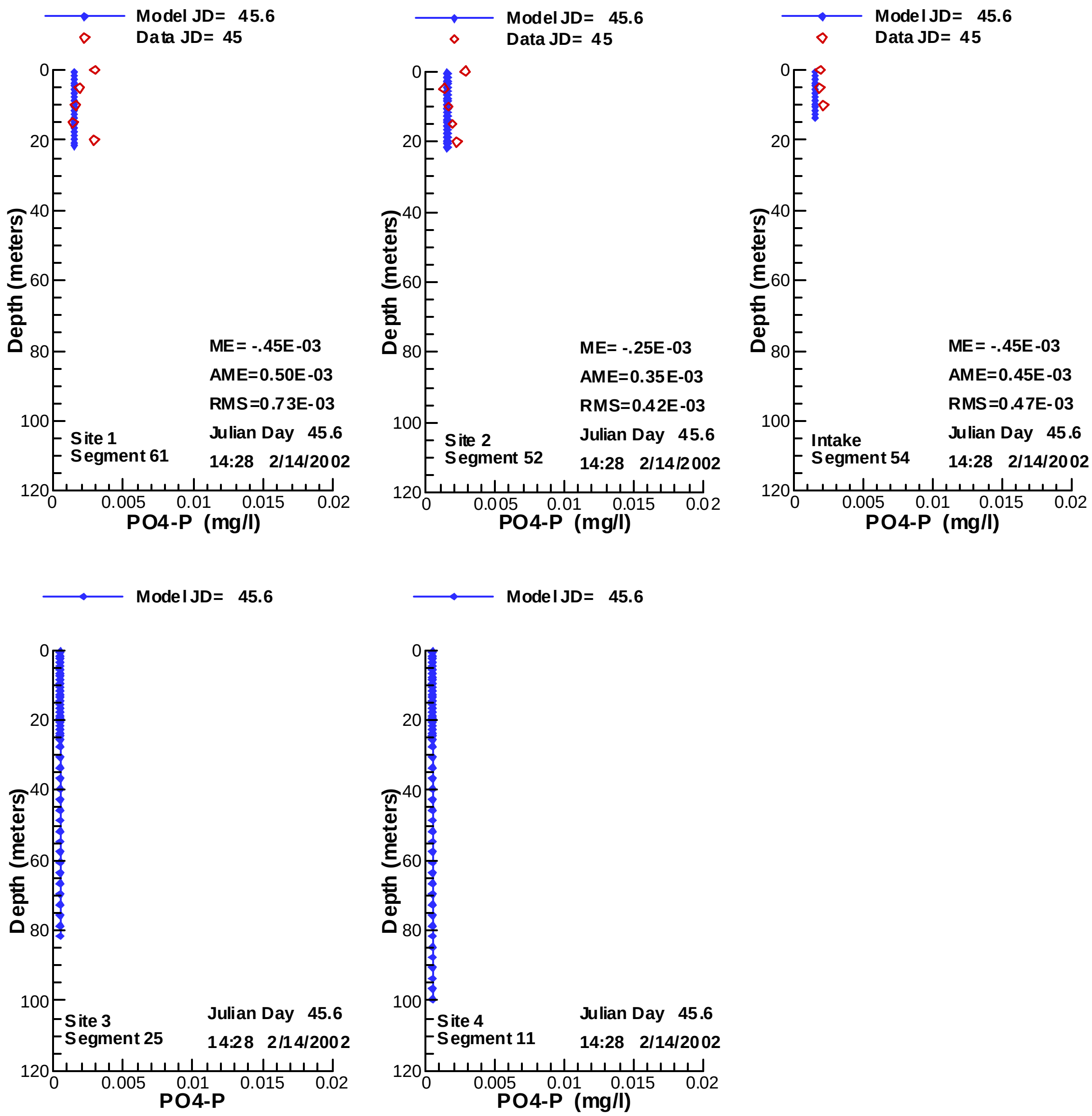

Figure 135. Vertical profiles of PO4-P compared with data for 2/14/2002.

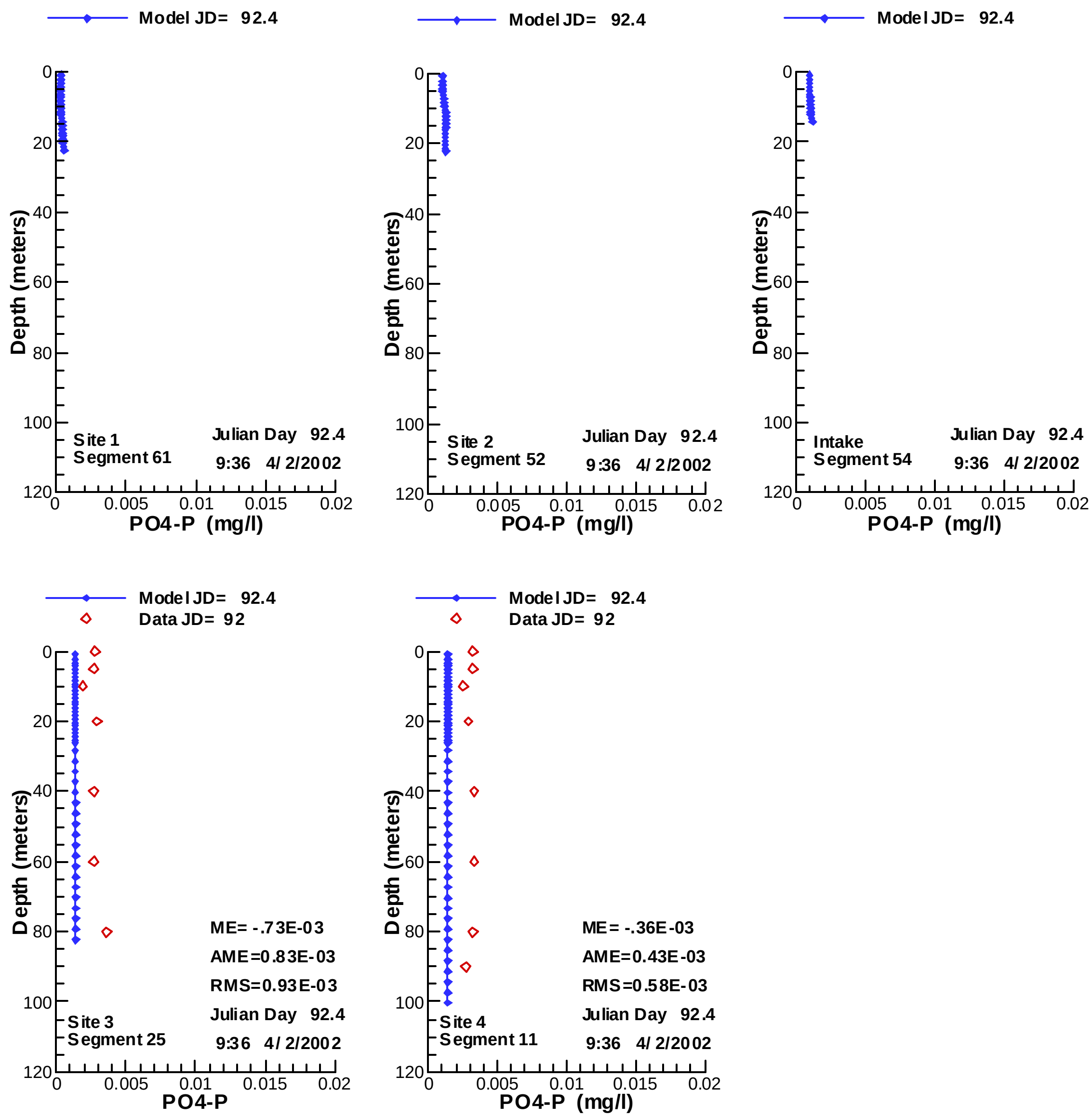

Figure 136. Vertical profiles of PO4-P compared with data for 4/ 2/2002.

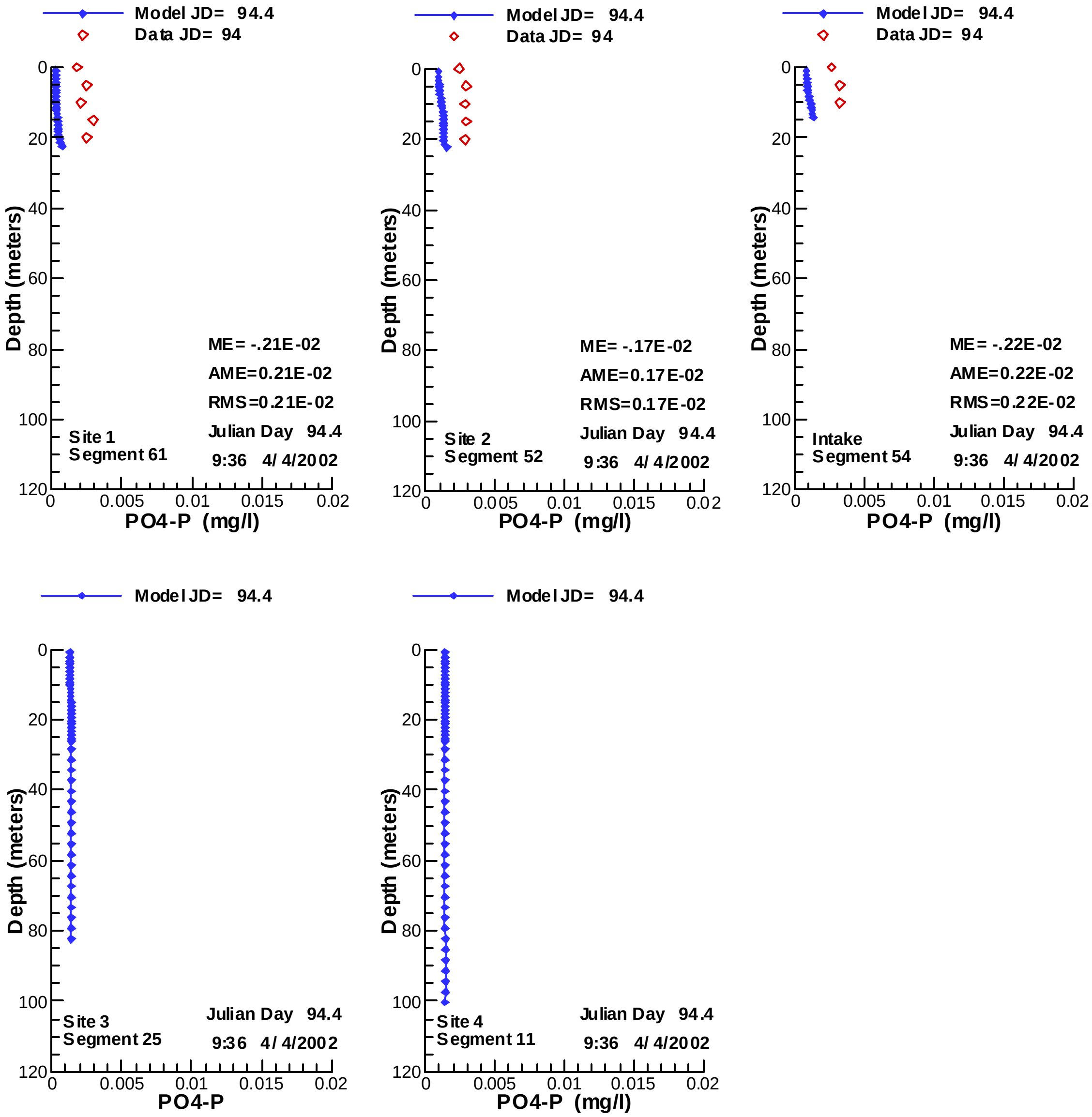

Figure 137. Vertical profiles of PO4-P compared with data for 4/ 4/2002.

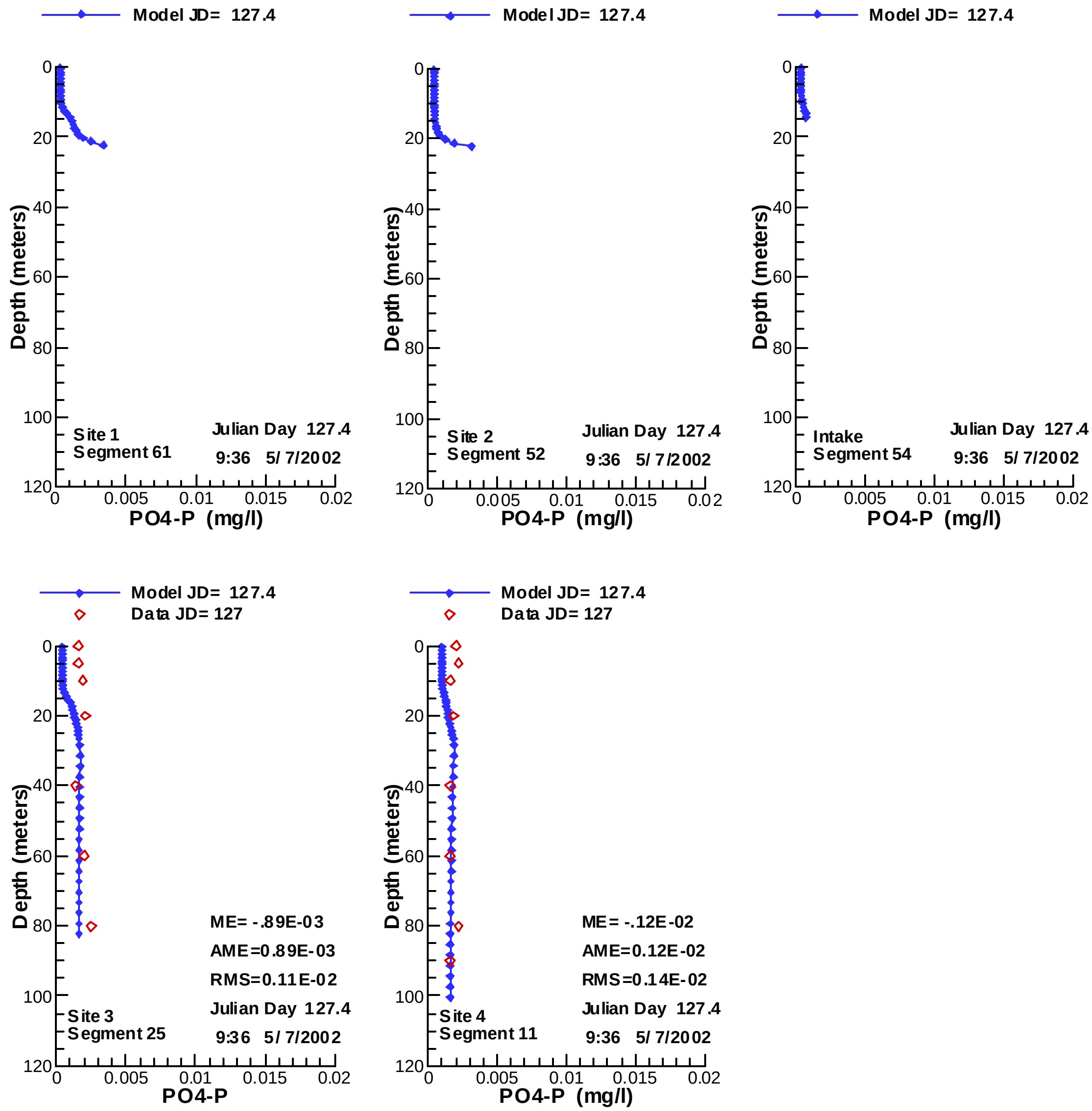

Figure 138. Vertical profiles of PO4-P compared with data for 5/ 7/2002.

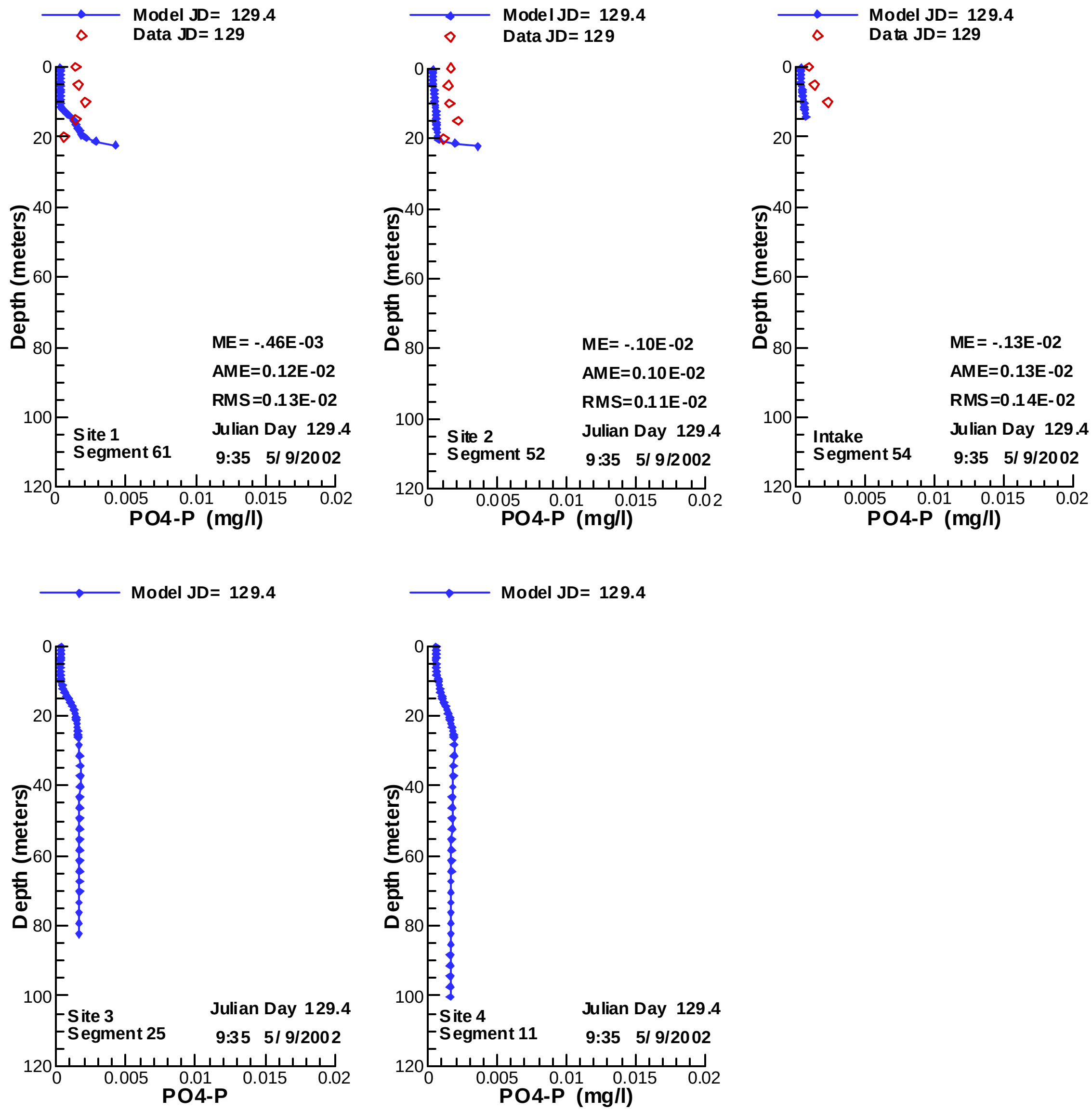

Figure 139. Vertical profiles of PO4-P compared with data for 5/ 9/2002.

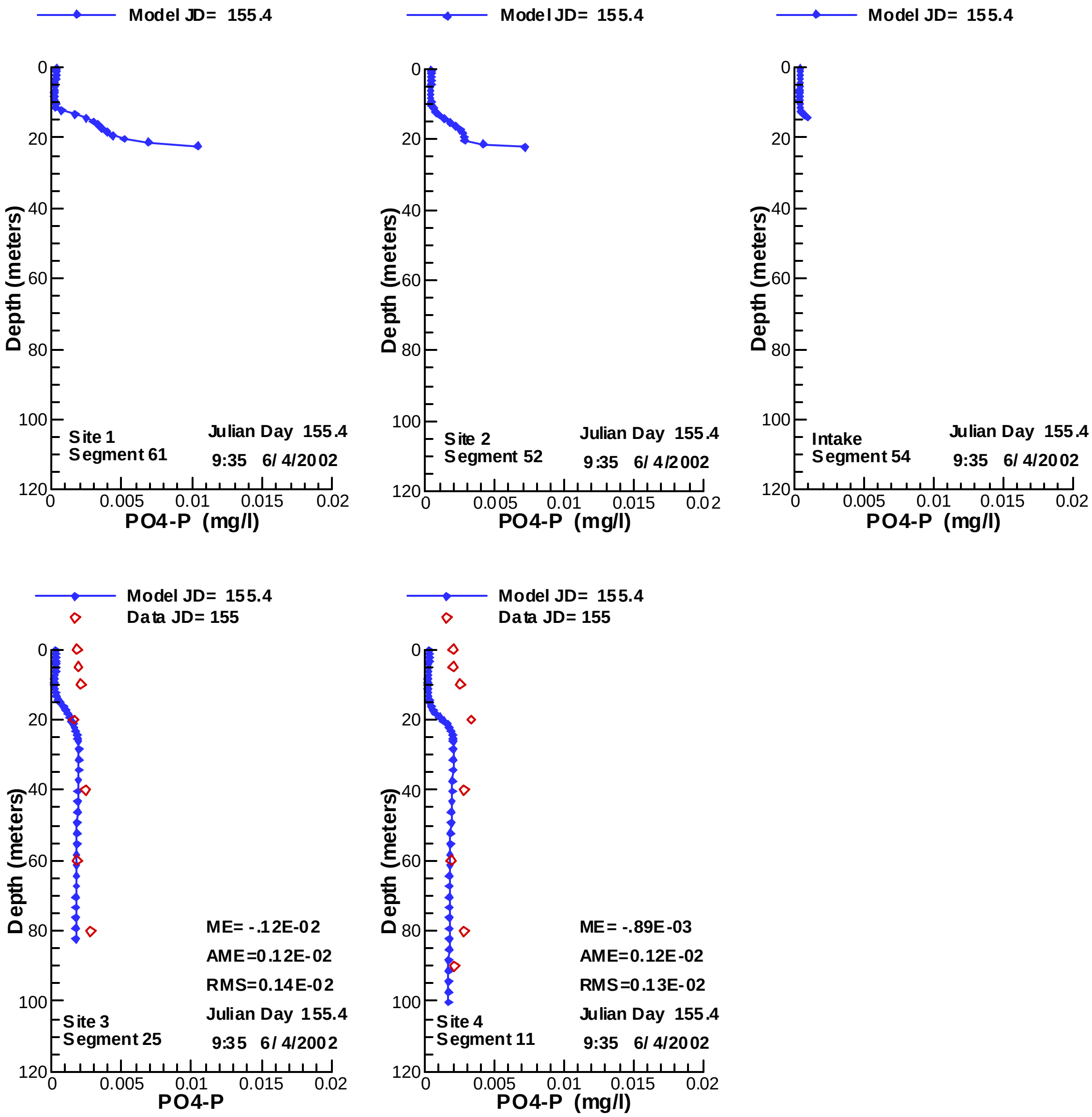

Figure 140. Vertical profiles of PO4-P compared with data for 6/ 4/2002.

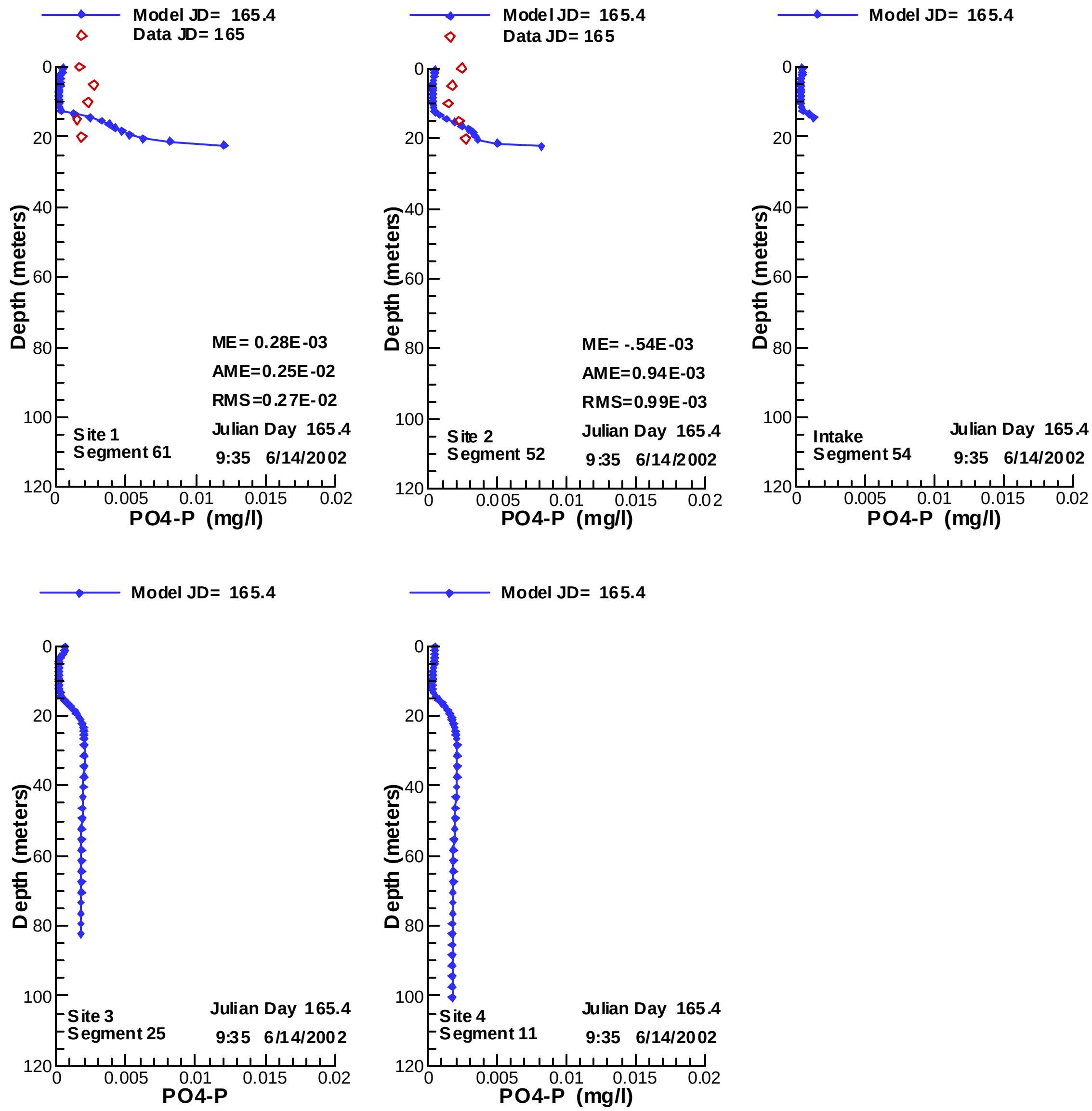

Figure 141. Vertical profiles of PO4-P compared with data for 6/14/2002.

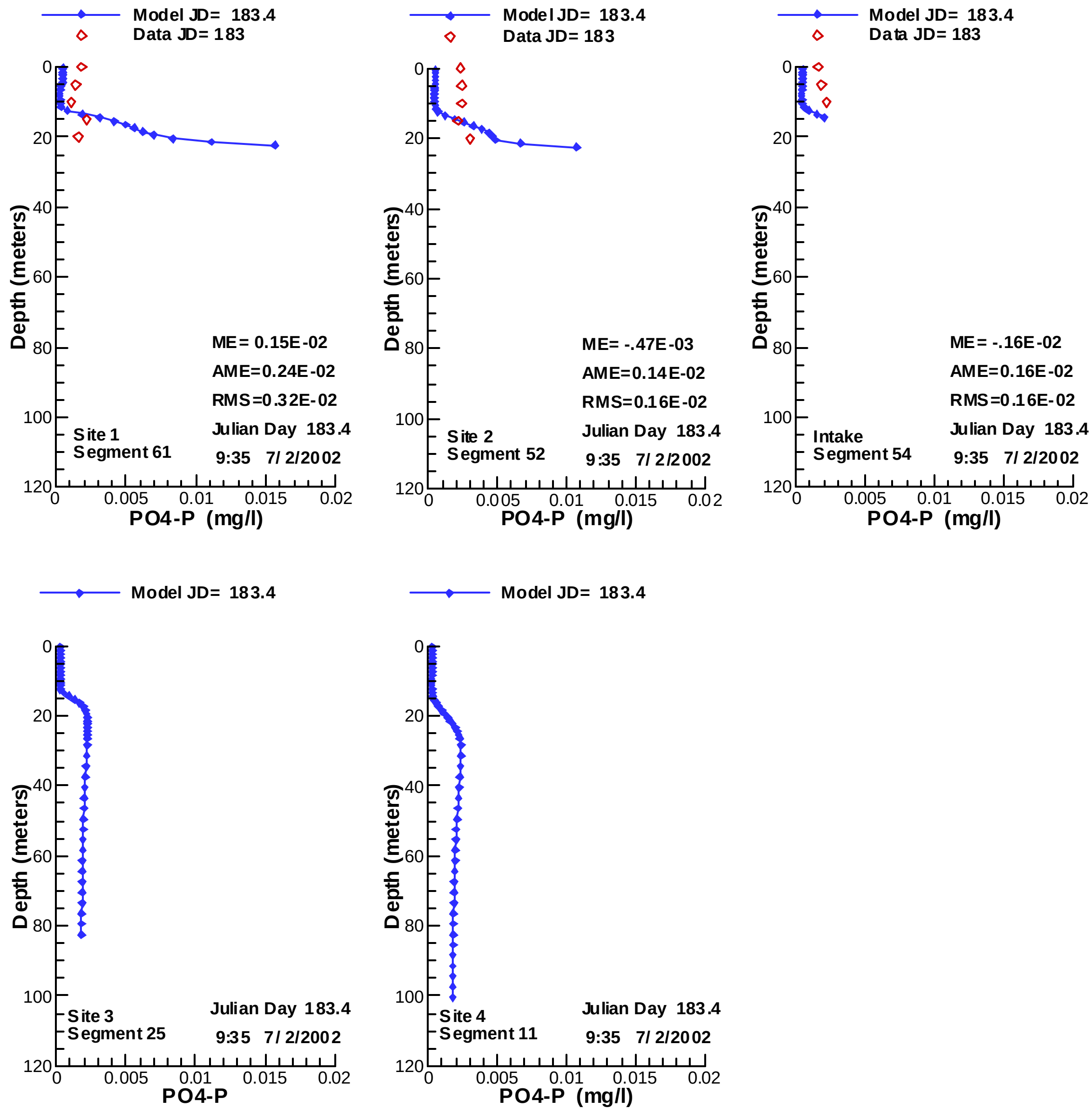

Figure 142. Vertical profiles of PO4-P compared with data for 7/ 2/2002.

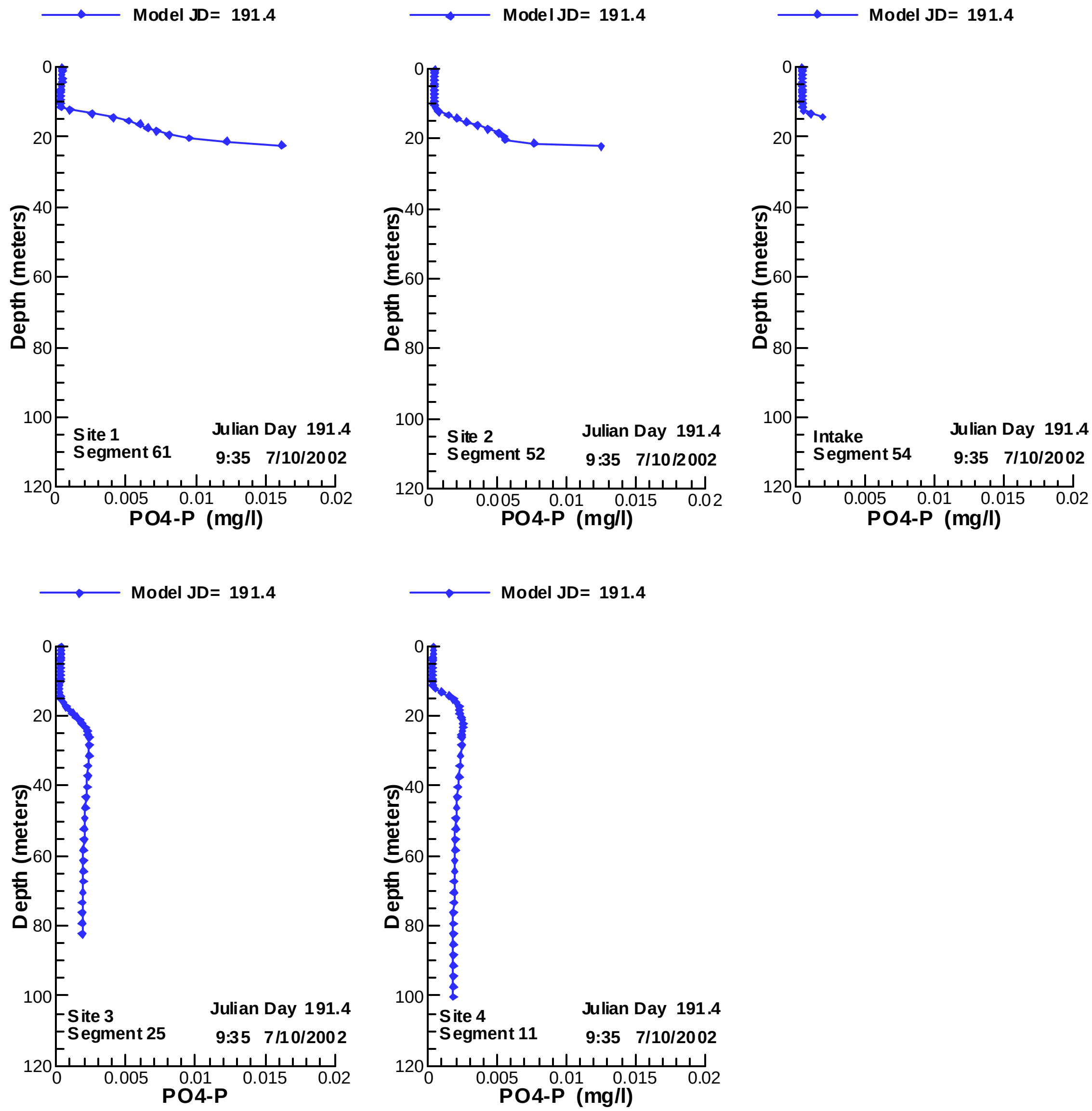

Figure 143. Vertical profiles of PO4-P compared with data for 7/10/2002.

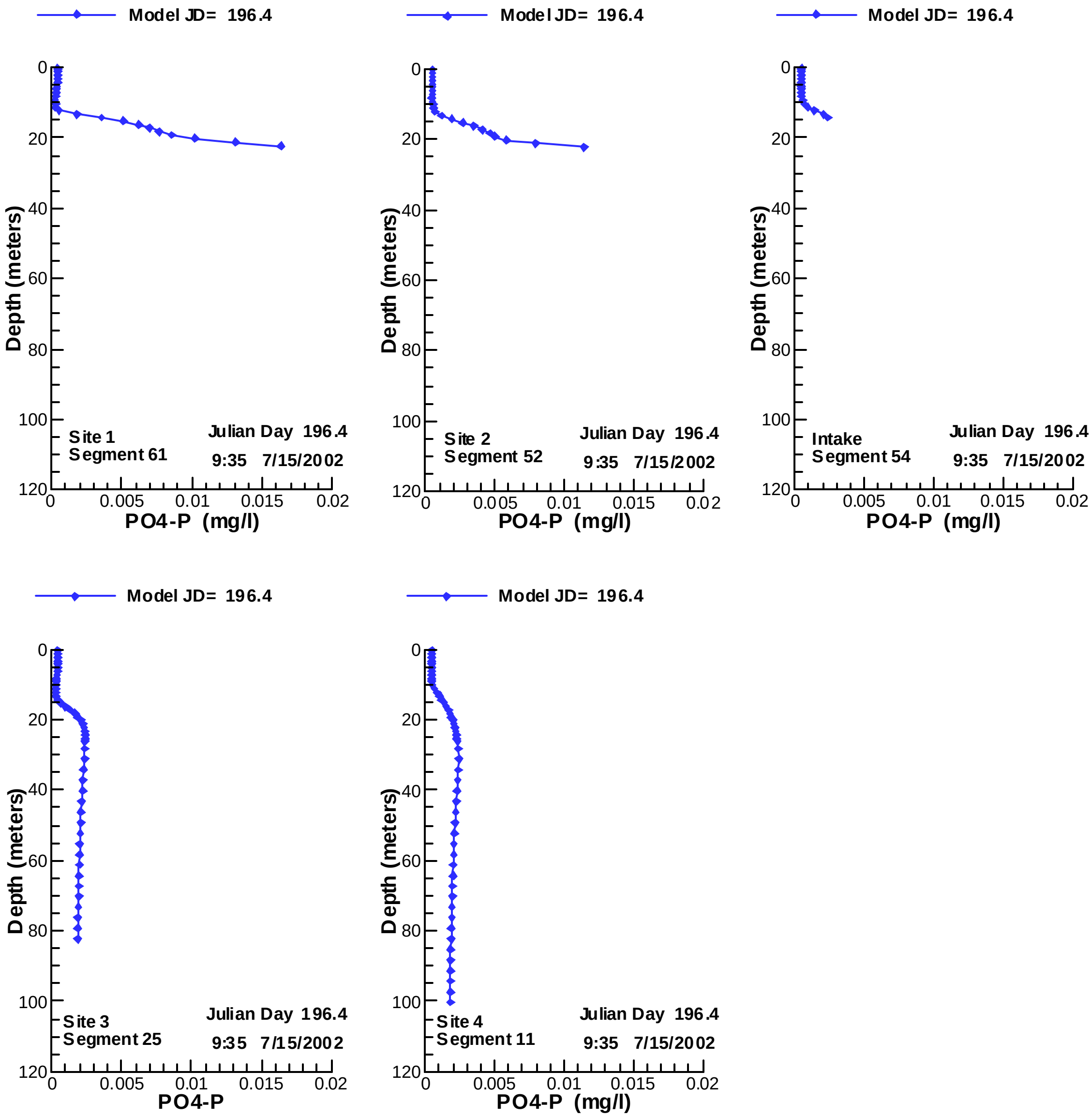

Figure 144. Vertical profiles of PO4-P compared with data for 7/15/2002.

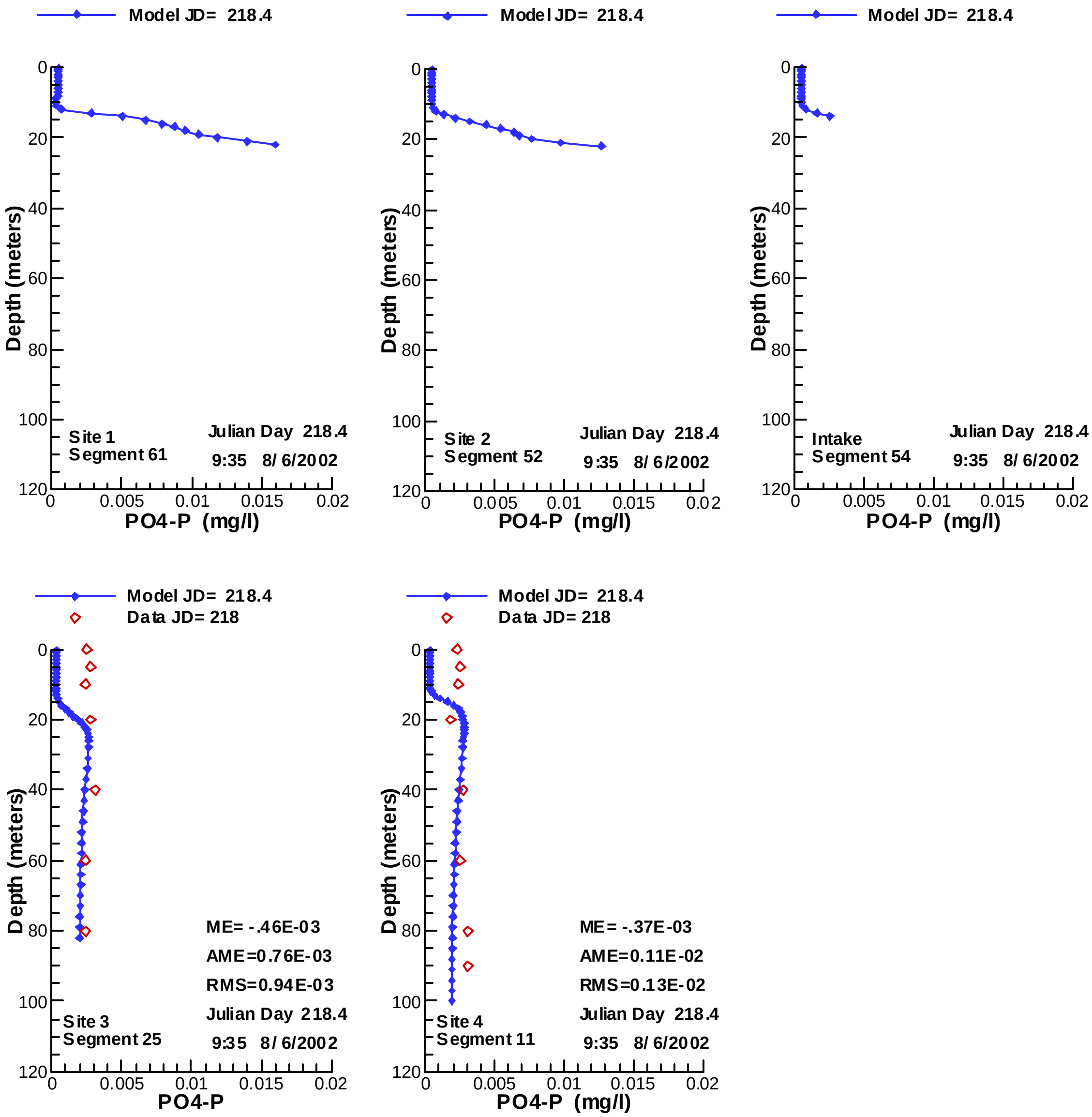

Figure 145. Vertical profiles of PO4-P compared with data for 8/ 6/2002.

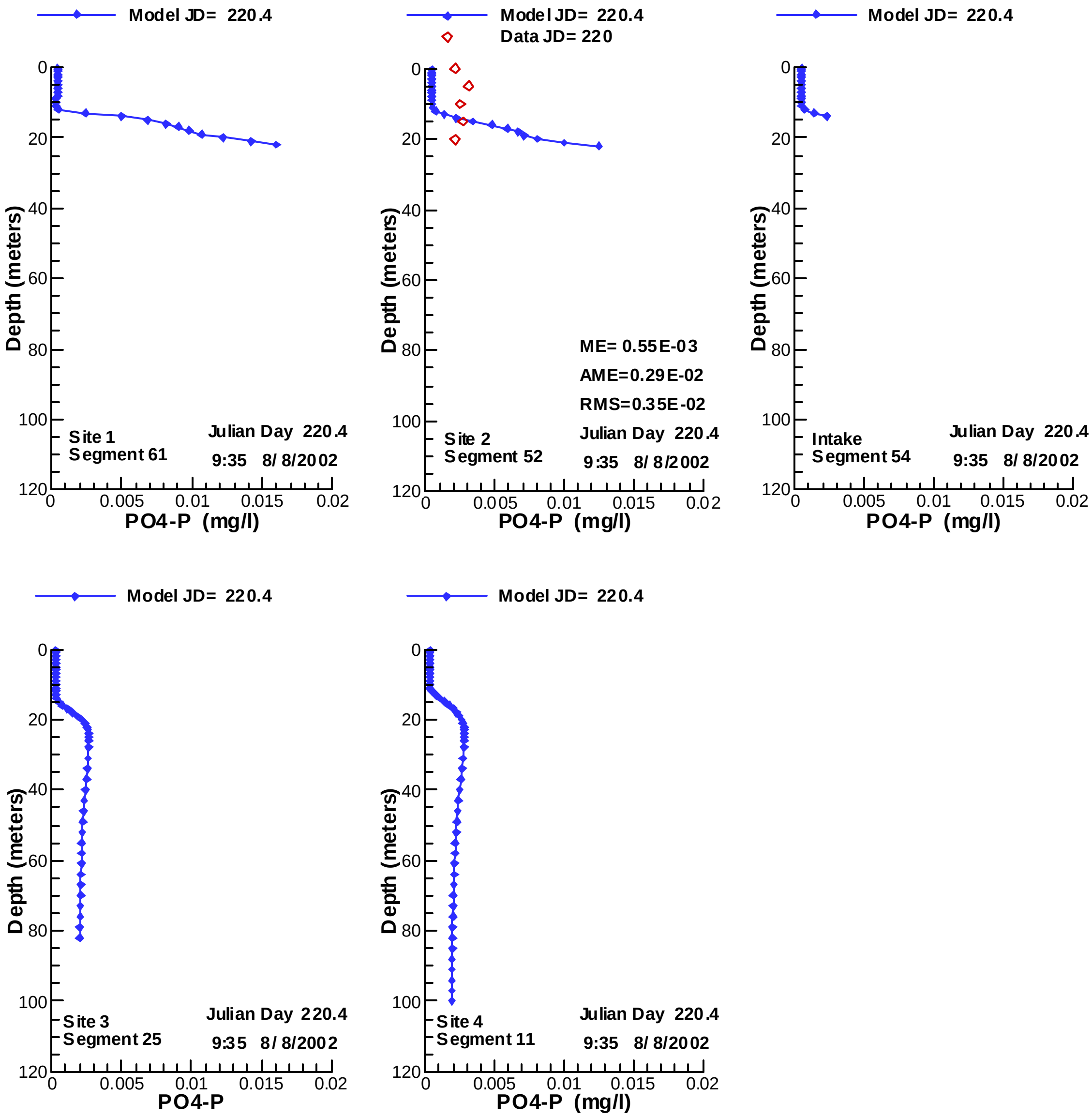

Figure 146. Vertical profiles of PO4-P compared with data for 8/ 8/2002.

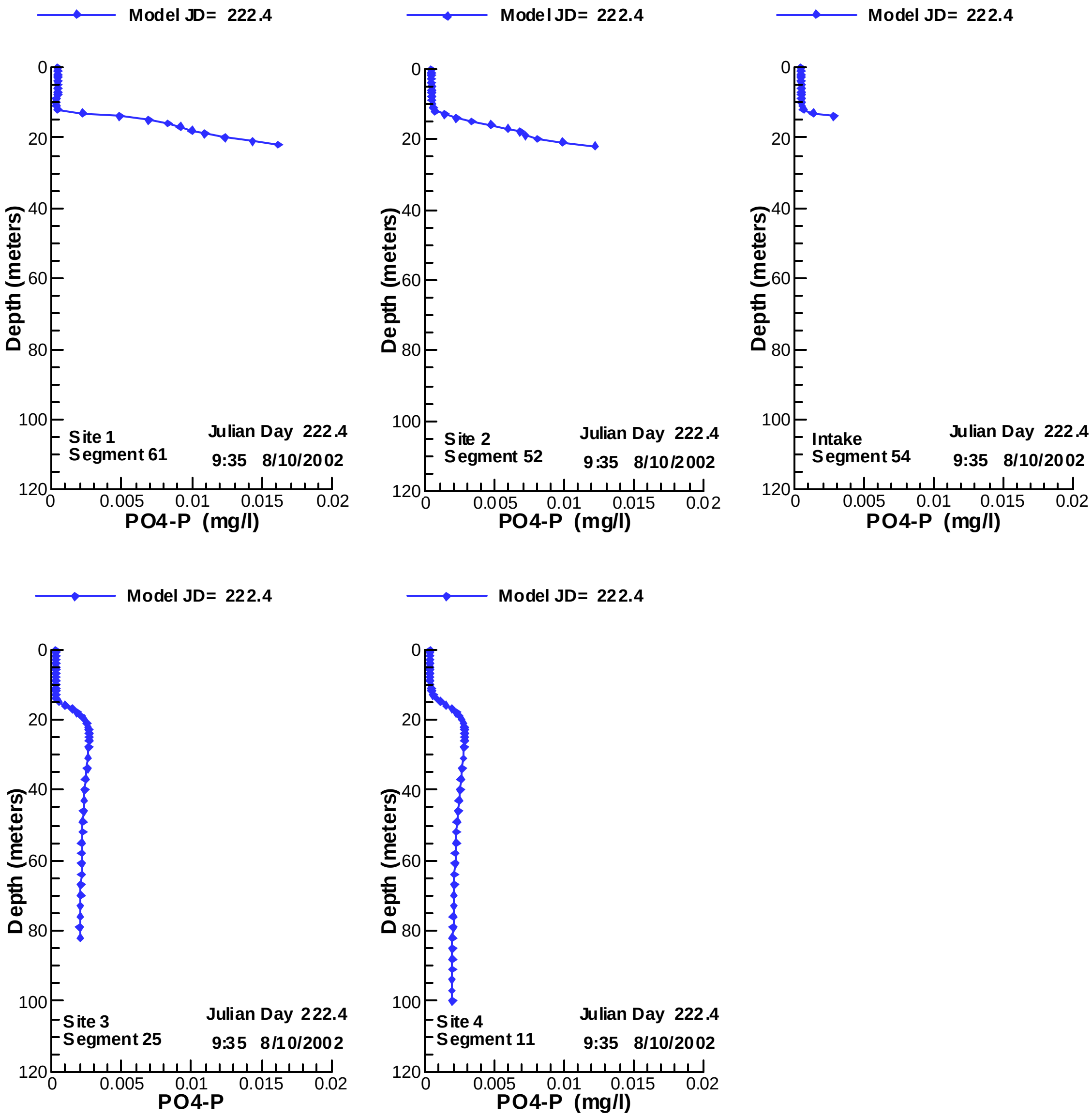

Figure 147. Vertical profiles of PO4-P compared with data for 8/10/2002.

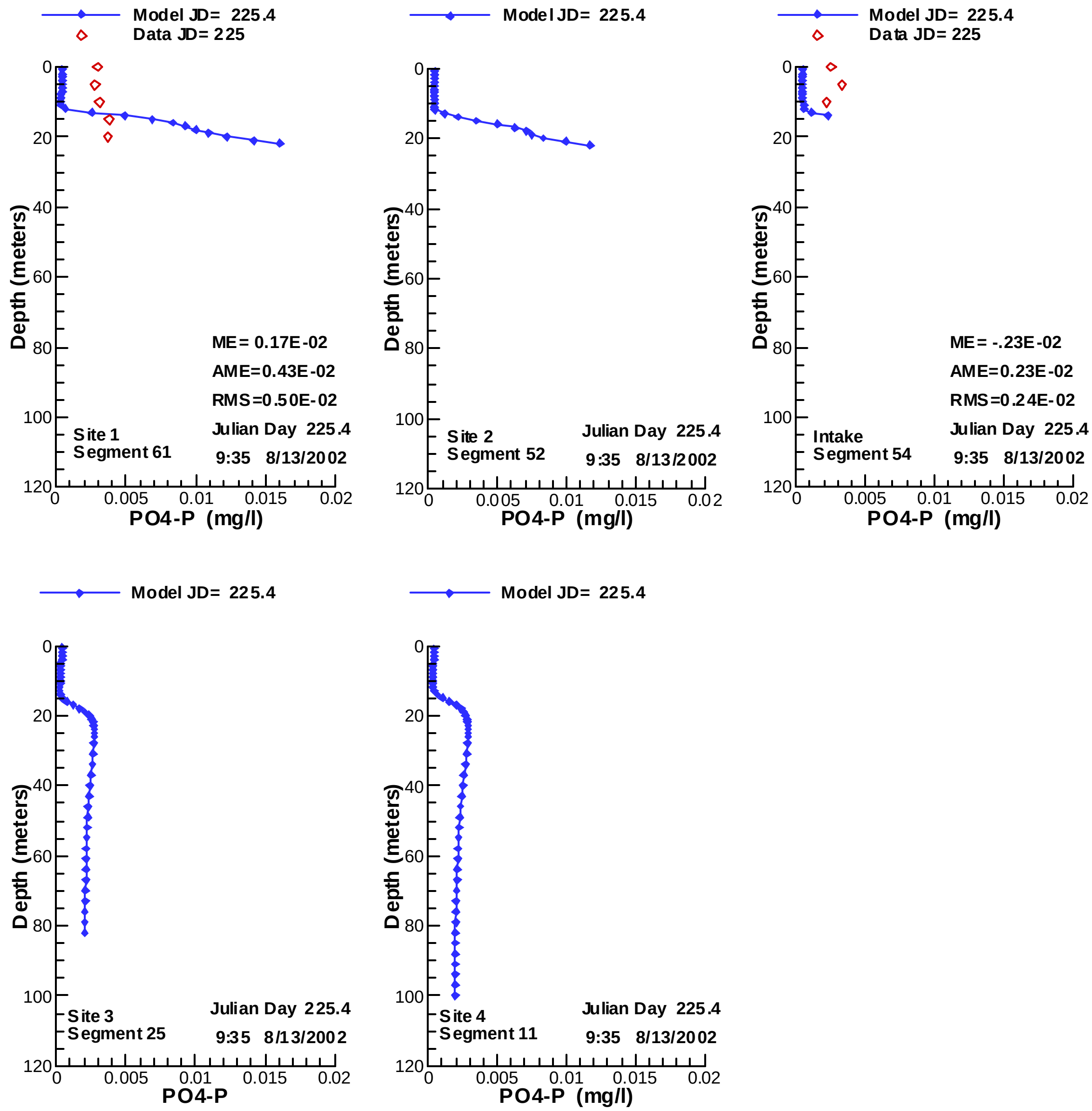

Figure 148. Vertical profiles of PO4-P compared with data for 8/13/2002.

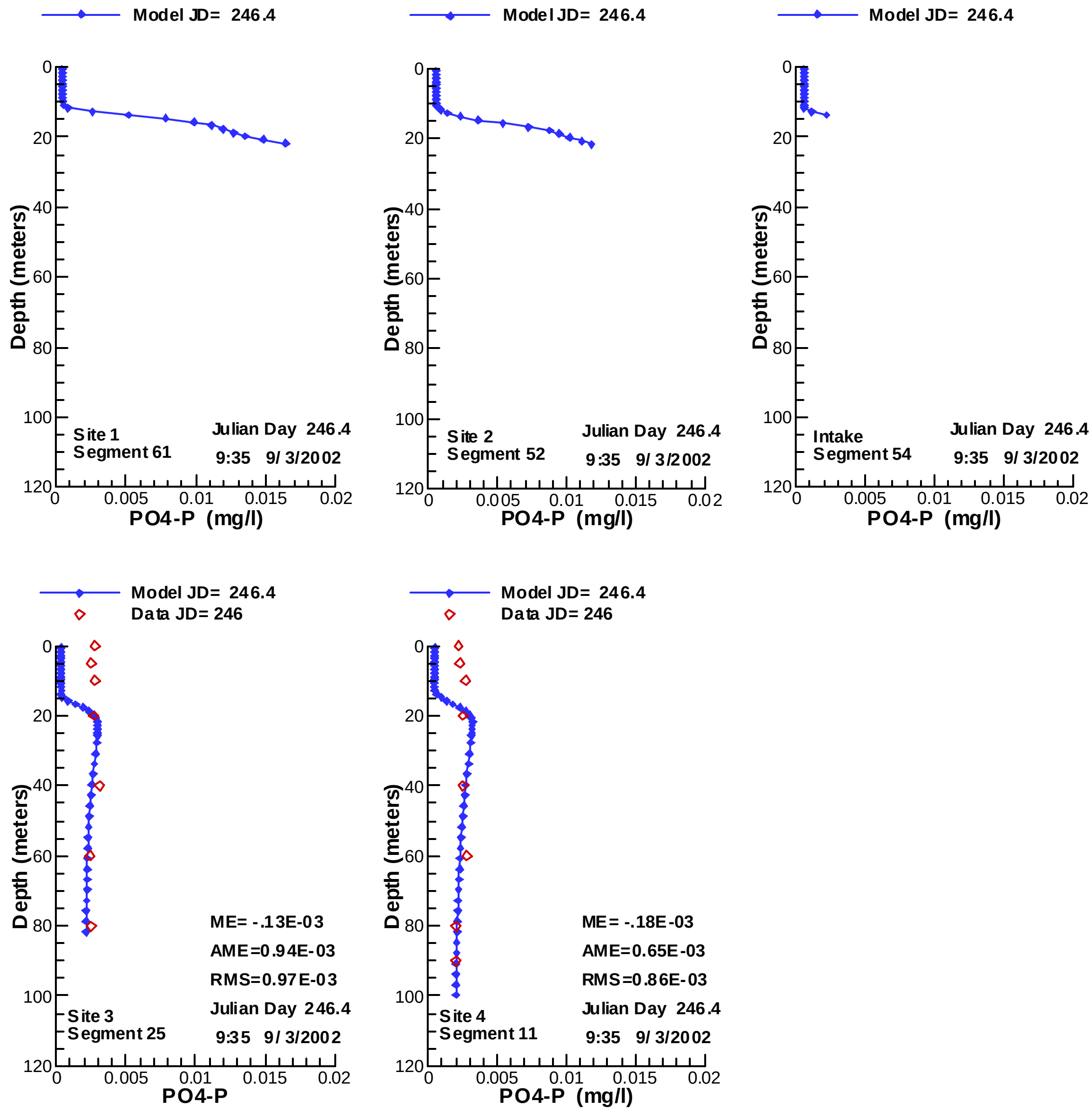

Figure 149. Vertical profiles of PO4-P compared with data for 9/ 3/2002.

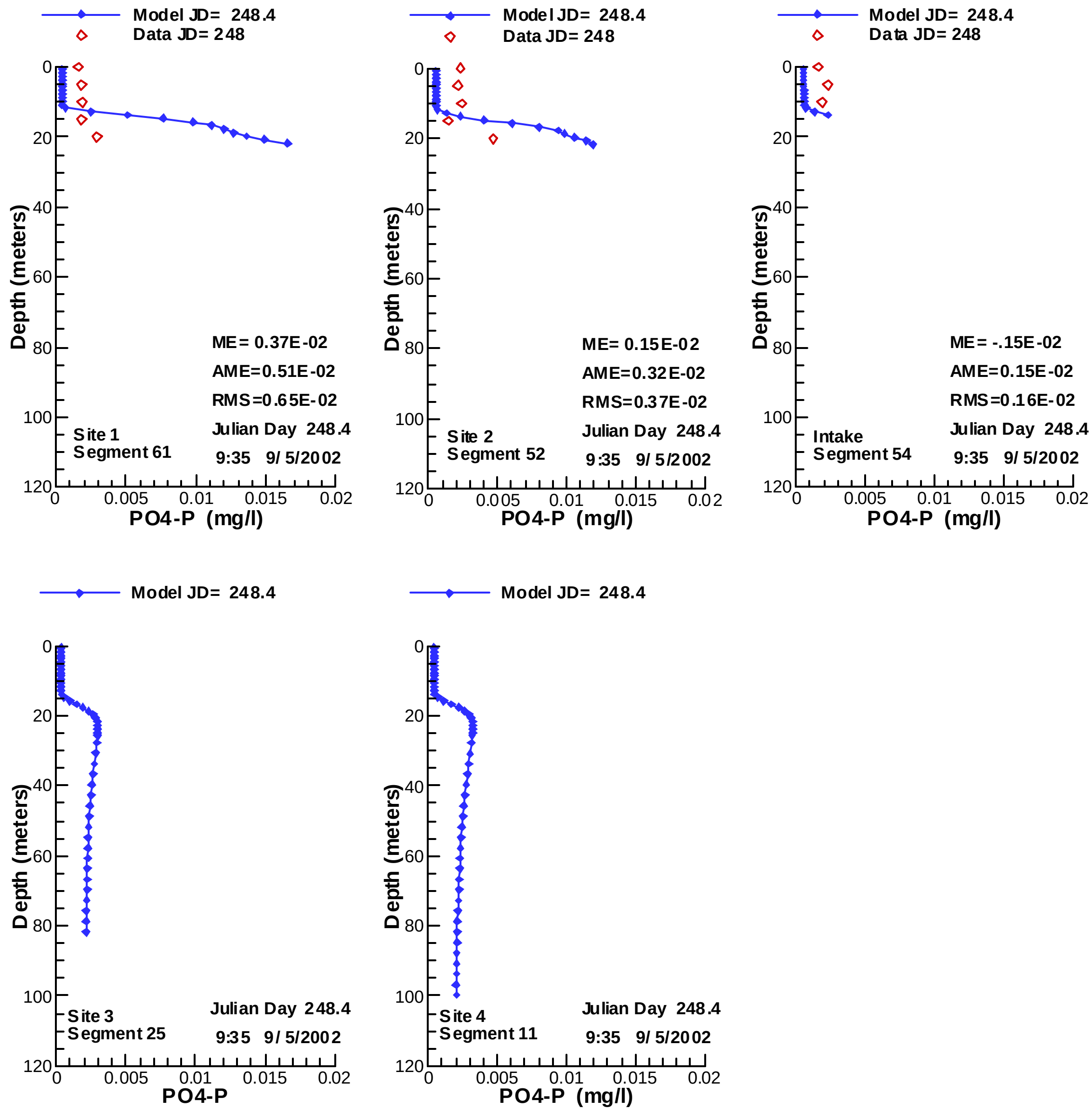

Figure 150. Vertical profiles of PO4-P compared with data for 9/ 5/2002.

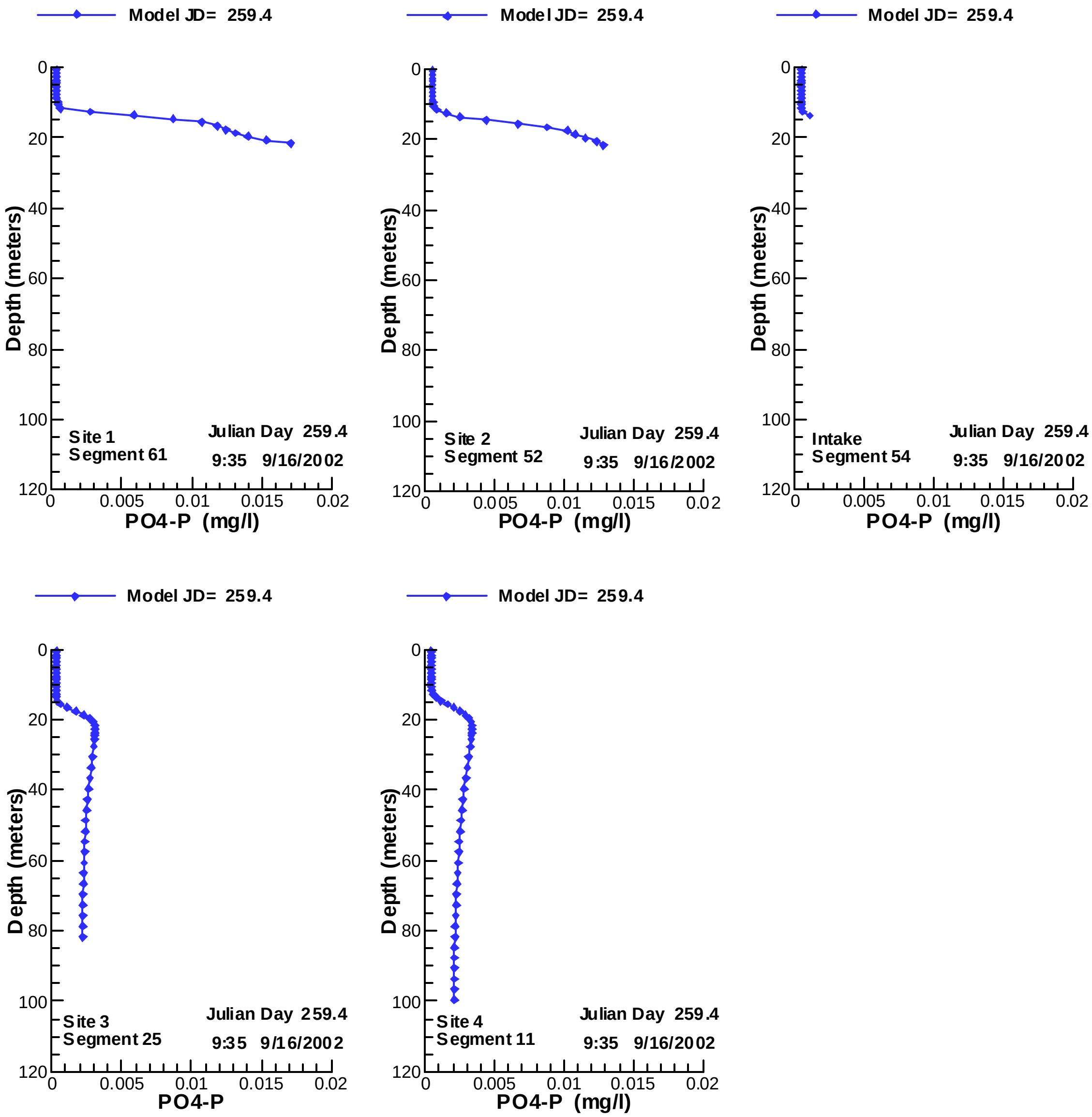

Figure 151. Vertical profiles of PO4-P compared with data for 9/16/2002.

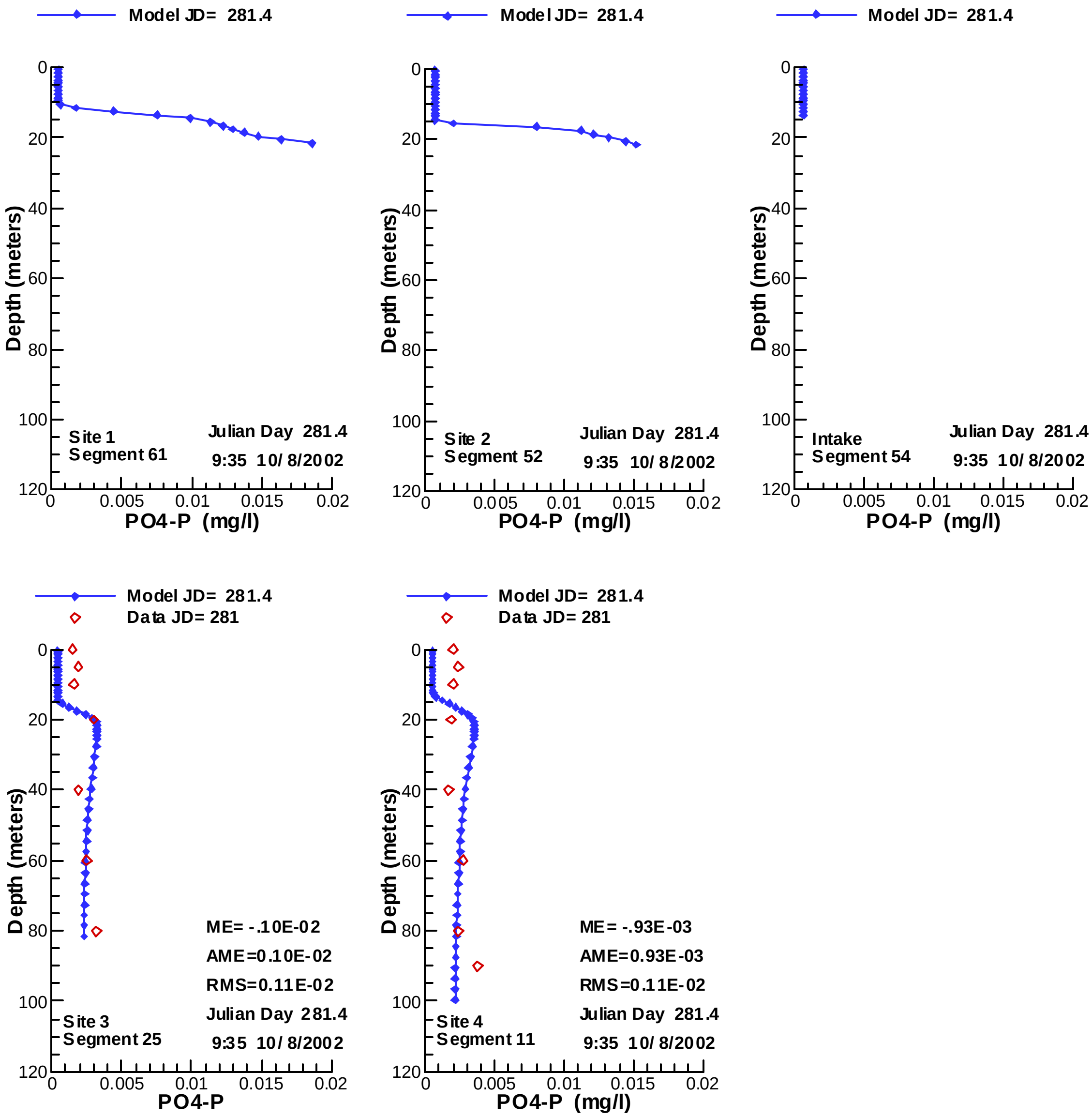

Figure 152. Vertical profiles of PO4-P compared with data for 10/ 8/2002.

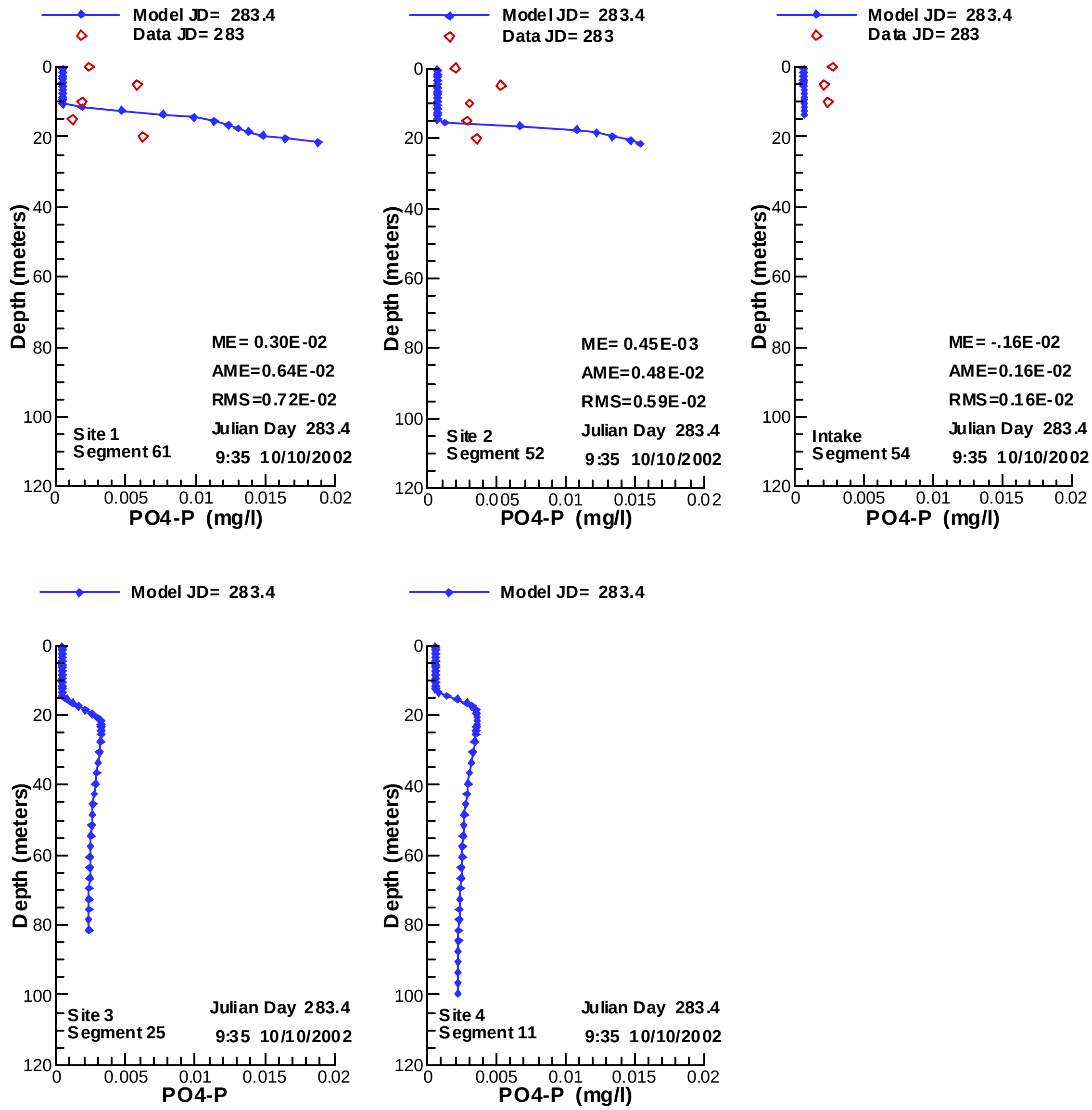

Figure 153. Vertical profiles of PO4-P compared with data for 10/10/2002.

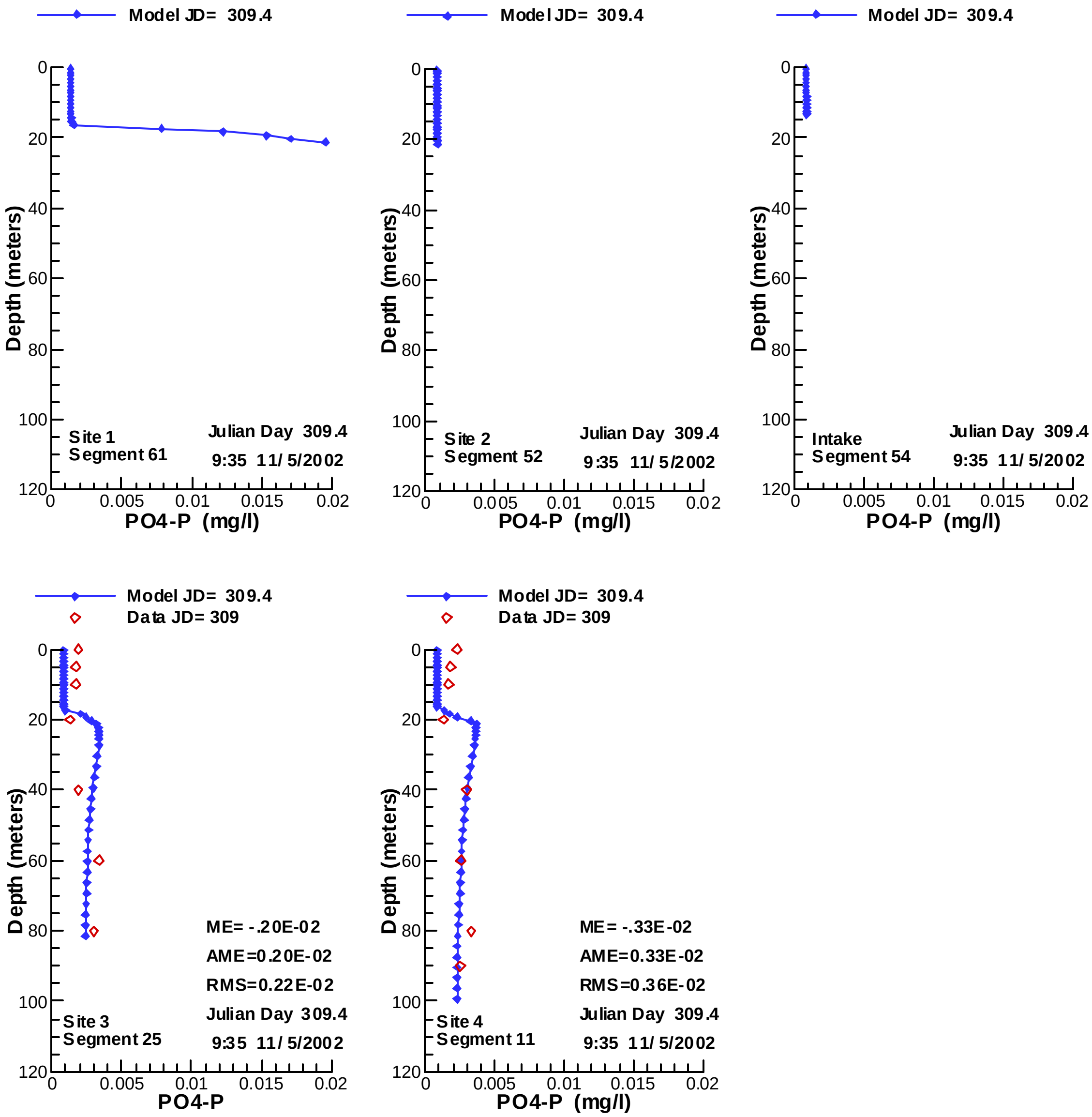

Figure 154. Vertical profiles of PO4-P compared with data for 11/ 5/2002.

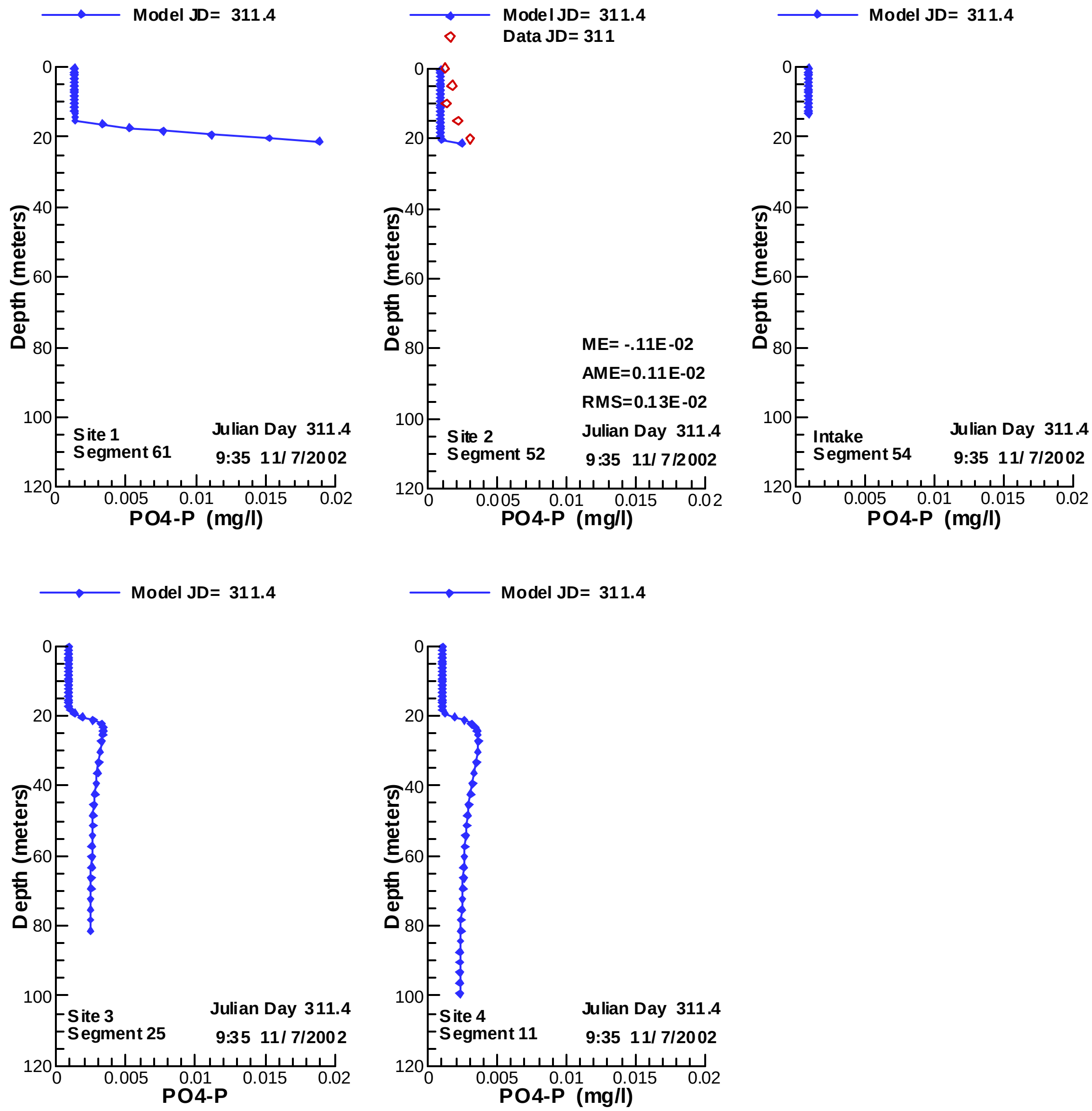

Figure 155. Vertical profiles of PO4-P compared with data for 11/ 7/2002.

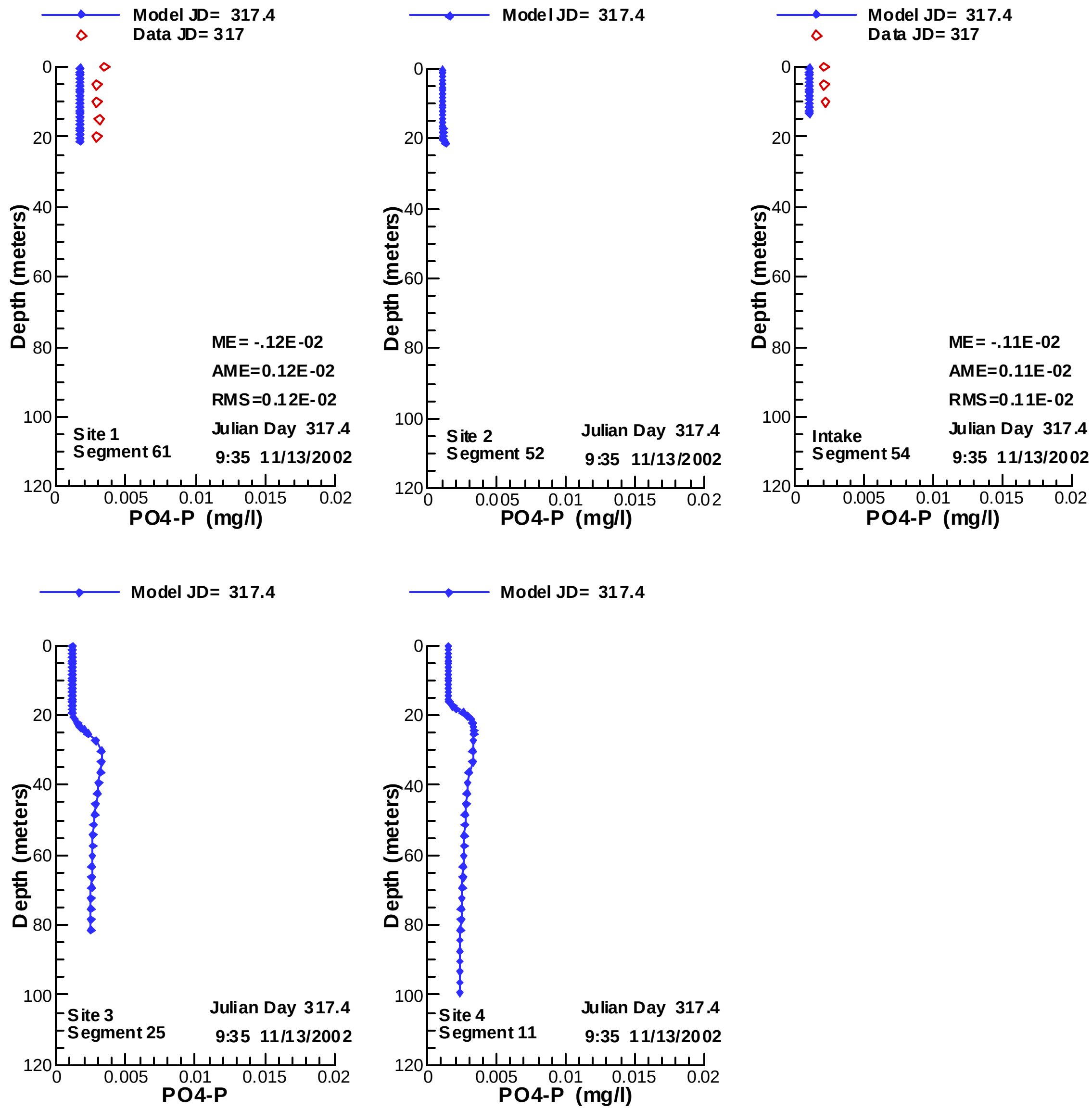

Figure 156. Vertical profiles of PO4-P compared with data for 11/13/2002.

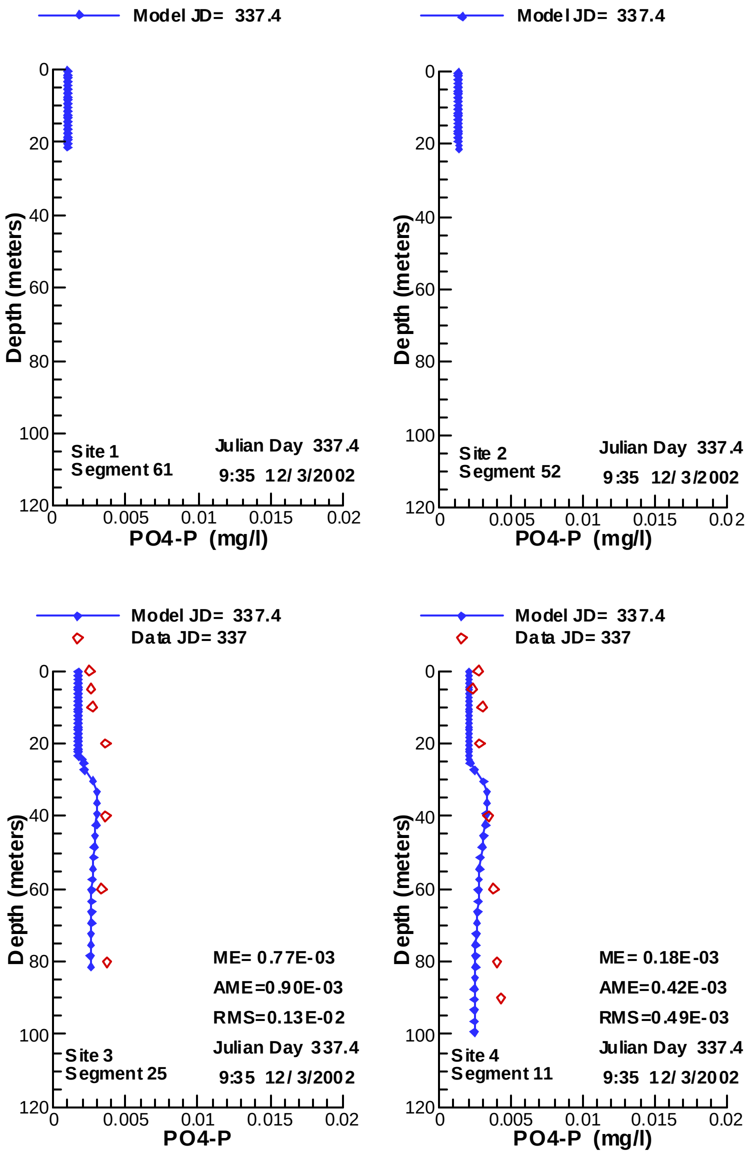

Figure 157. Vertical profiles of PO4-P compared with data for 12/ 3/2002.

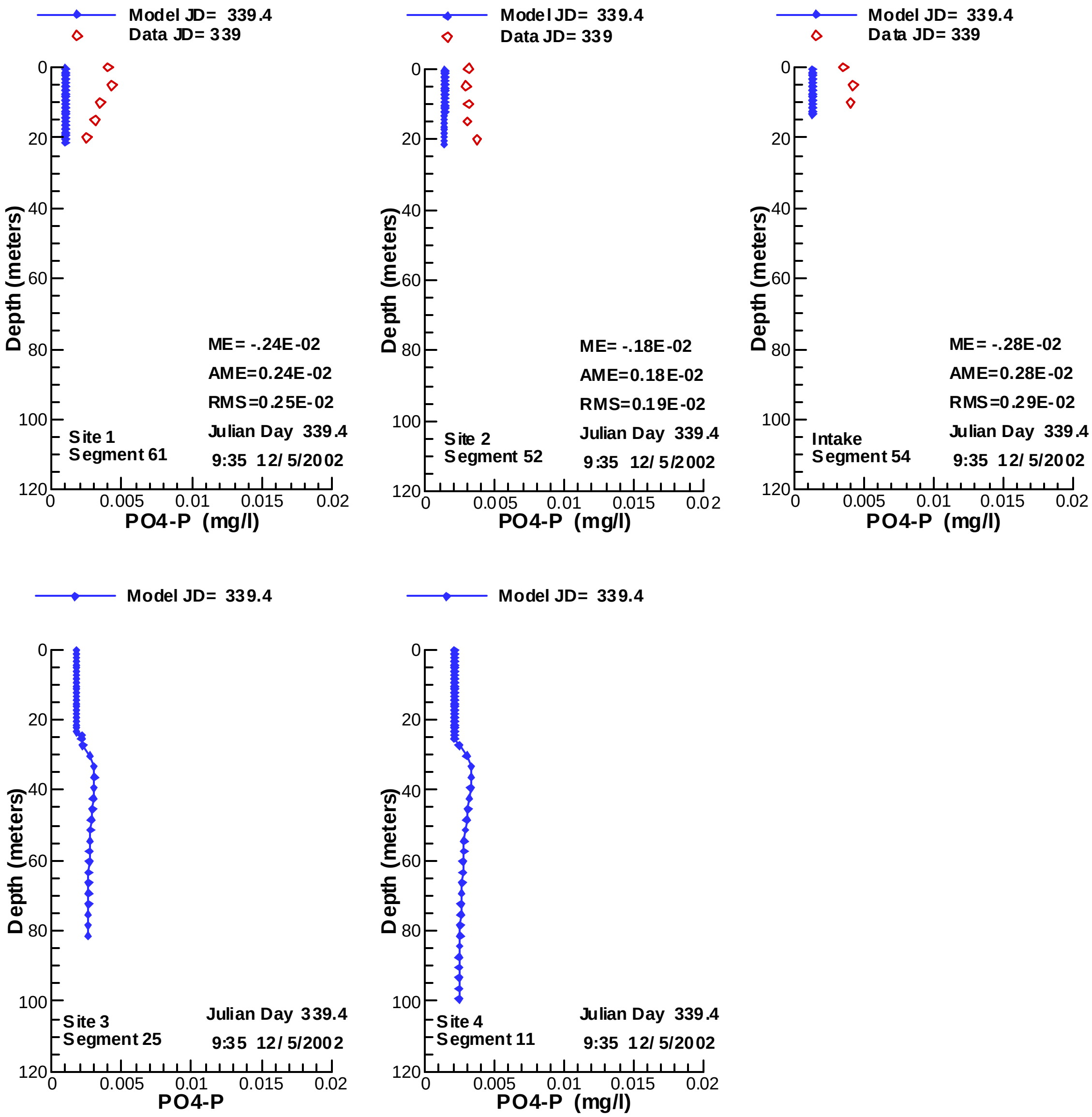

Figure 158. Vertical profiles of PO4-P compared with data for 12/ 5/2002.

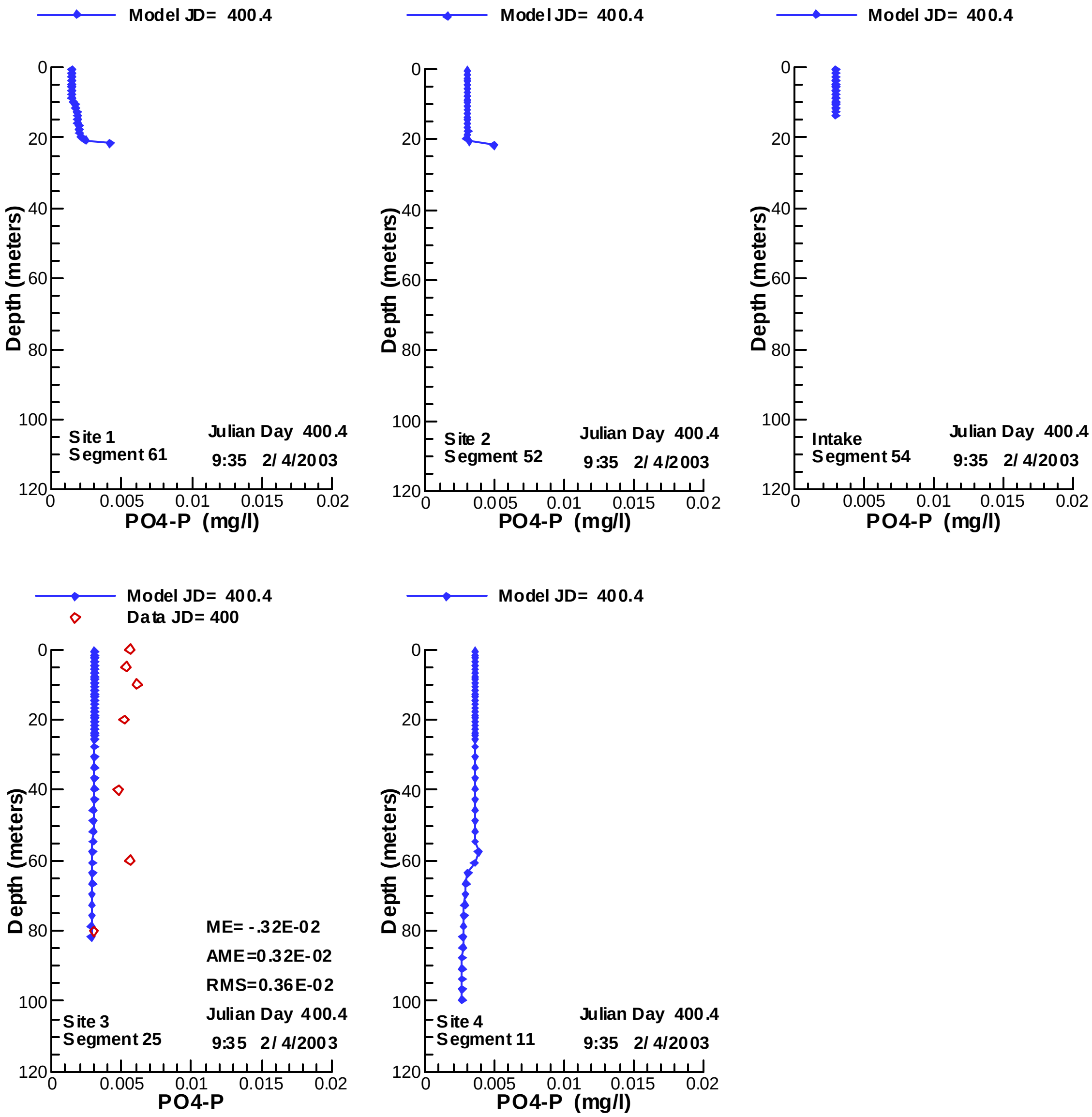

Figure 159. Vertical profiles of PO4-P compared with data for 2/ 4/2003.

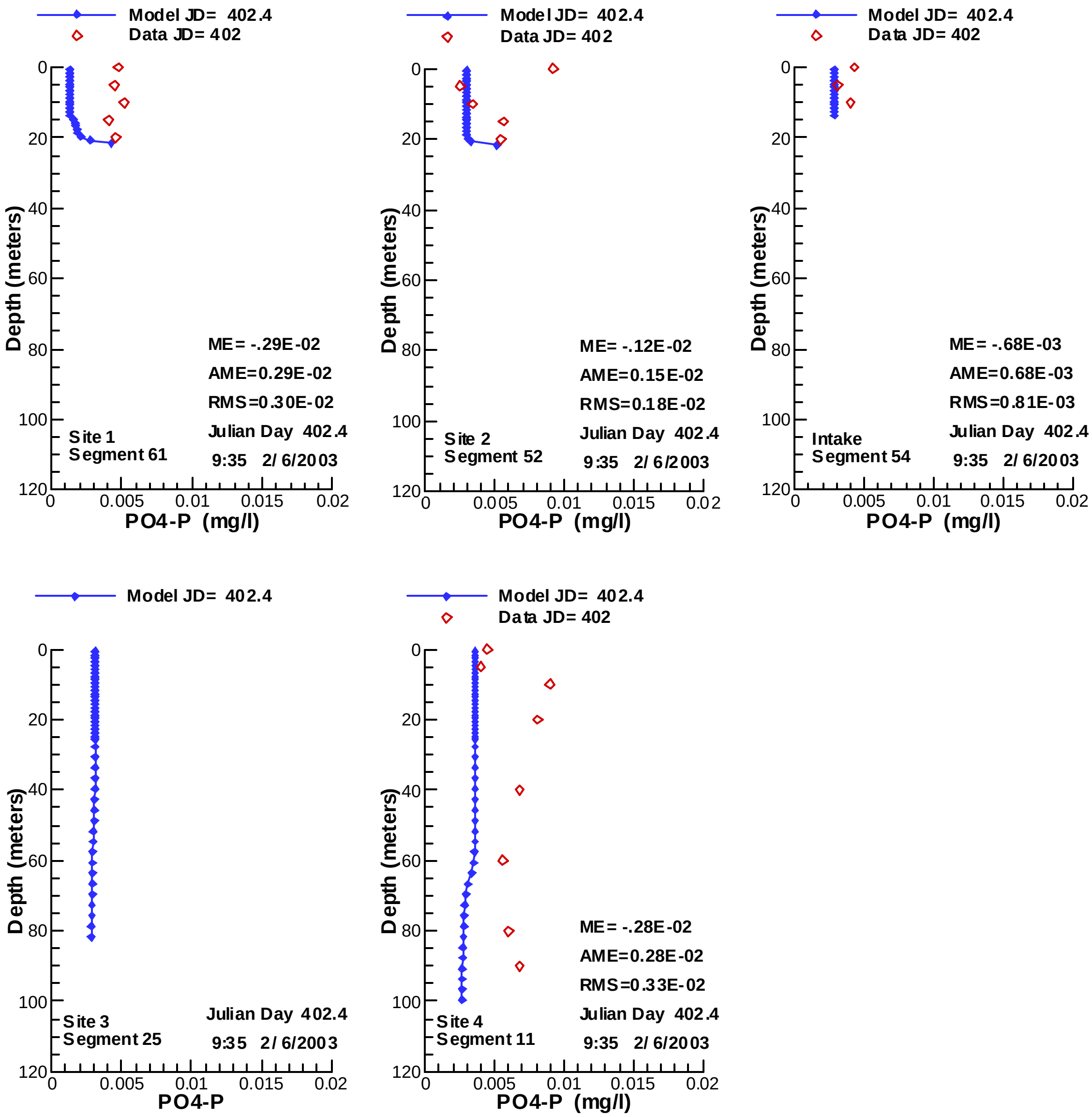

Figure 160. Vertical profiles of PO4-P compared with data for 2/ 6/2003.

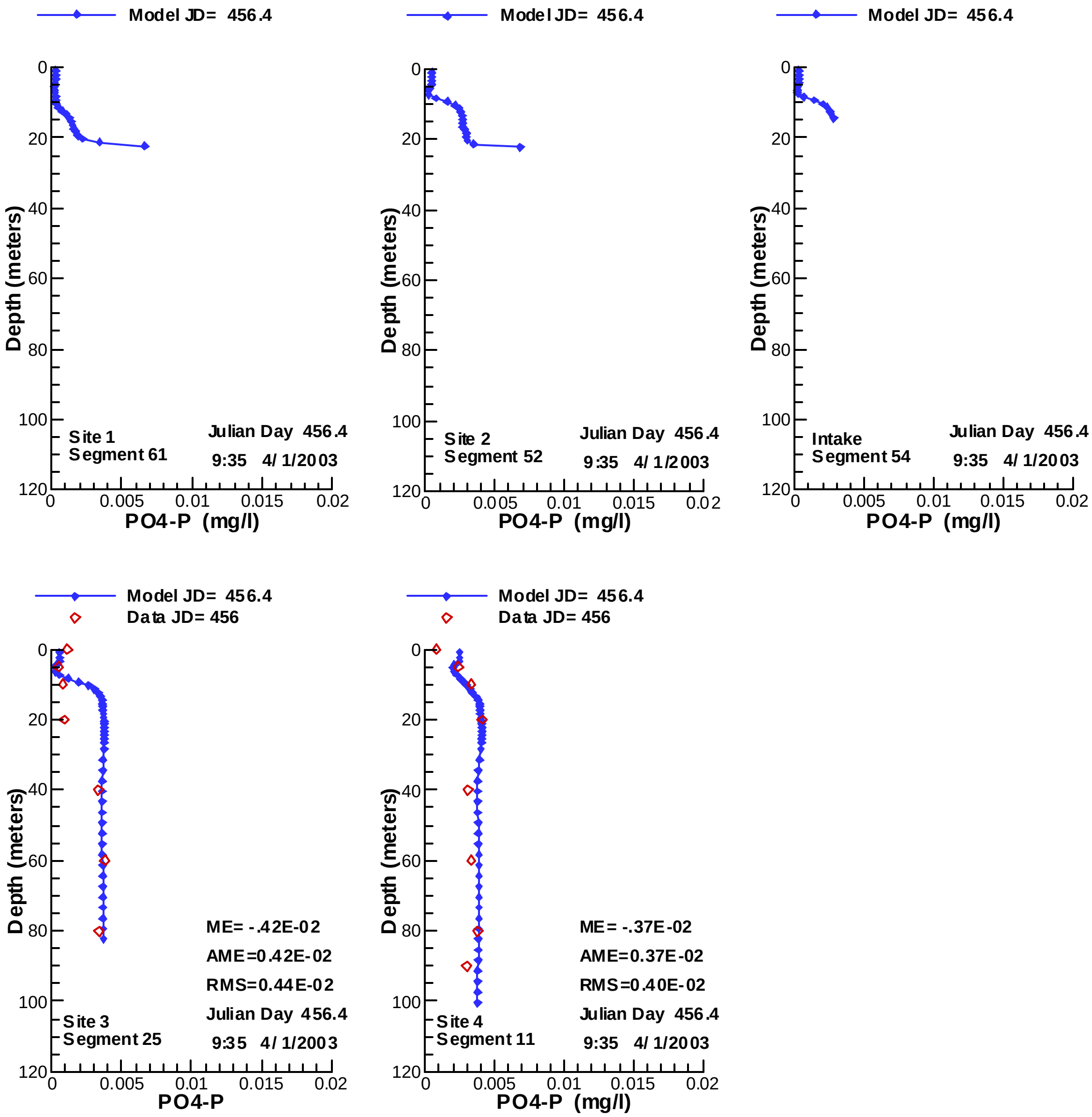

Figure 161. Vertical profiles of PO4-P compared with data for 4/ 1/2003.

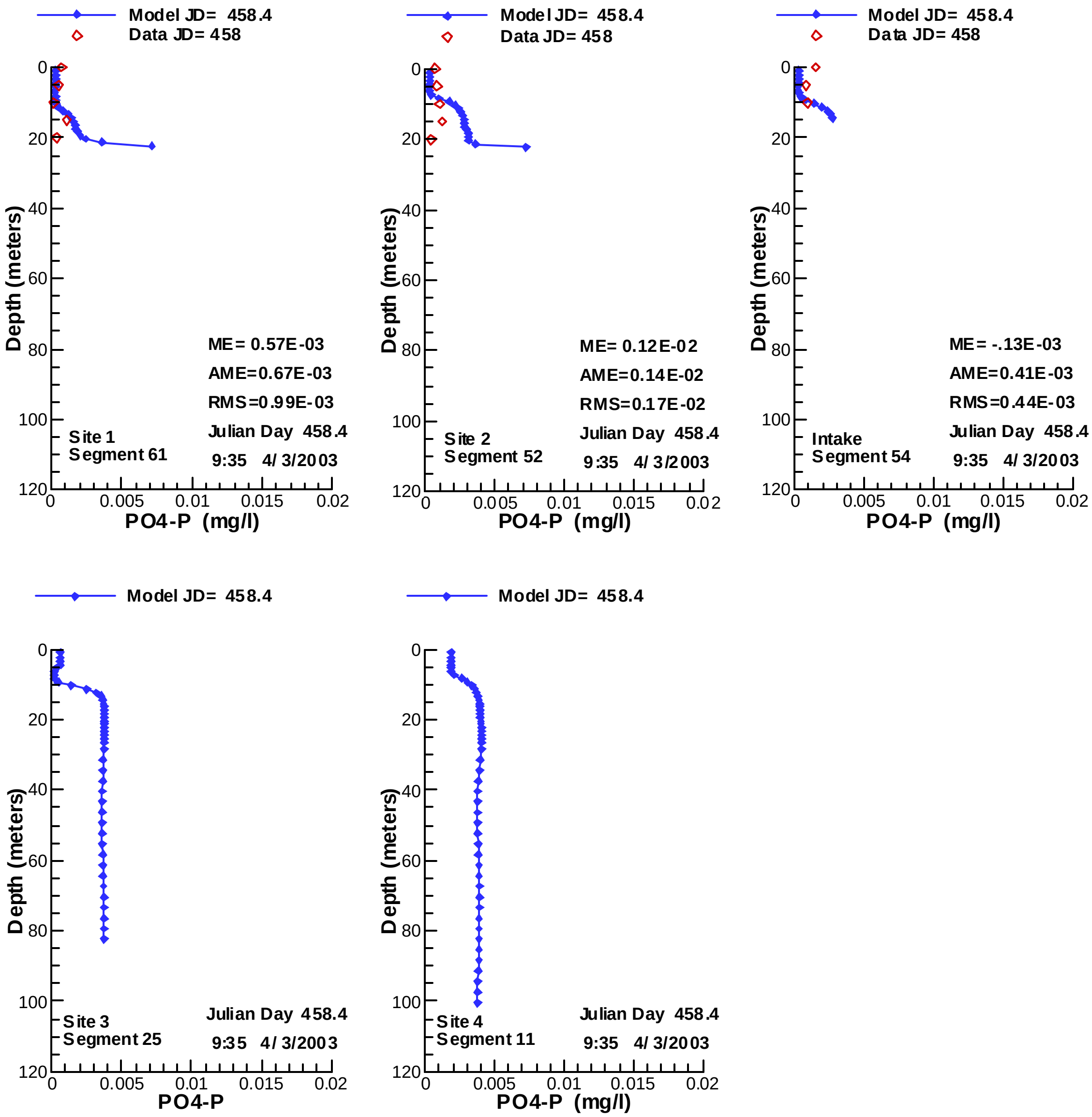

Figure 162. Vertical profiles of PO4-P compared with data for 4/ 3/2003.

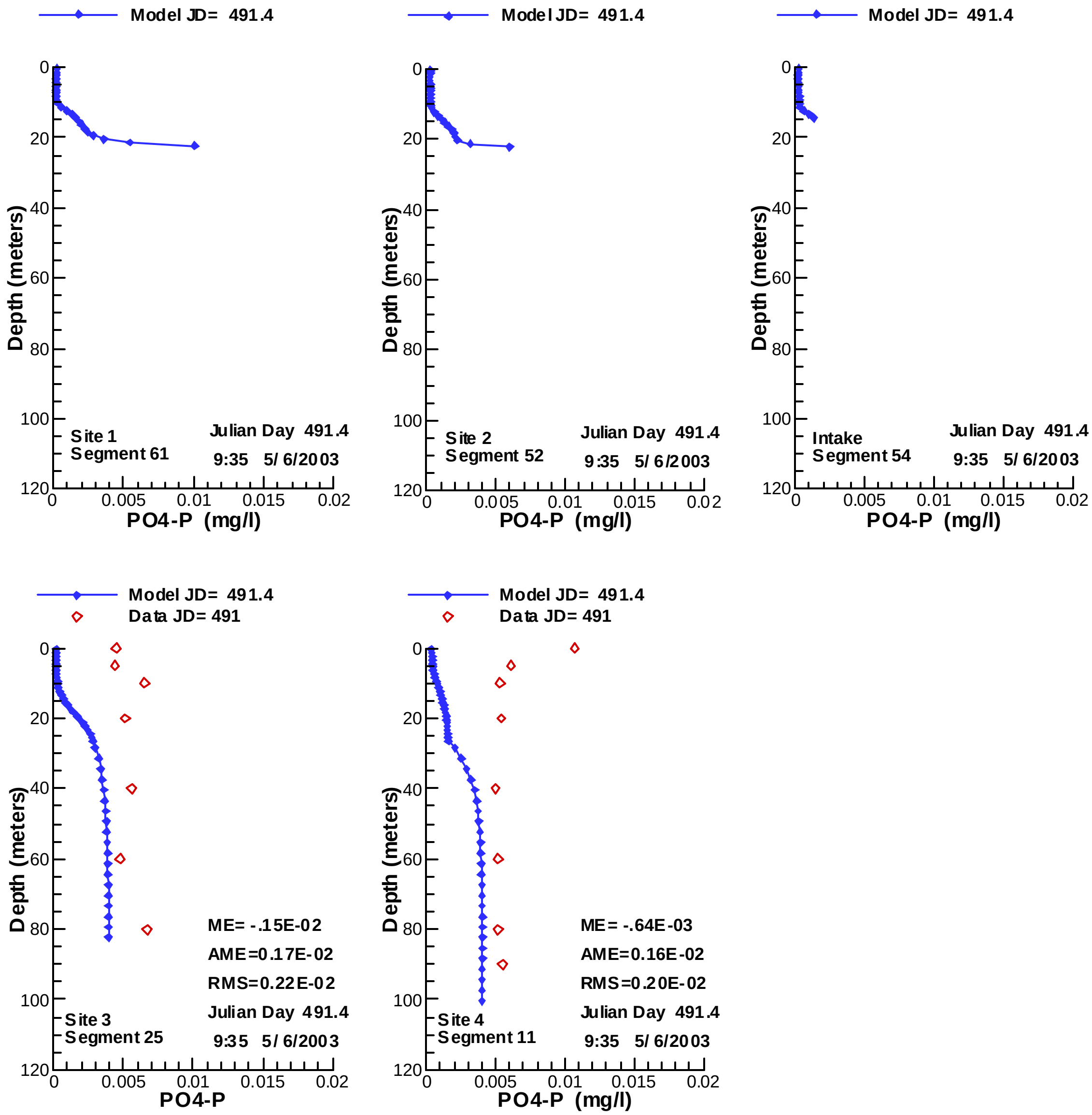

Figure 163. Vertical profiles of PO4-P compared with data for 5/ 6/2003.

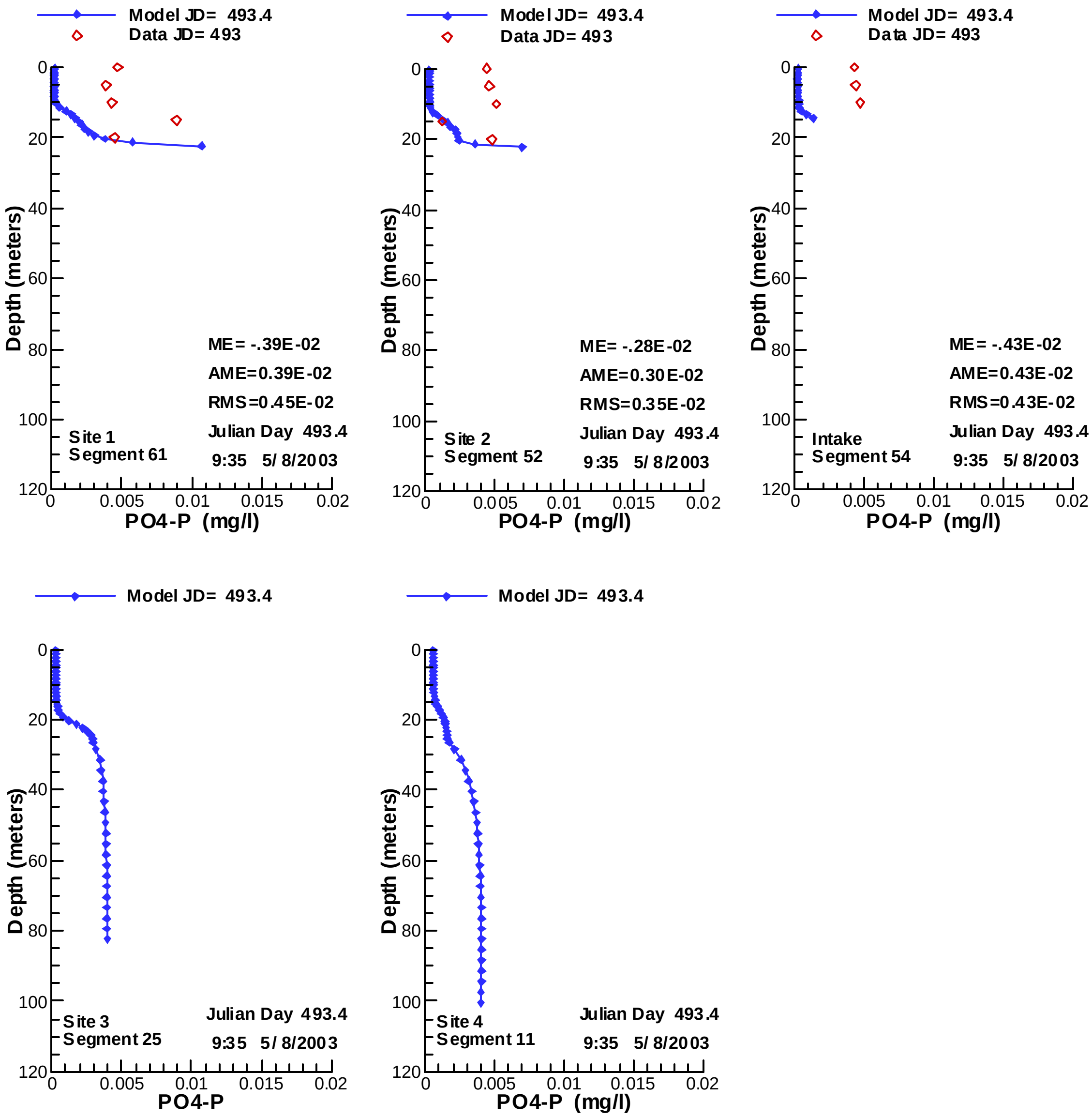

Figure 164. Vertical profiles of PO4-P compared with data for 5/ 8/2003.

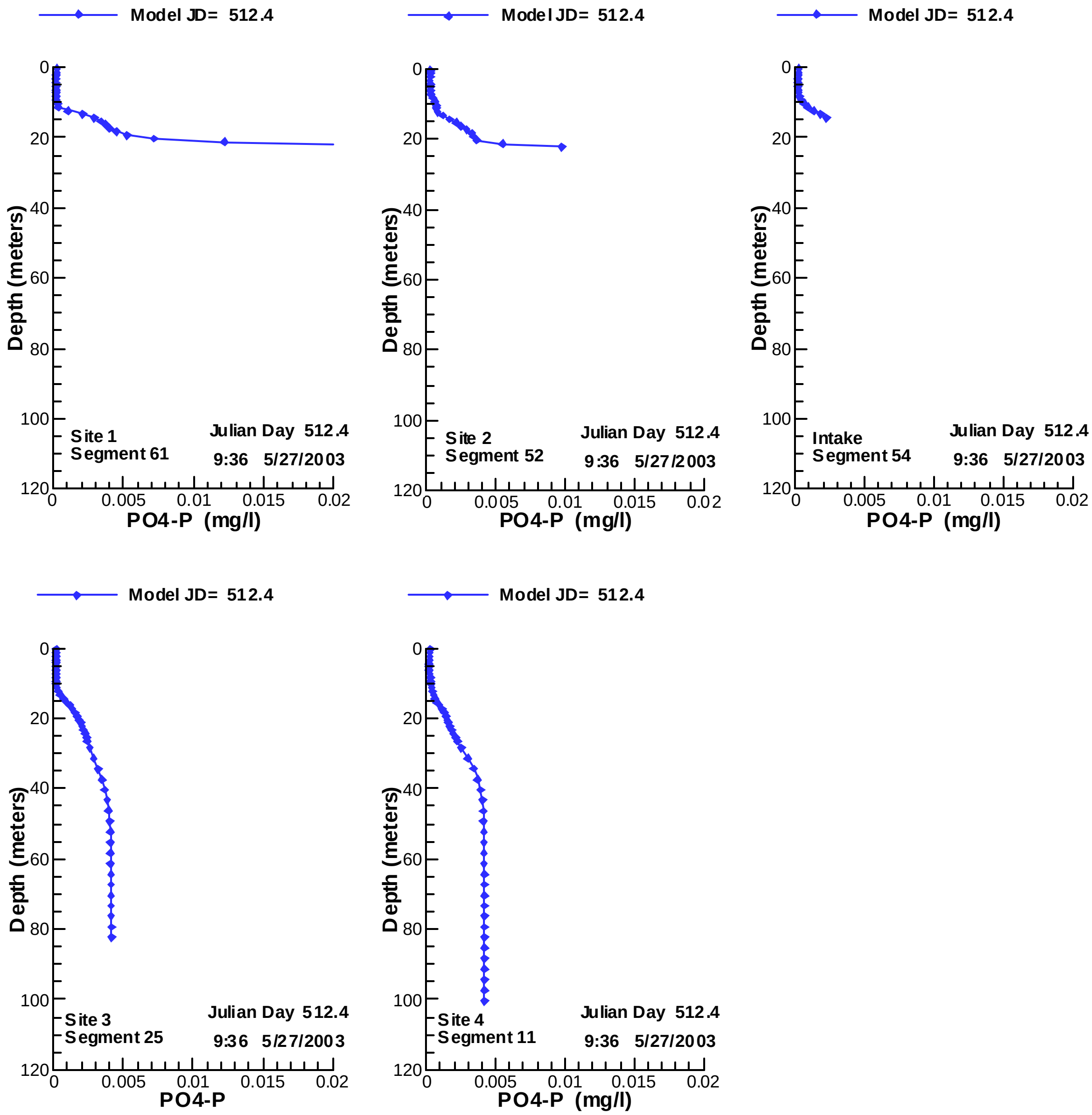

Figure 165. Vertical profiles of PO4-P compared with data for 5/27/2003.

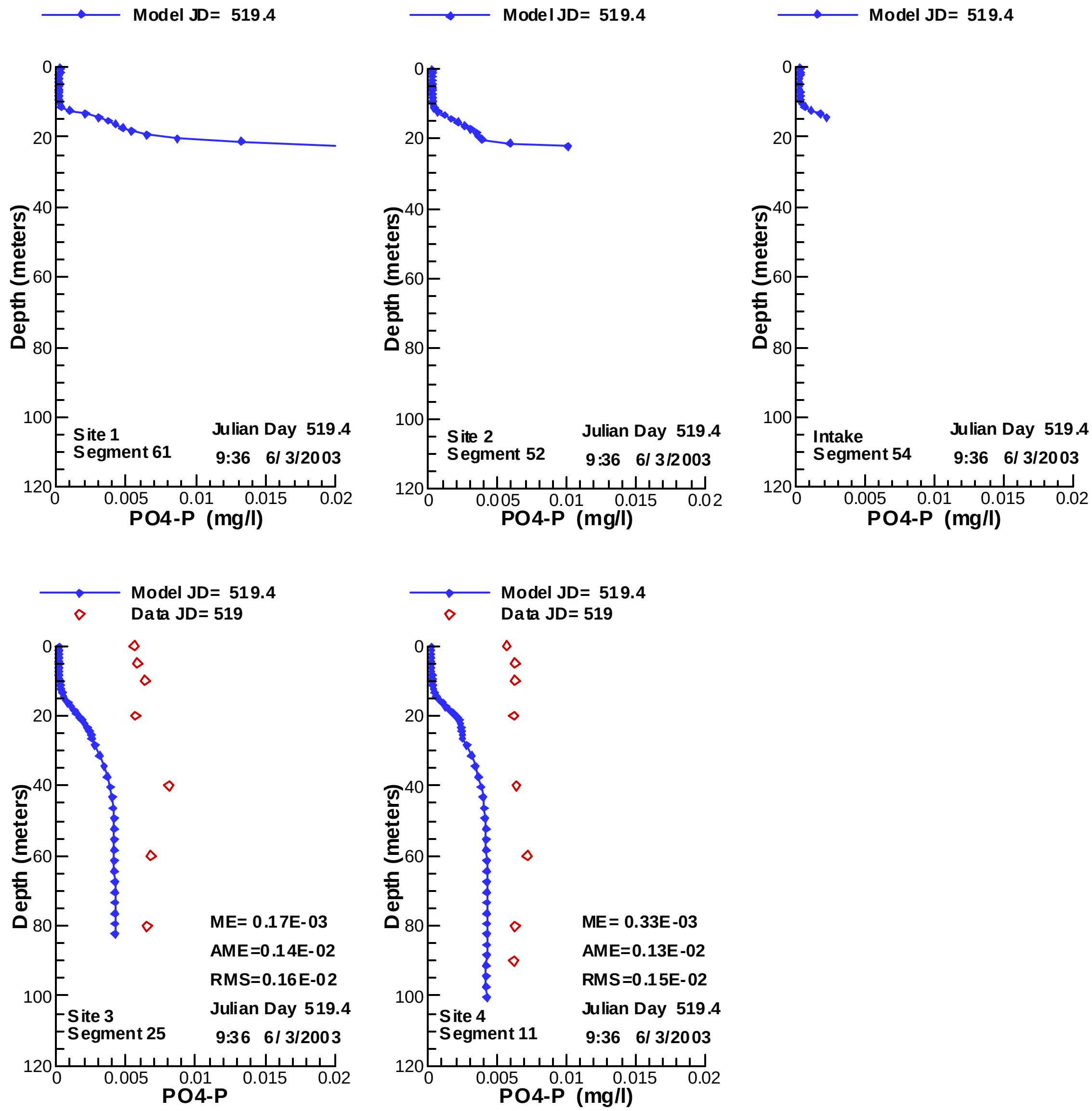

Figure 166. Vertical profiles of PO4-P compared with data for 6/ 3/2003.

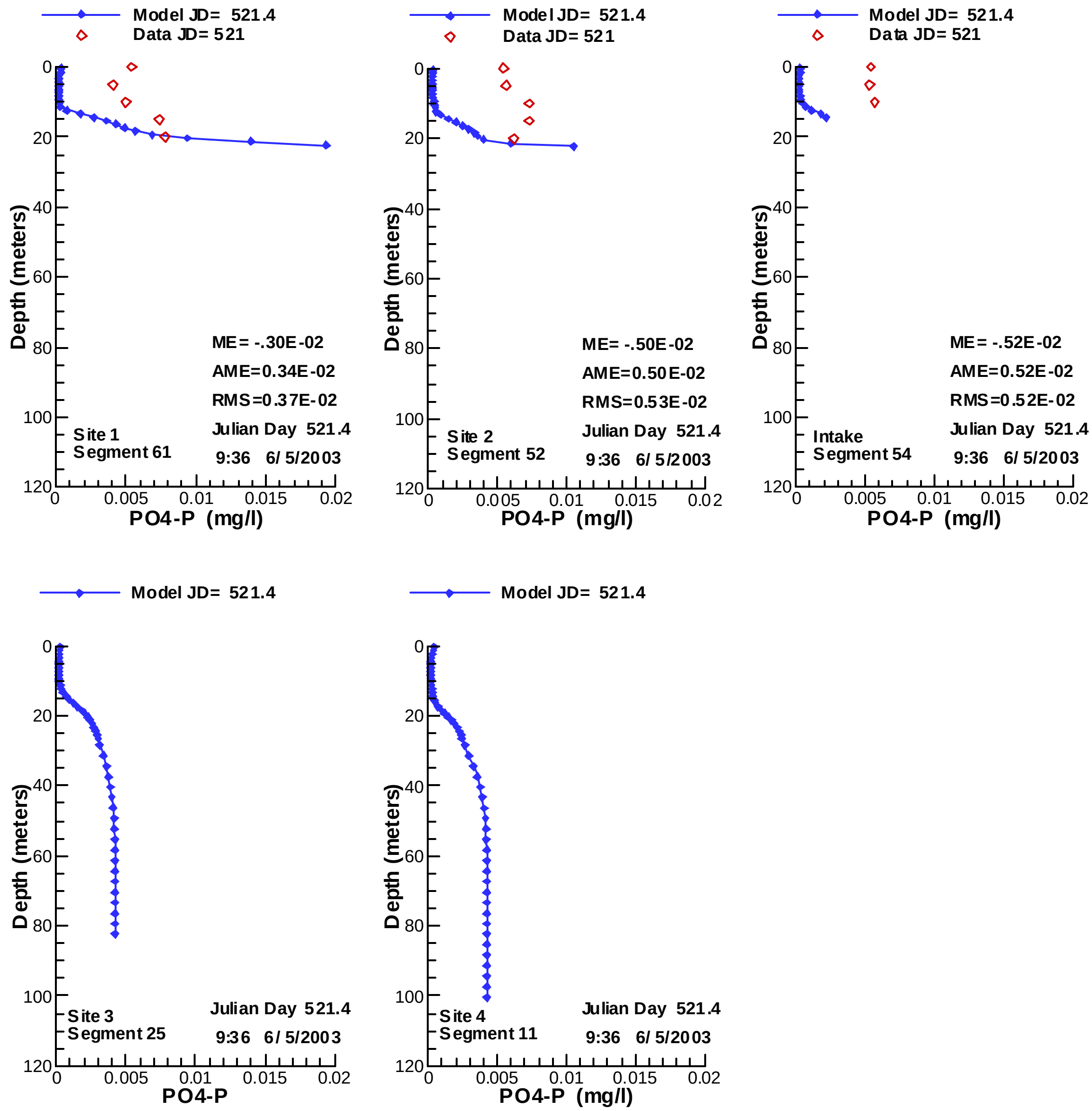

Figure 167. Vertical profiles of PO4-P compared with data for 6/ 5/2003.

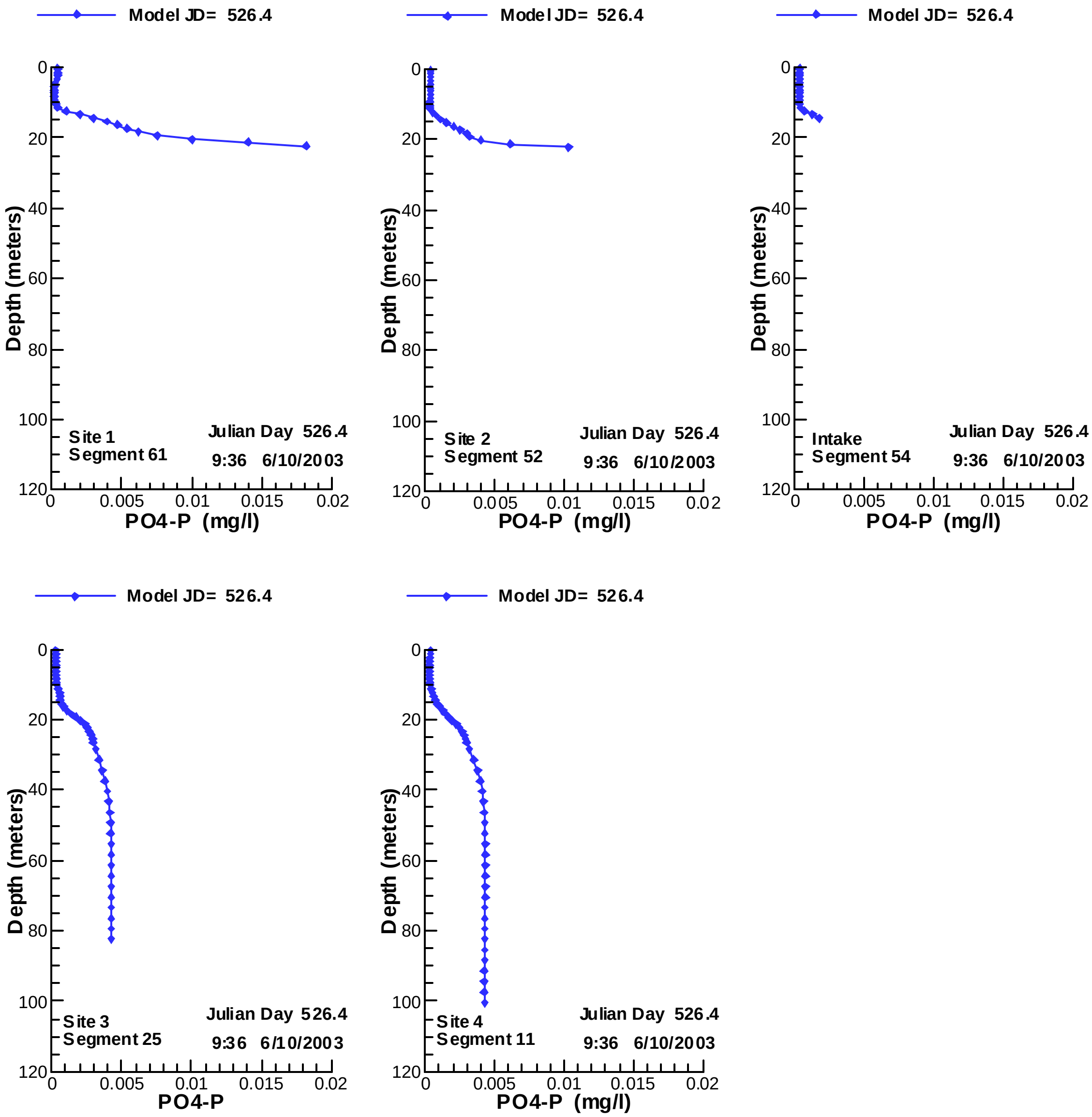

Figure 168. Vertical profiles of PO4-P compared with data for 6/10/2003.

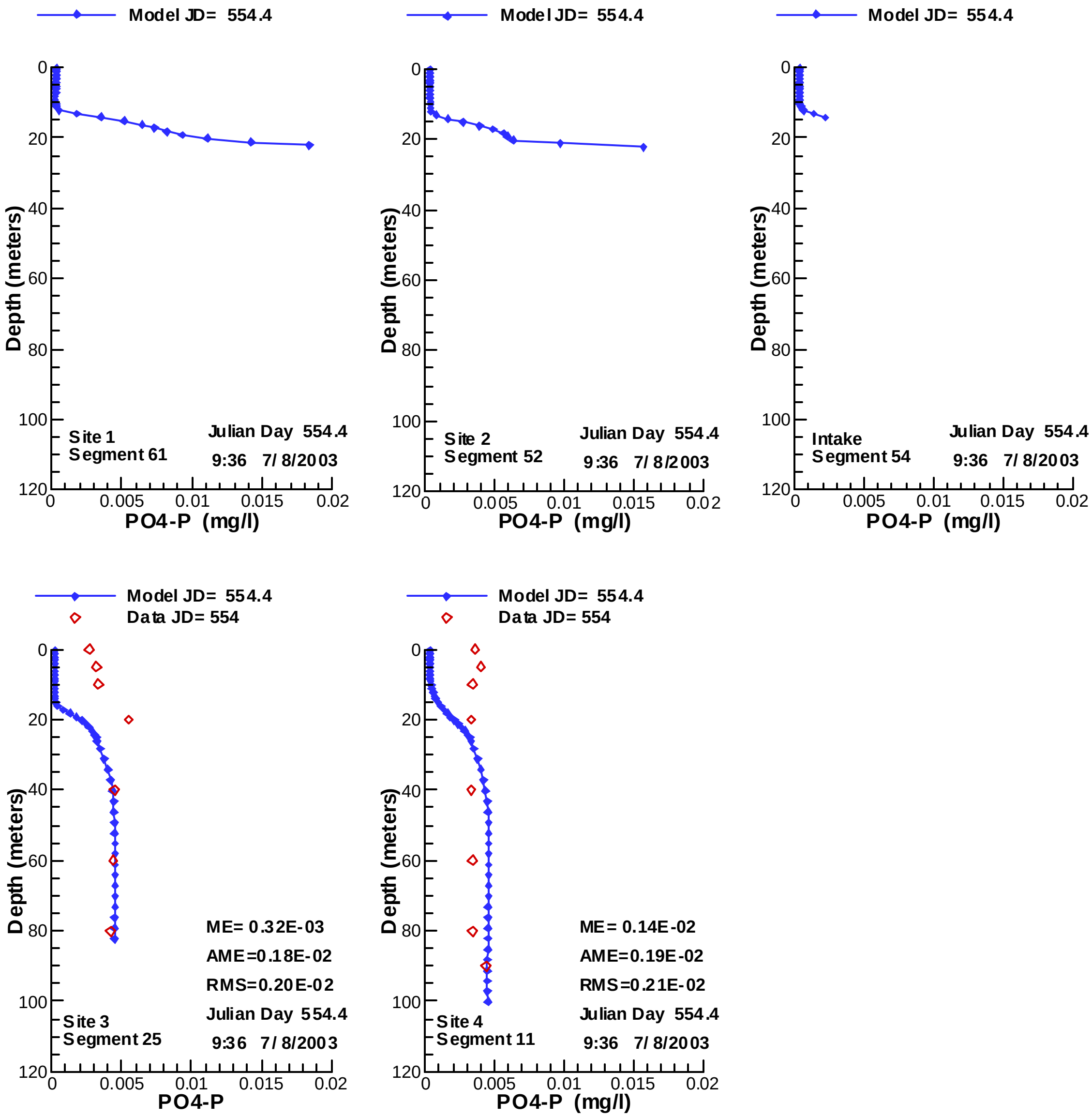

Figure 169. Vertical profiles of PO4-P compared with data for 7/ 8/2003.

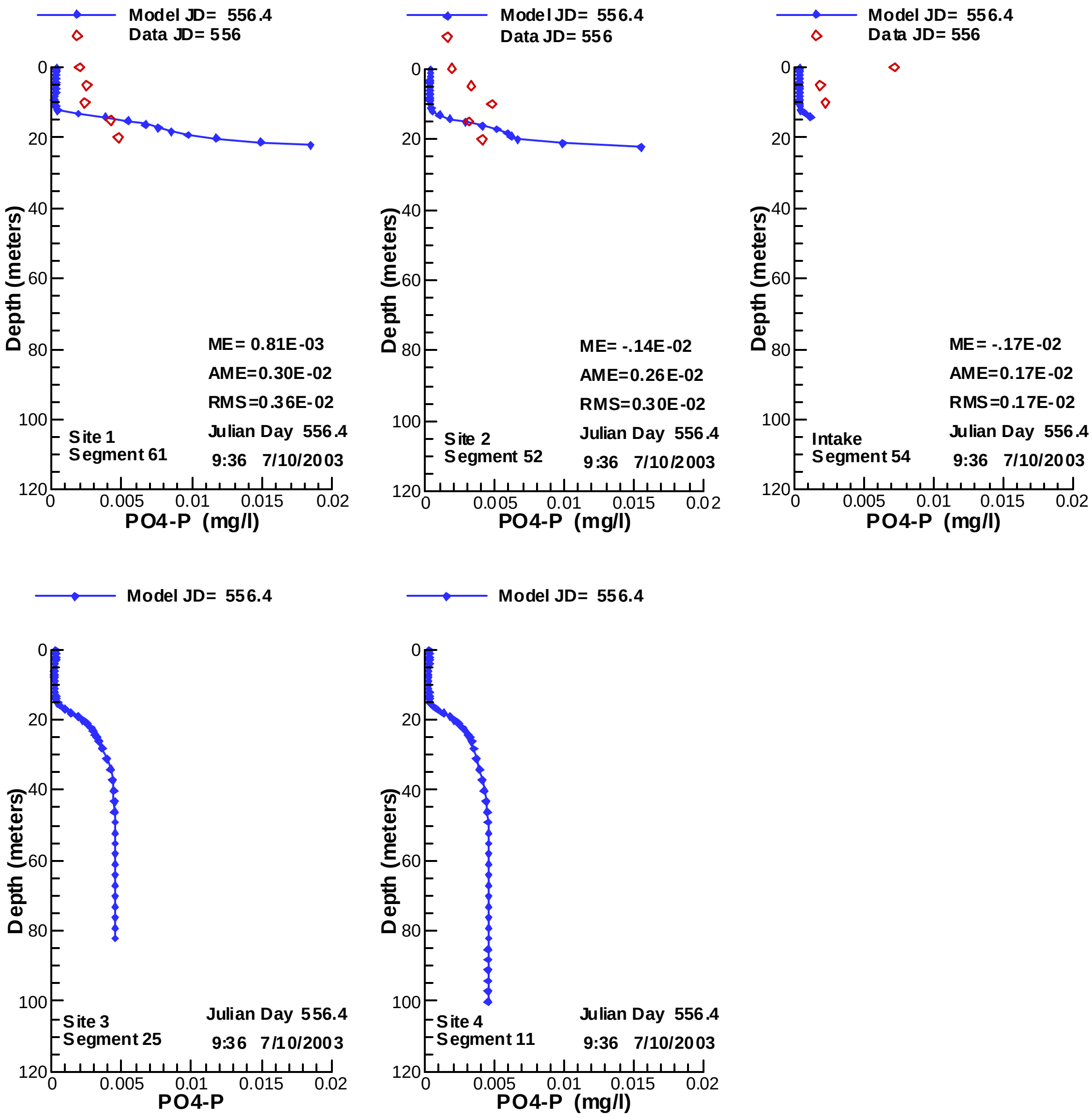

Figure 170. Vertical profiles of PO4-P compared with data for 7/10/2003.

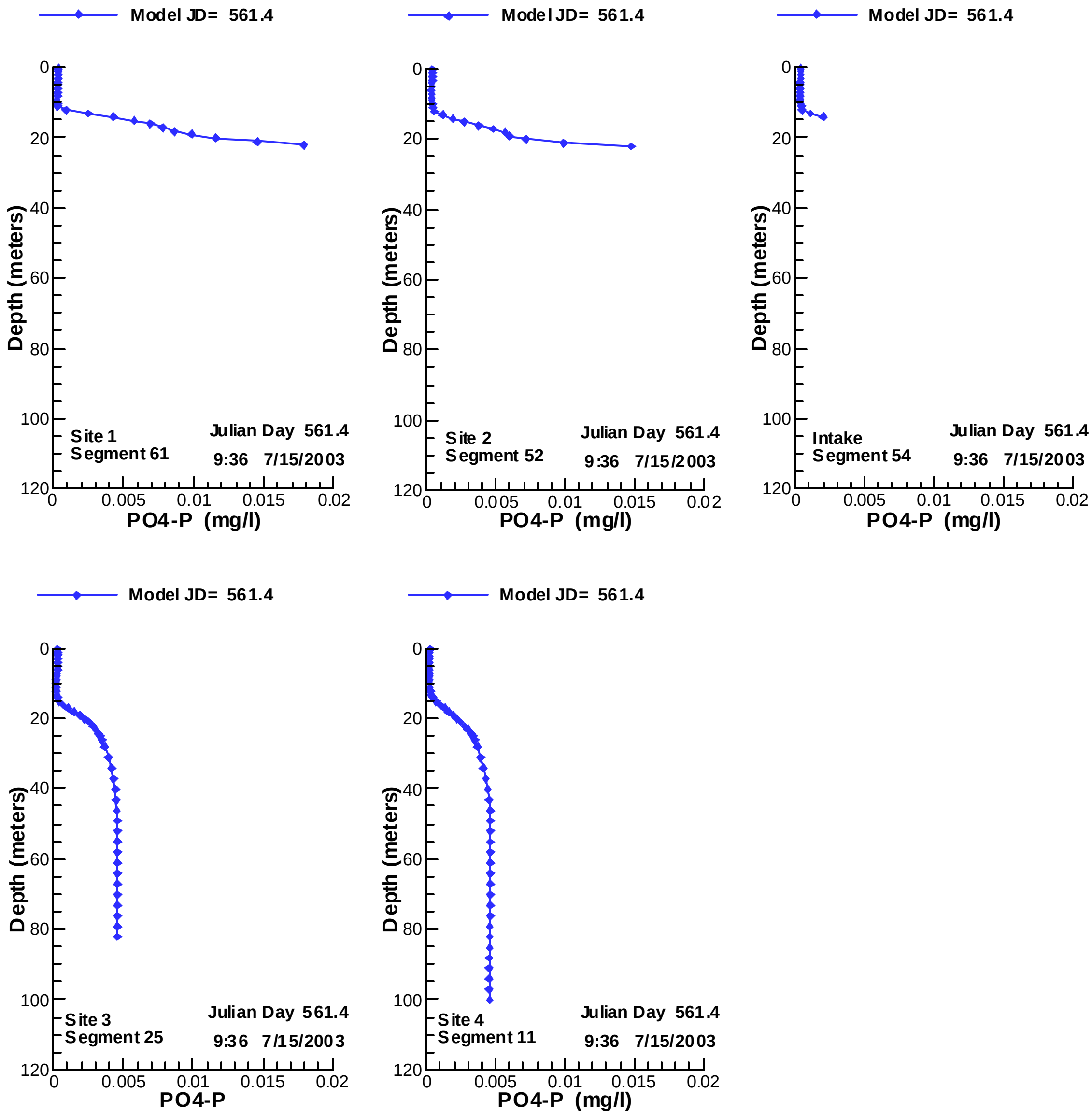

Figure 171. Vertical profiles of PO4-P compared with data for 7/15/2003.

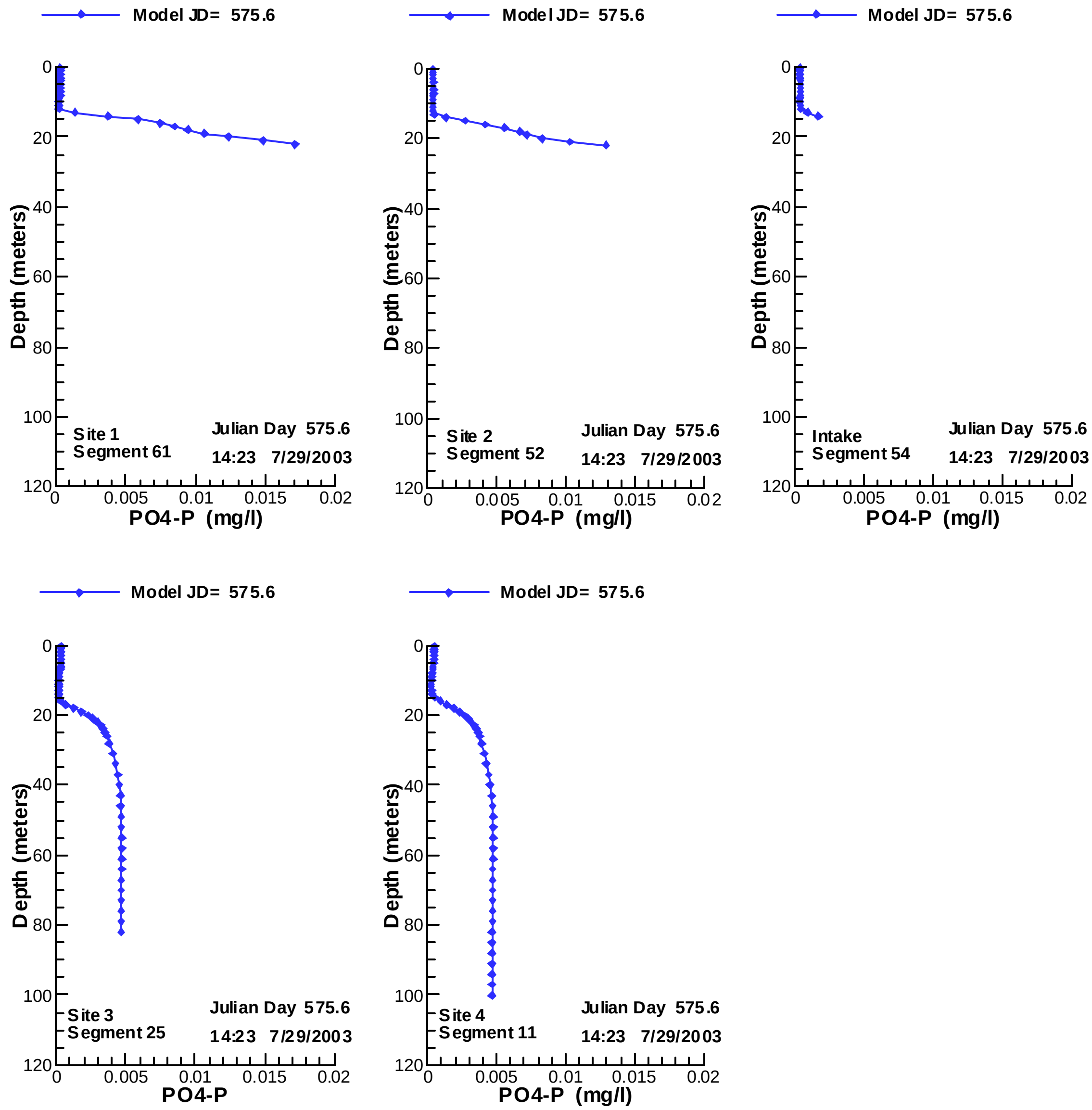

Figure 172. Vertical profiles of PO4-P compared with data for 7/29/2003.

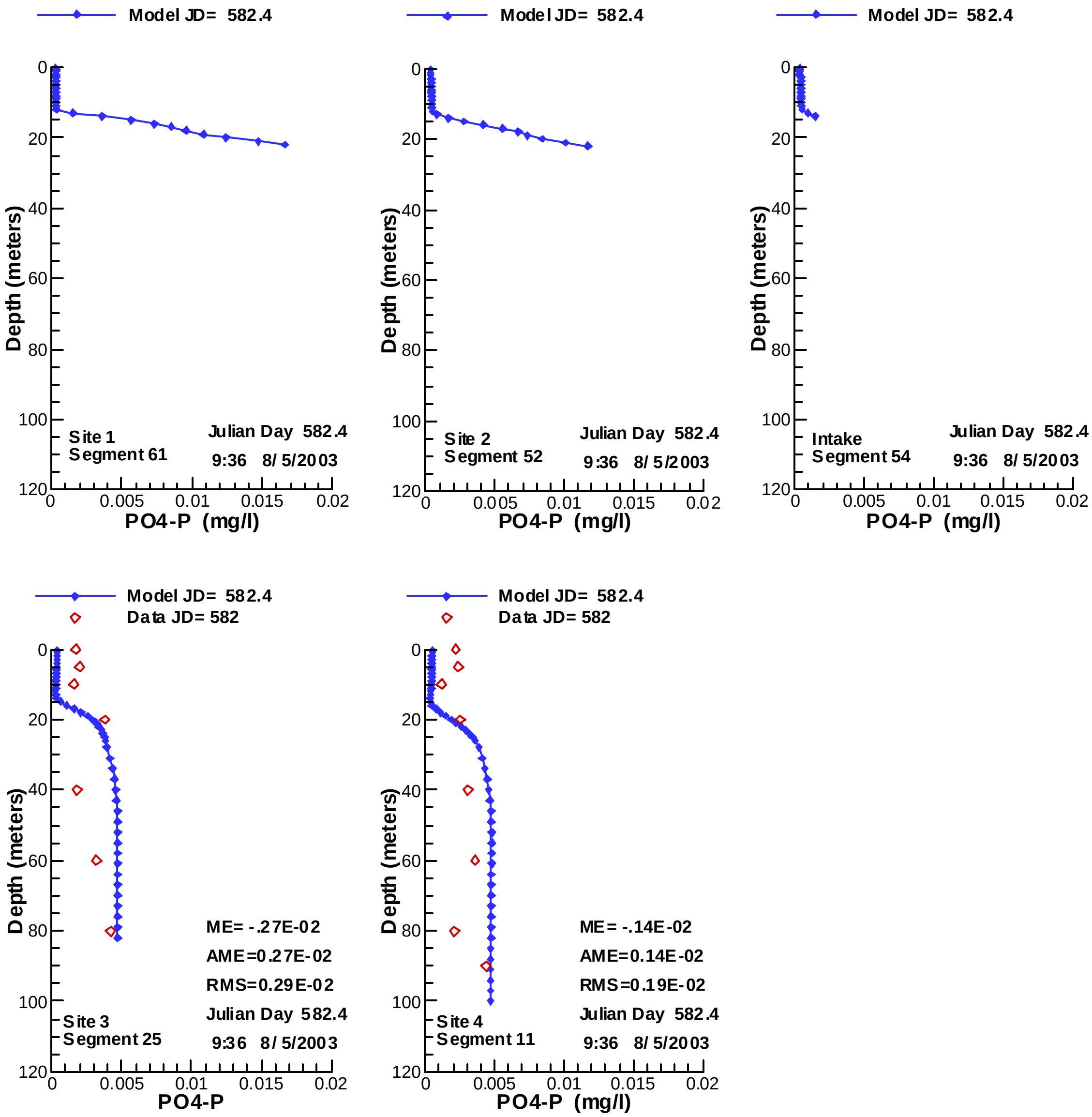

Figure 173. Vertical profiles of PO4-P compared with data for 8/ 5/2003.

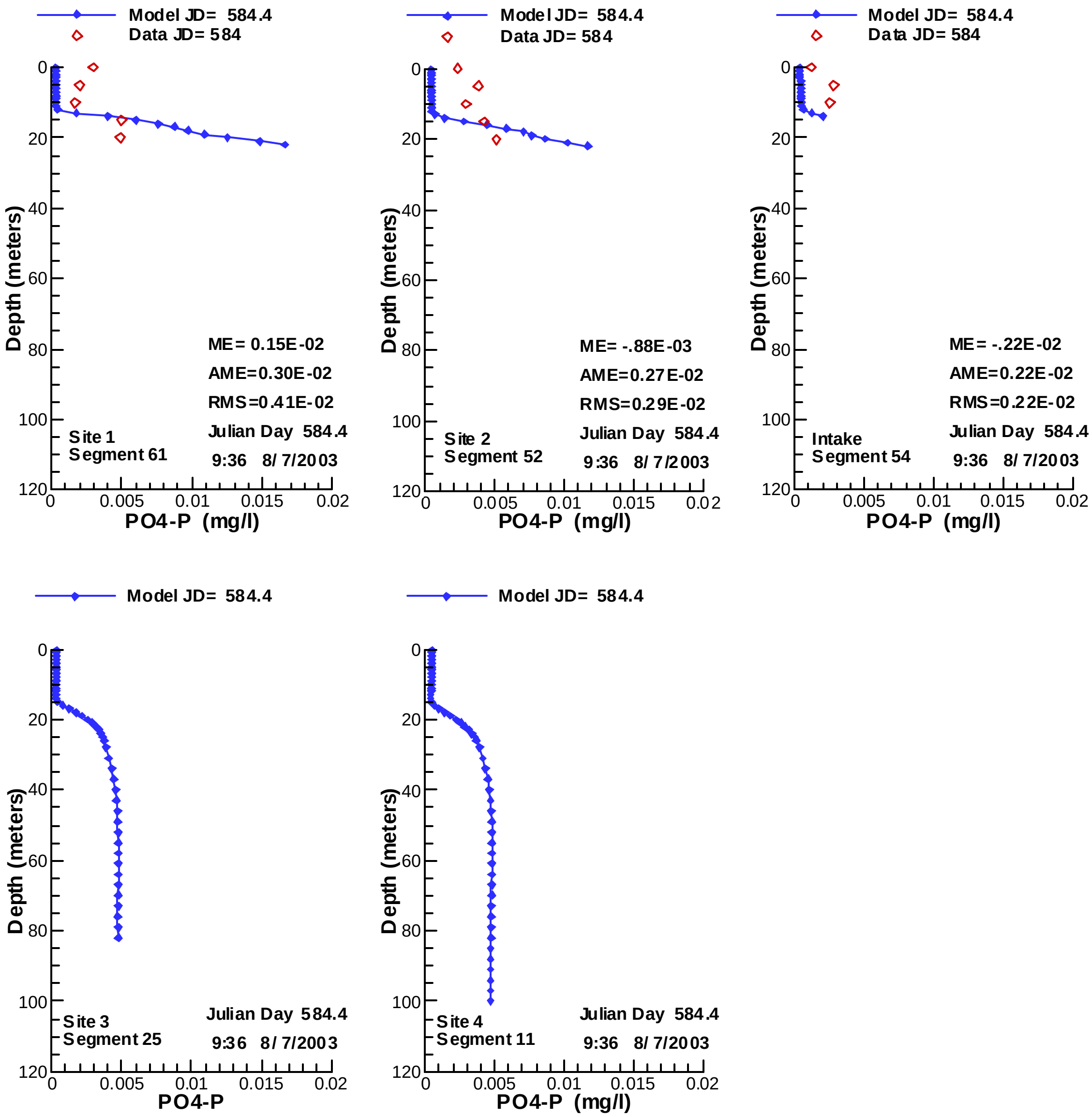

Figure 174. Vertical profiles of PO4-P compared with data for 8/ 7/2003.

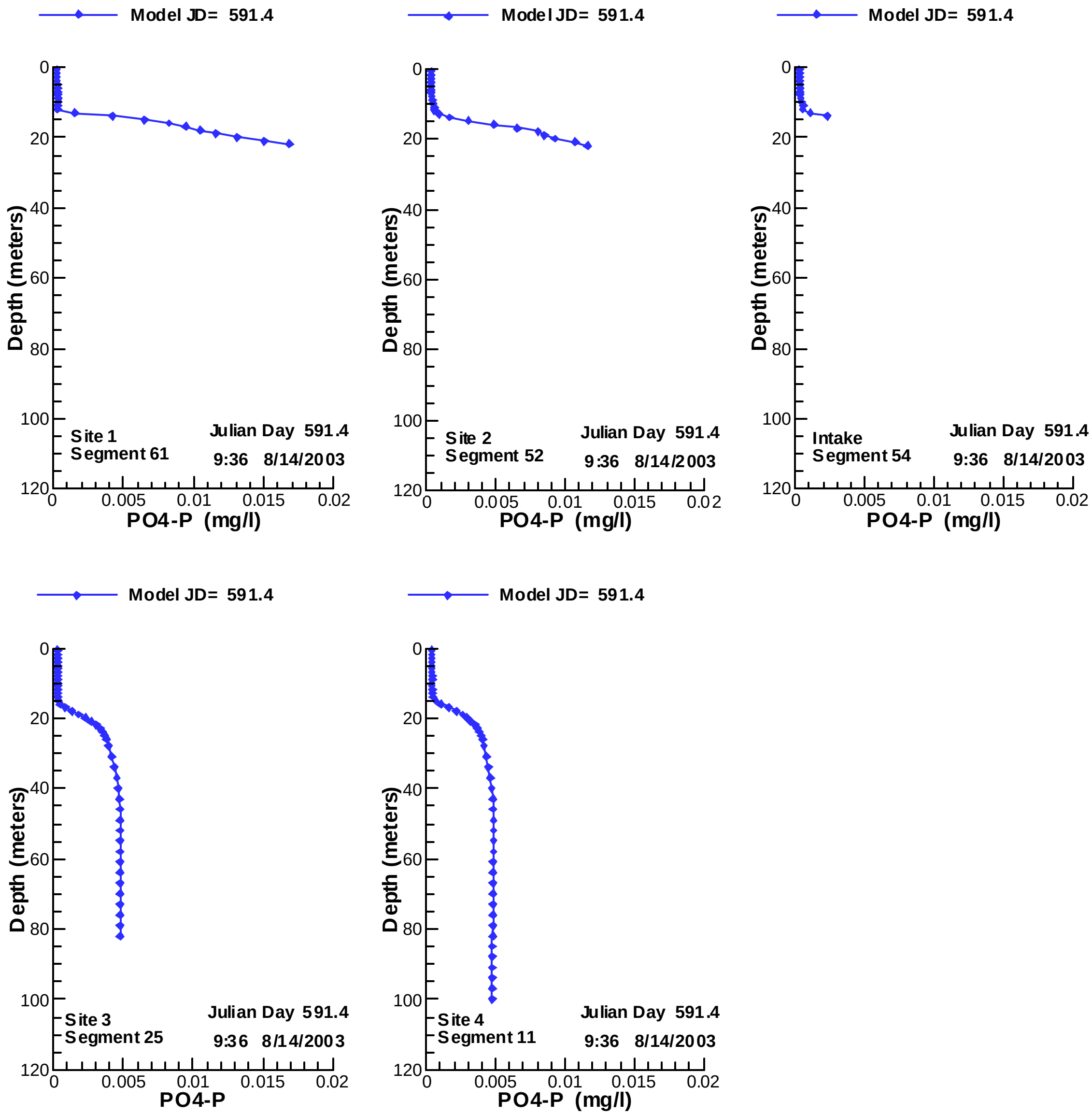

Figure 175. Vertical profiles of PO4-P compared with data for 8/14/2003.

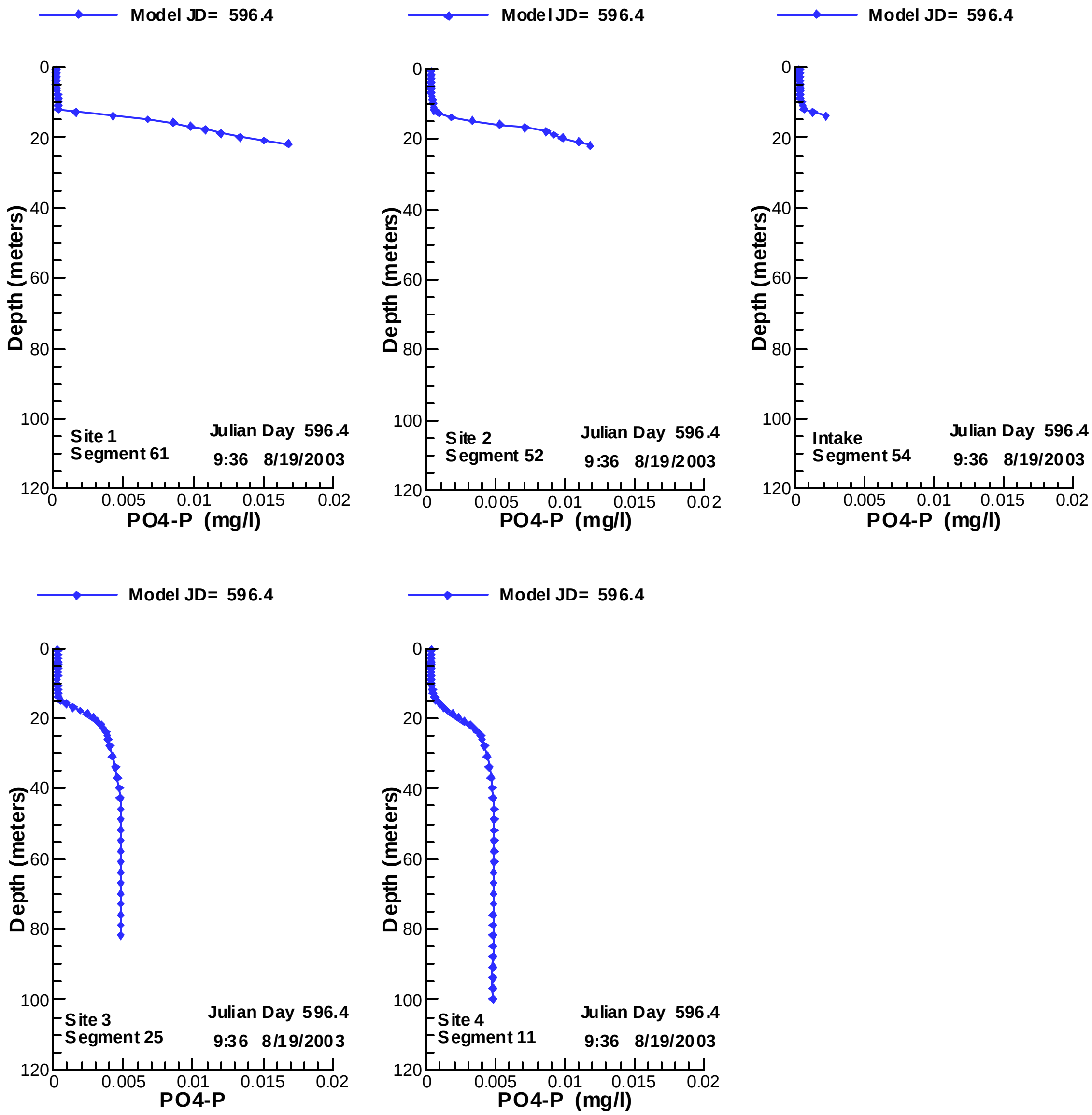

Figure 176. Vertical profiles of PO4-P compared with data for 8/19/2003.

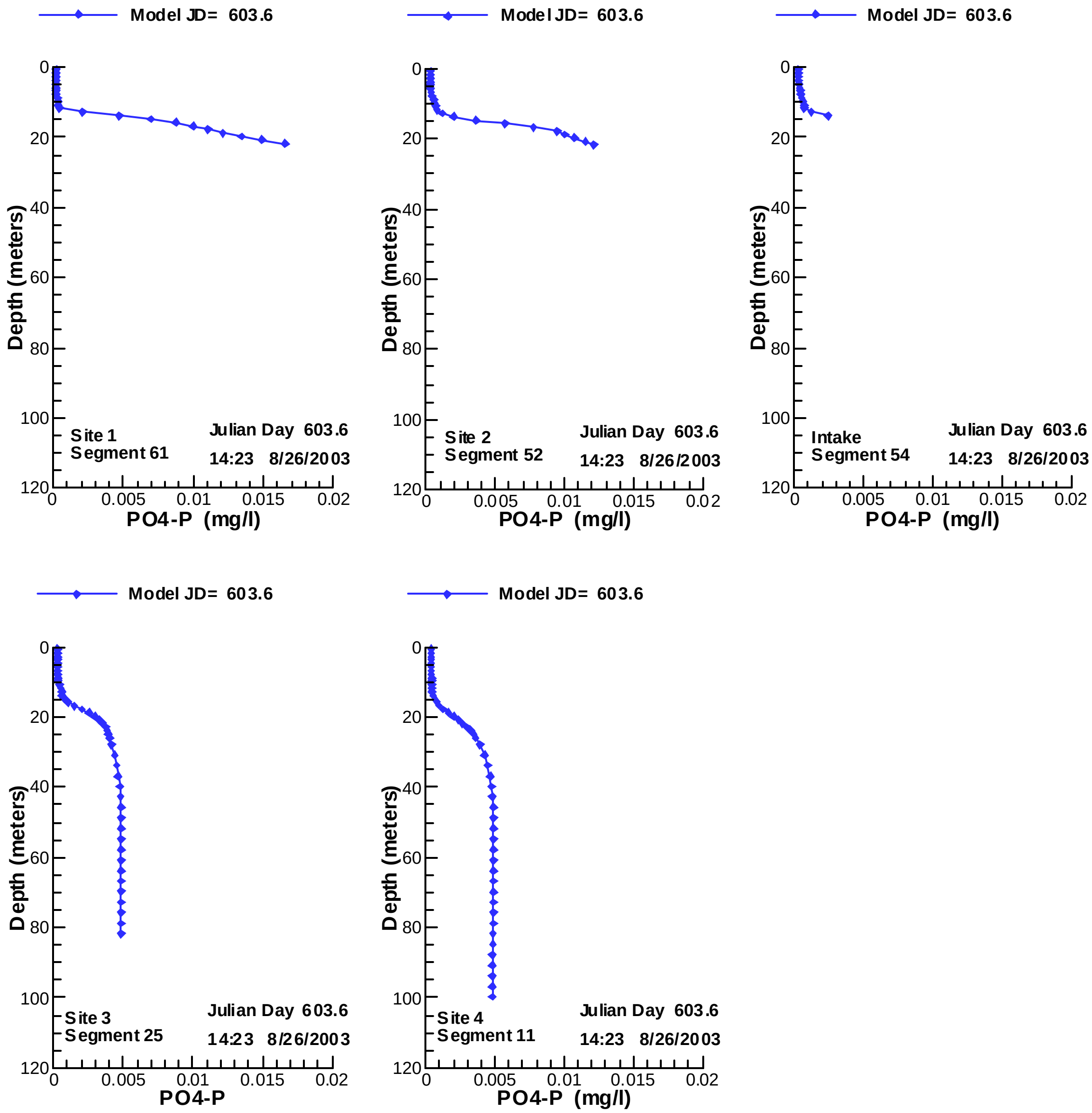

Figure 177. Vertical profiles of PO4-P compared with data for 8/26/2003.

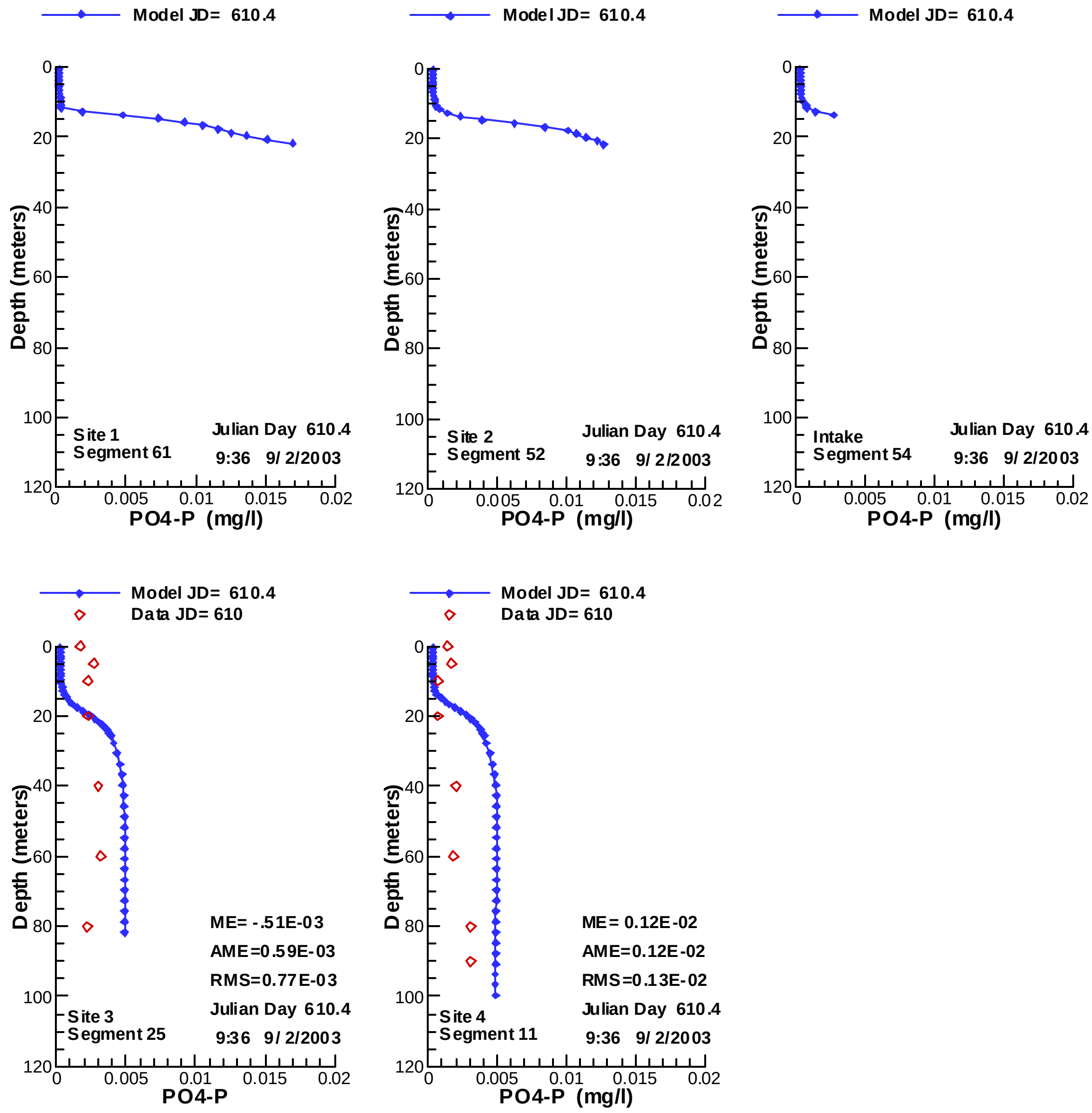

Figure 178. Vertical profiles of PO4-P compared with data for 9/ 2/2003.

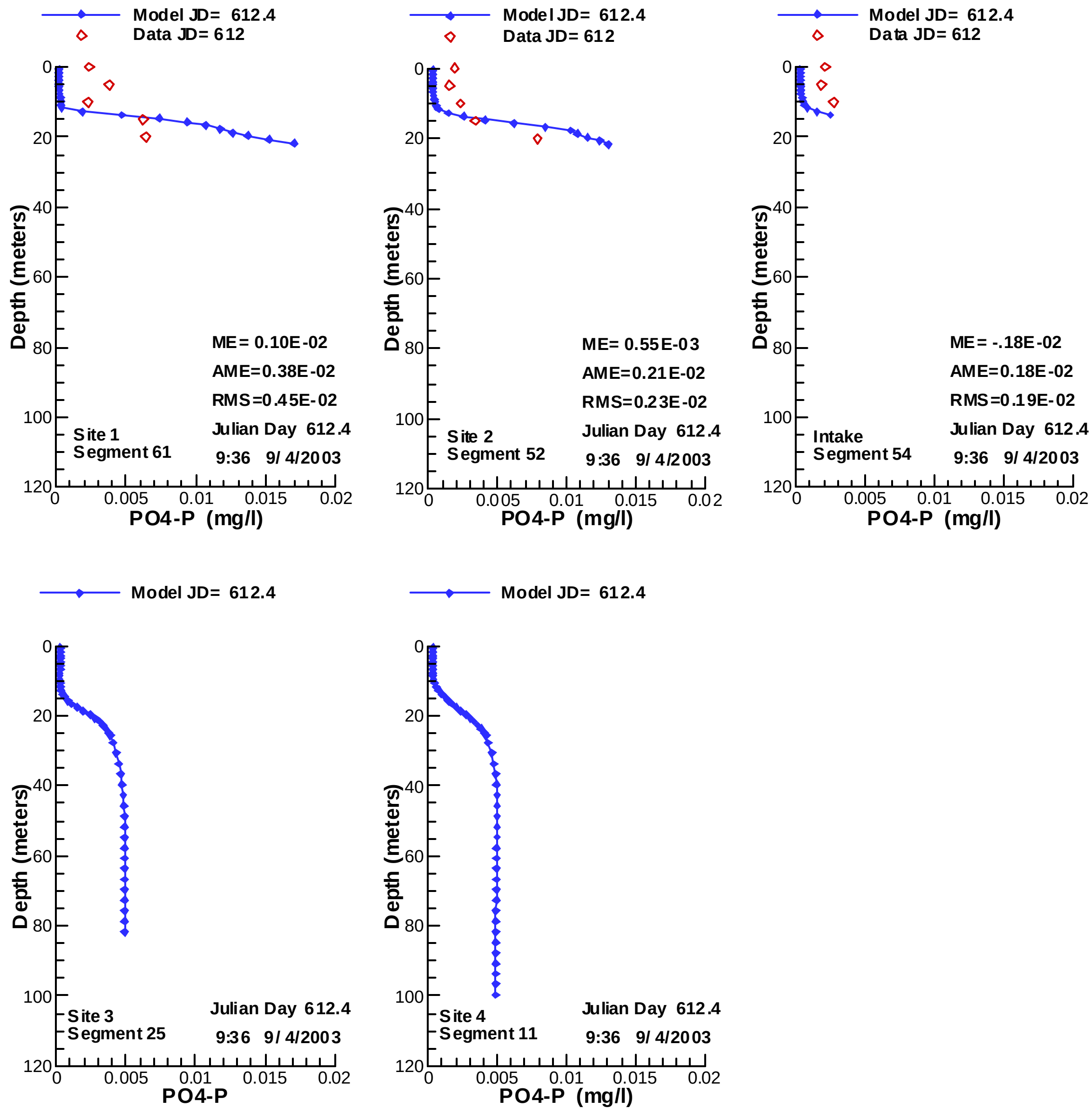

Figure 179. Vertical profiles of PO4-P compared with data for 9/ 4/2003.

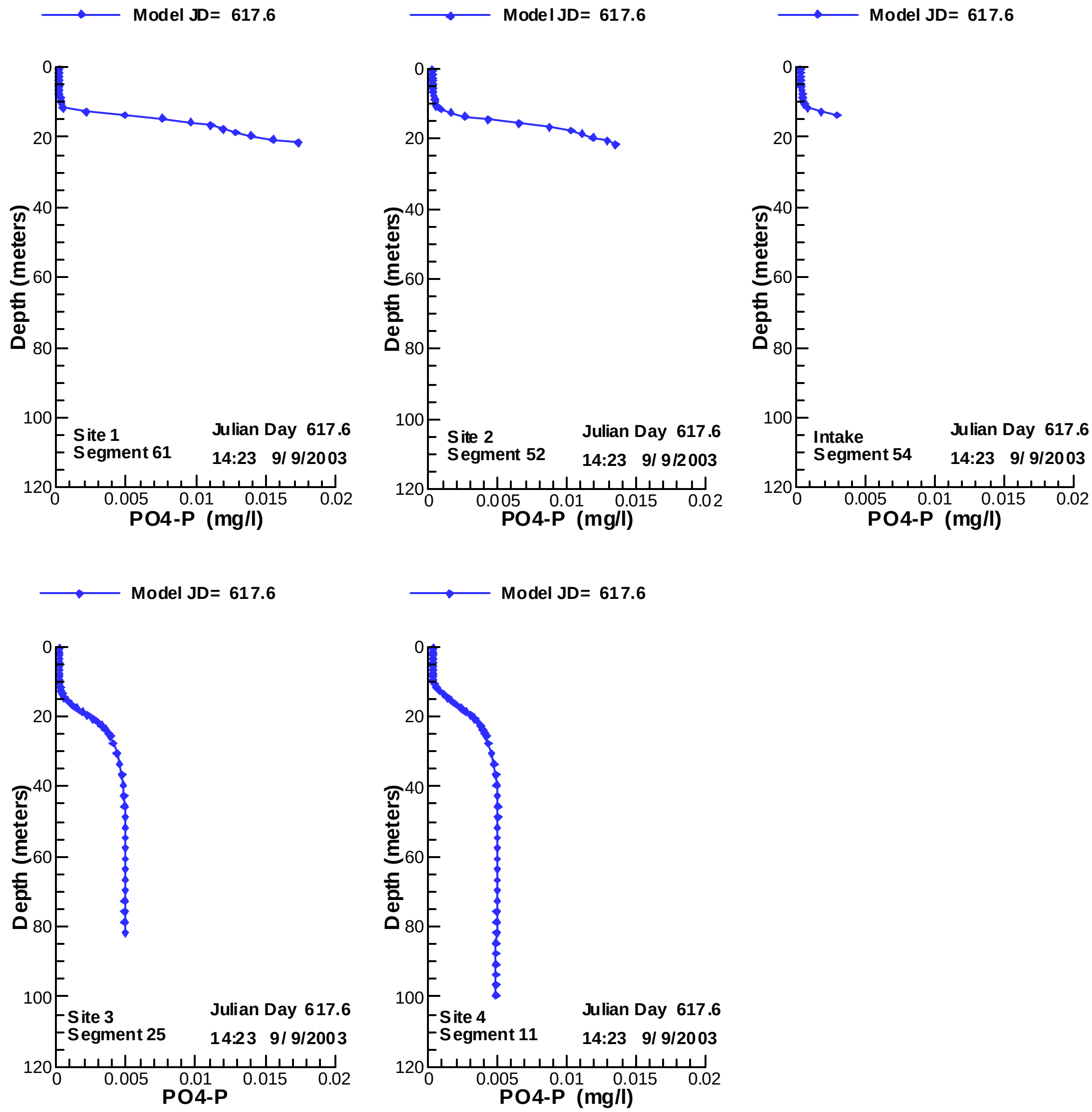

Figure 180. Vertical profiles of PO4-P compared with data for 9/ 9/2003.

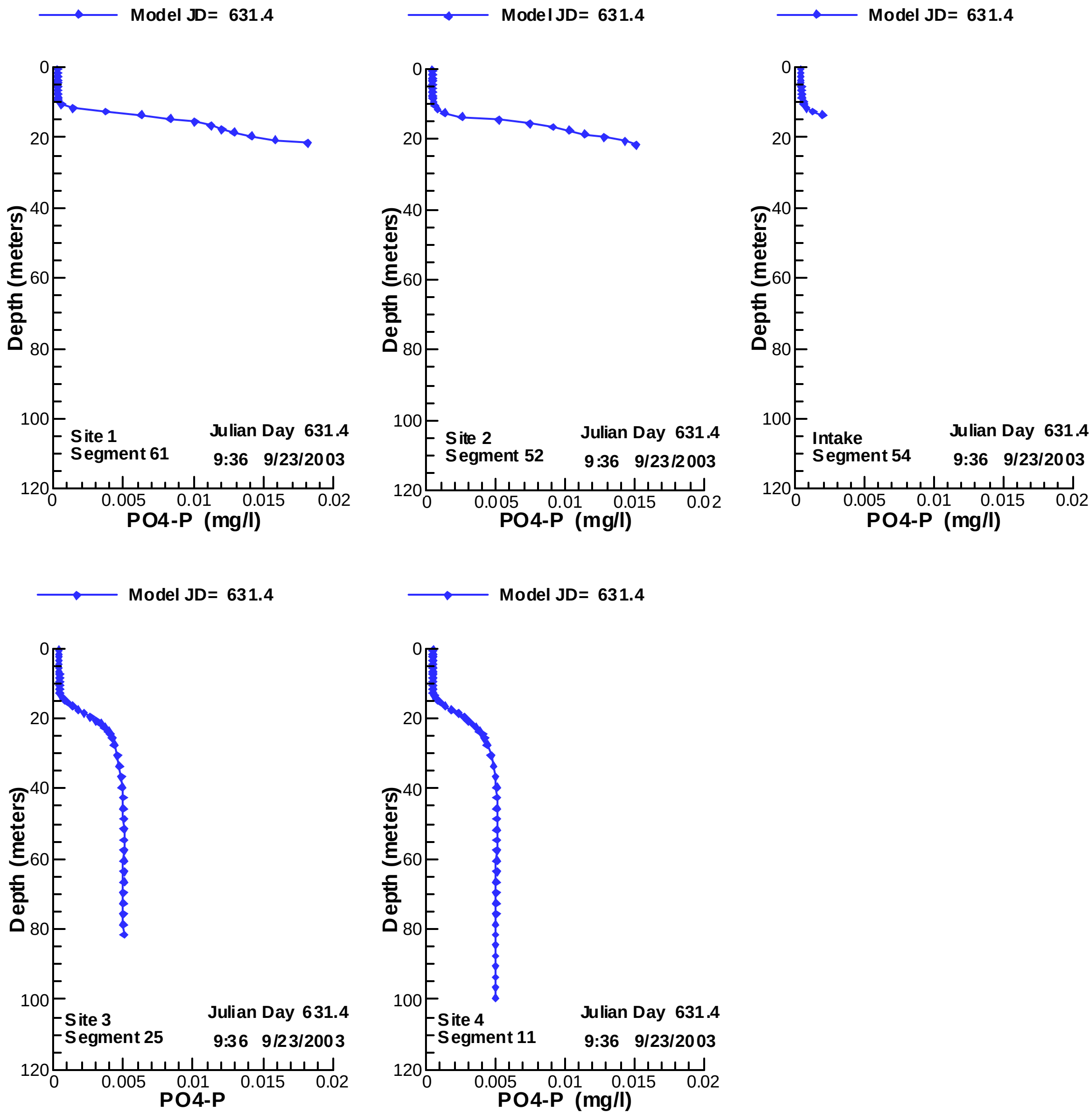

Figure 181. Vertical profiles of PO4-P compared with data for 9/23/2003.

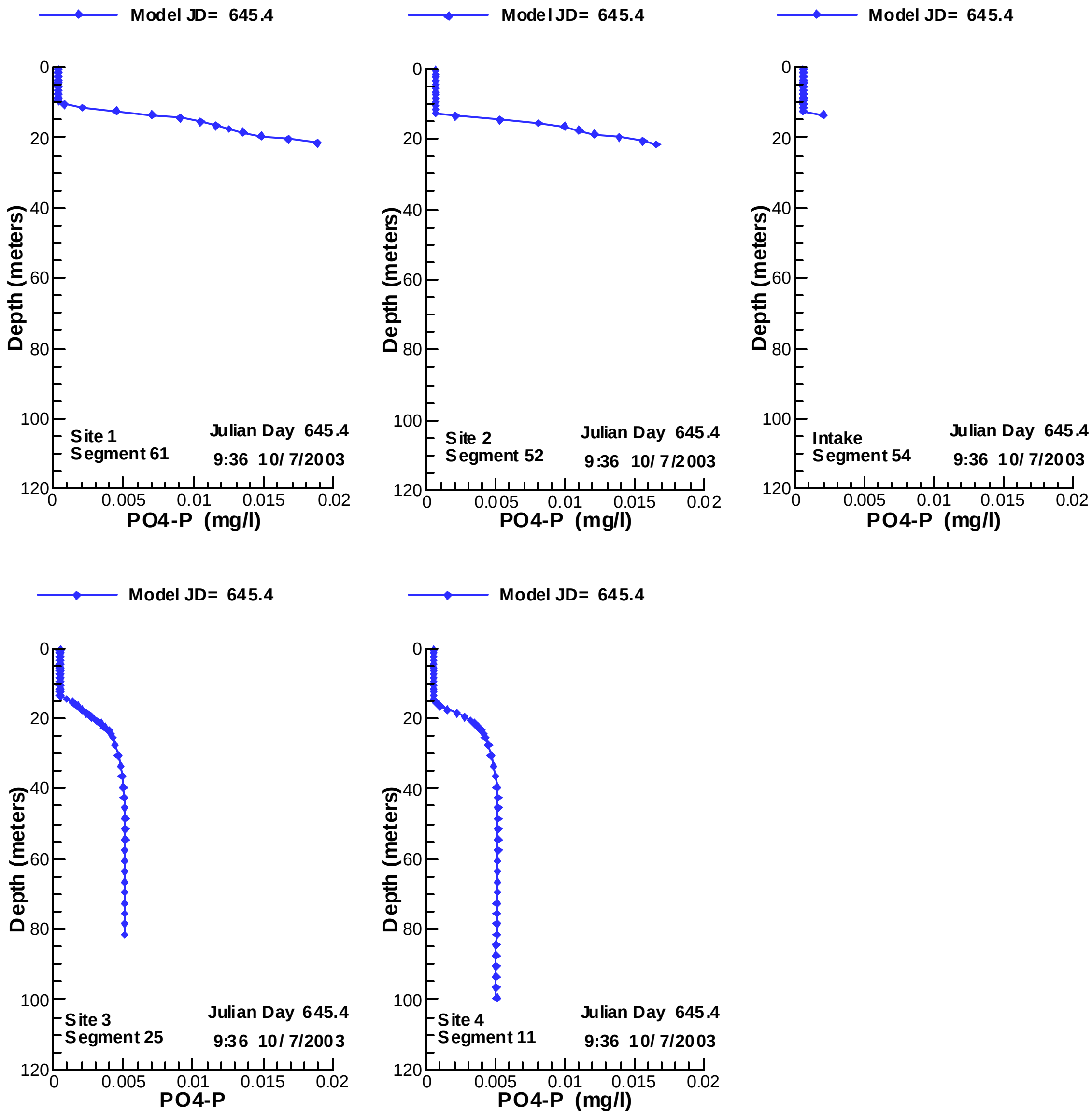

Figure 182. Vertical profiles of PO4-P compared with data for 10/ 7/2003.

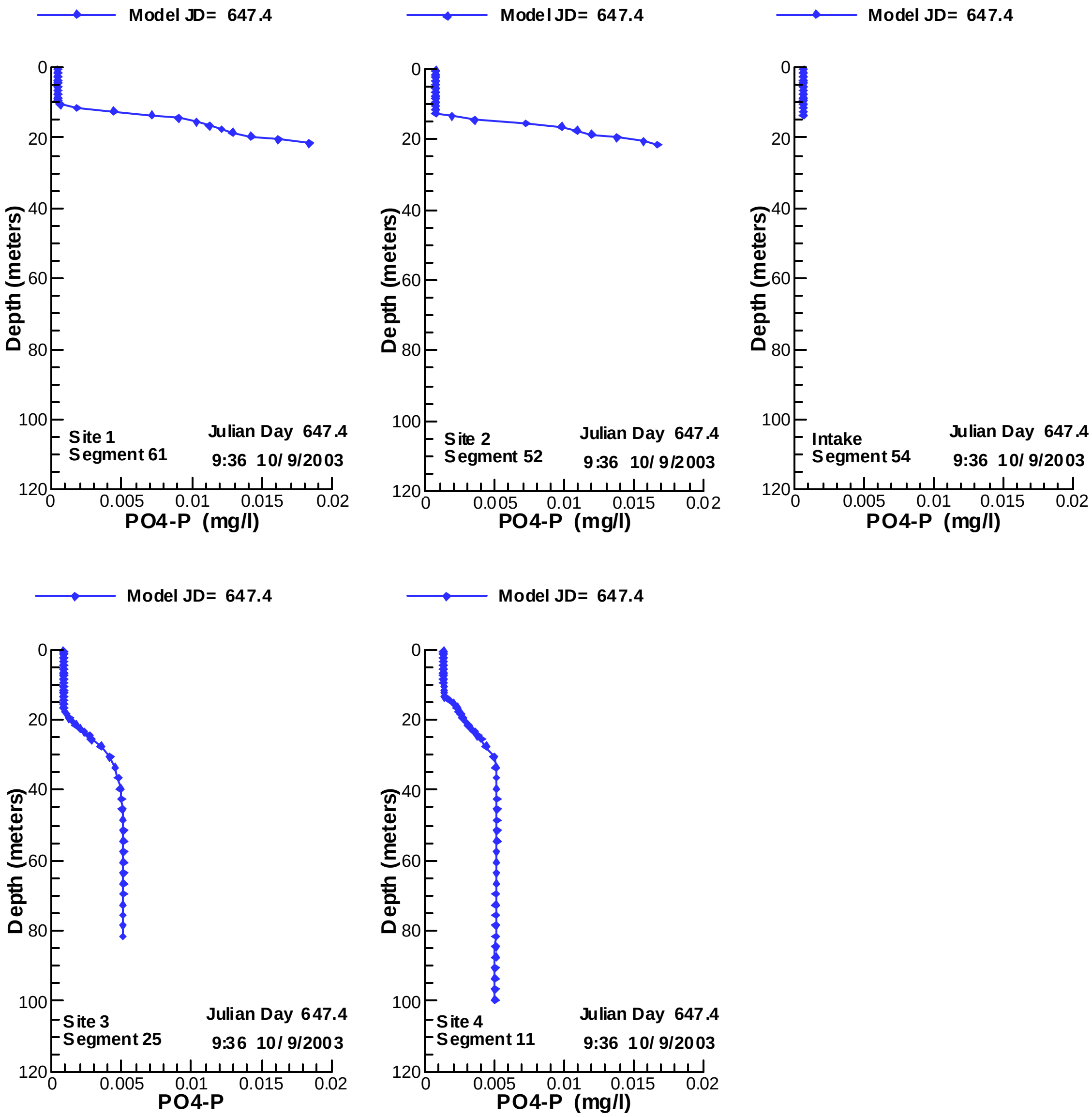

Figure 183. Vertical profiles of PO4-P compared with data for 10/ 9/2003.

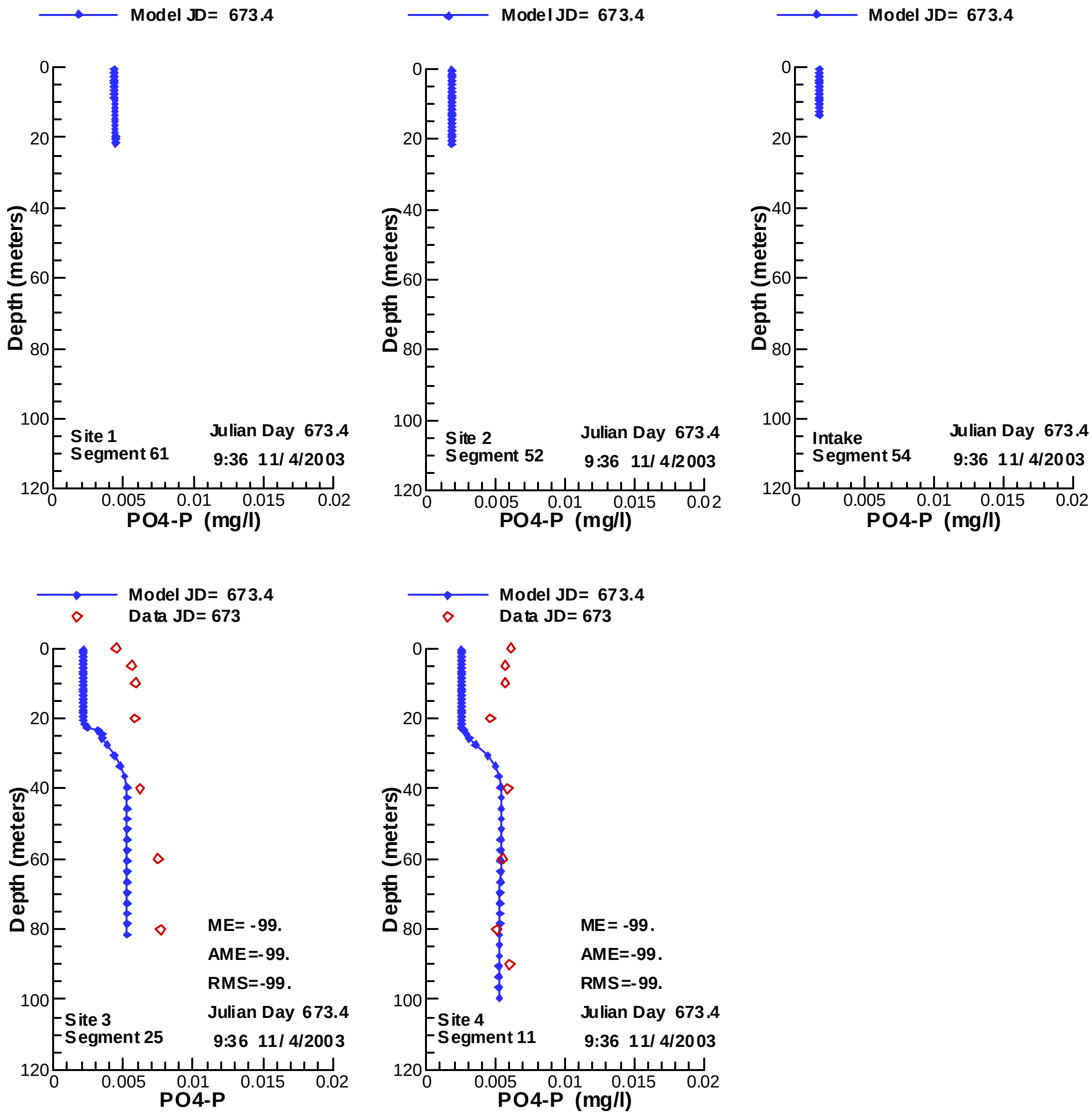

Figure 184. Vertical profiles of PO4-P compared with data for 11/ 4/2003.

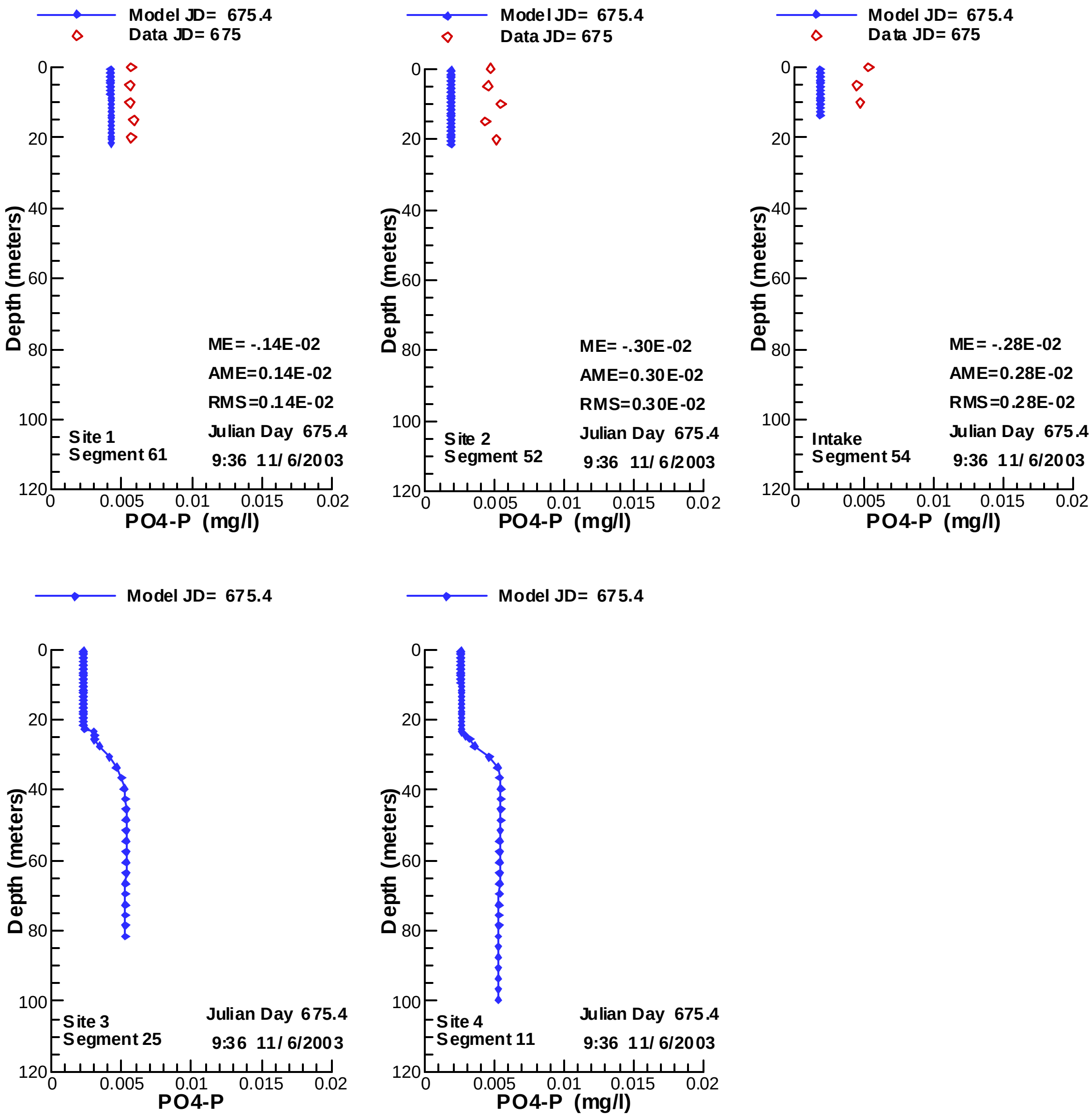

Figure 185. Vertical profiles of PO4-P compared with data for 11/ 6/2003.

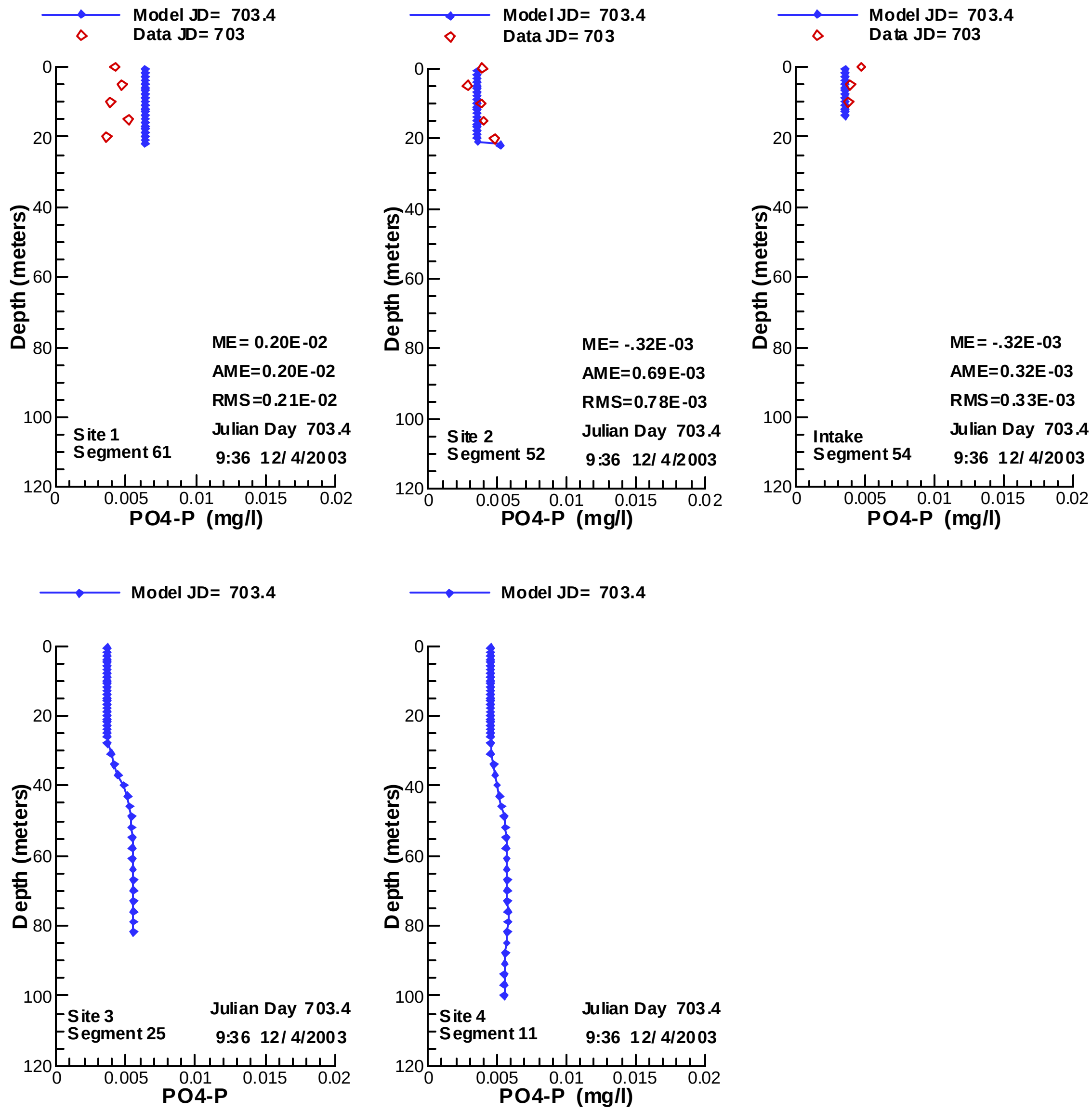

Figure 186. Vertical profiles of PO4-P compared with data for 12/ 4/2003.

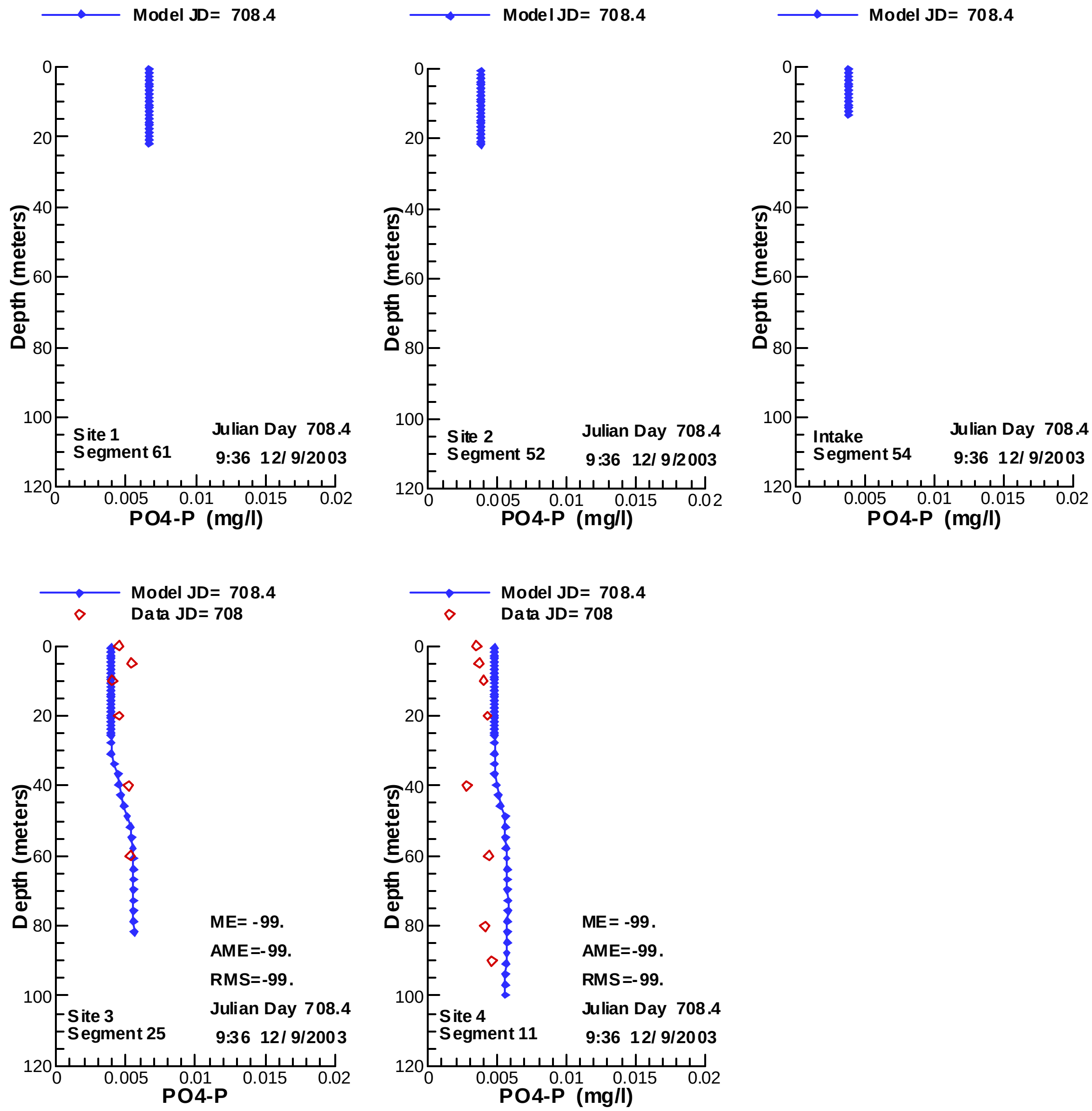

Figure 187. Vertical profiles of PO4-P compared with data for 12/ 9/2003.

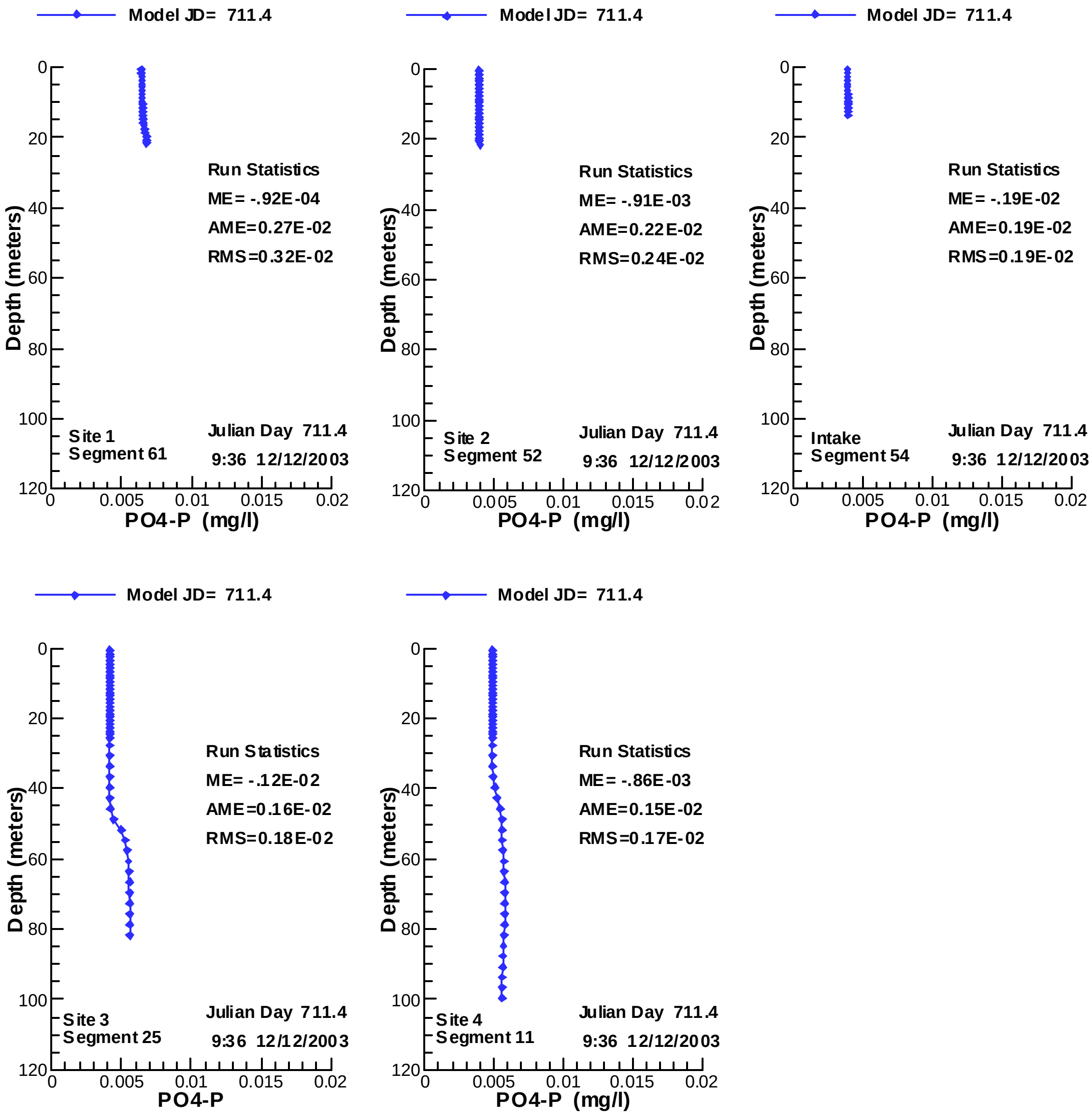

Figure 188. Vertical profiles of PO4-P compared with data for 12/12/2003.

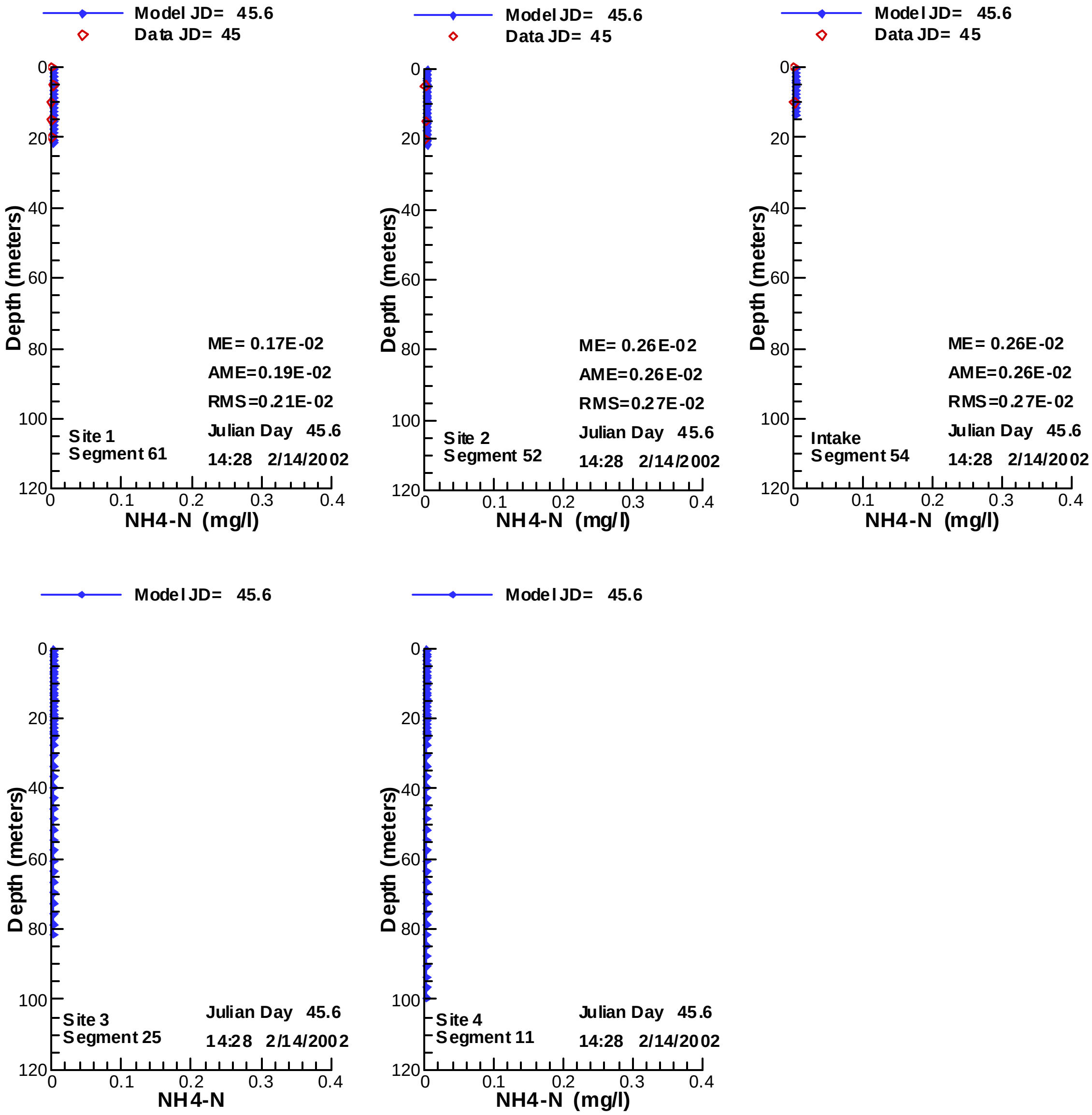

Figure 189. Vertical profiles of NH4-N compared with data for 2/14/2002.

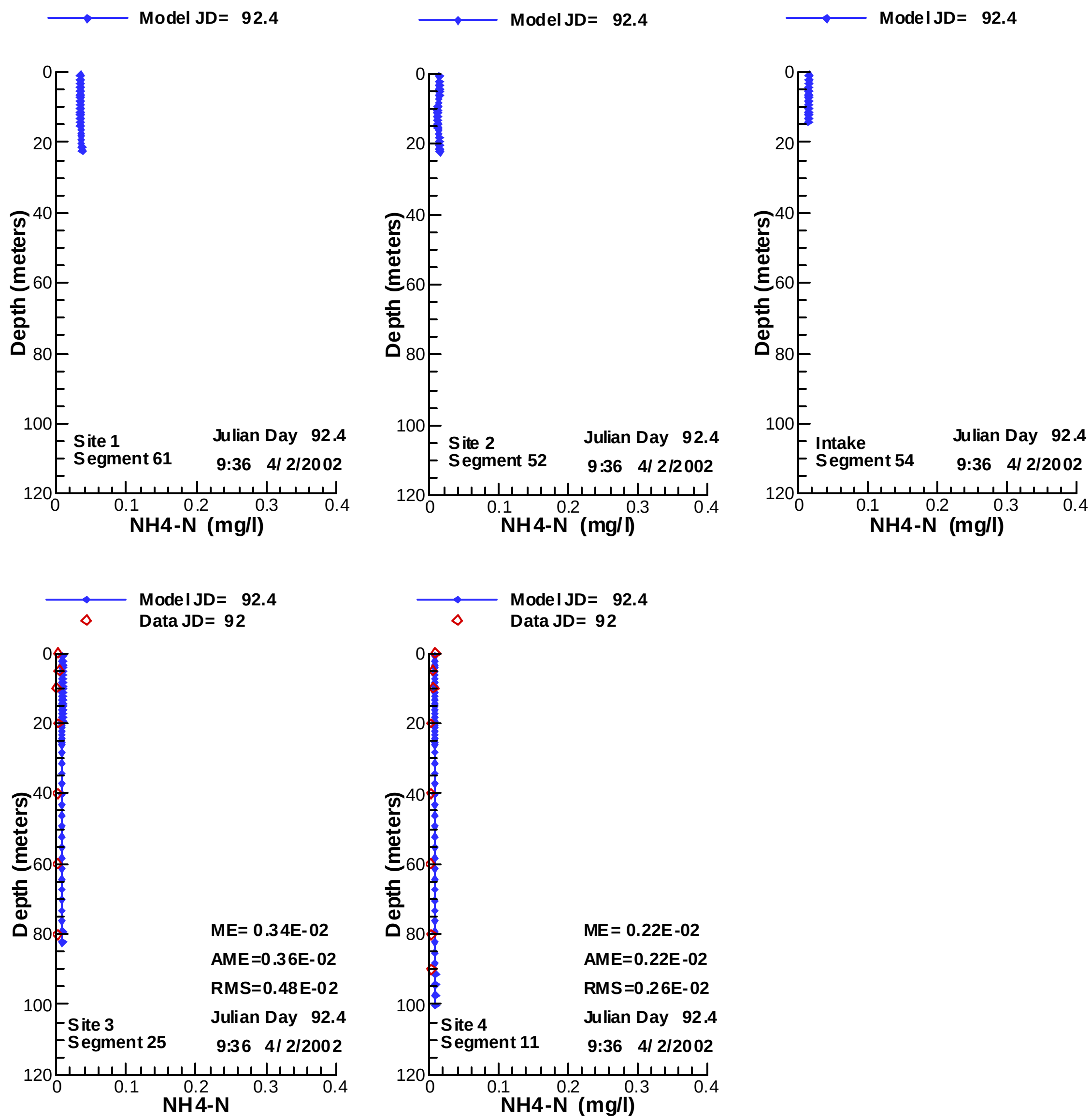

Figure 190. Vertical profiles of NH4-N compared with data for 4/ 2/2002.

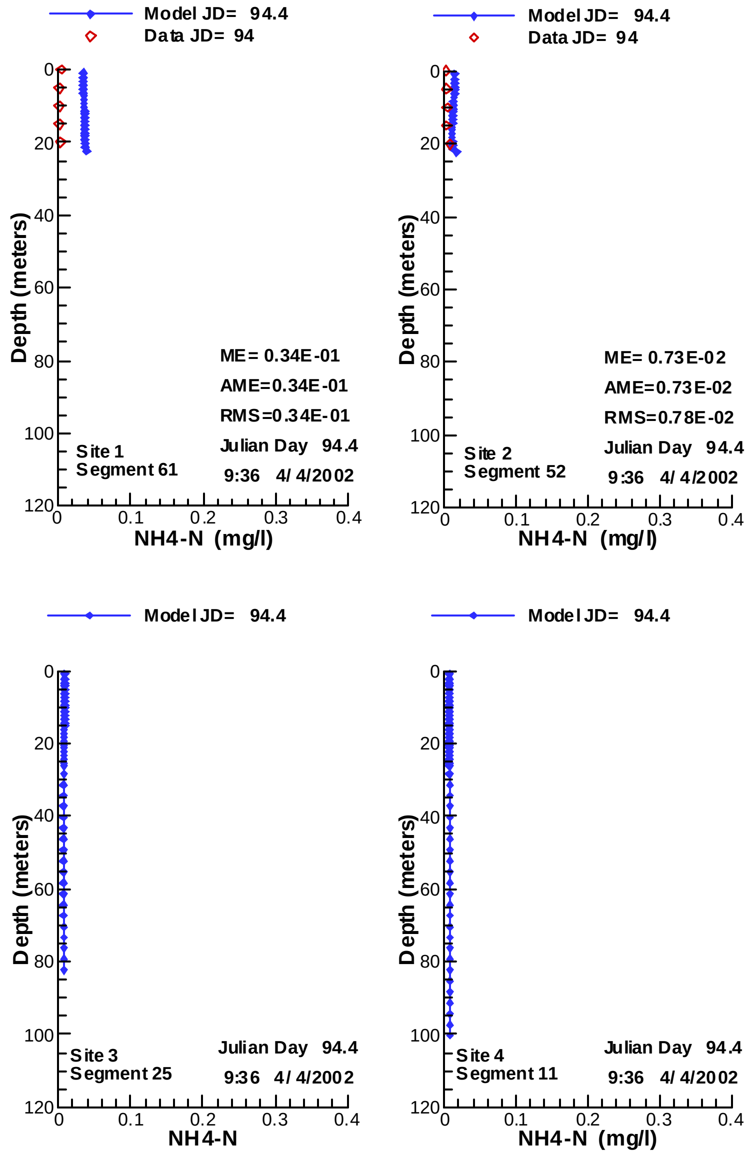

Figure 191. Vertical profiles of NH4-N compared with data for 4/ 4/2002.

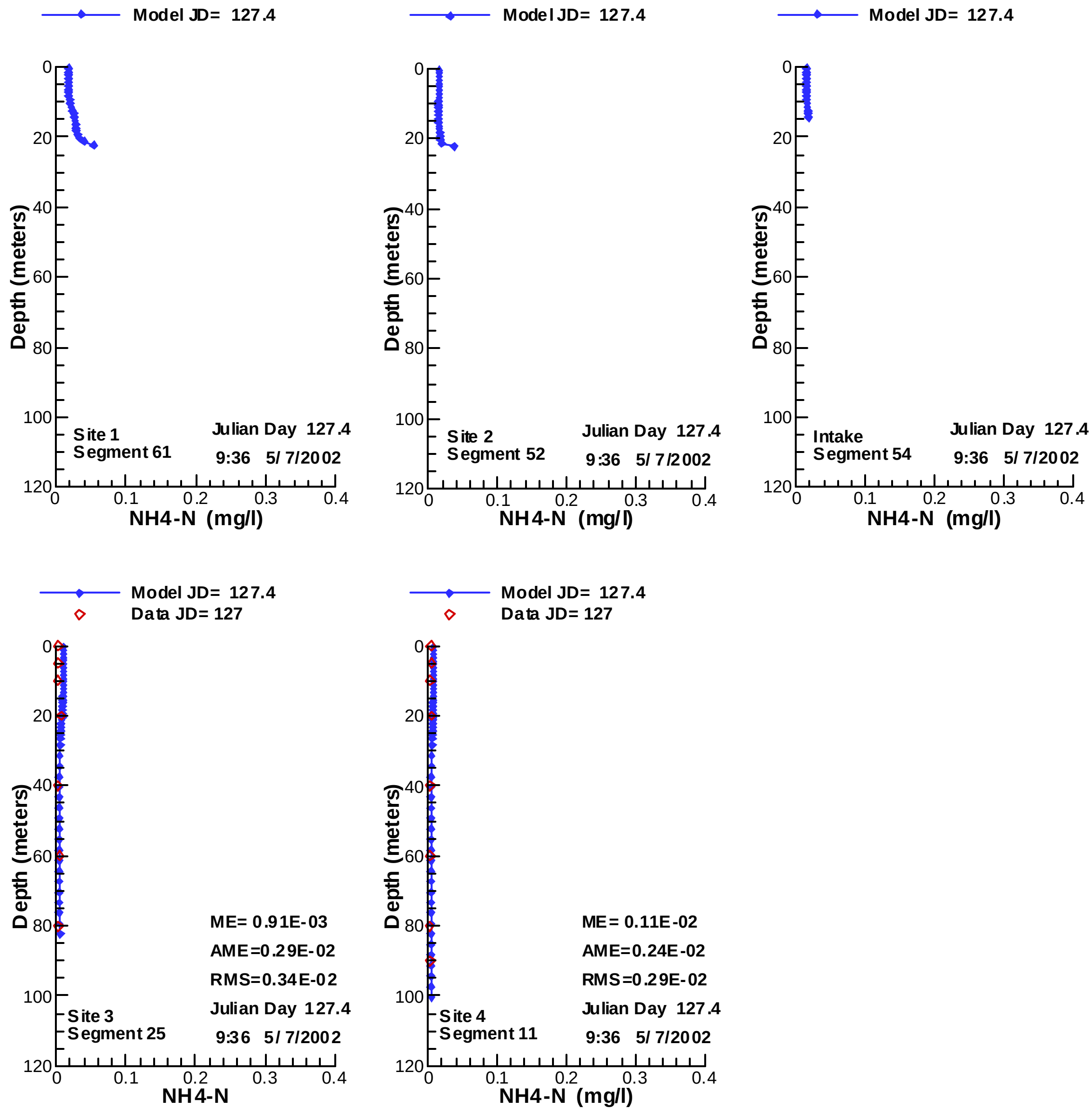

Figure 192. Vertical profiles of NH4-N compared with data for 5/ 7/2002.

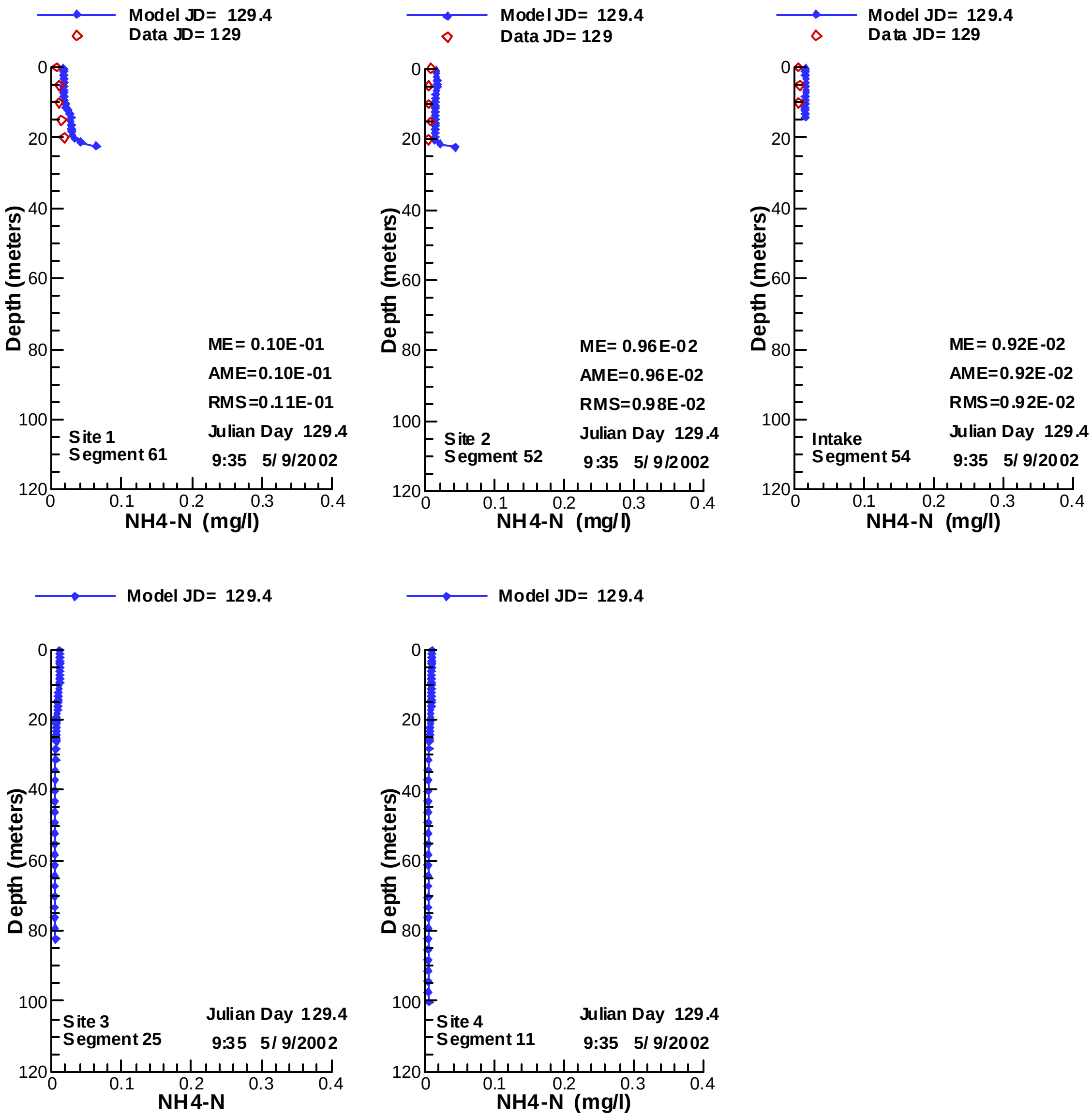

Figure 193. Vertical profiles of NH4-N compared with data for 5/ 9/2002.

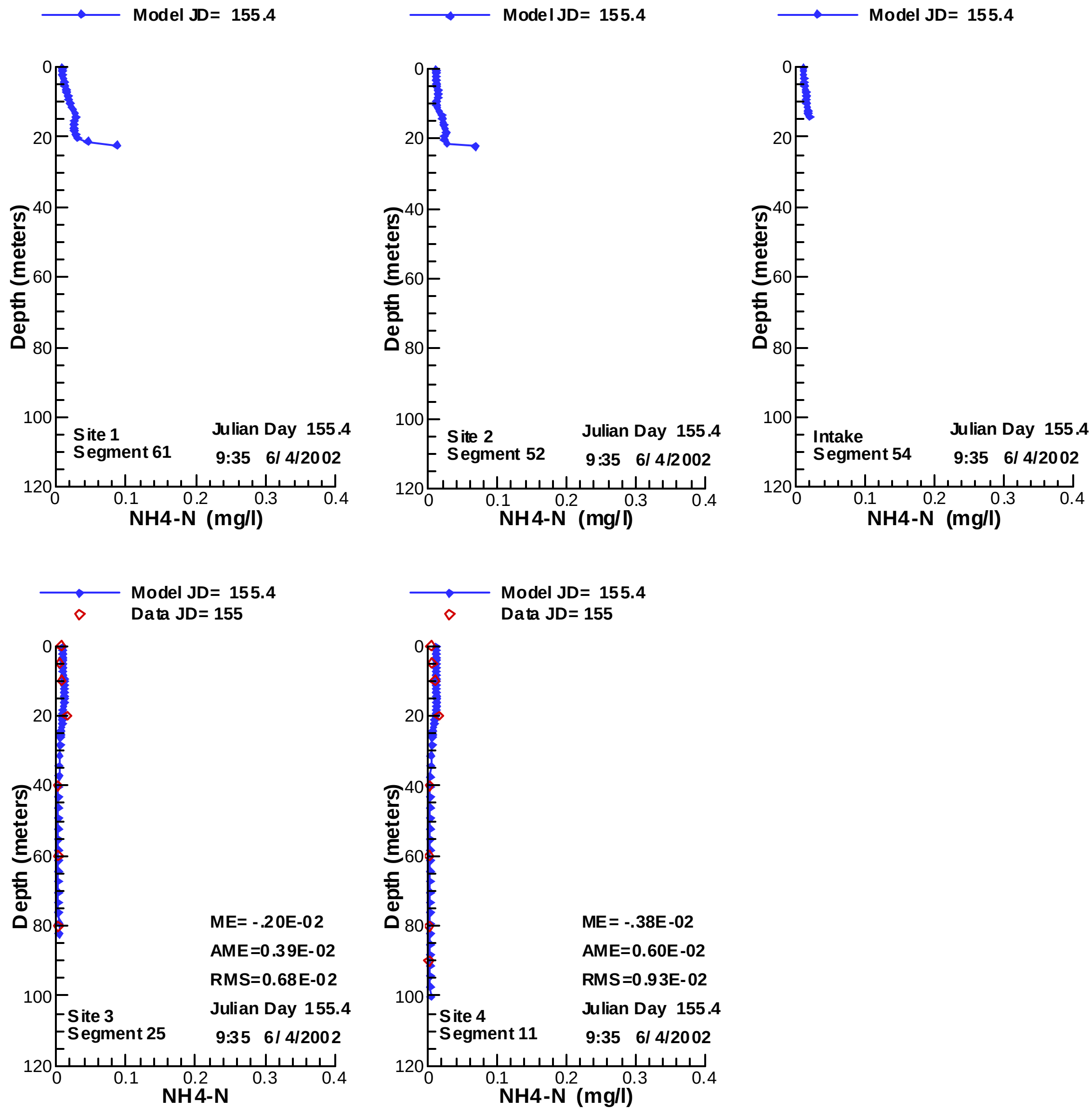

Figure 194. Vertical profiles of NH4-N compared with data for 6/ 4/2002.

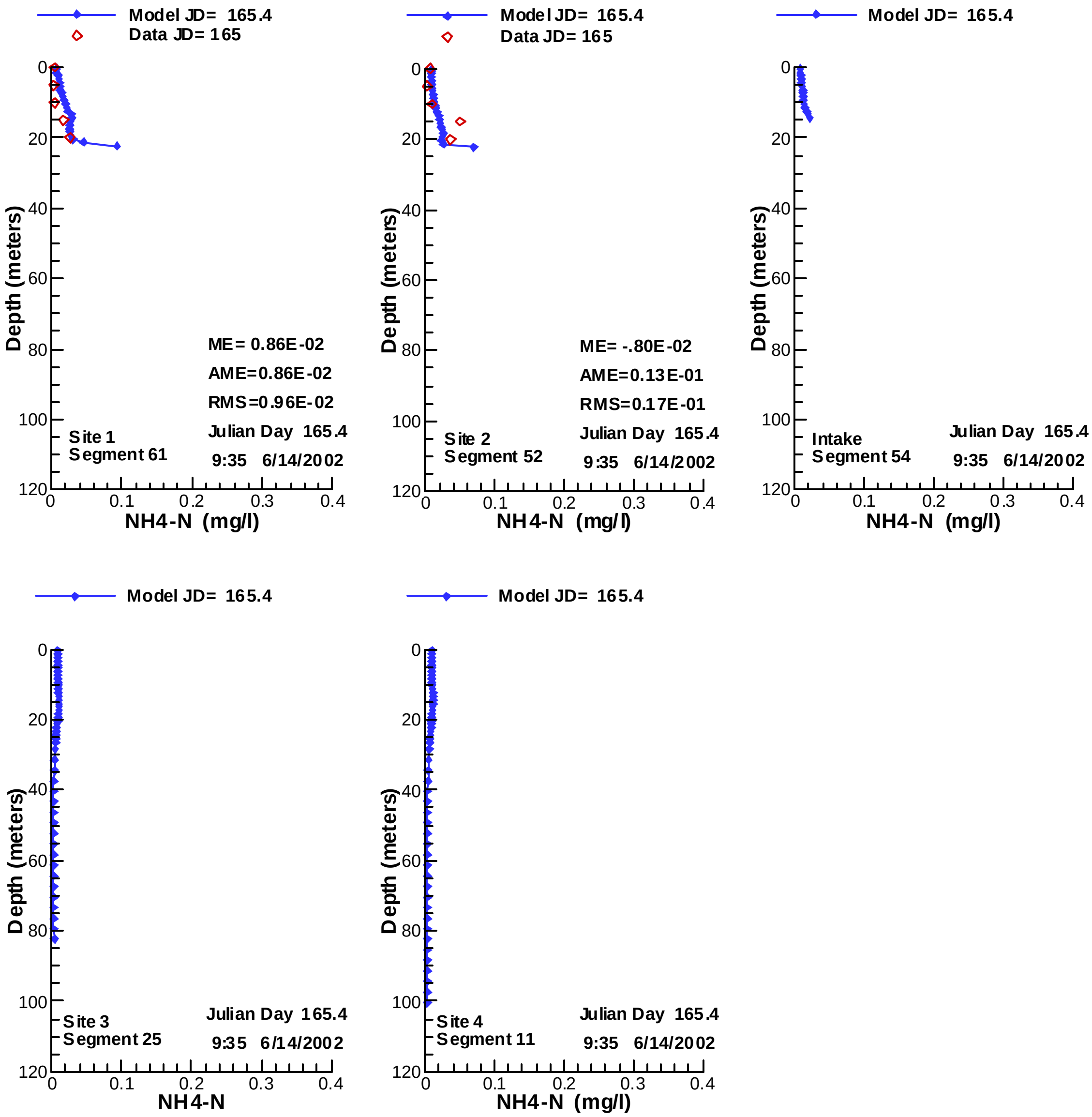

Figure 195. Vertical profiles of NH4-N compared with data for 6/14/2002.

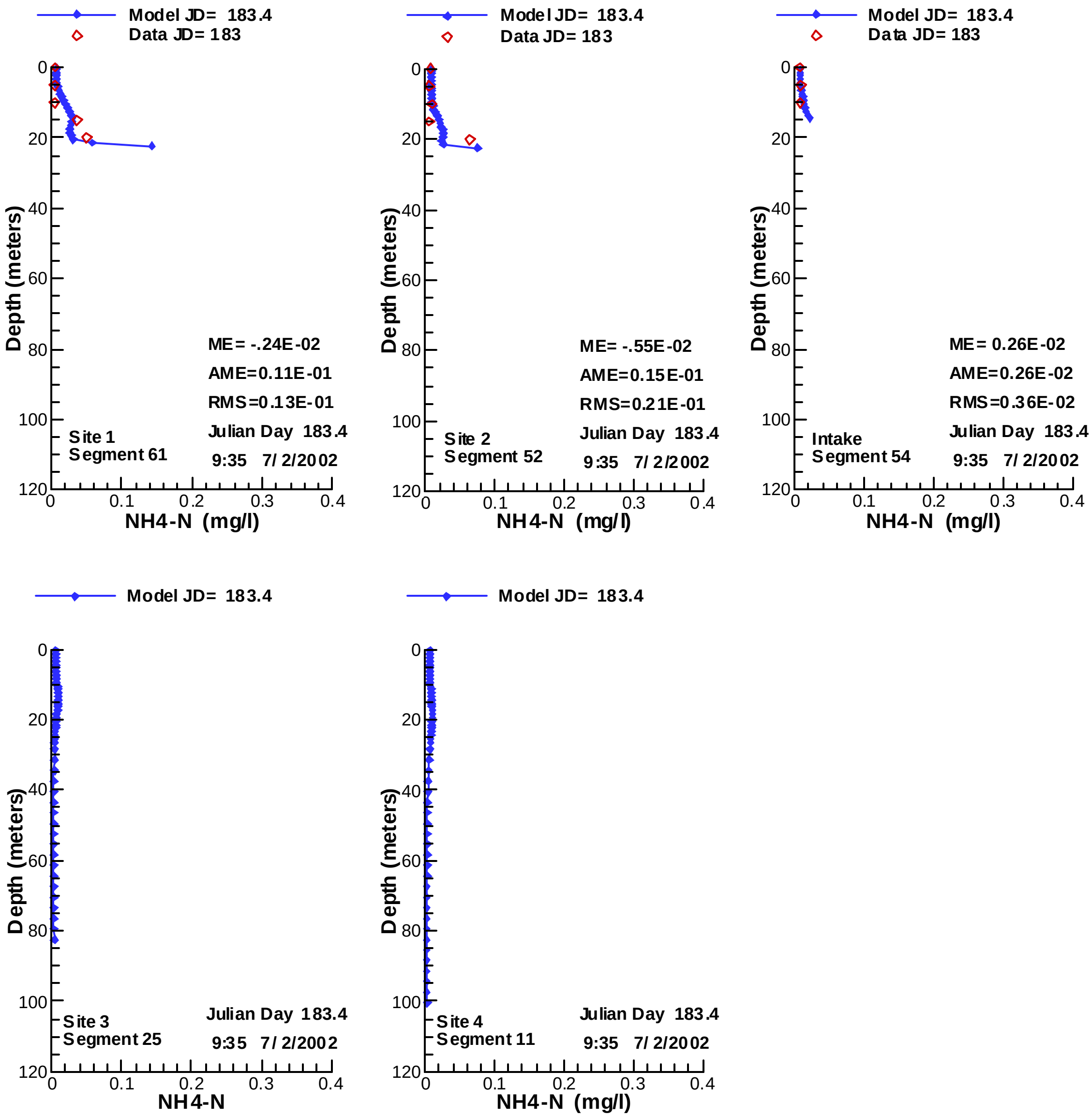

Figure 196. Vertical profiles of NH4-N compared with data for 7/ 2/2002.

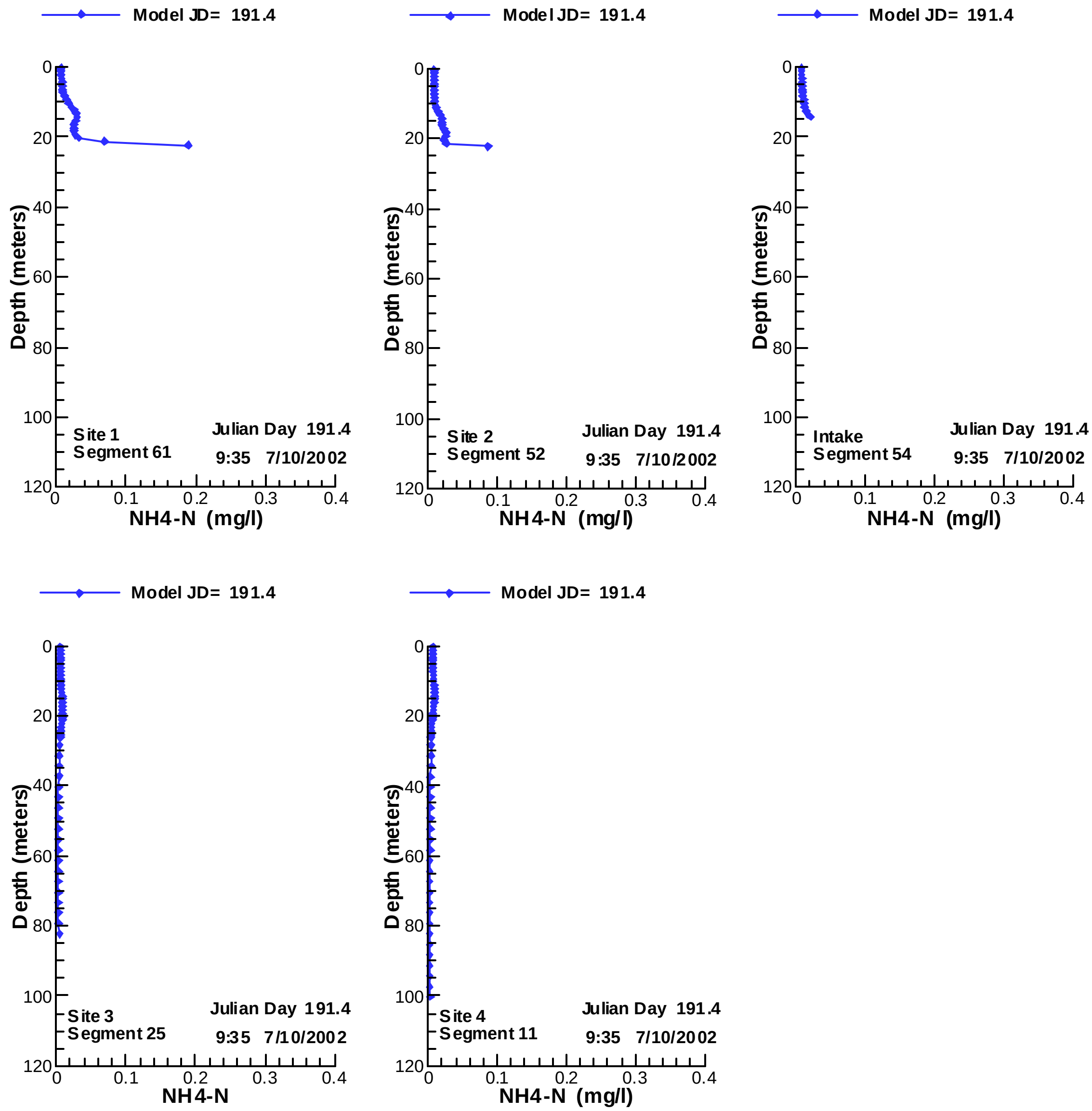

Figure 197. Vertical profiles of NH4-N compared with data for 7/10/2002.

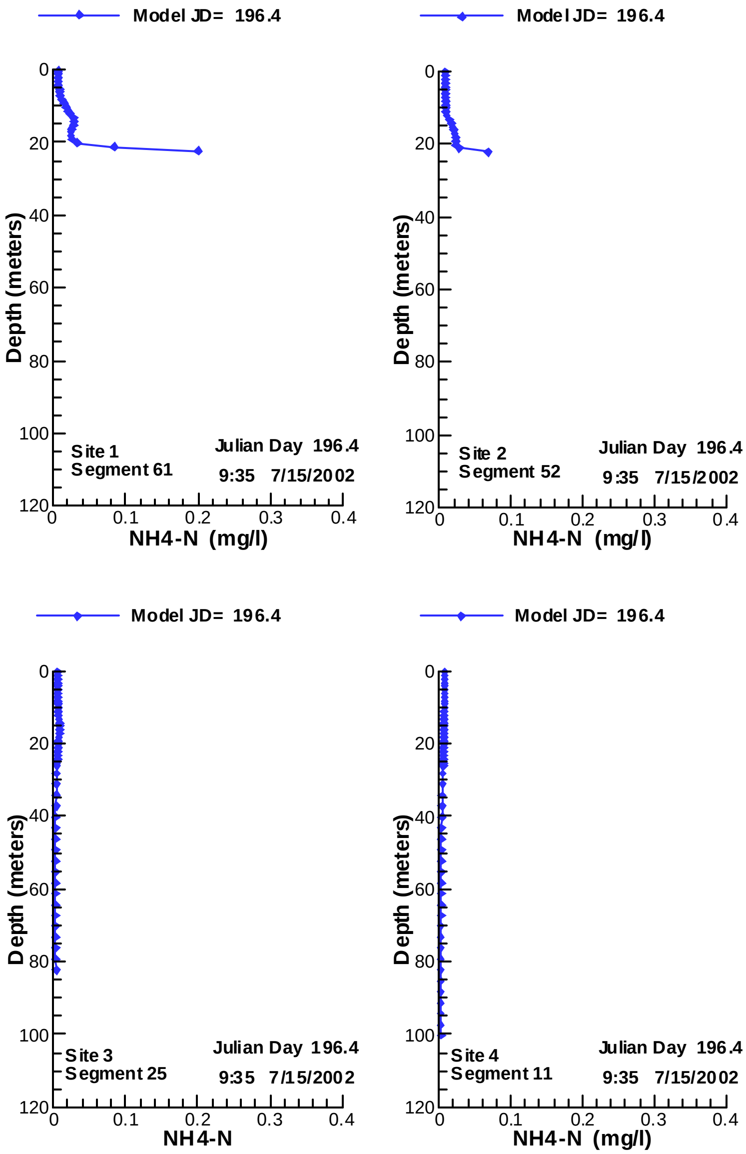

Figure 198. Vertical profiles of NH4-N compared with data for 7/15/2002.

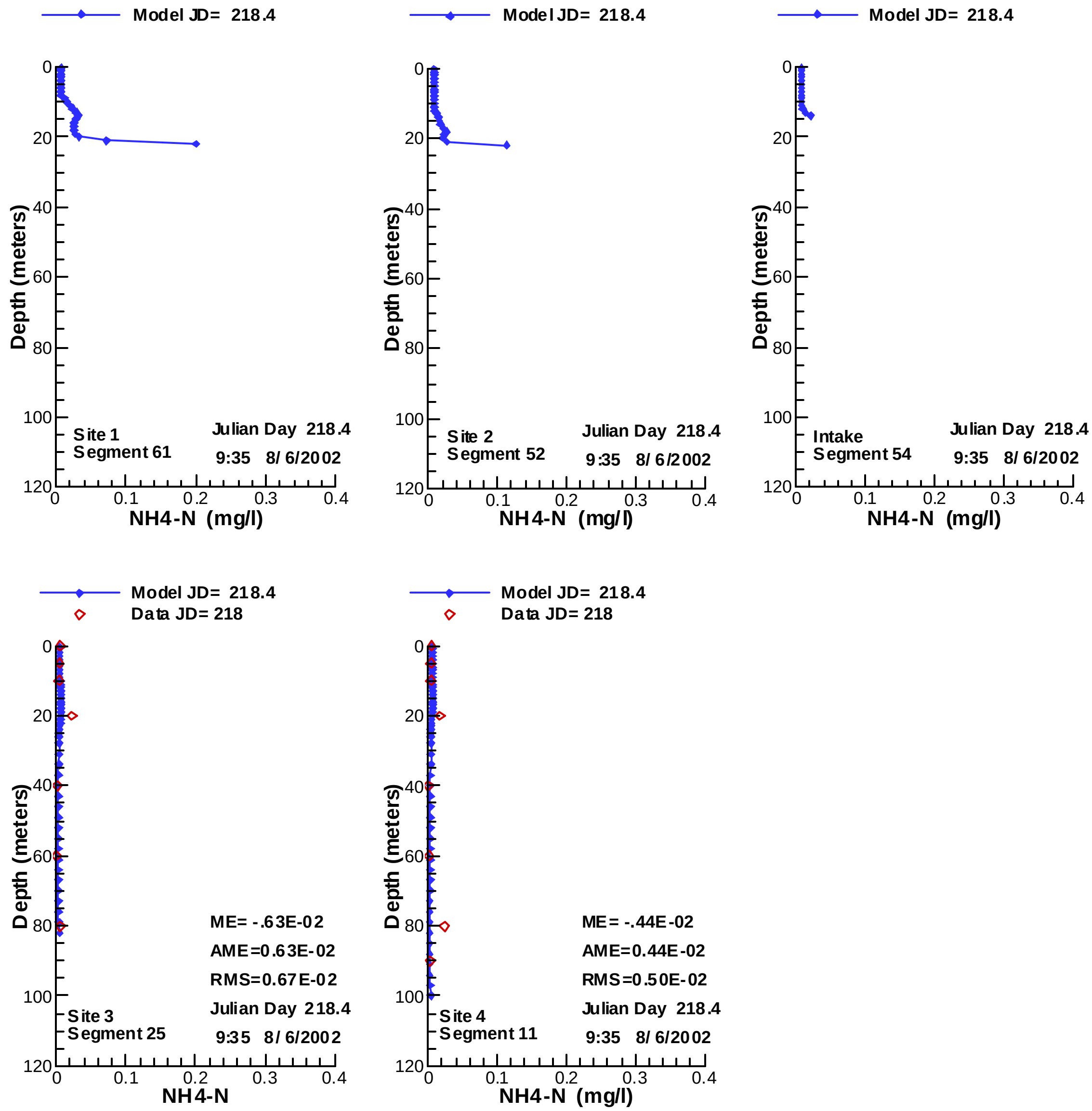

Figure 199. Vertical profiles of NH4-N compared with data for 8/ 6/2002.

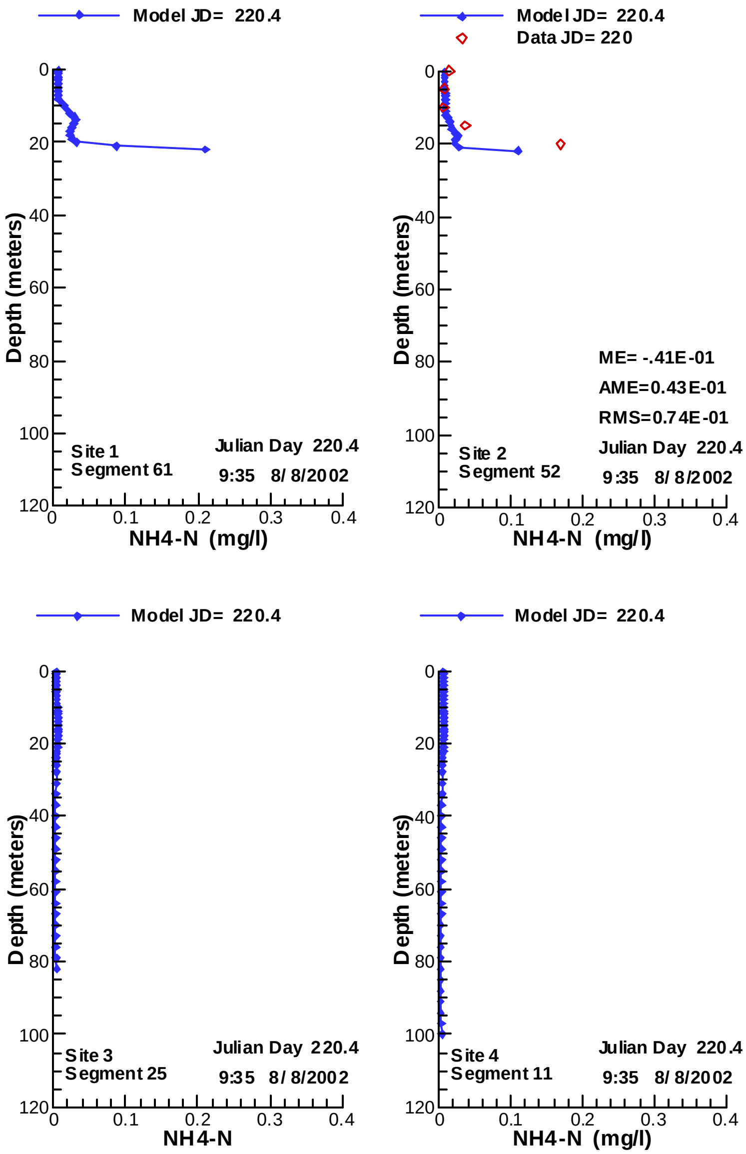

Figure 200. Vertical profiles of NH4-N compared with data for 8/ 8/2002.

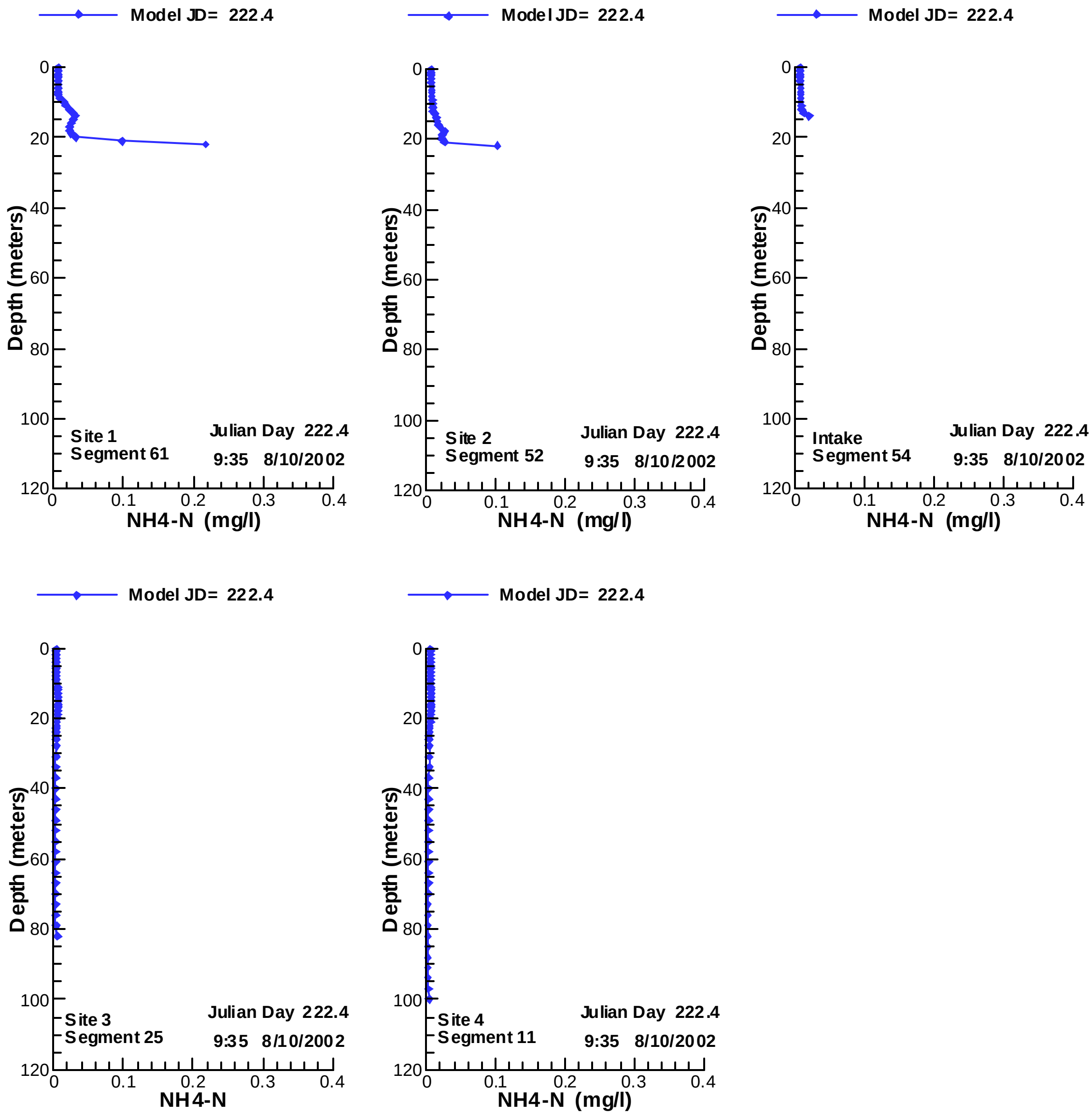

Figure 201. Vertical profiles of NH4-N compared with data for 8/10/2002.

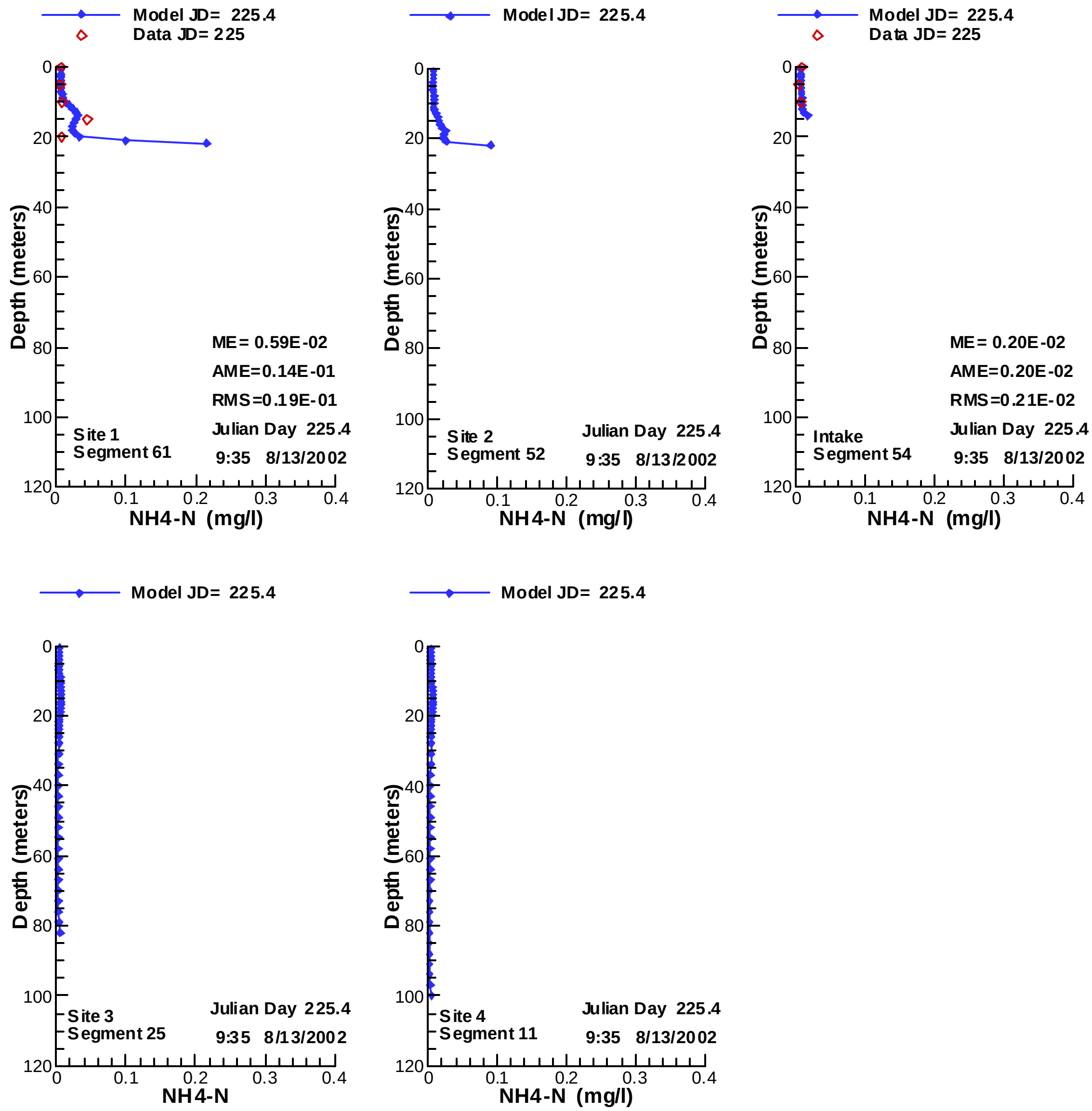

Figure 202. Vertical profiles of NH4-N compared with data for 8/13/2002.

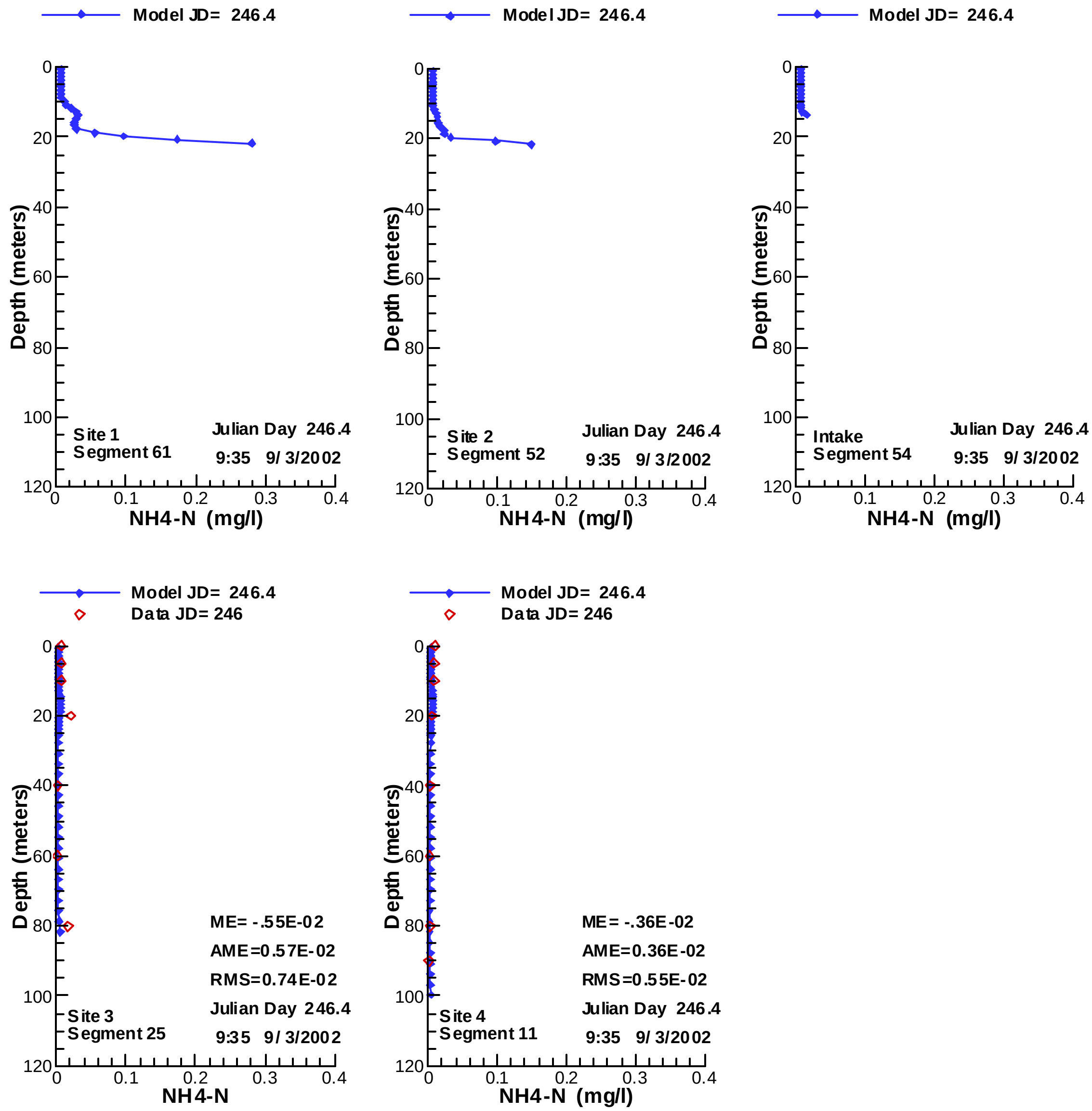

Figure 203. Vertical profiles of NH4-N compared with data for 9/ 3/2002.

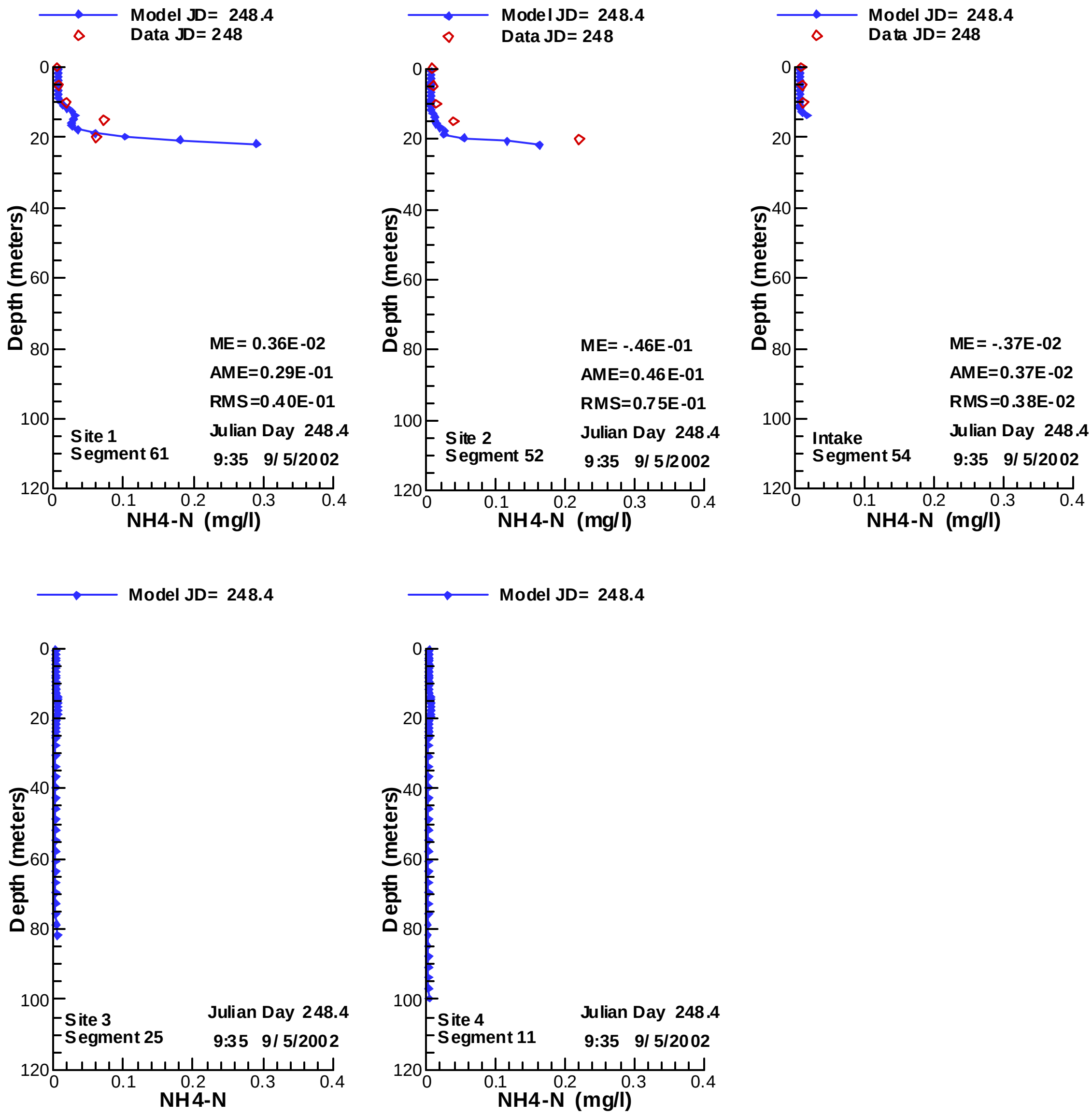

Figure 204. Vertical profiles of NH4-N compared with data for 9/ 5/2002.

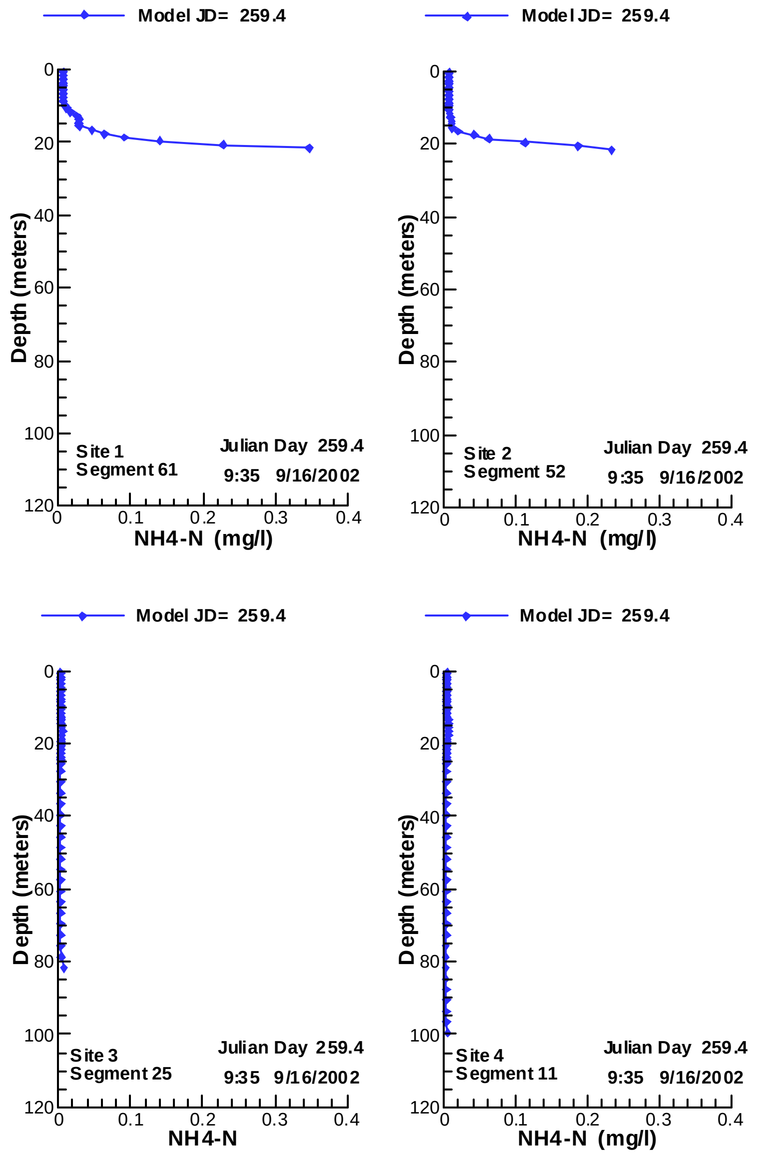

Figure 205. Vertical profiles of NH4-N compared with data for 9/16/2002.

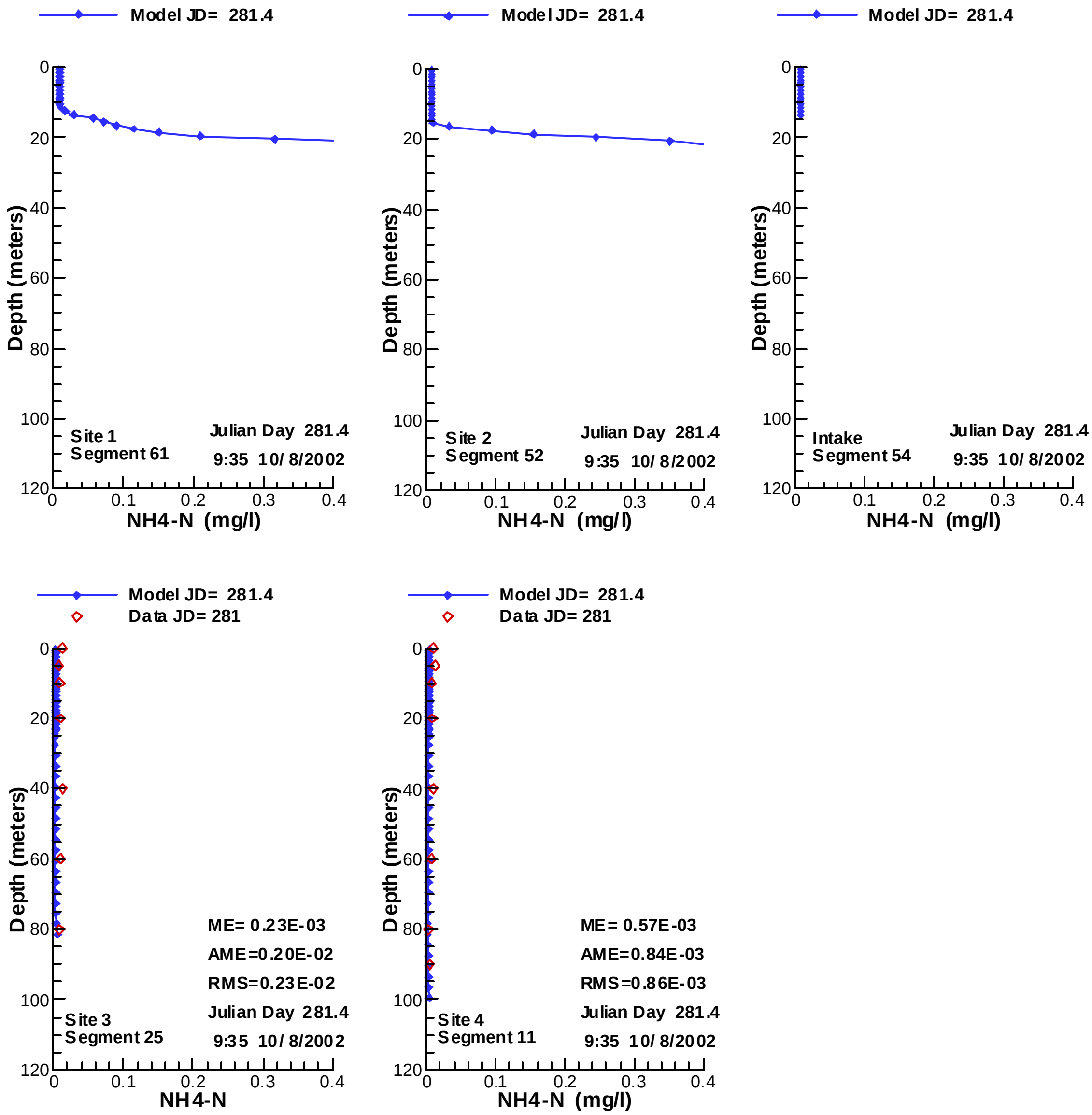

Figure 206. Vertical profiles of NH4-N compared with data for 10/ 8/2002.

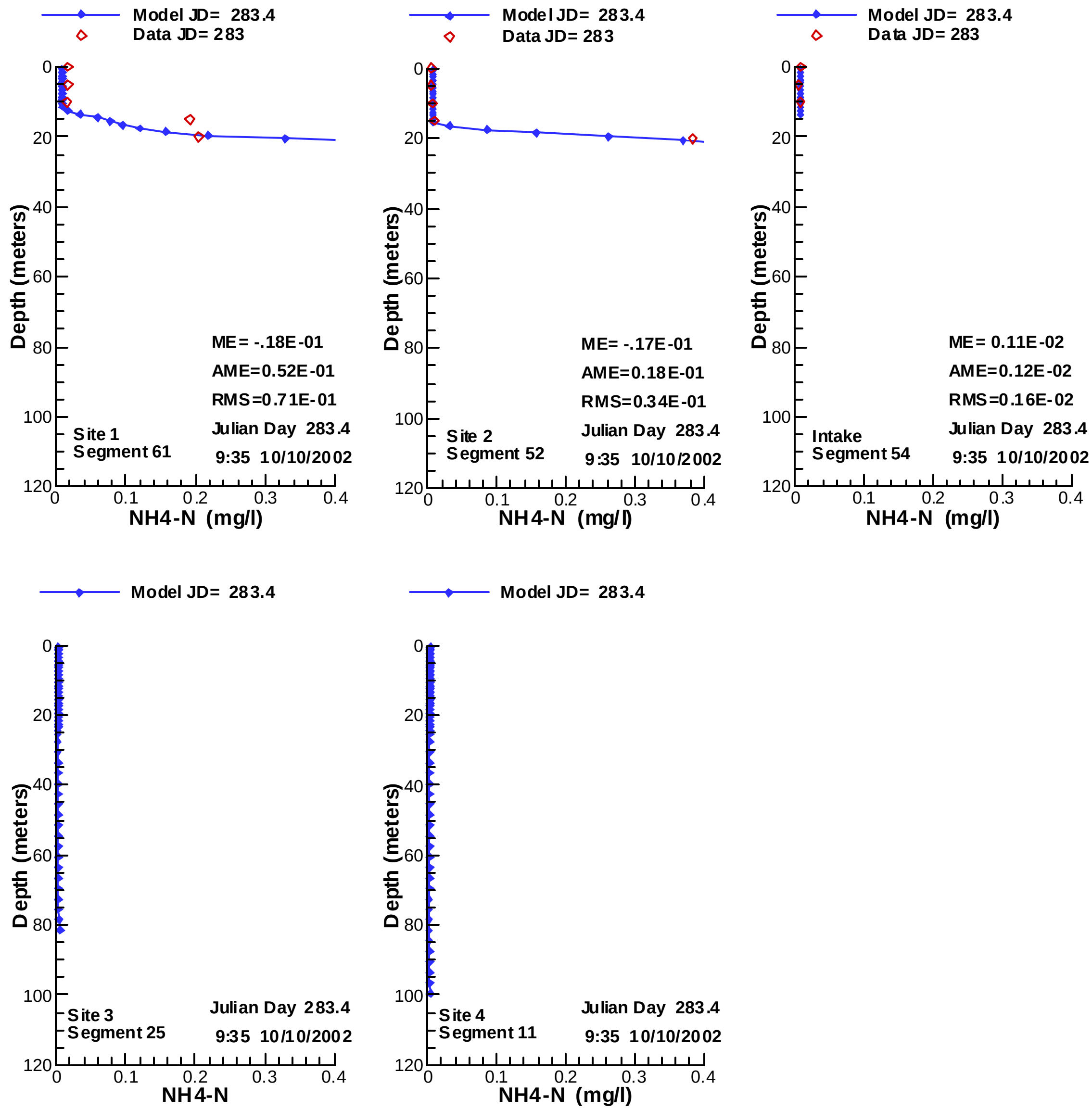

Figure 207. Vertical profiles of NH4-N compared with data for 10/10/2002.

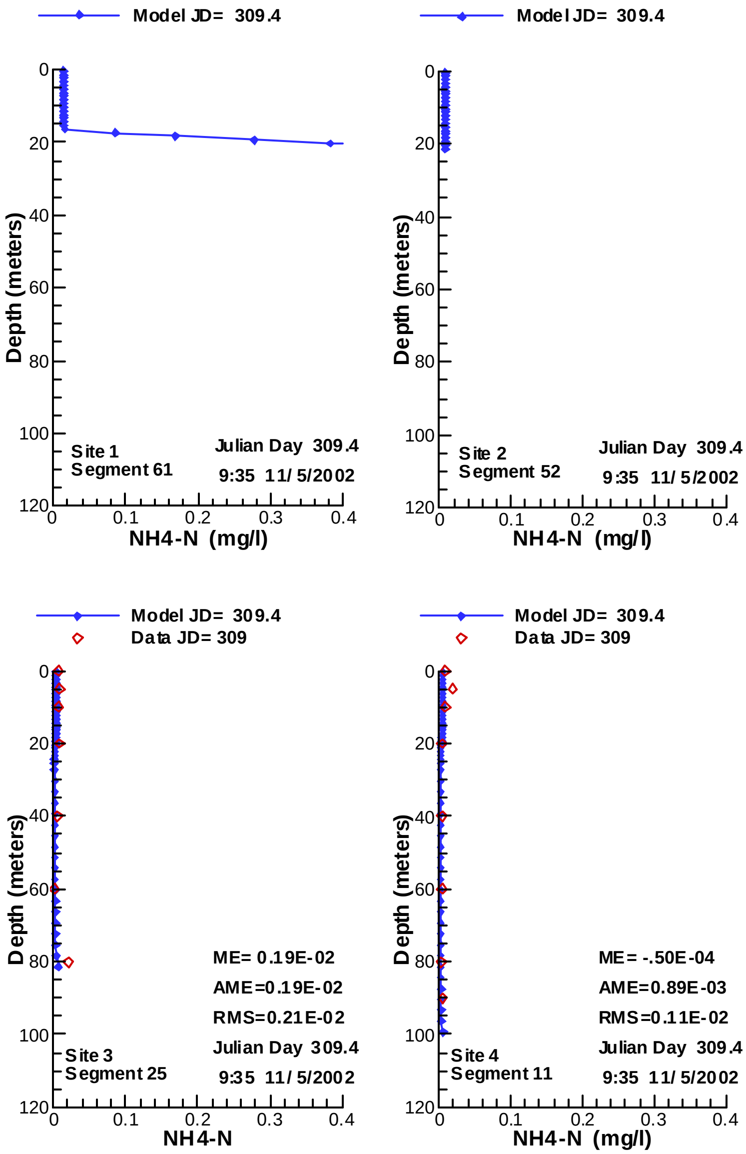

Figure 208. Vertical profiles of NH4-N compared with data for 11/ 5/2002.

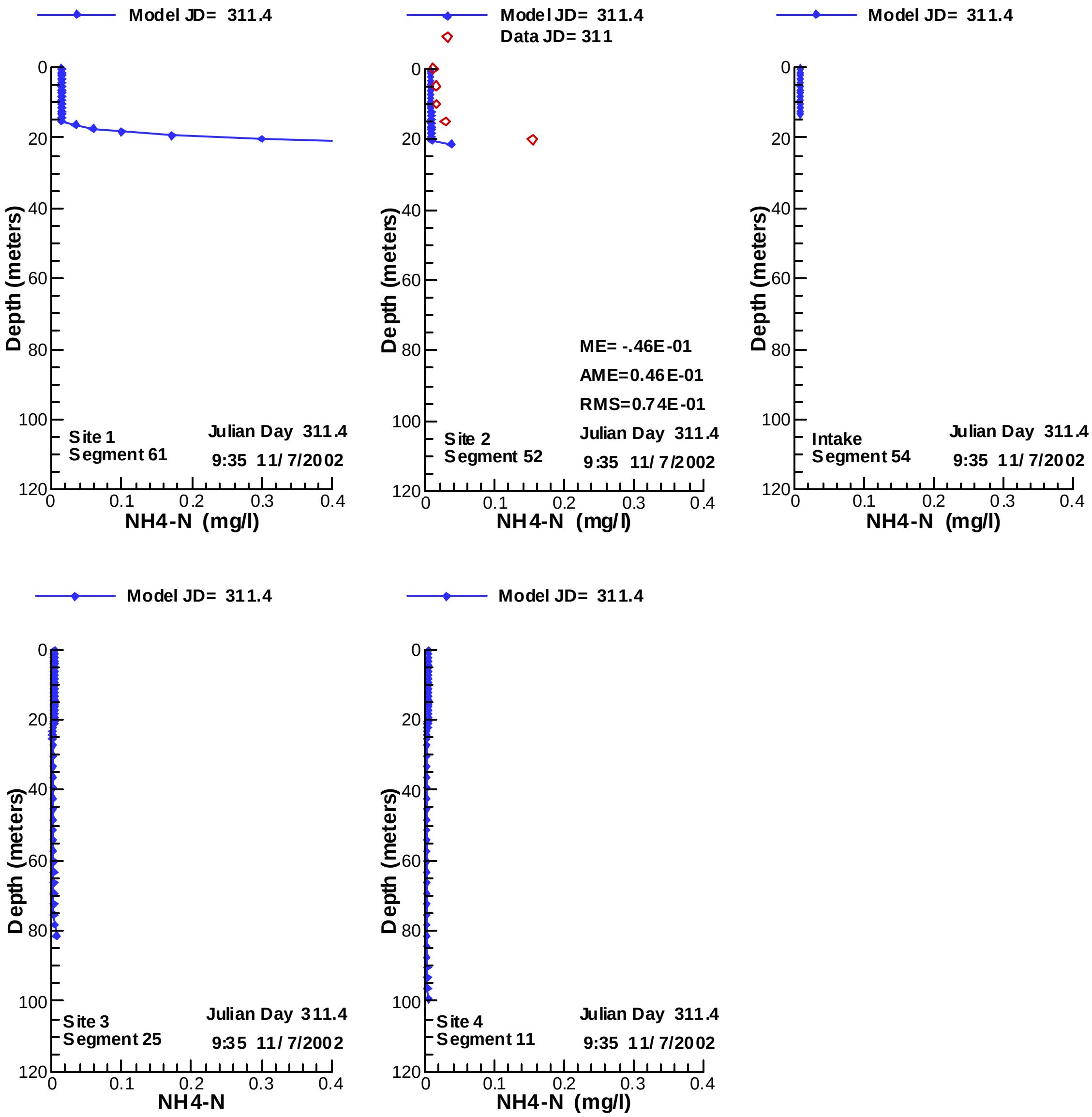

Figure 209. Vertical profiles of NH4-N compared with data for 11/ 7/2002.

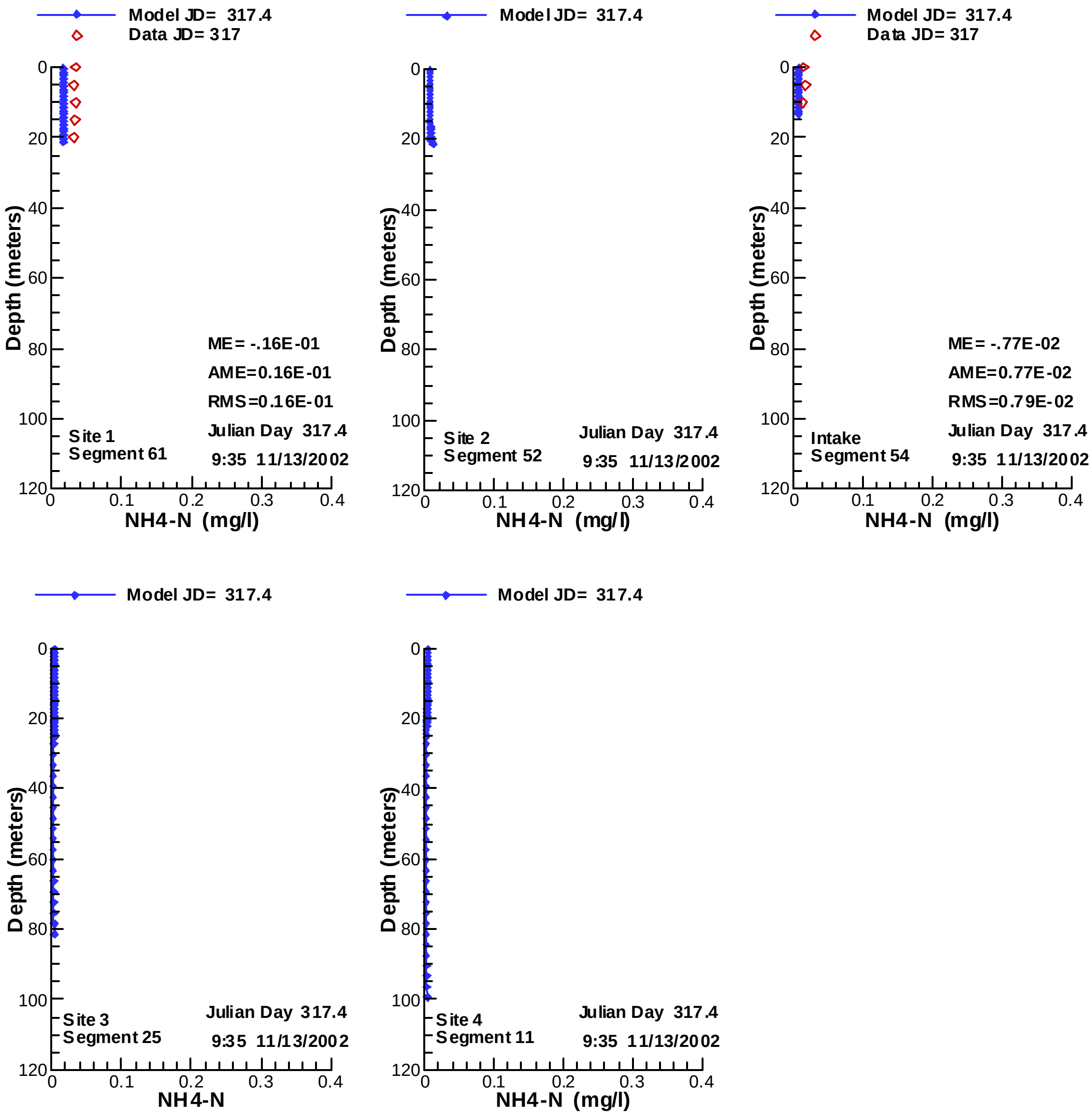

Figure 210. Vertical profiles of NH4-N compared with data for 11/13/2002.

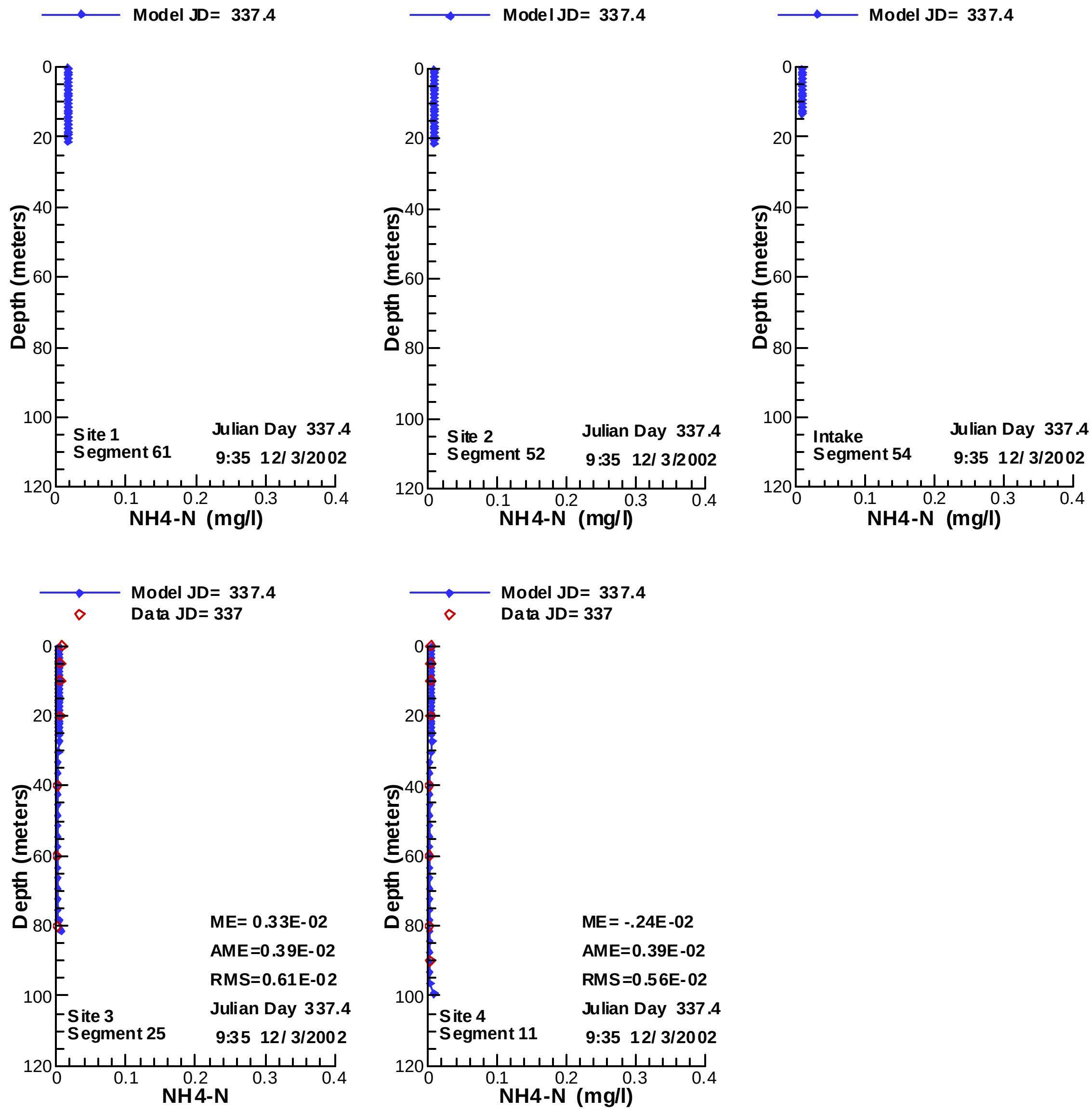

Figure 211. Vertical profiles of NH4-N compared with data for 12/ 3/2002.

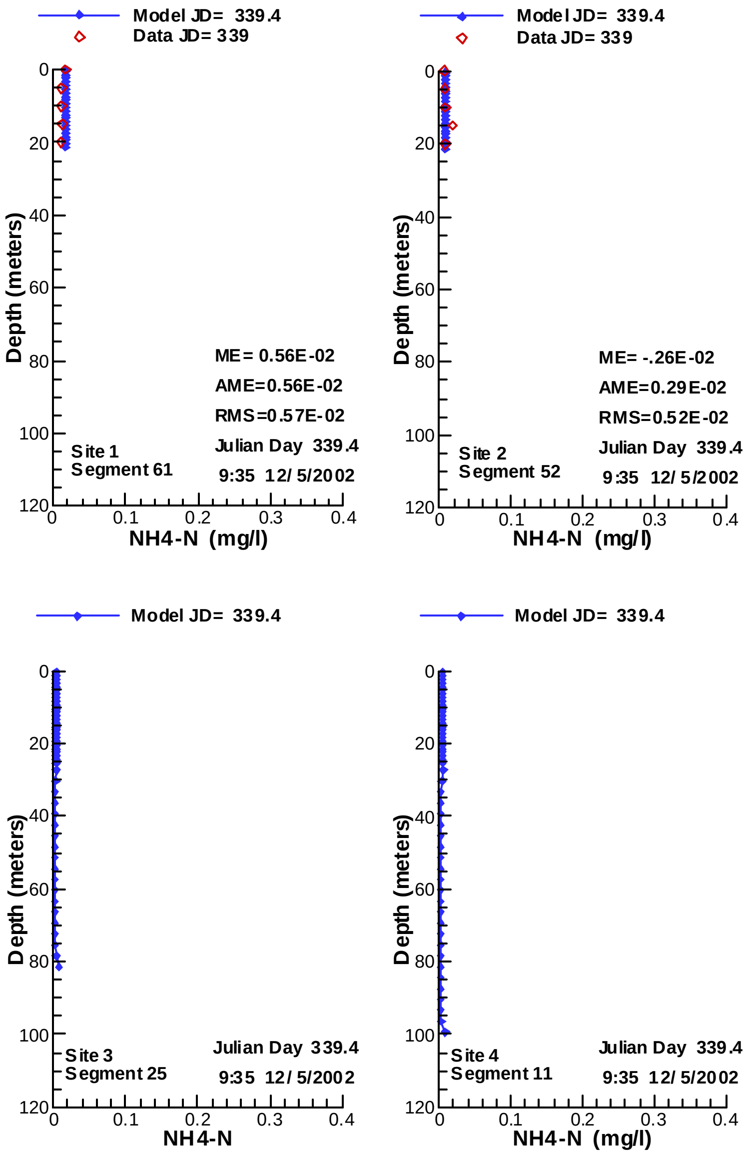

Figure 212. Vertical profiles of NH4-N compared with data for 12/ 5/2002.

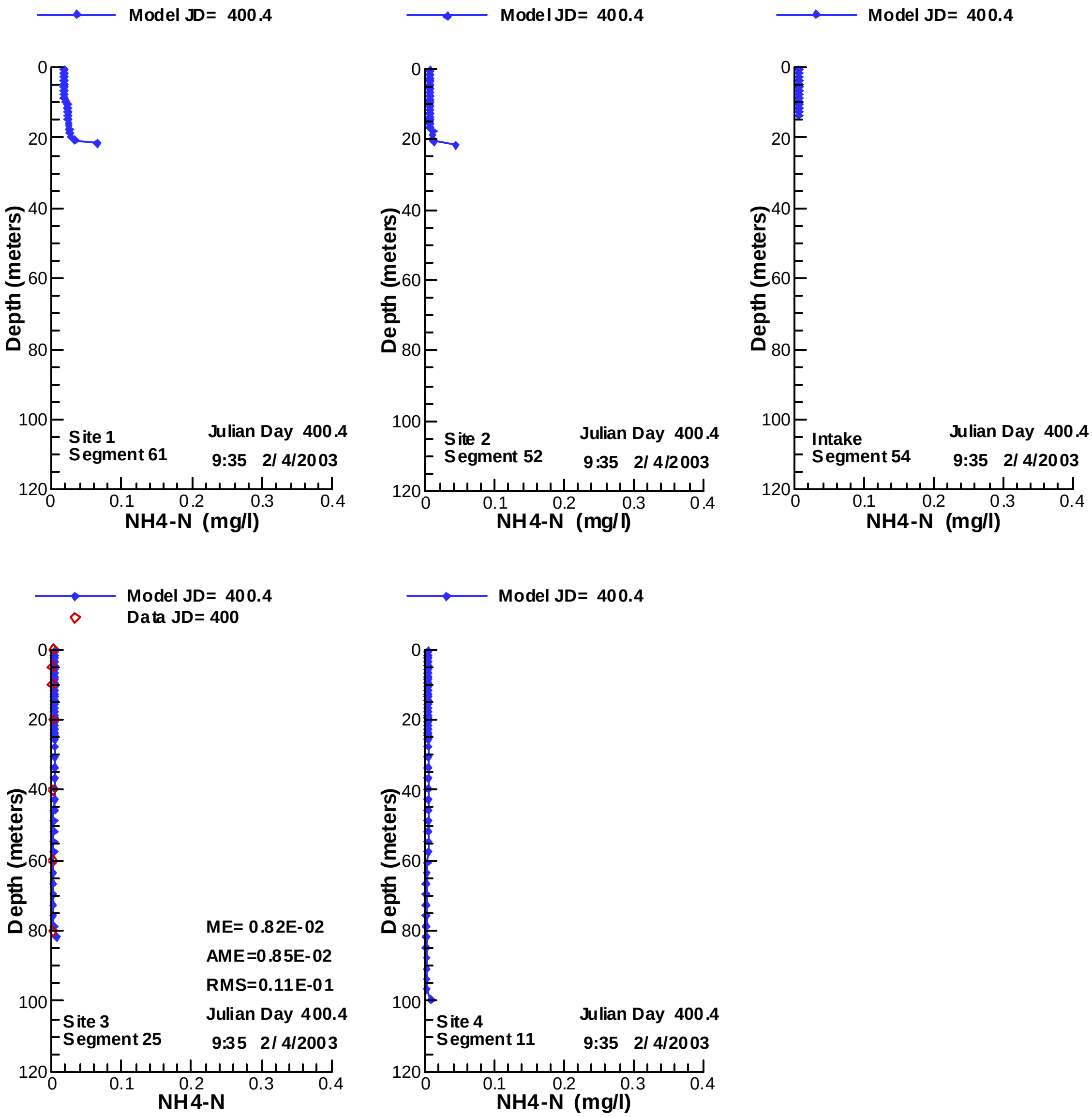

Figure 213. Vertical profiles of NH4-N compared with data for 2/ 4/2003.

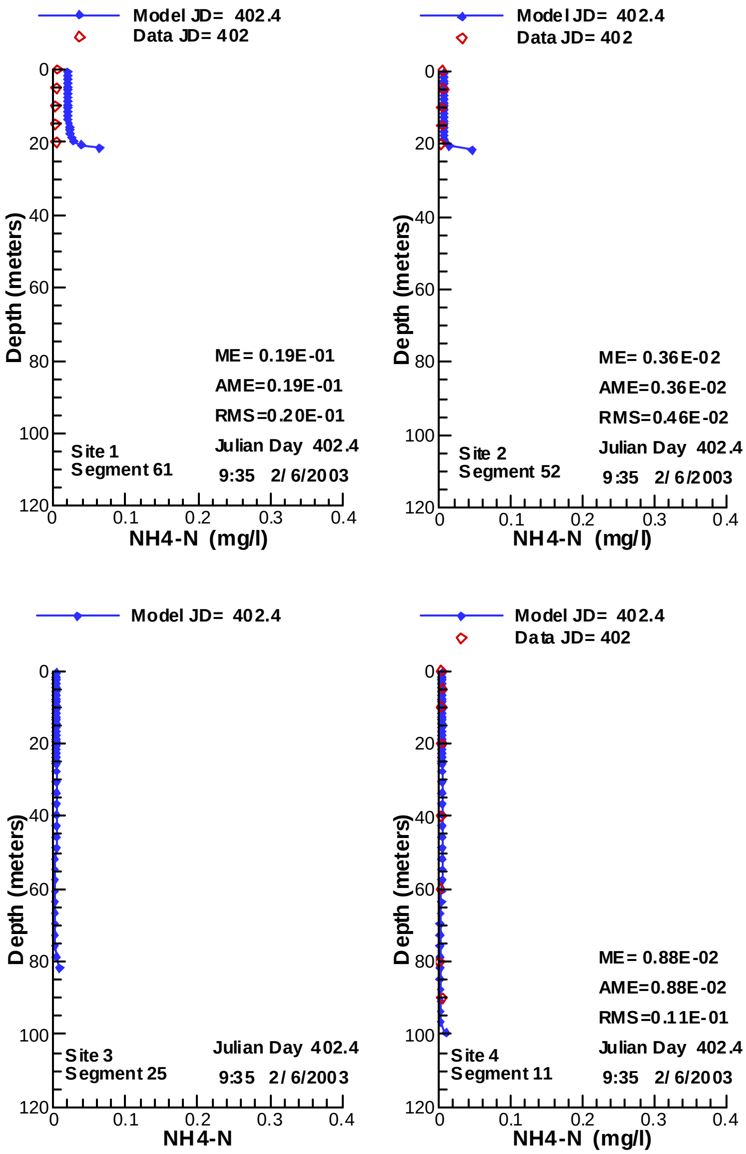

Figure 214. Vertical profiles of NH4-N compared with data for 2/ 6/2003.

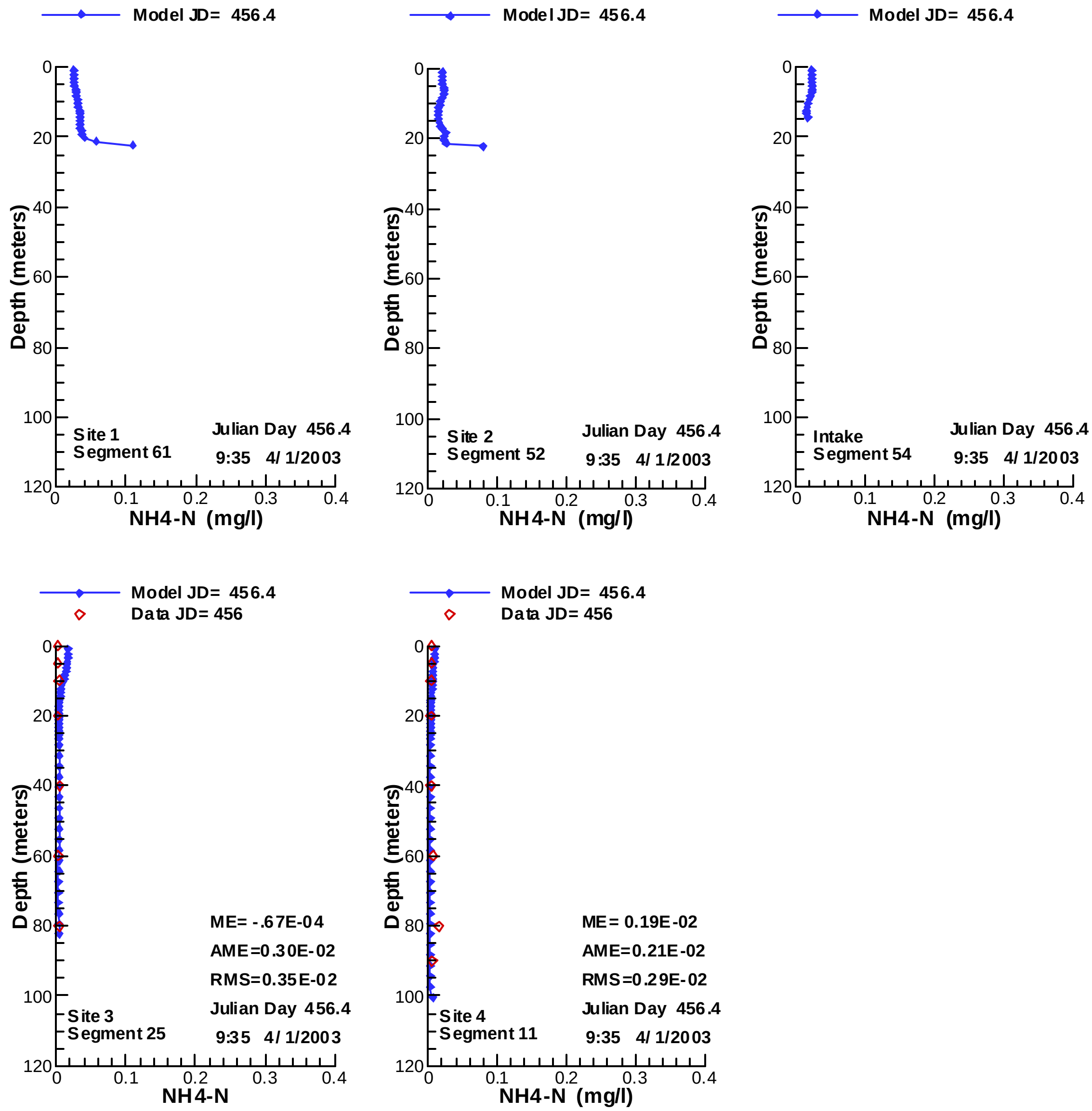

Figure 215. Vertical profiles of NH4-N compared with data for 4/ 1/2003.

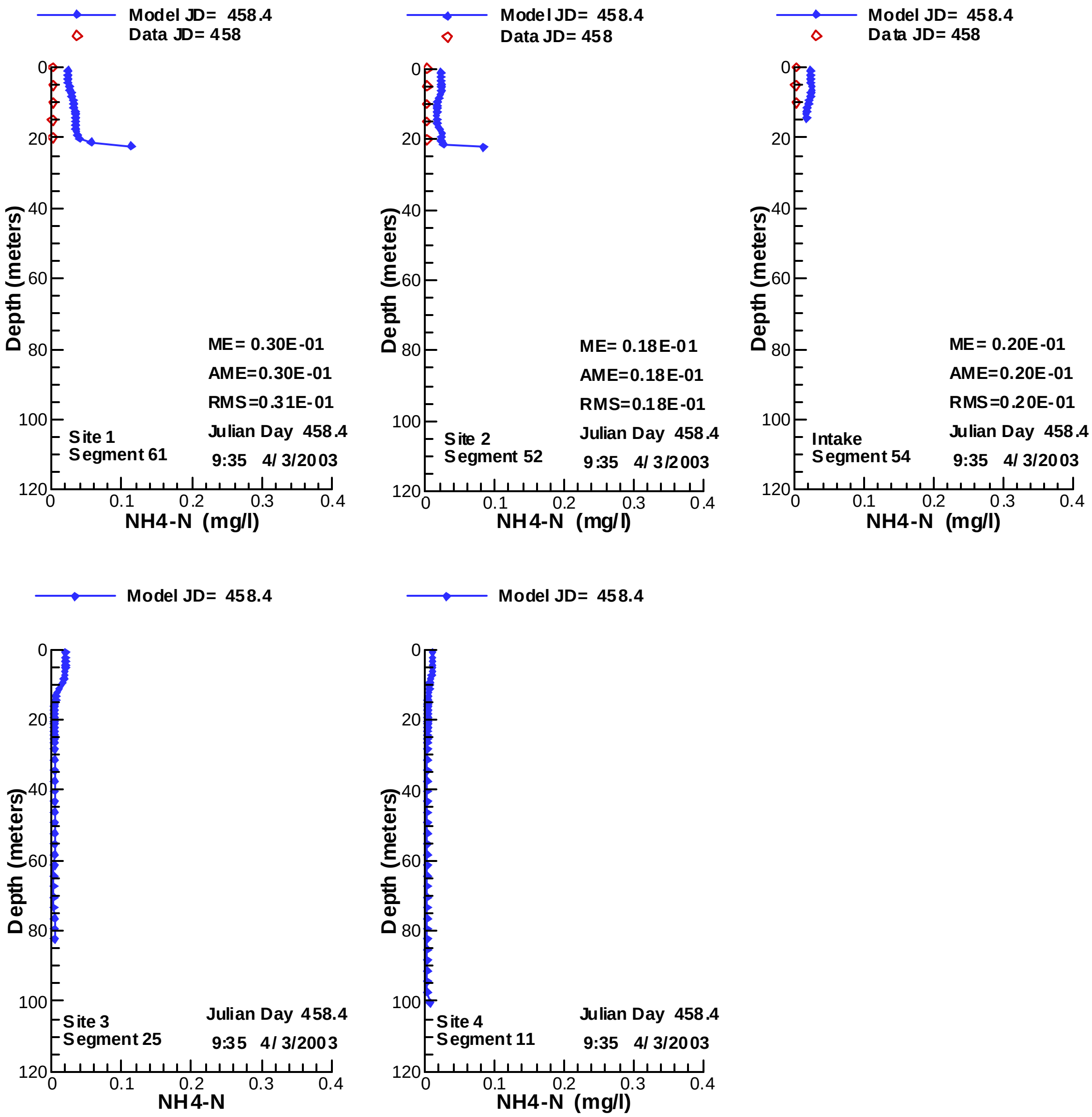

Figure 216. Vertical profiles of NH4-N compared with data for 4/ 3/2003.

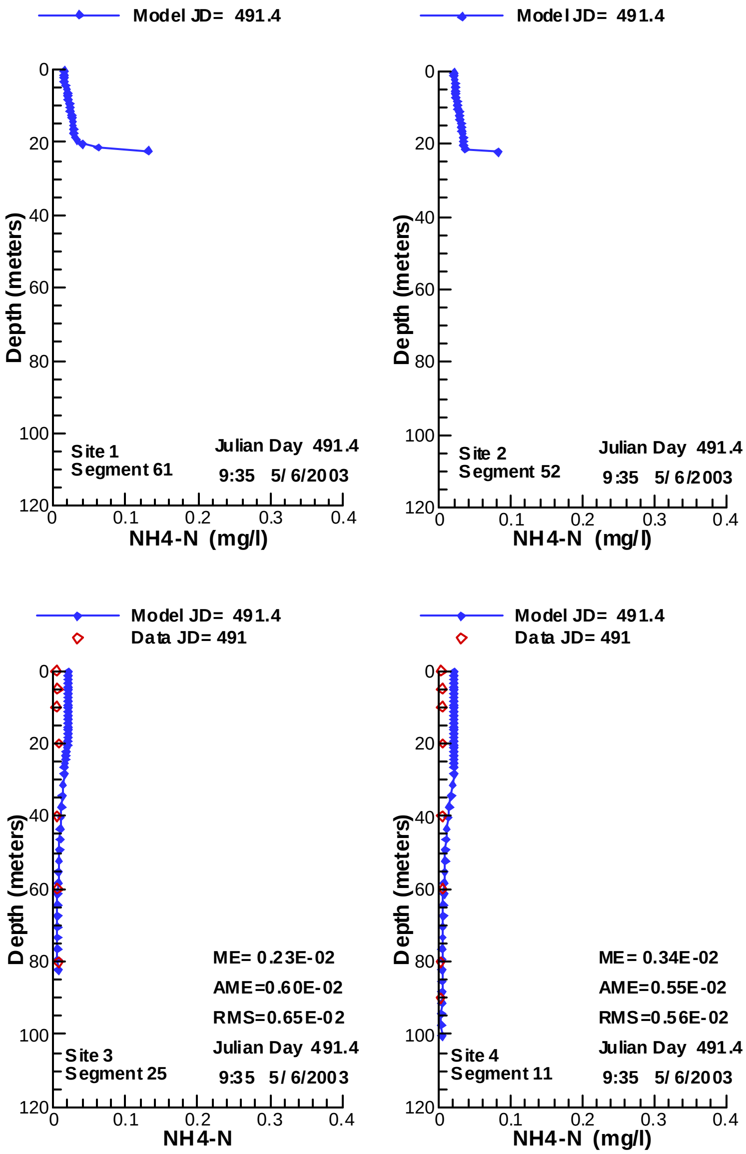

Figure 217. Vertical profiles of NH4-N compared with data for 5/ 6/2003.

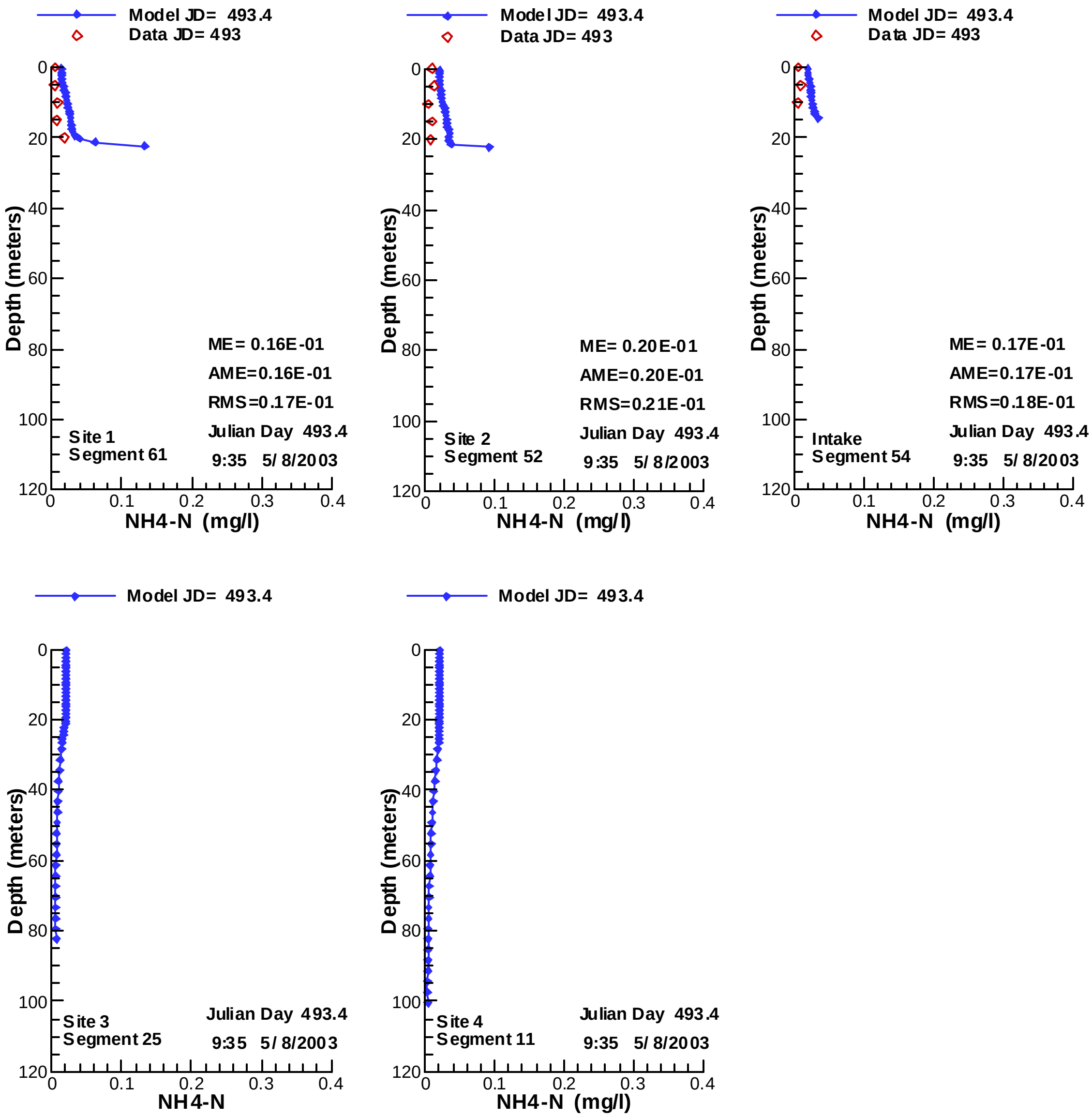

Figure 218. Vertical profiles of NH4-N compared with data for 5/ 8/2003.

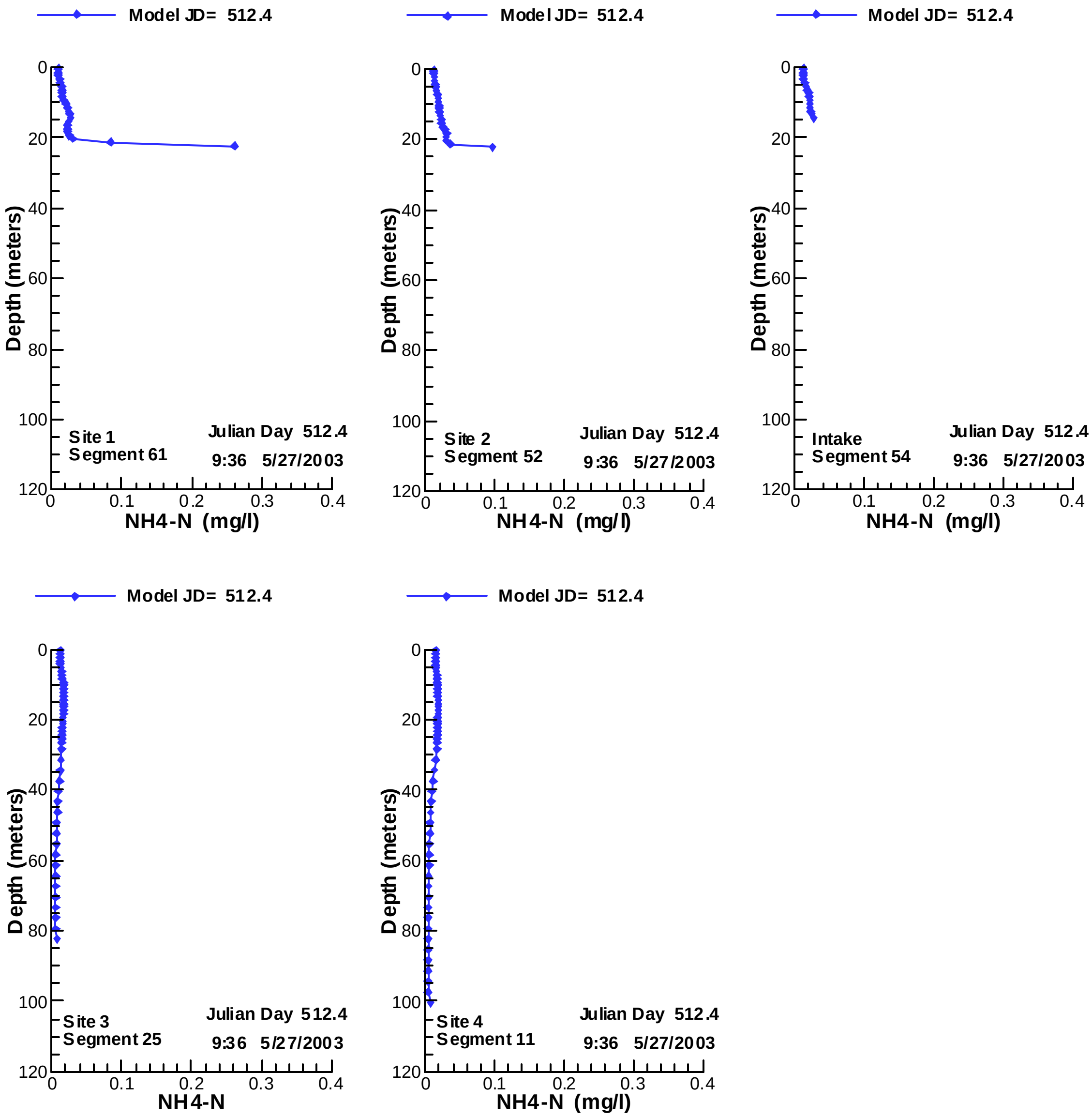

Figure 219. Vertical profiles of NH4-N compared with data for 5/27/2003.

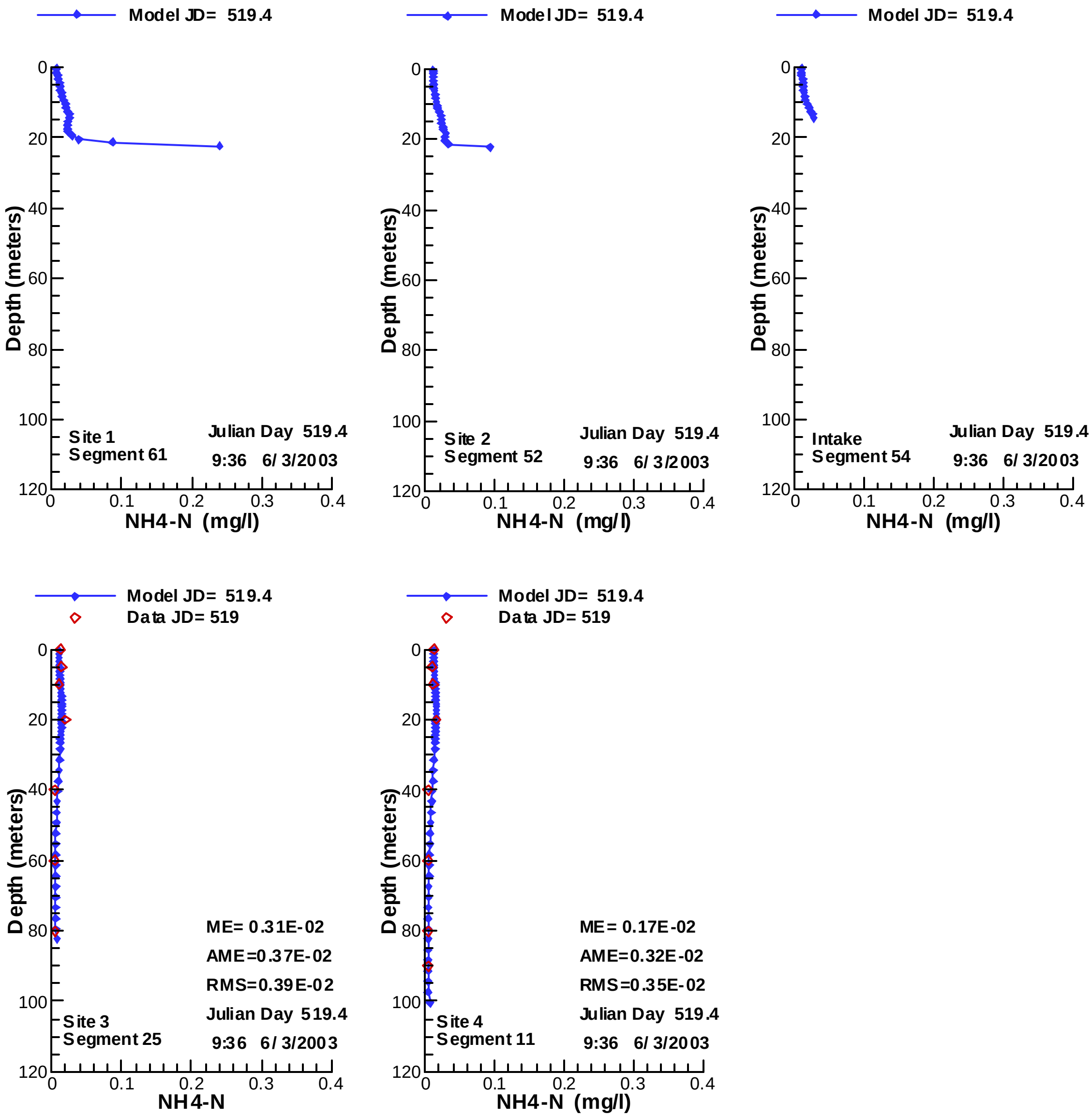

Figure 220. Vertical profiles of NH4-N compared with data for 6/ 3/2003.

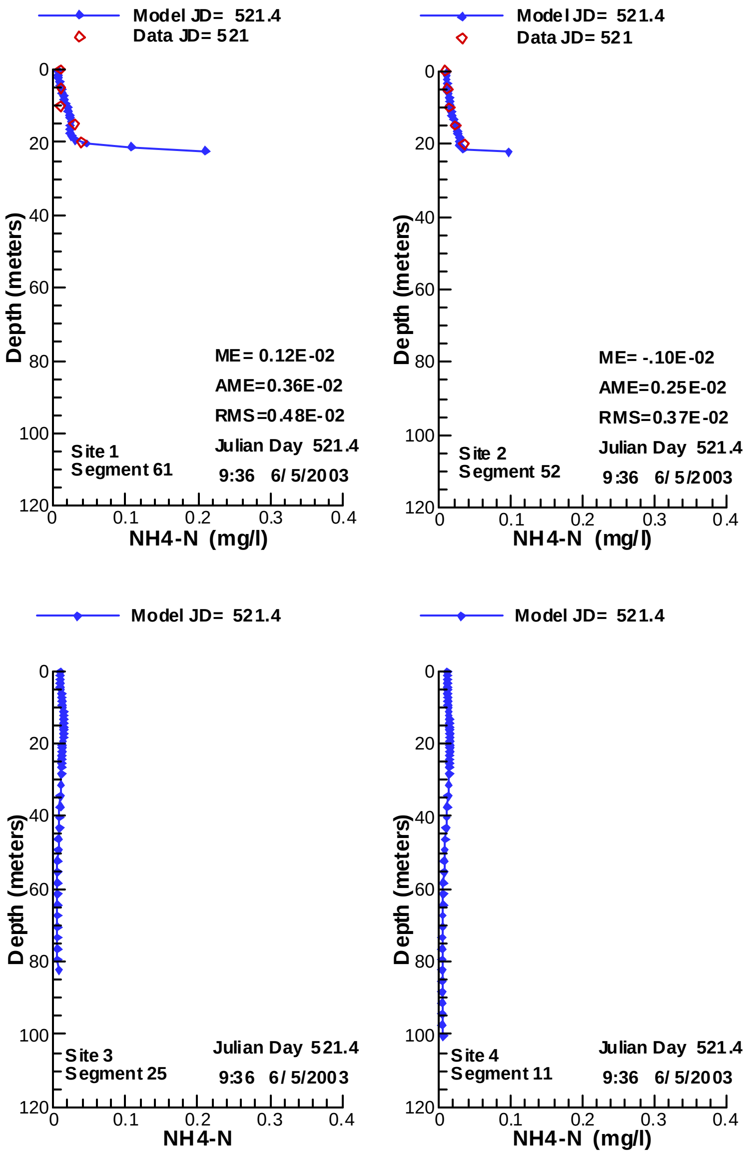

Figure 221. Vertical profiles of NH4-N compared with data for 6/ 5/2003.

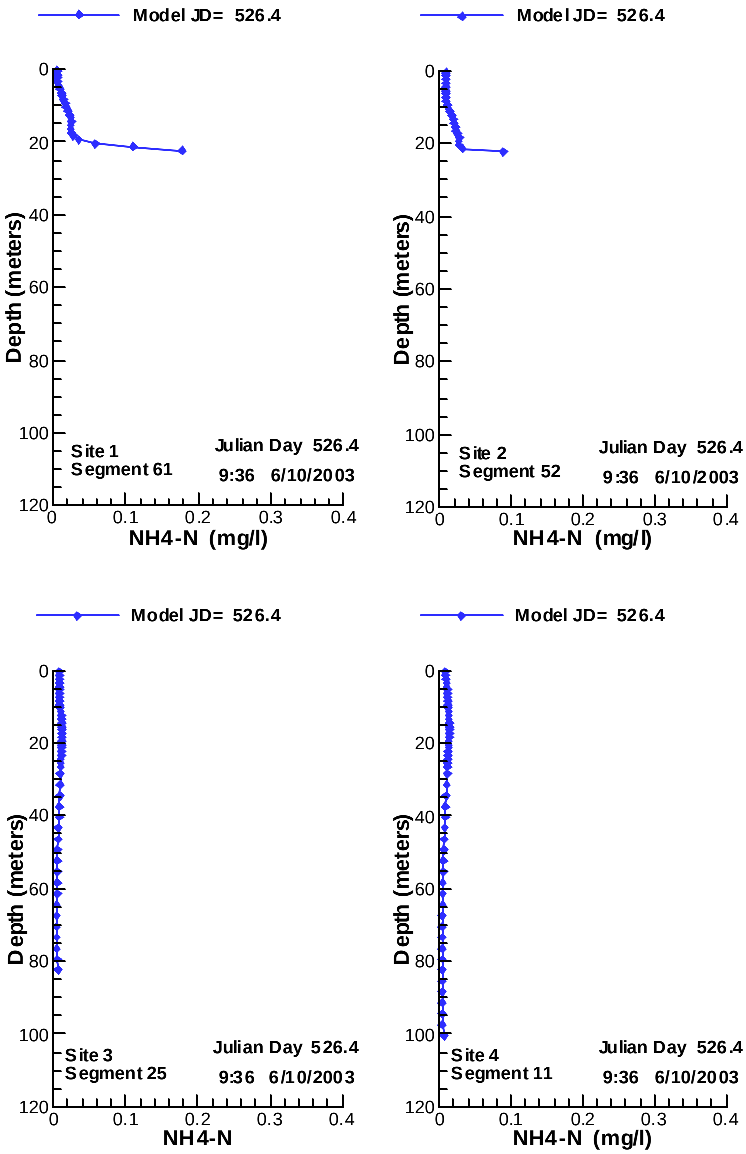

Figure 222. Vertical profiles of NH4-N compared with data for 6/10/2003.

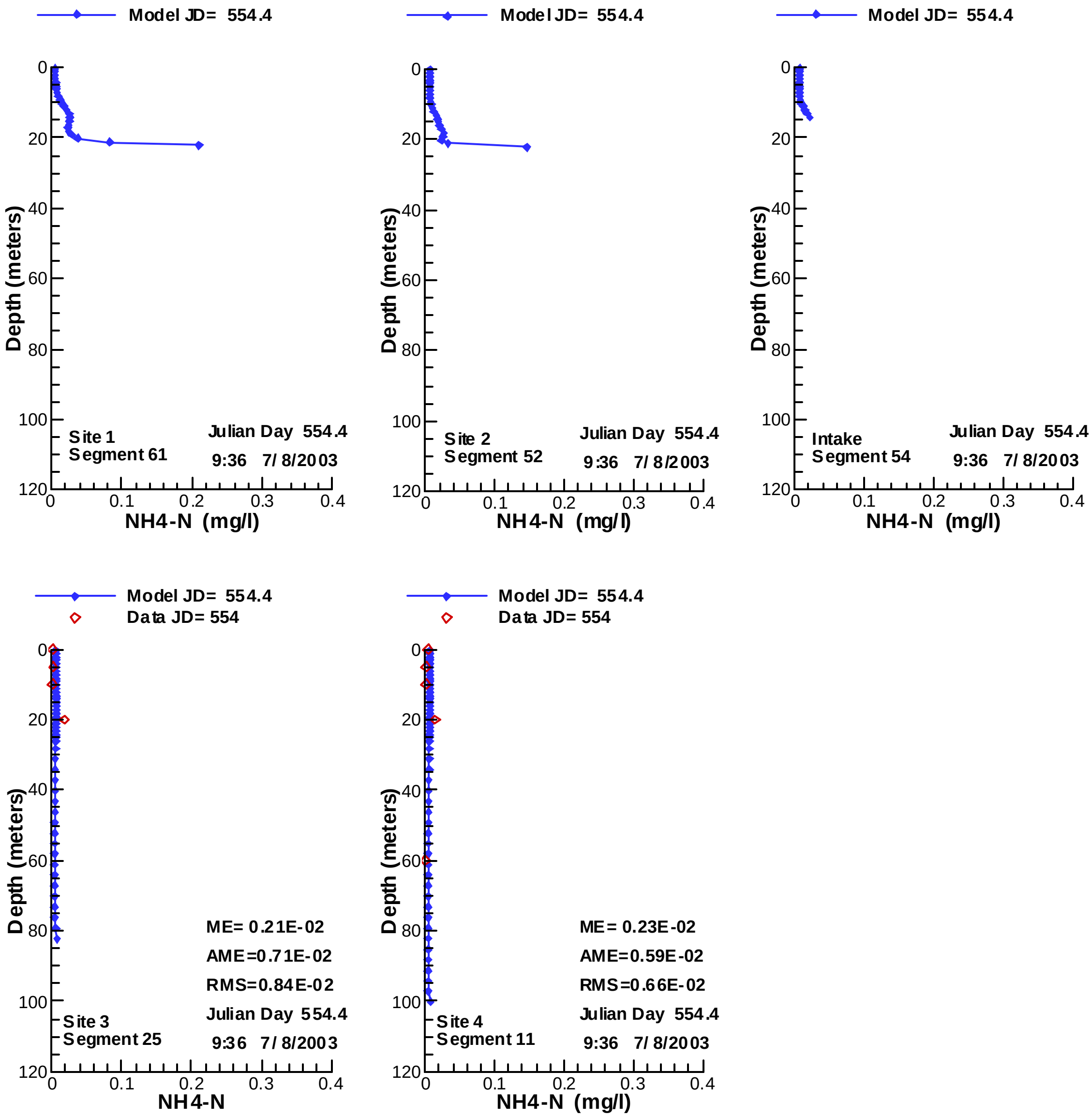

Figure 223. Vertical profiles of NH4-N compared with data for 7/ 8/2003.

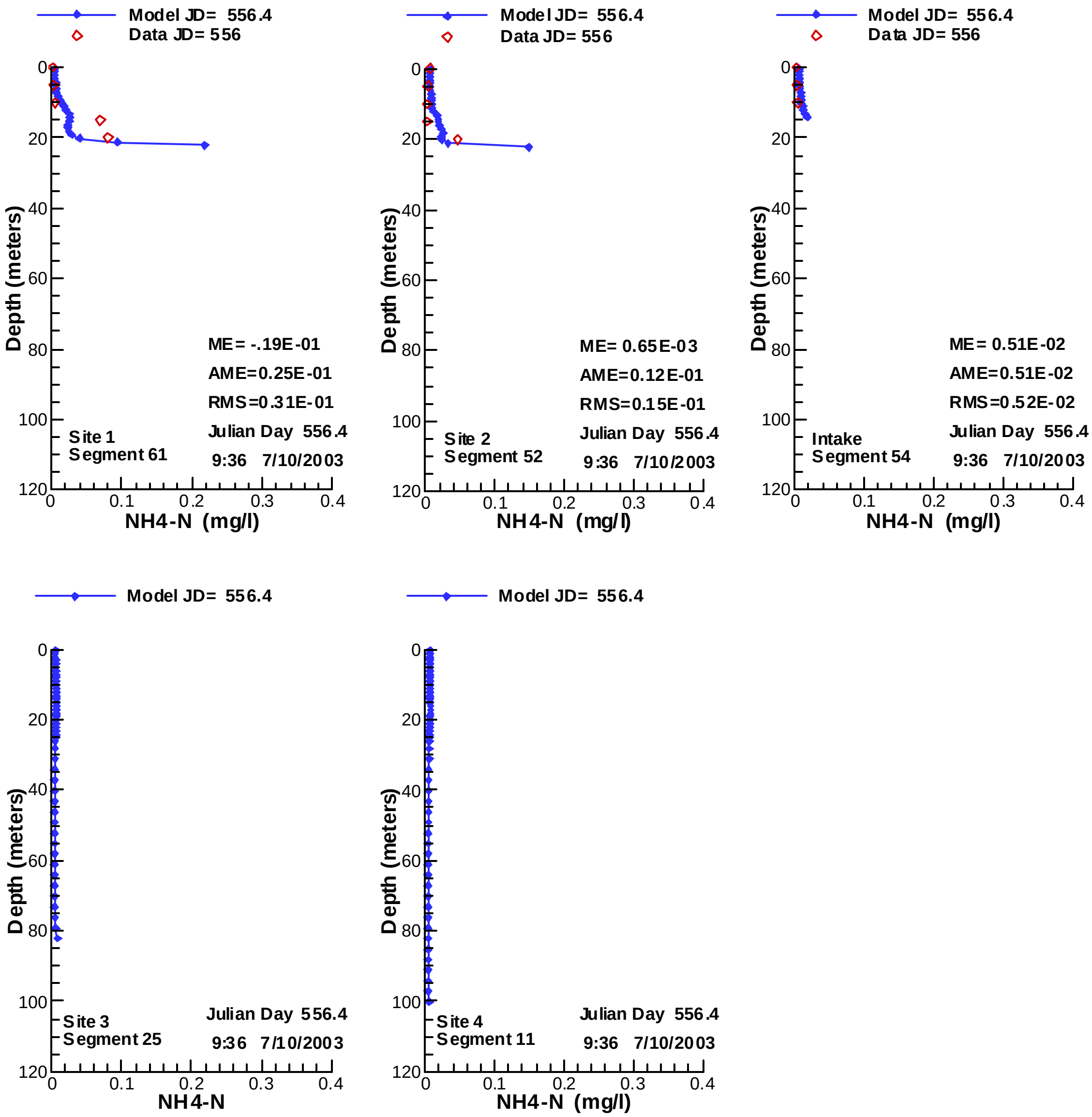

Figure 224. Vertical profiles of NH4-N compared with data for 7/10/2003.

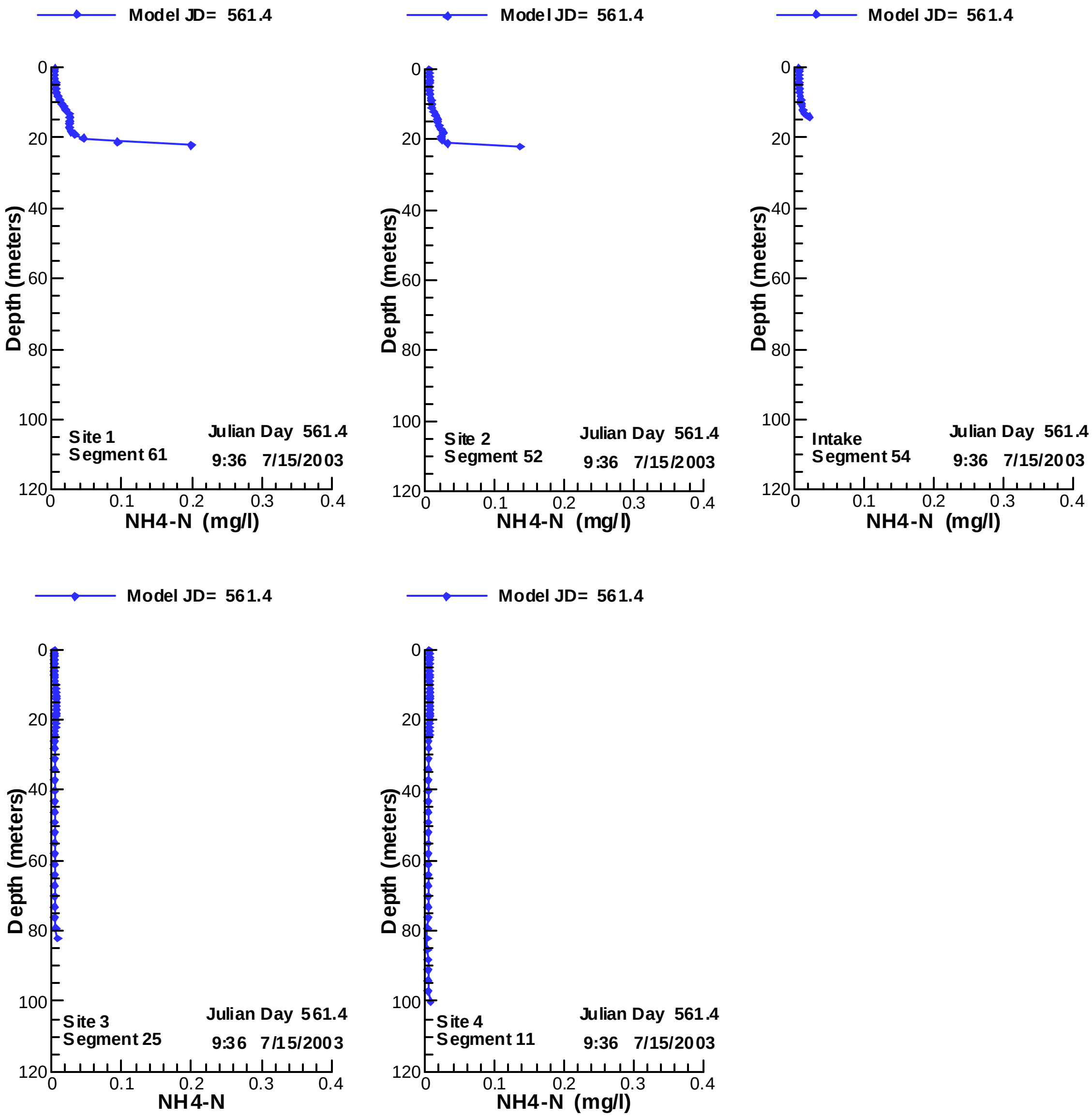

Figure 225. Vertical profiles of NH4-N compared with data for 7/15/2003.

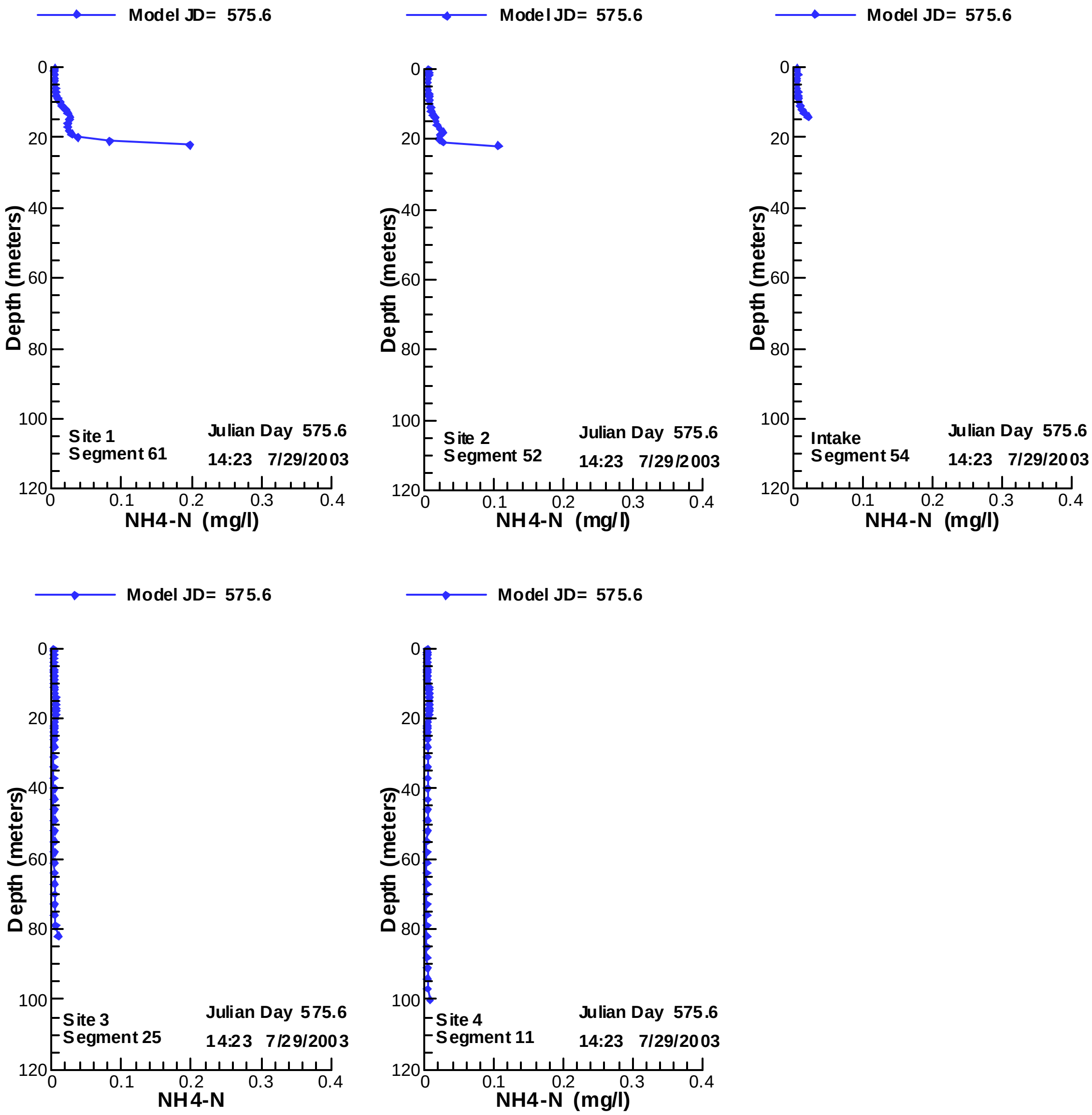

Figure 226. Vertical profiles of NH4-N compared with data for 7/29/2003.

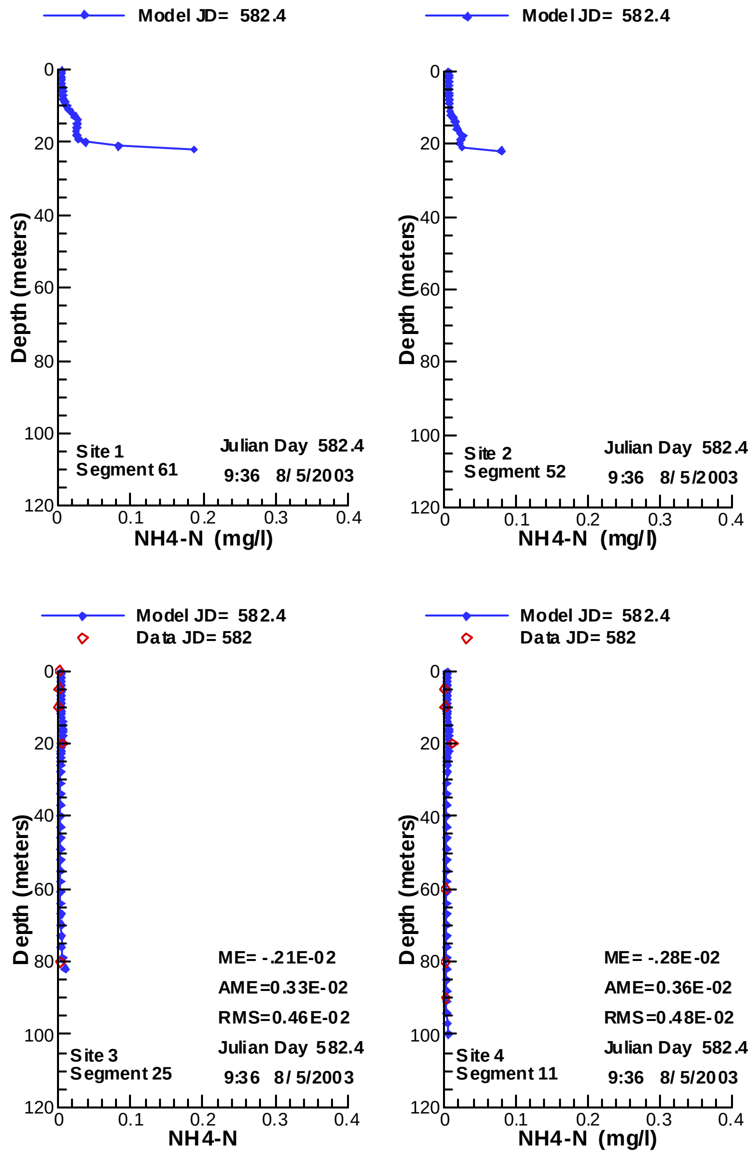

Figure 227. Vertical profiles of NH4-N compared with data for 8/ 5/2003.

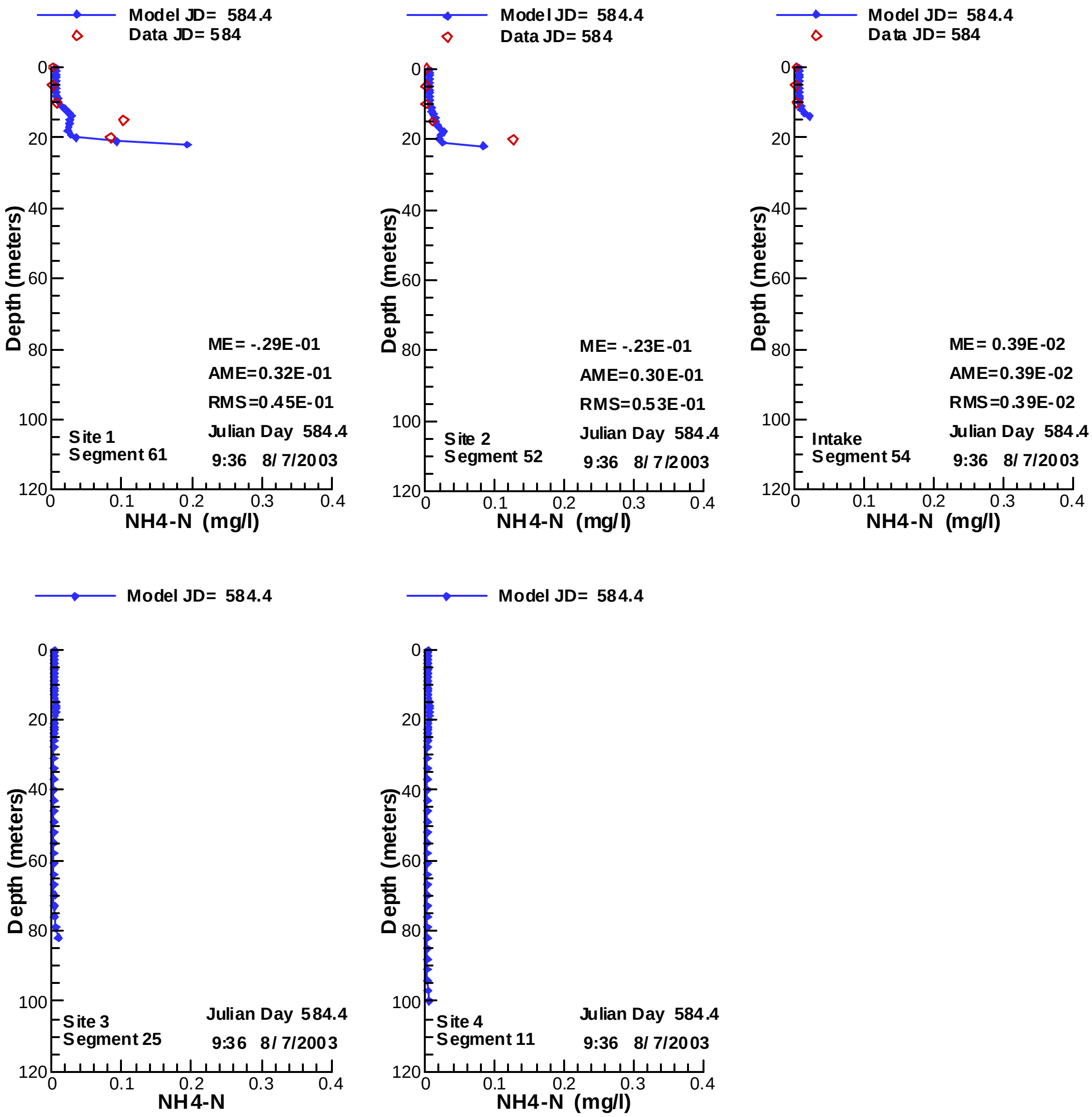

Figure 228. Vertical profiles of NH4-N compared with data for 8/ 7/2003.

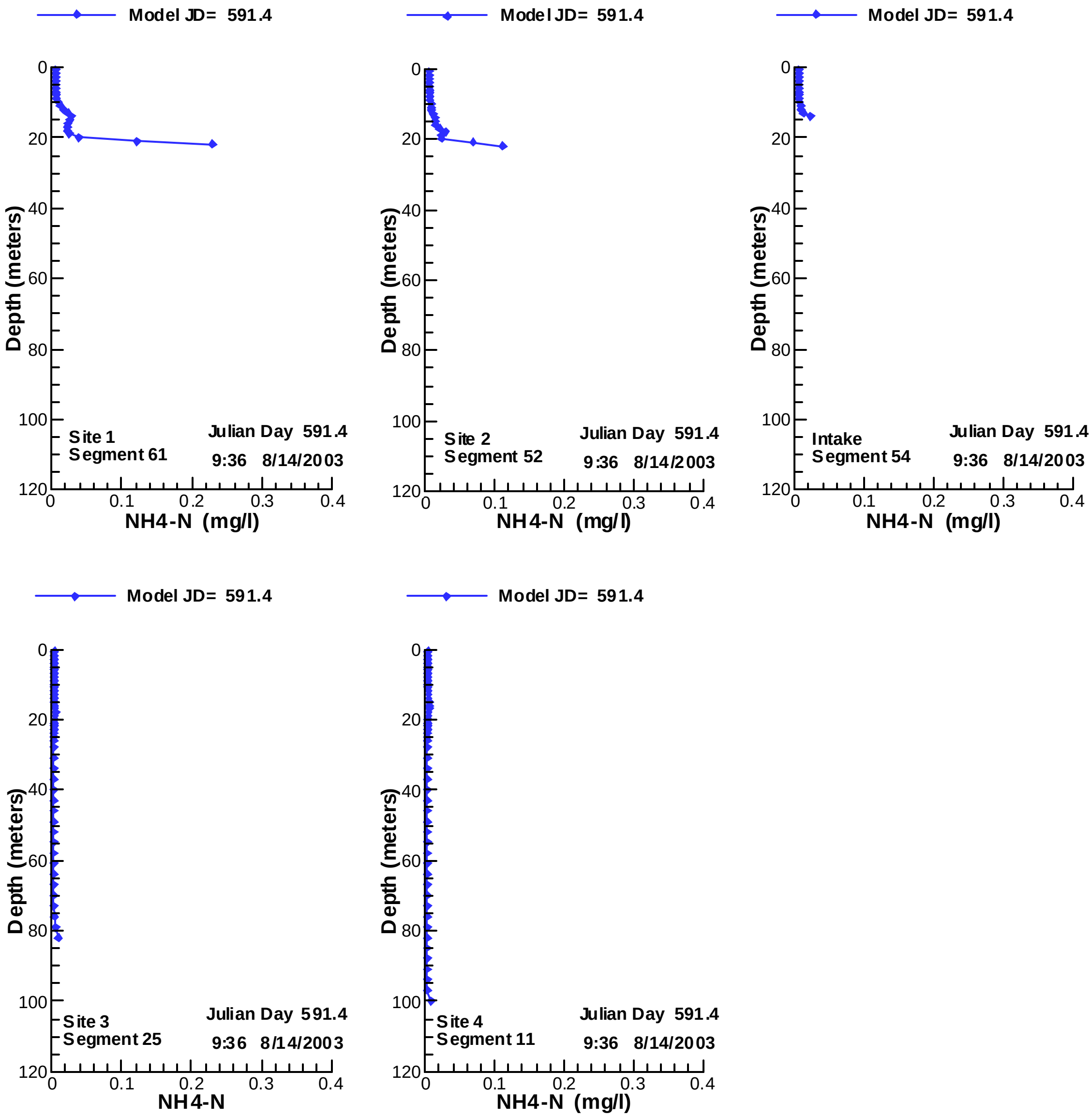

Figure 229. Vertical profiles of NH4-N compared with data for 8/14/2003.

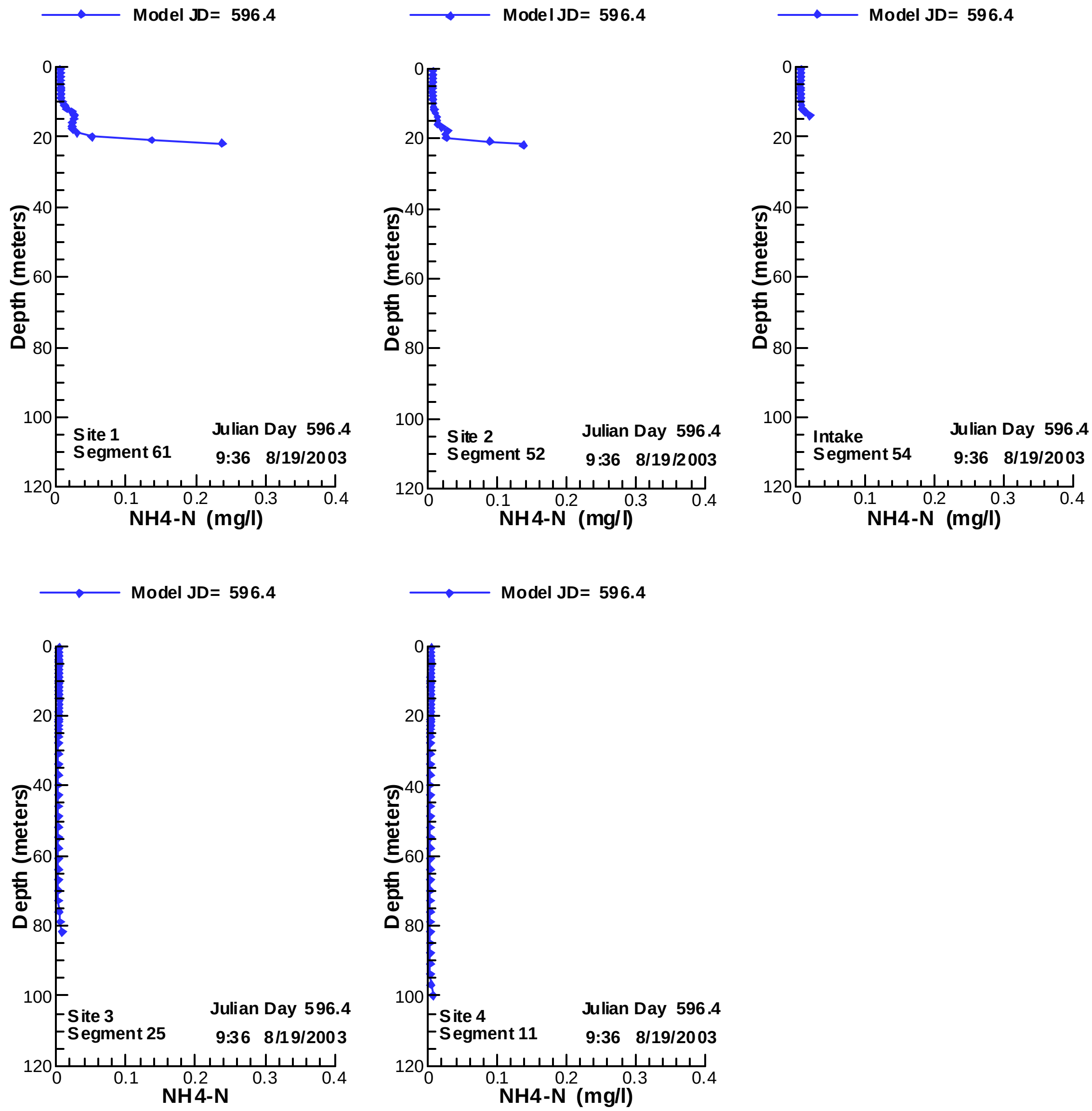

Figure 230. Vertical profiles of NH4-N compared with data for 8/19/2003.

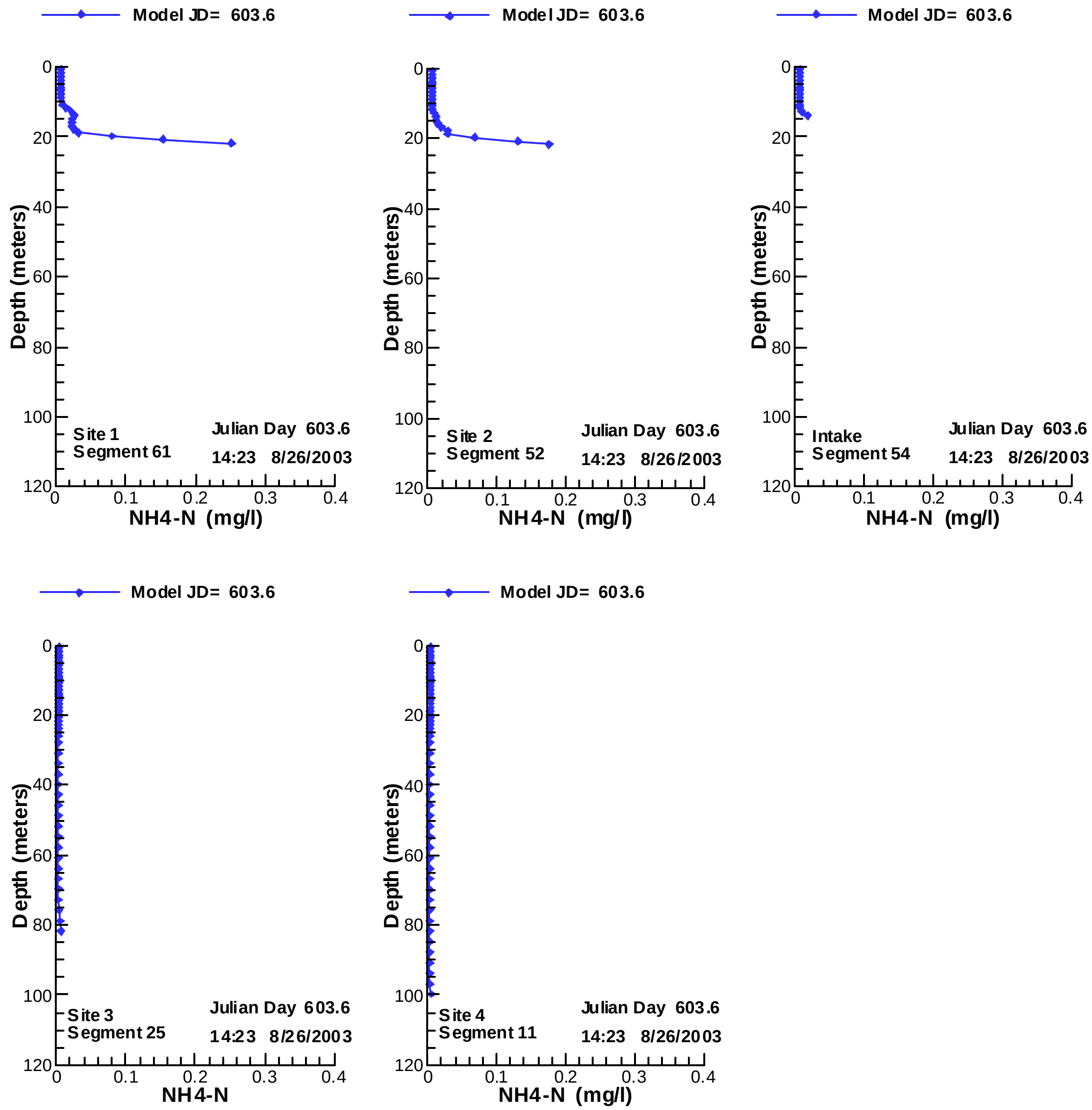

Figure 231. Vertical profiles of NH4-N compared with data for 8/26/2003.

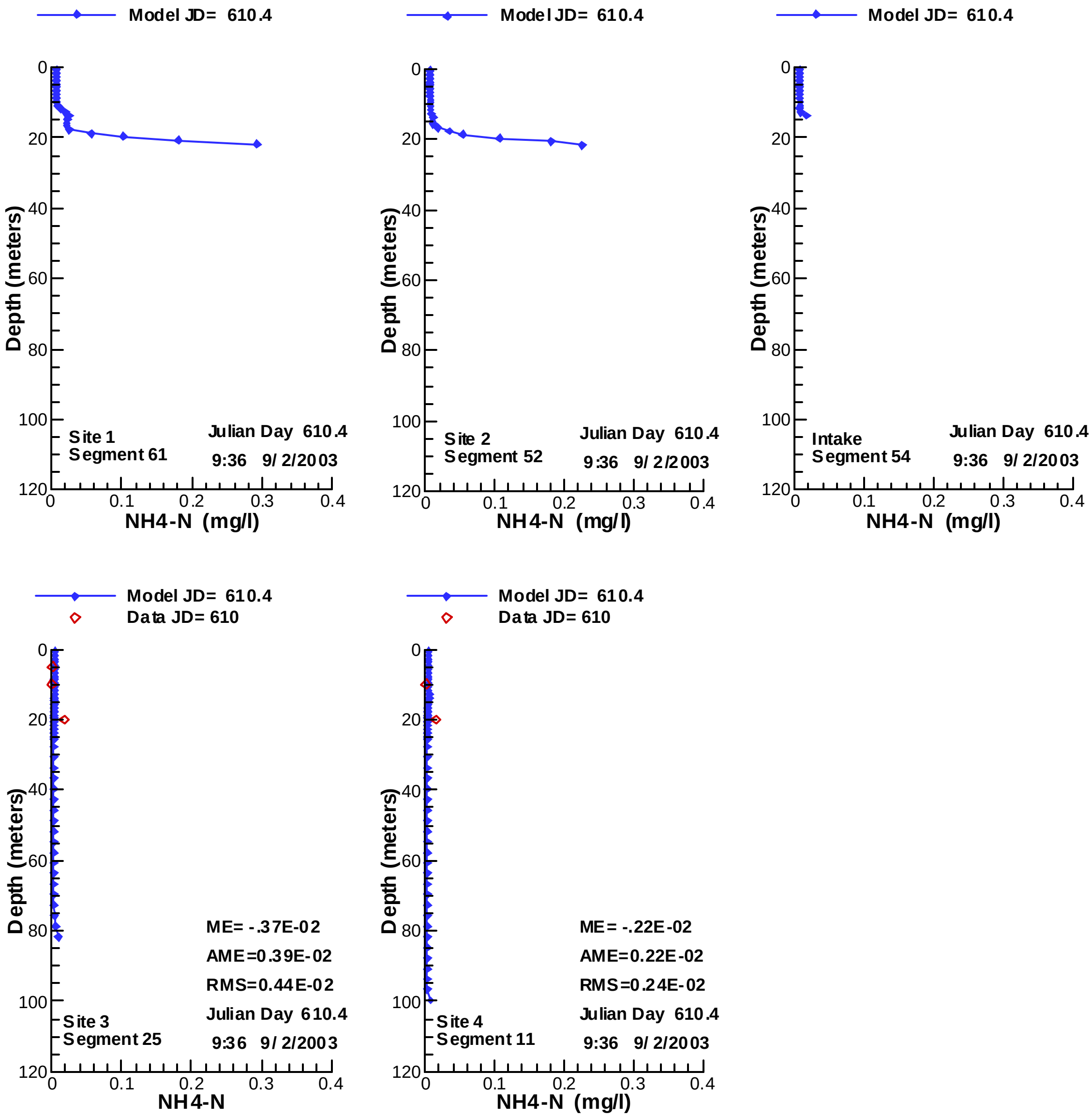

Figure 232. Vertical profiles of NH4-N compared with data for 9/ 2/2003.

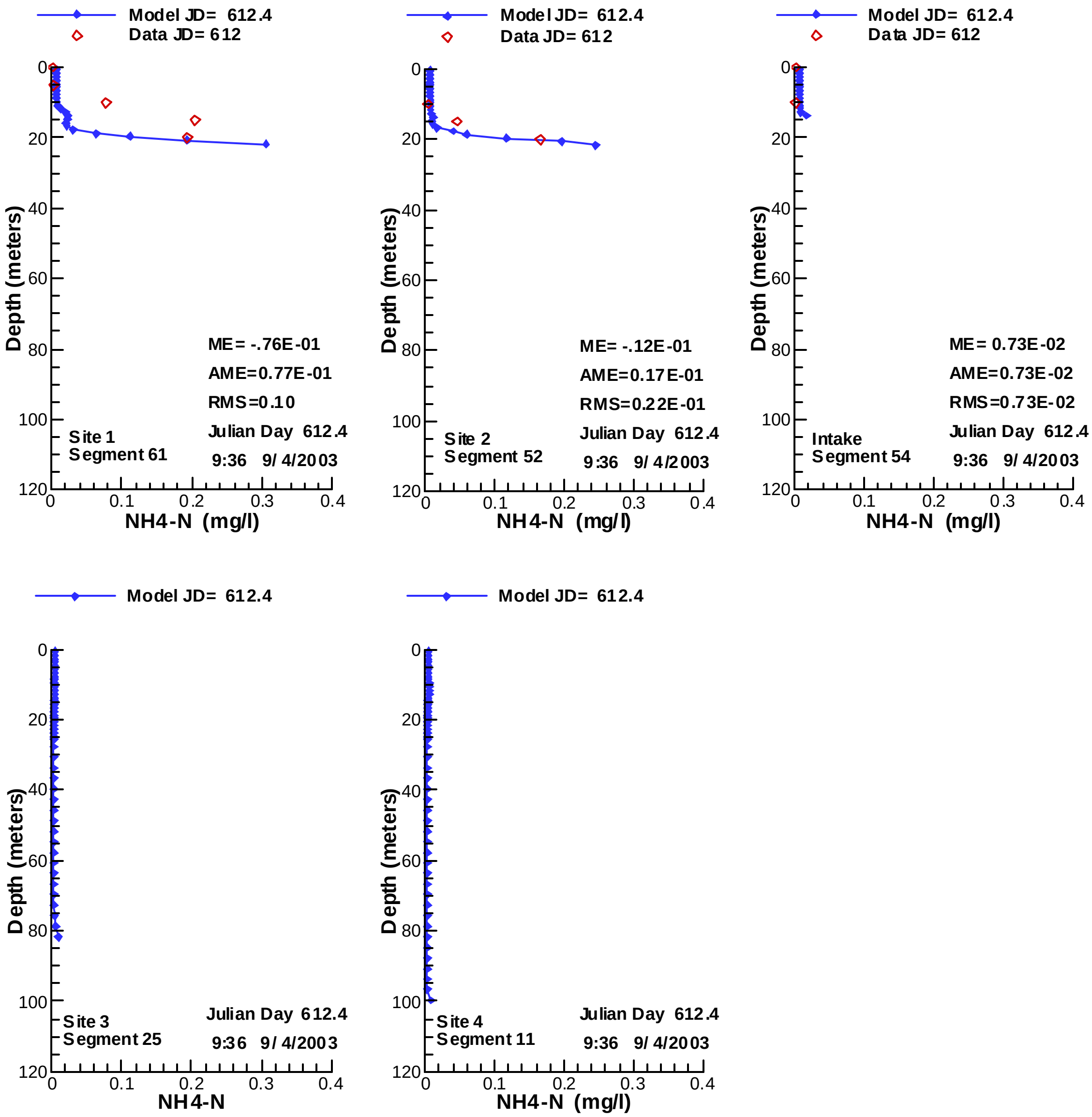

Figure 233. Vertical profiles of NH4-N compared with data for 9/ 4/2003.

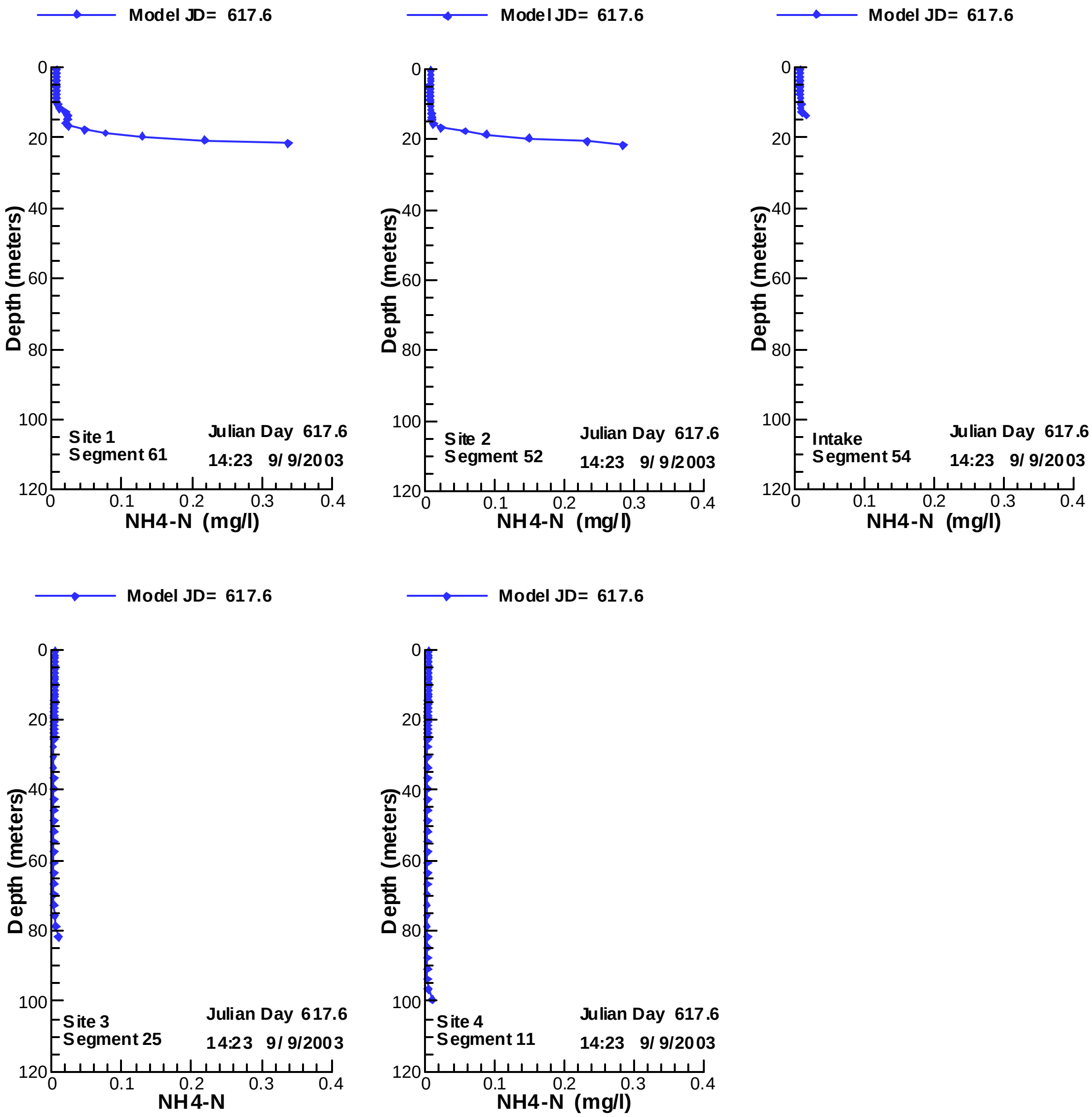

Figure 234. Vertical profiles of NH4-N compared with data for 9/ 9/2003.

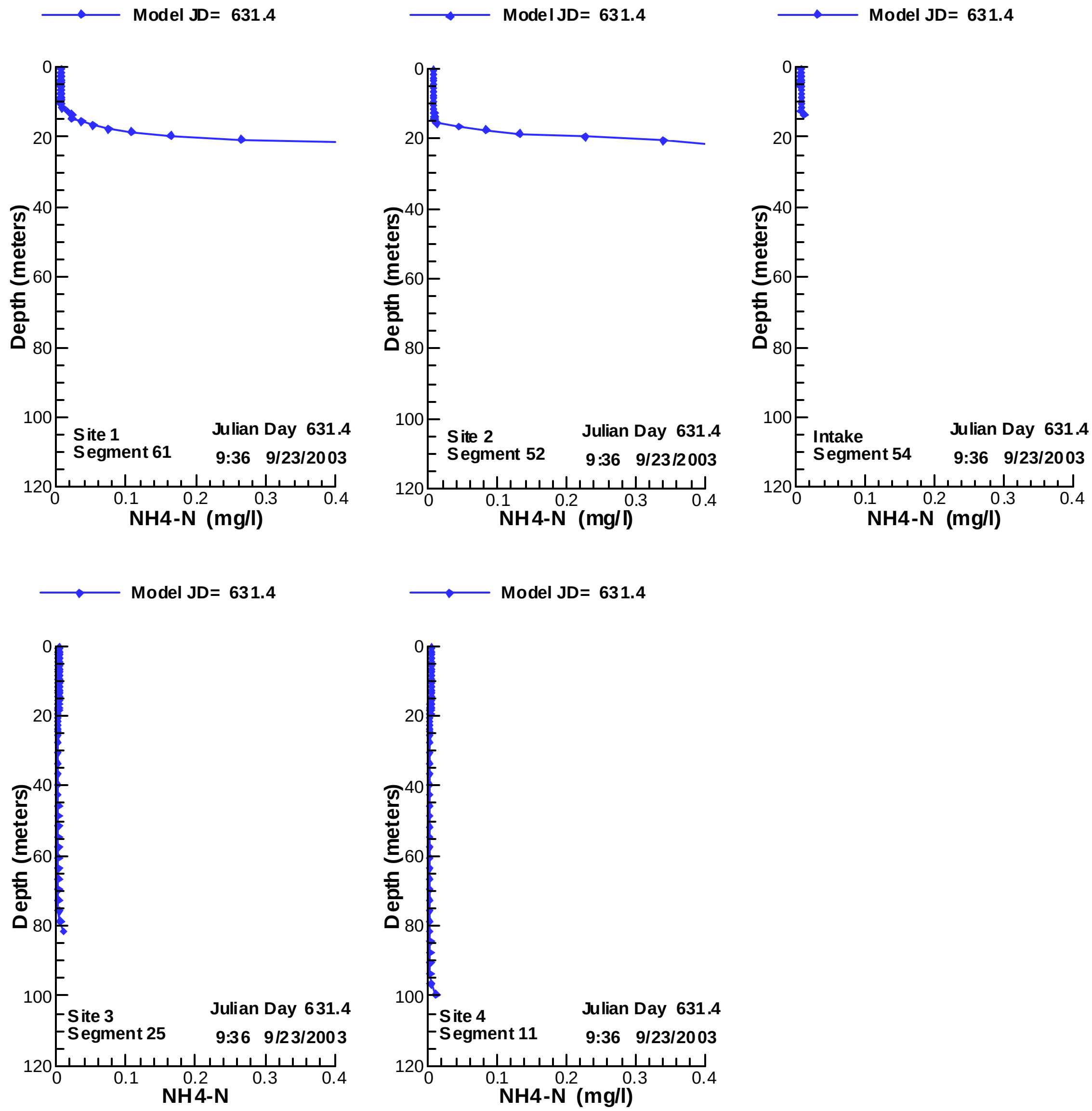

Figure 235. Vertical profiles of NH4-N compared with data for 9/23/2003.

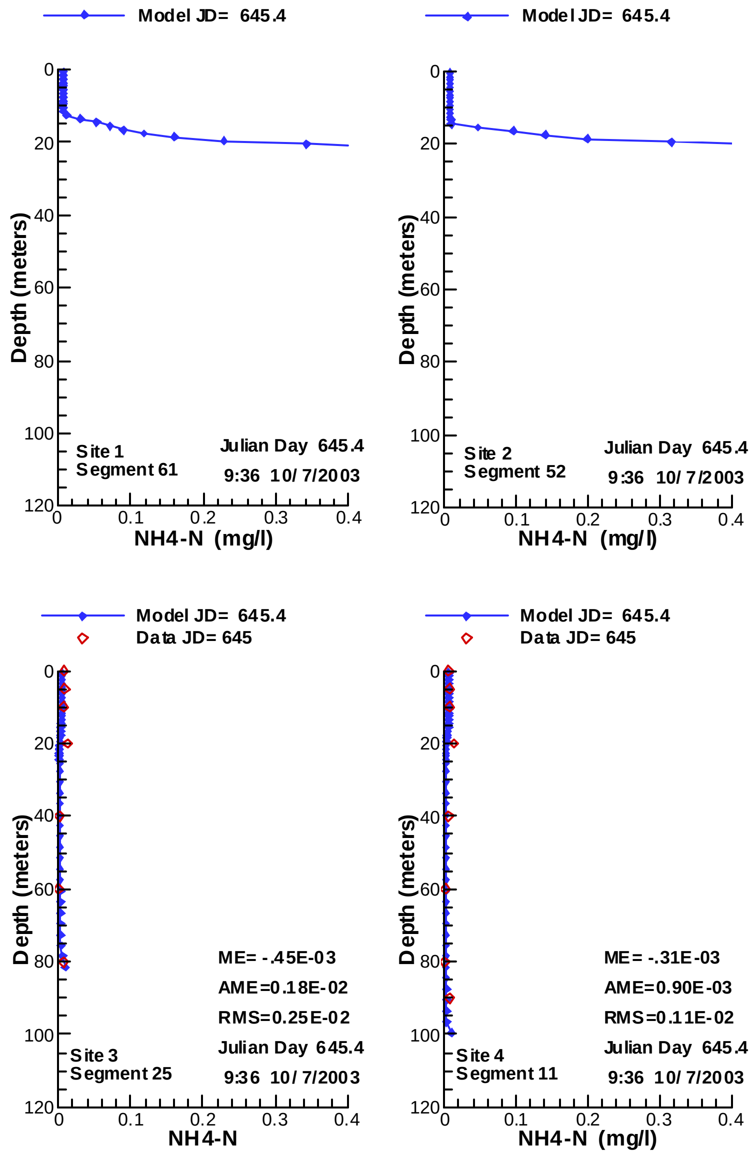

Figure 236. Vertical profiles of NH4-N compared with data for 10/ 7/2003.

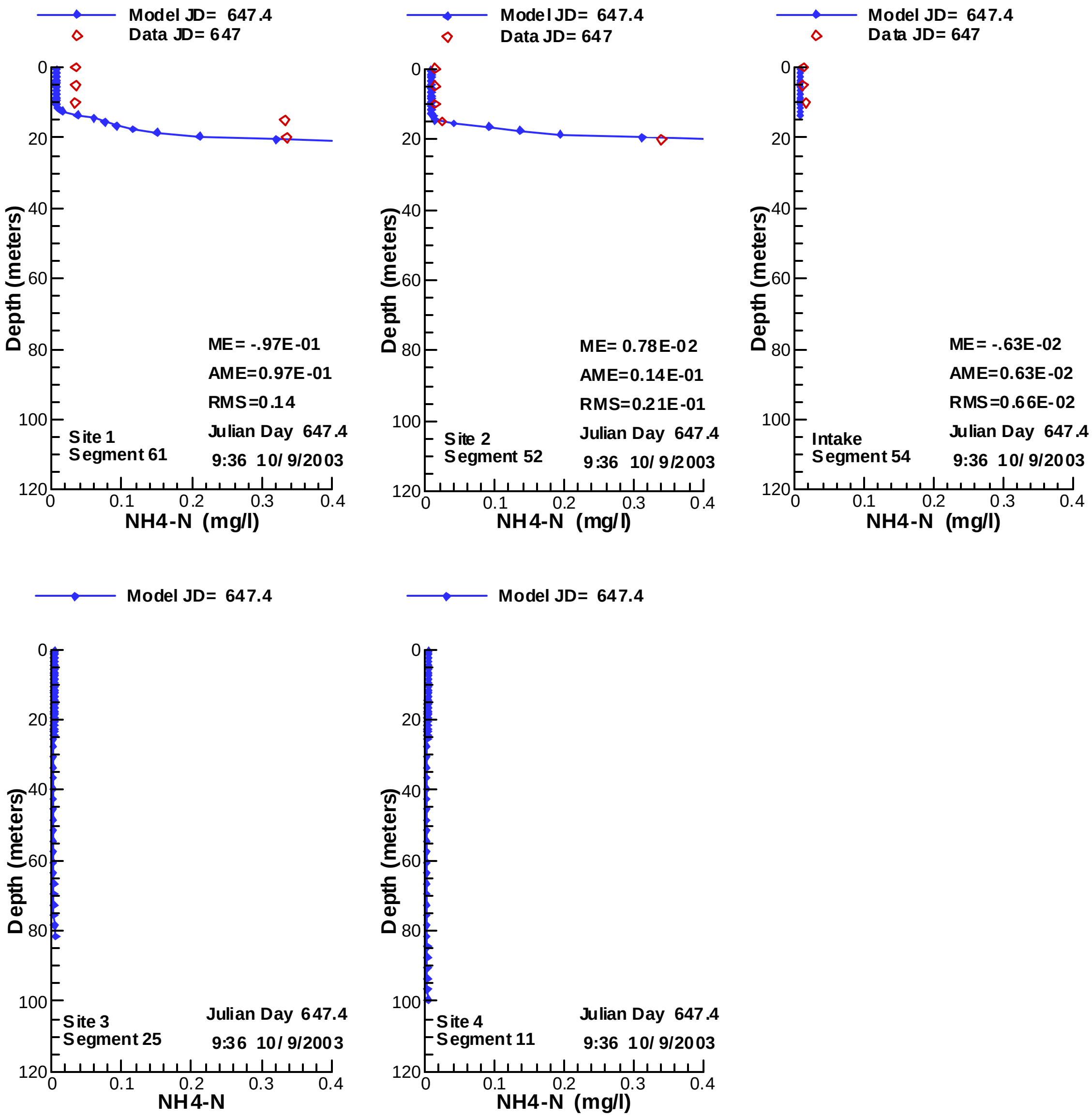

Figure 237. Vertical profiles of NH4-N compared with data for 10/ 9/2003.

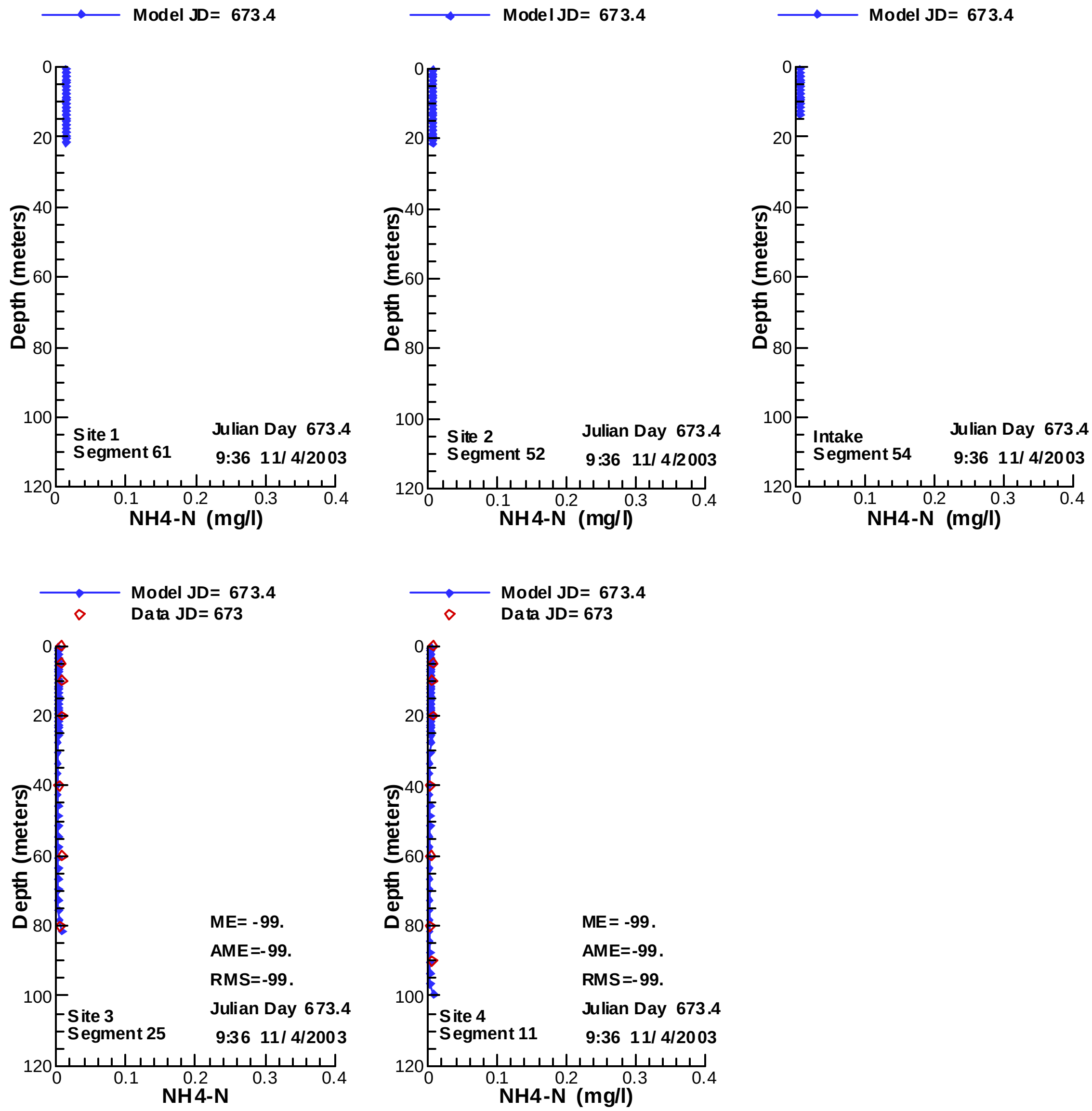

Figure 238. Vertical profiles of NH4-N compared with data for 11/ 4/2003.

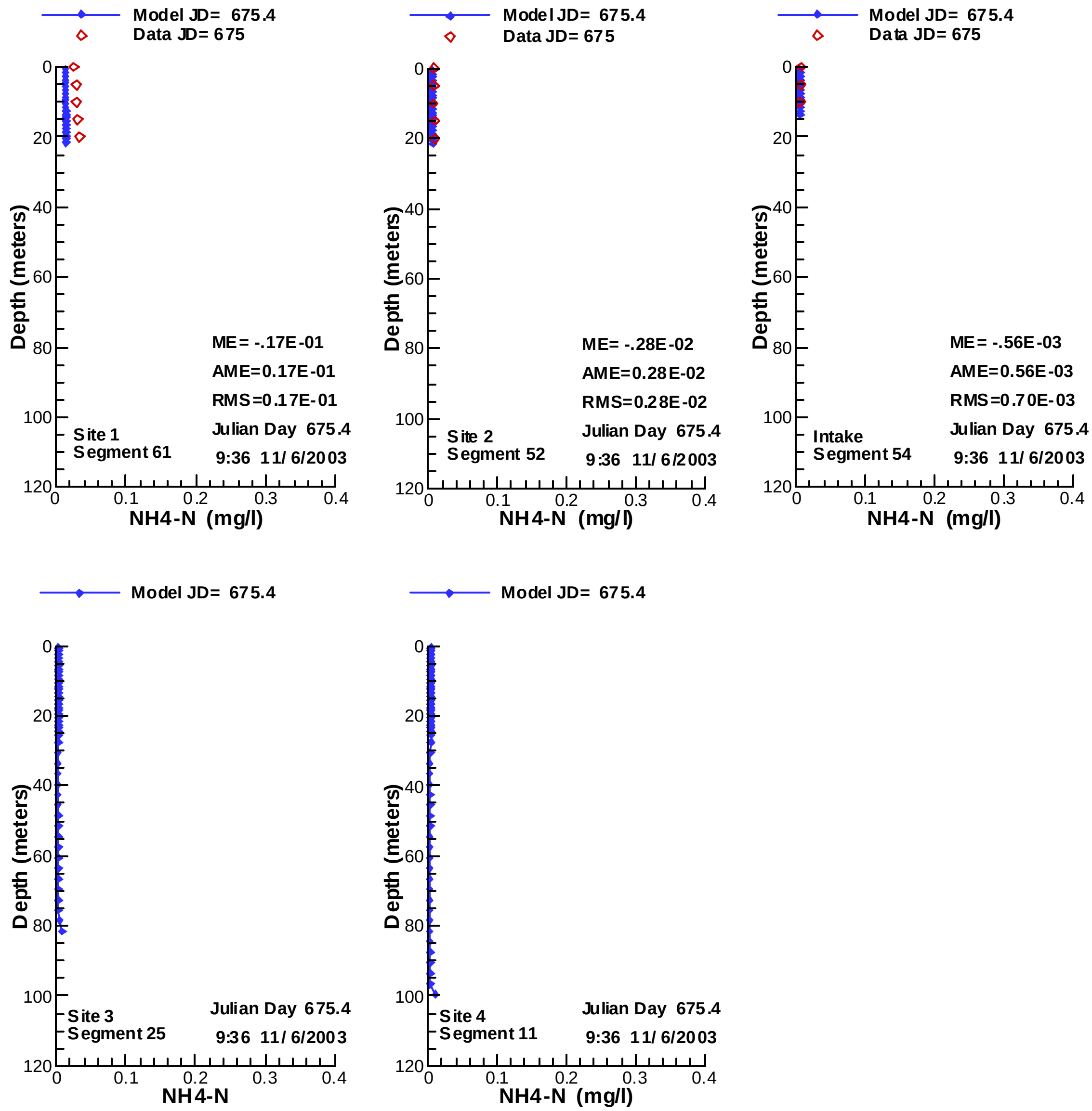

Figure 239. Vertical profiles of NH4-N compared with data for 11/ 6/2003.

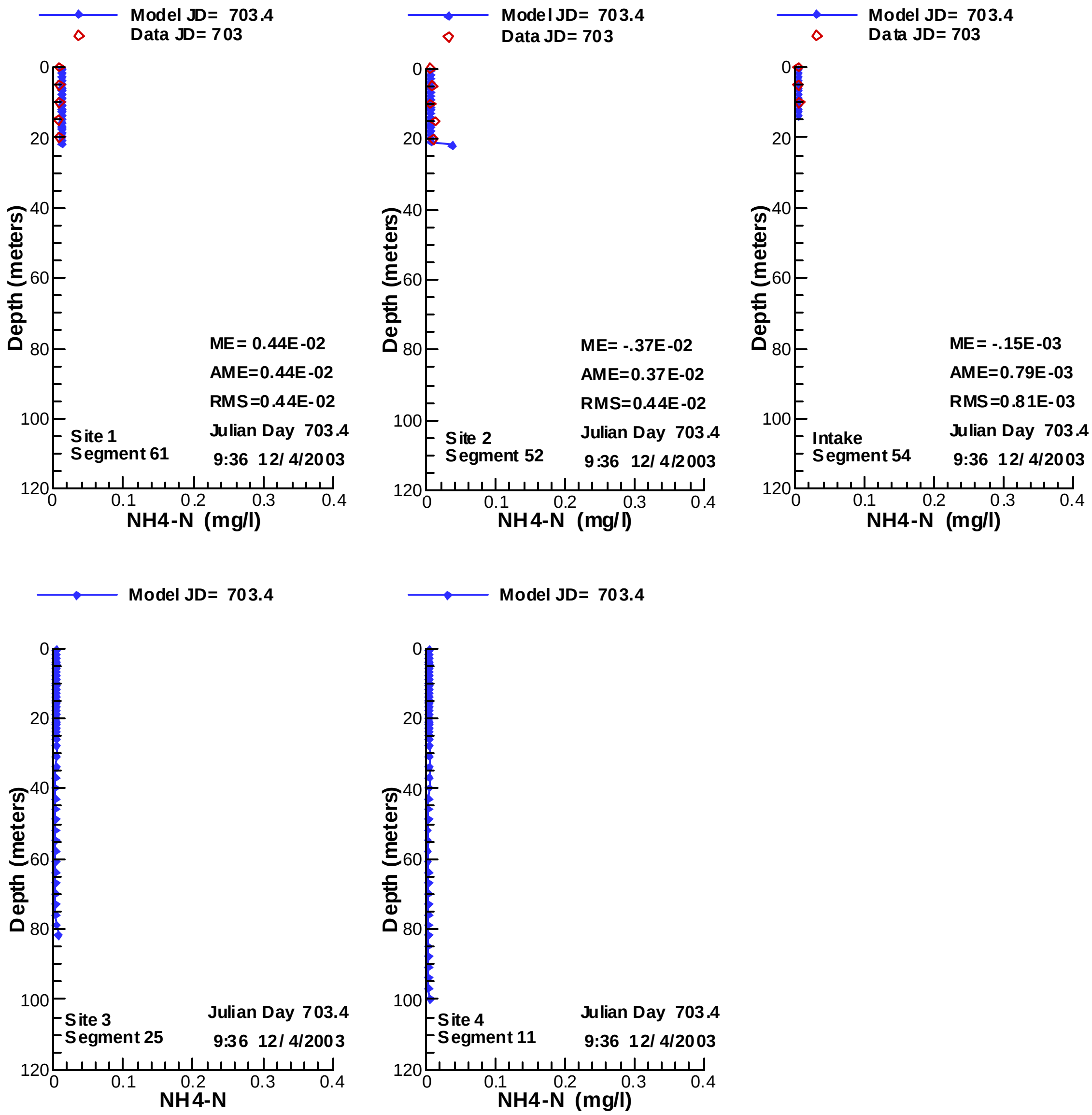

Figure 240. Vertical profiles of NH4-N compared with data for 12/ 4/2003.

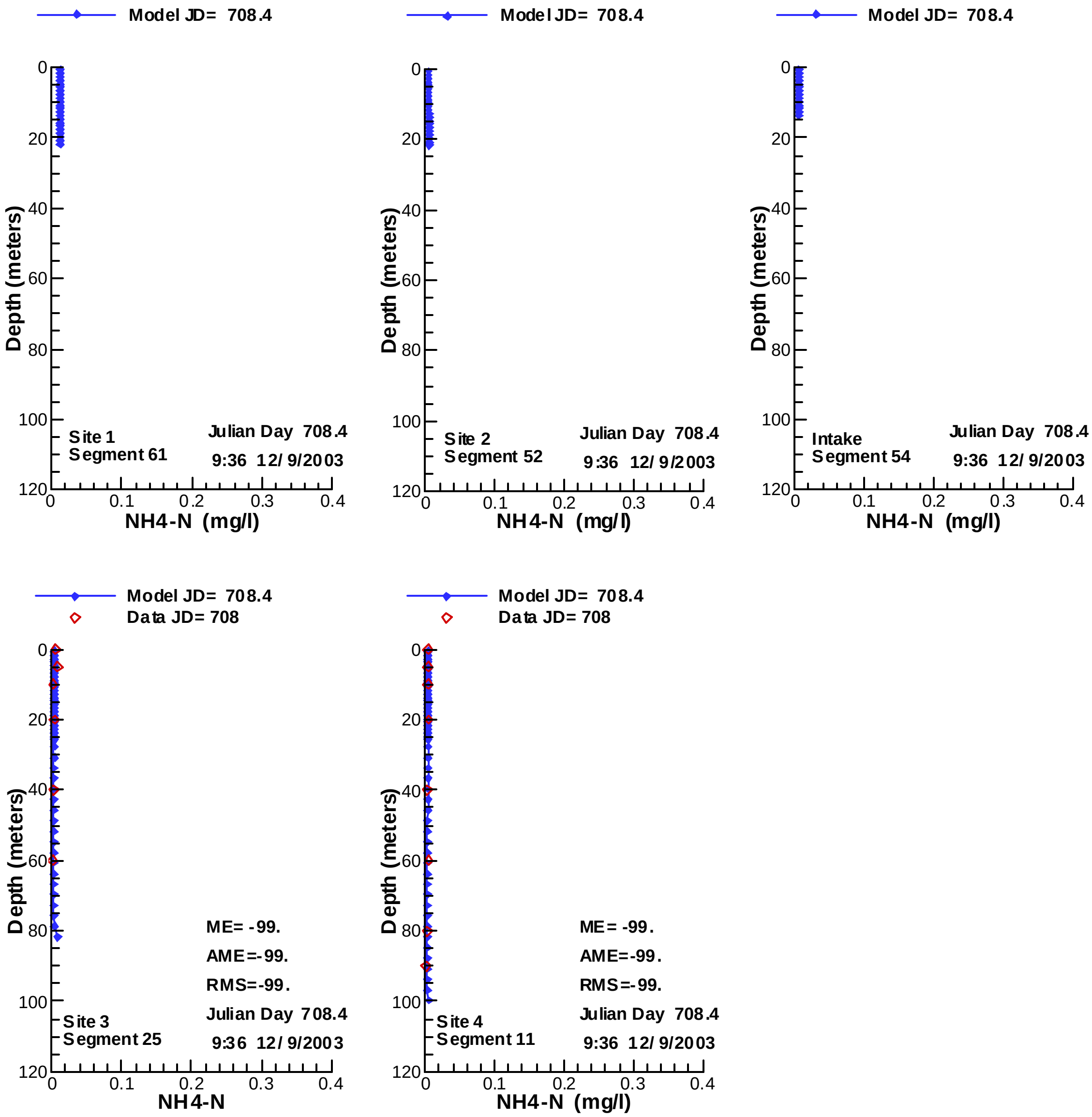

Figure 241. Vertical profiles of NH4-N compared with data for 12/ 9/2003.

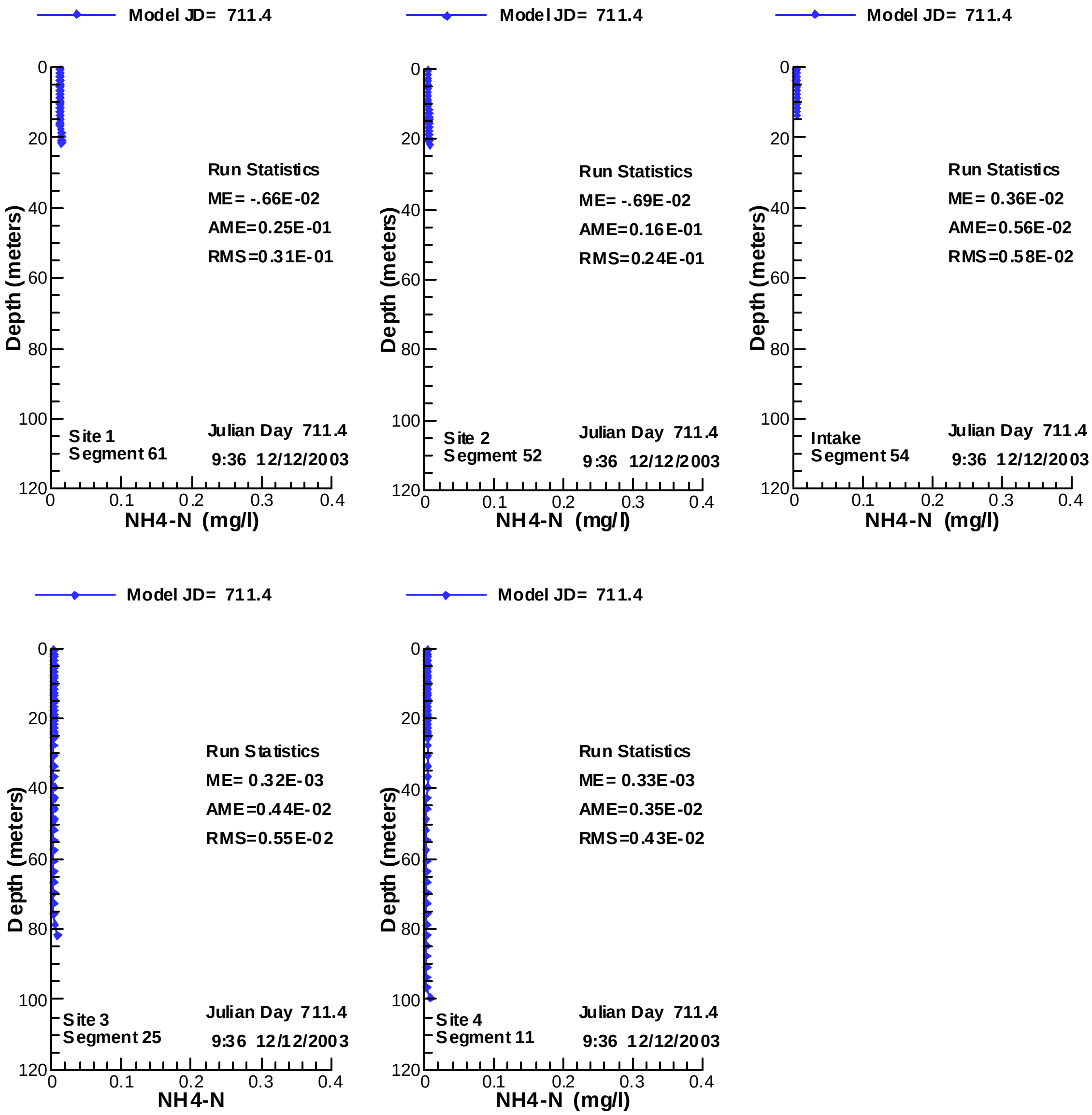

Figure 242. Vertical profiles of NH4-N compared with data for 12/12/2003.

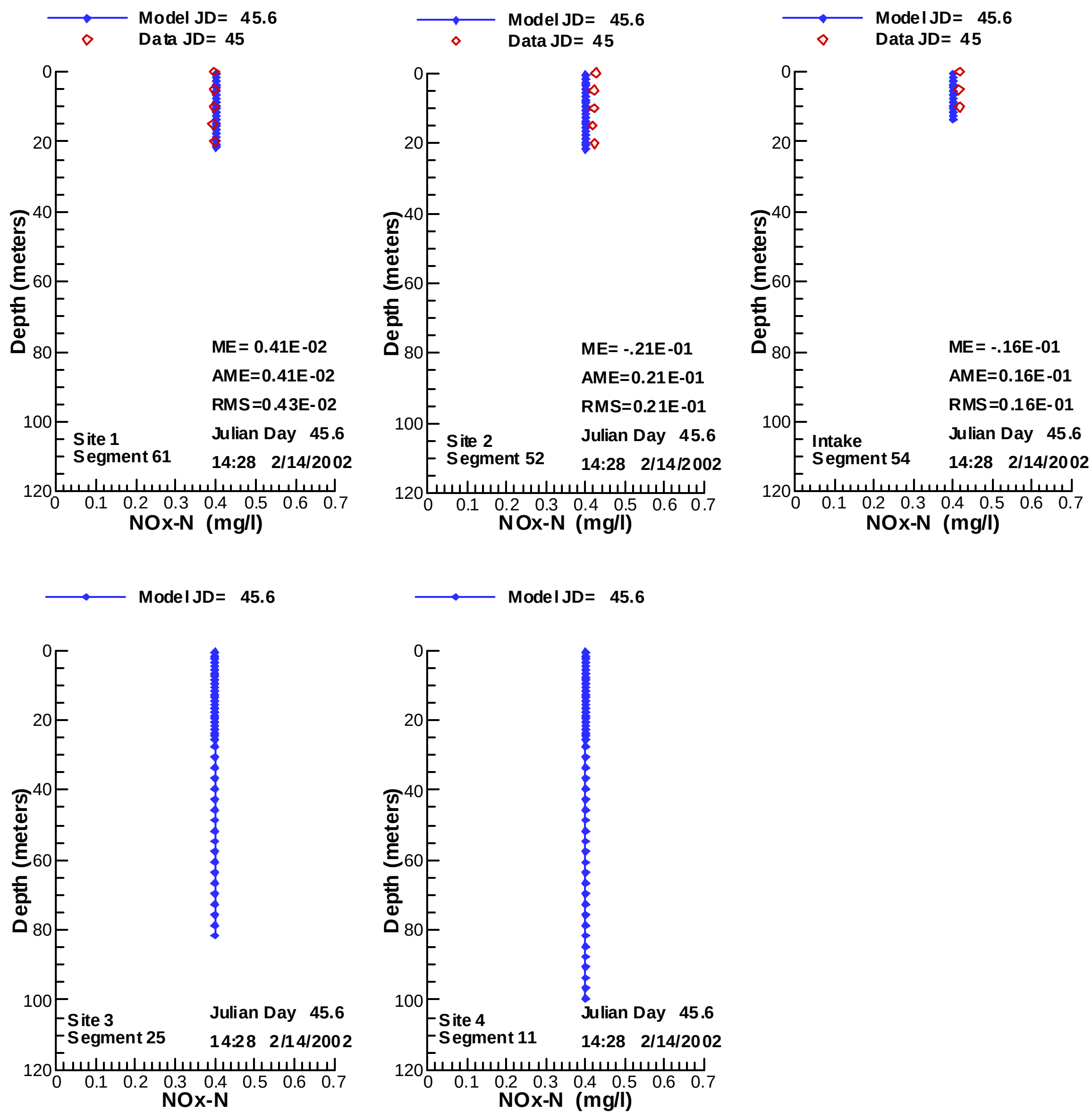

Figure 243. Vertical profiles of NOx-N compared with data for 2/14/2002.

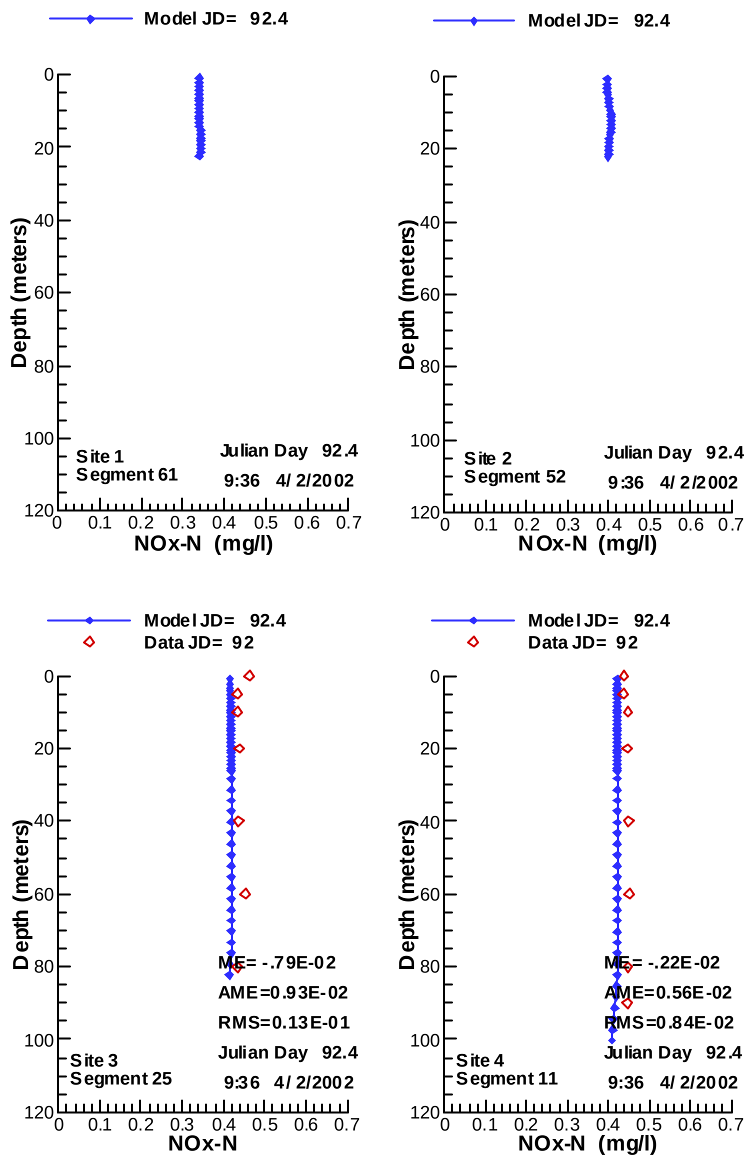

Figure 244. Vertical profiles of NOx-N compared with data for 4/ 2/2002.

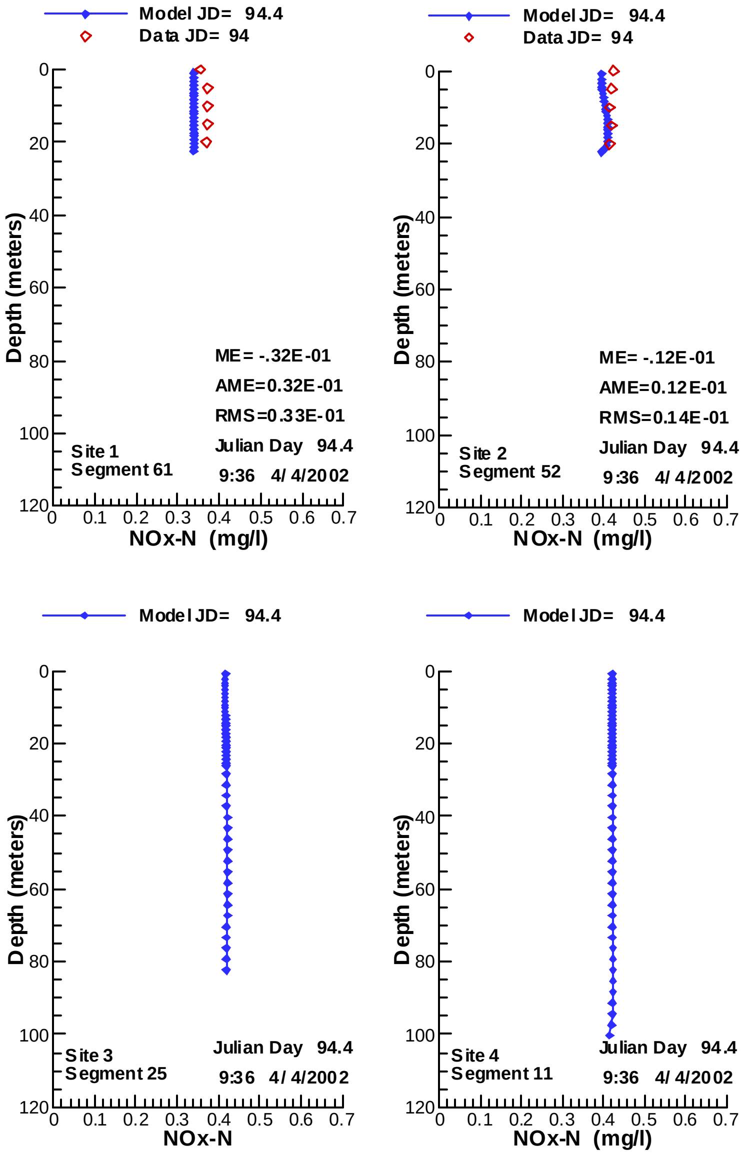

Figure 245. Vertical profiles of NOx-N compared with data for 4/ 4/2002.

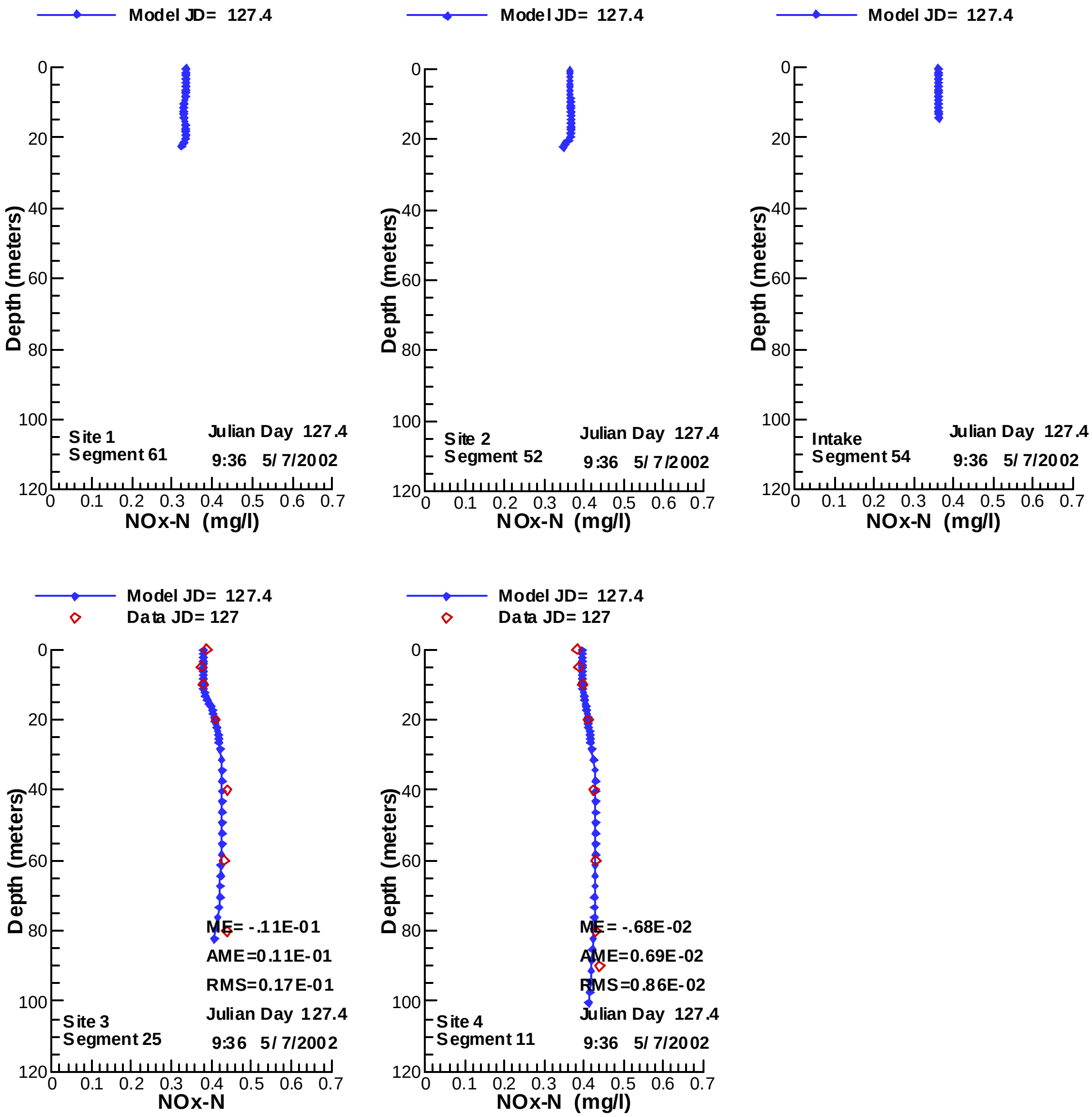

Figure 246. Vertical profiles of NOx-N compared with data for 5/ 7/2002.

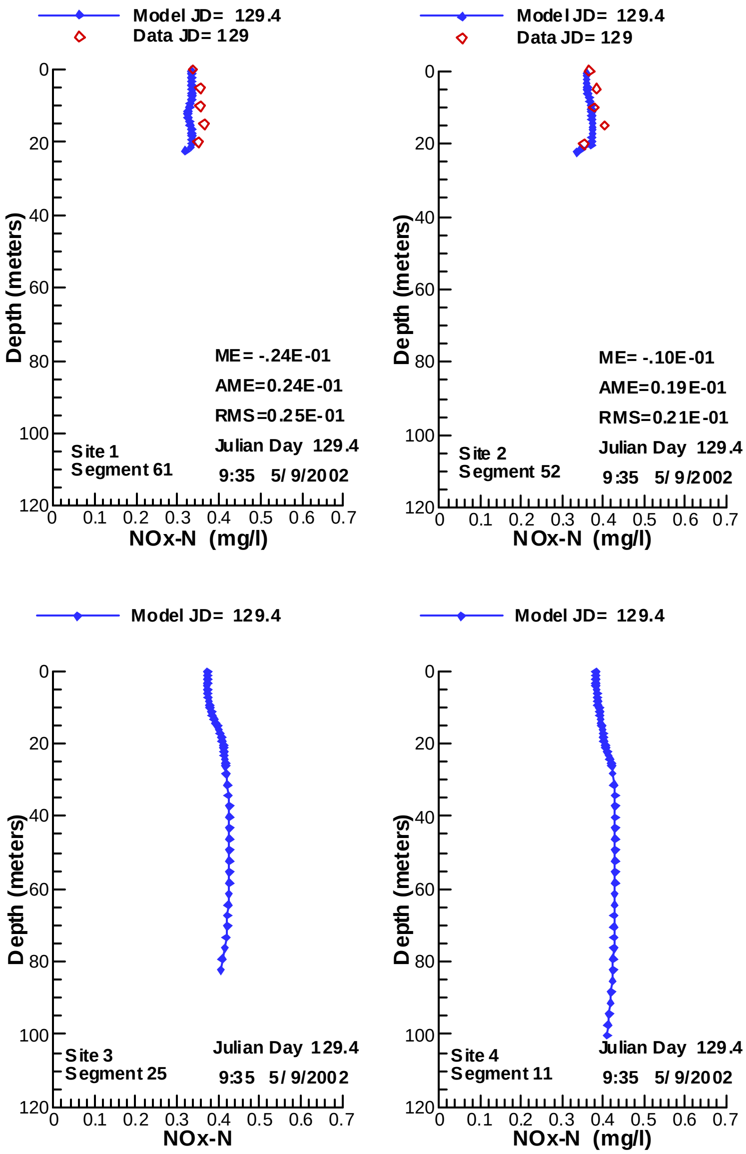

Figure 247. Vertical profiles of NOx-N compared with data for 5/ 9/2002.

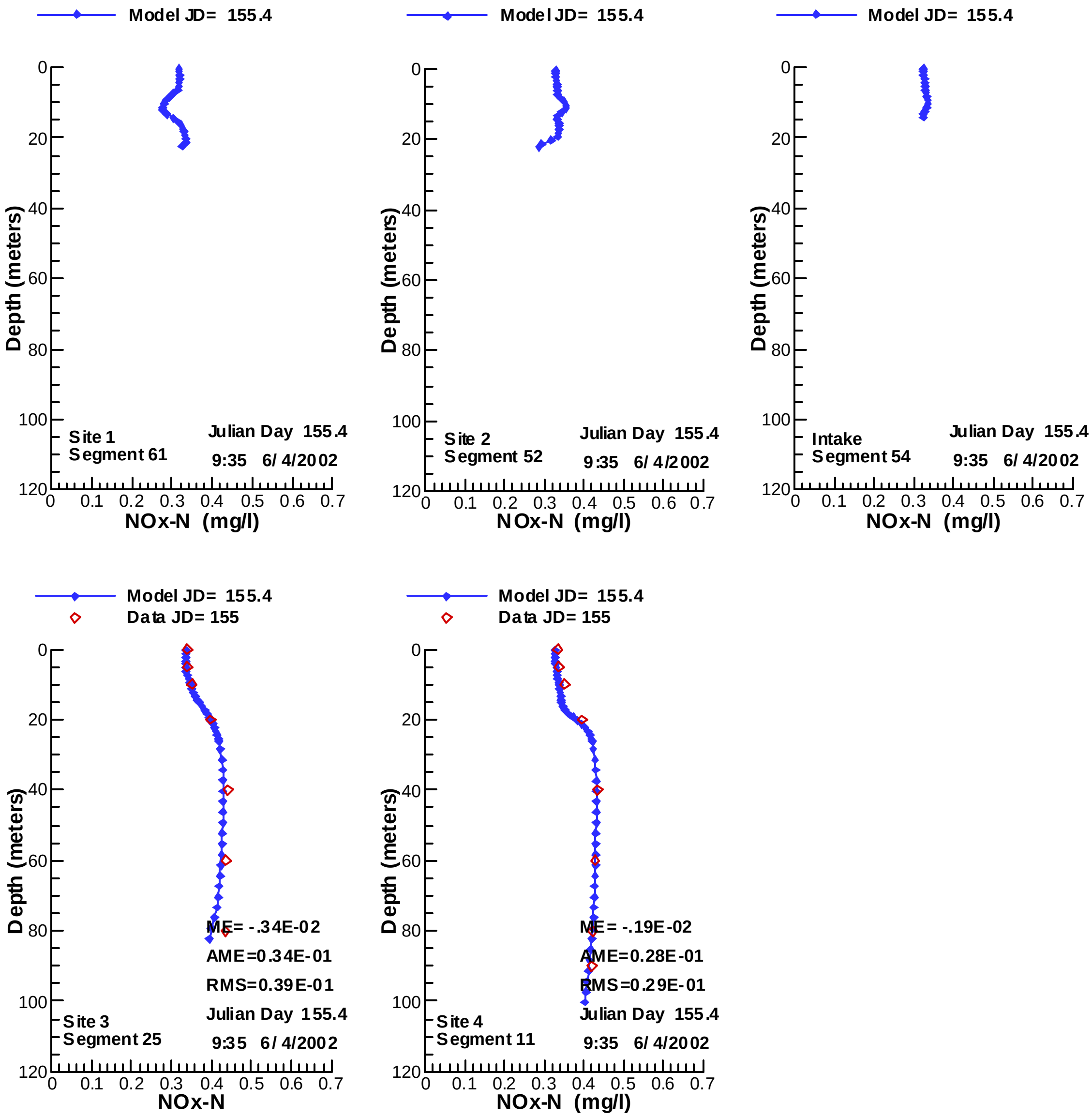

Figure 248. Vertical profiles of NOx-N compared with data for 6/ 4/2002.

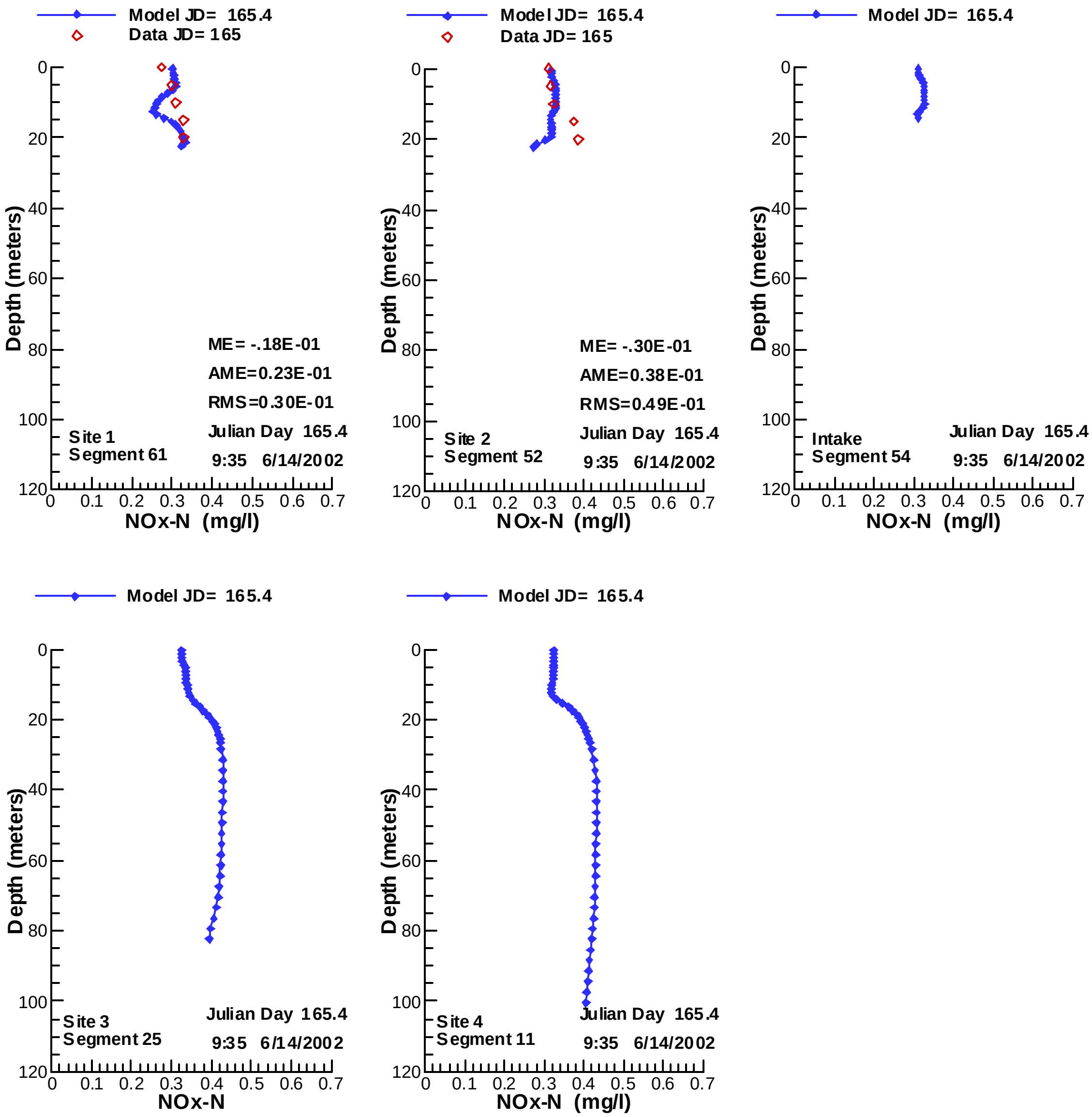

Figure 249. Vertical profiles of NOx-N compared with data for 6/14/2002.

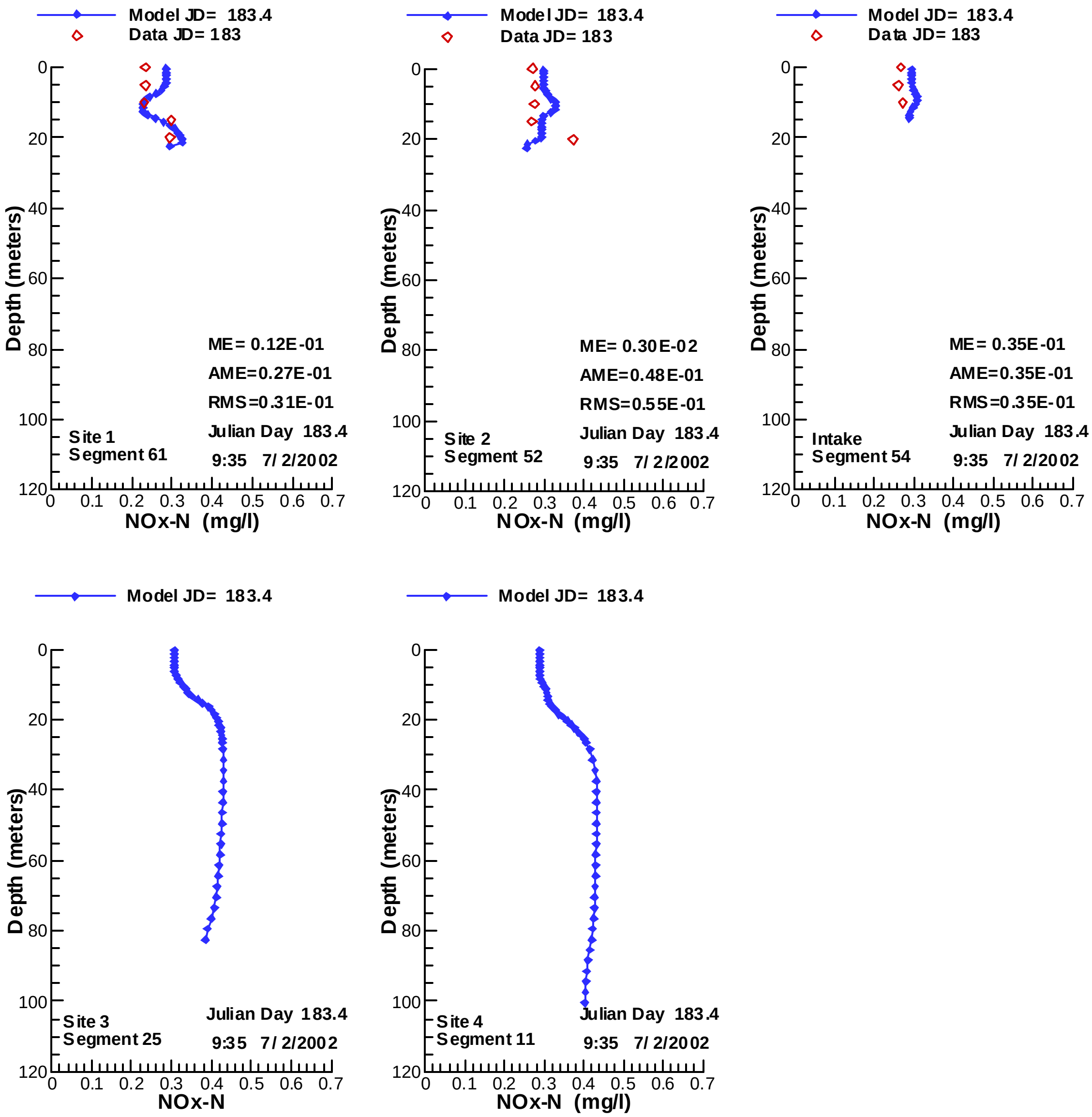

Figure 250. Vertical profiles of NOx-N compared with data for 7/ 2/2002.

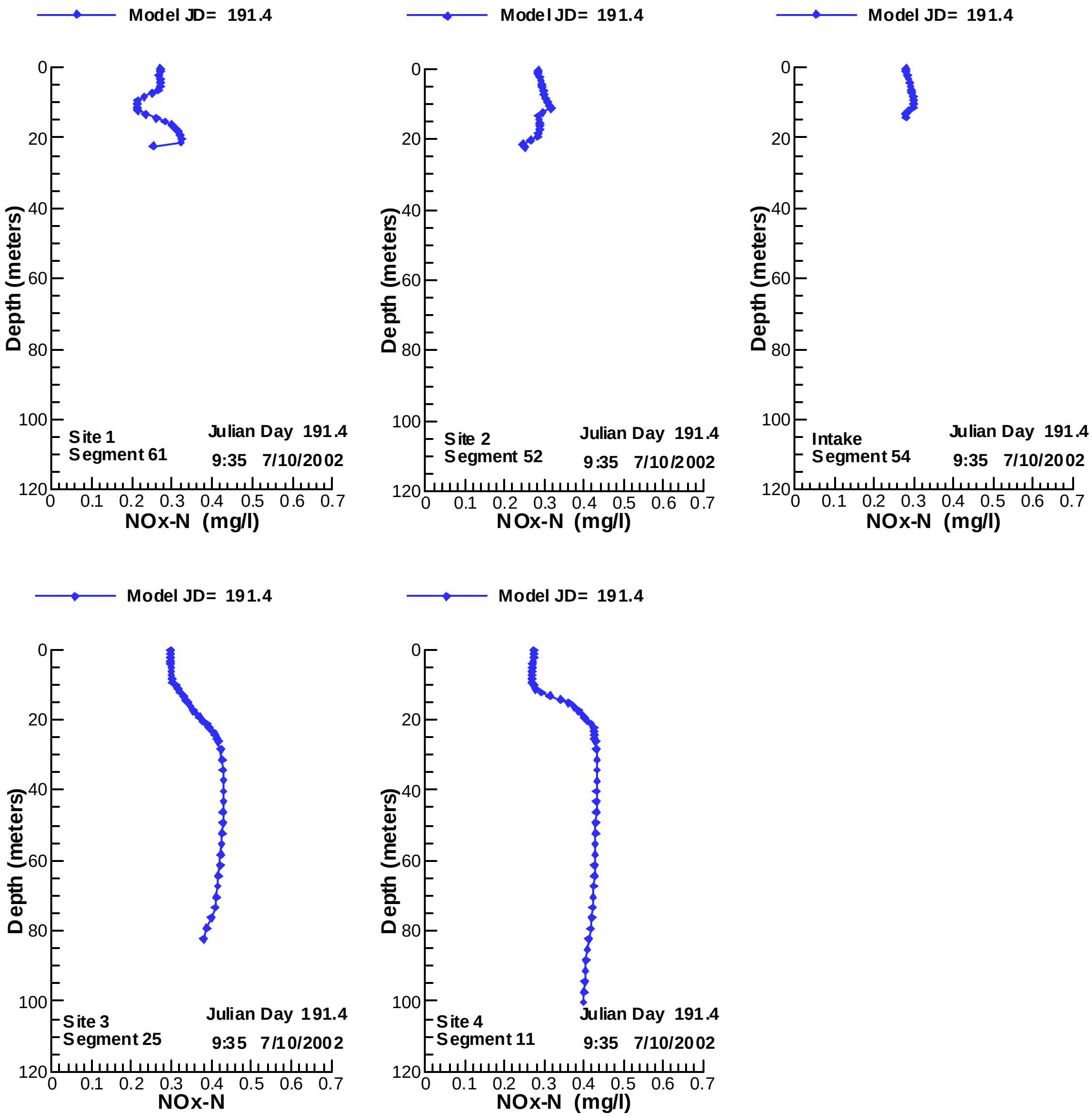

Figure 251. Vertical profiles of NOx-N compared with data for 7/10/2002.

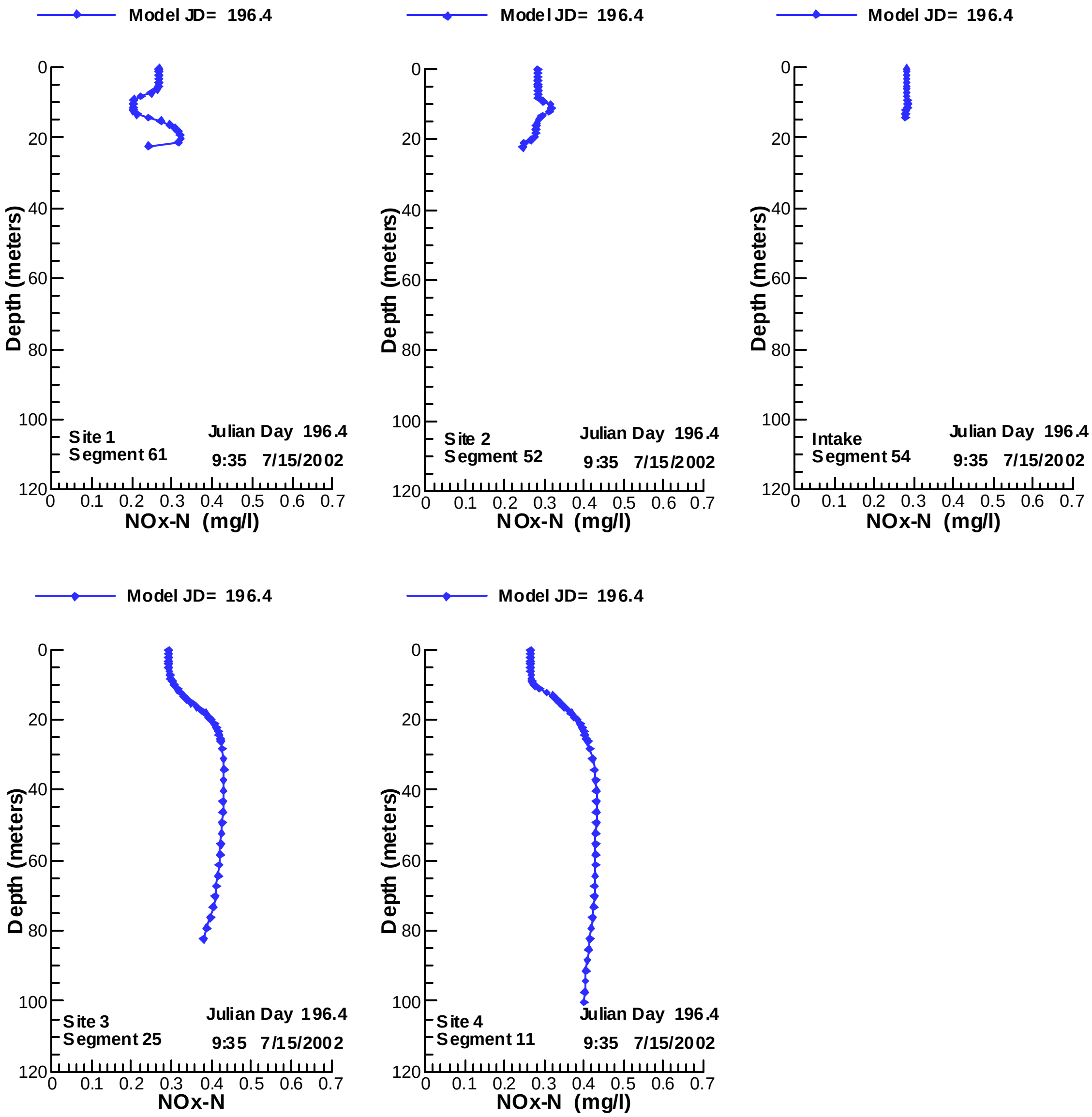

Figure 252. Vertical profiles of NOx-N compared with data for 7/15/2002.

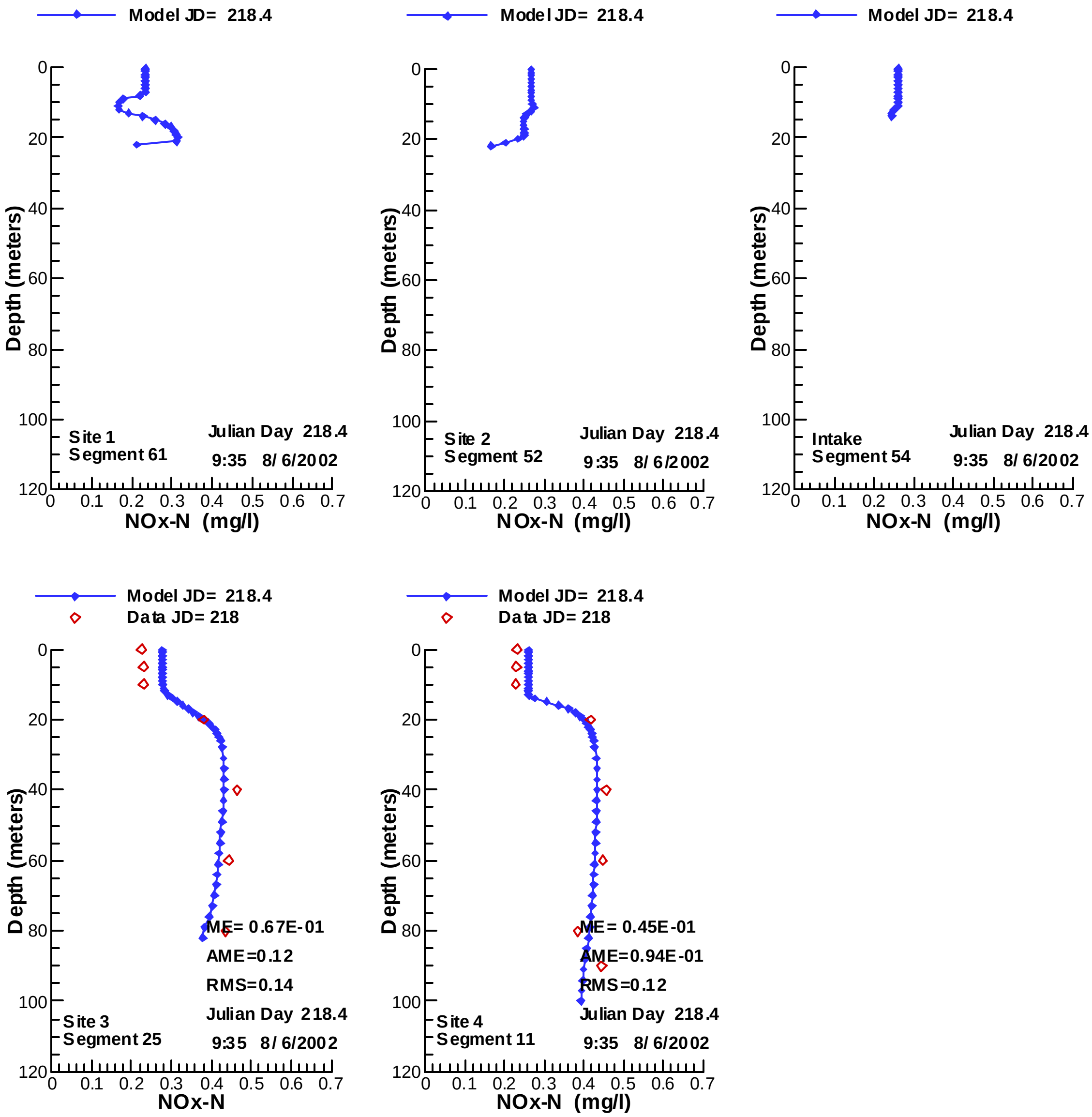

Figure 253. Vertical profiles of NOx-N compared with data for 8/ 6/2002.

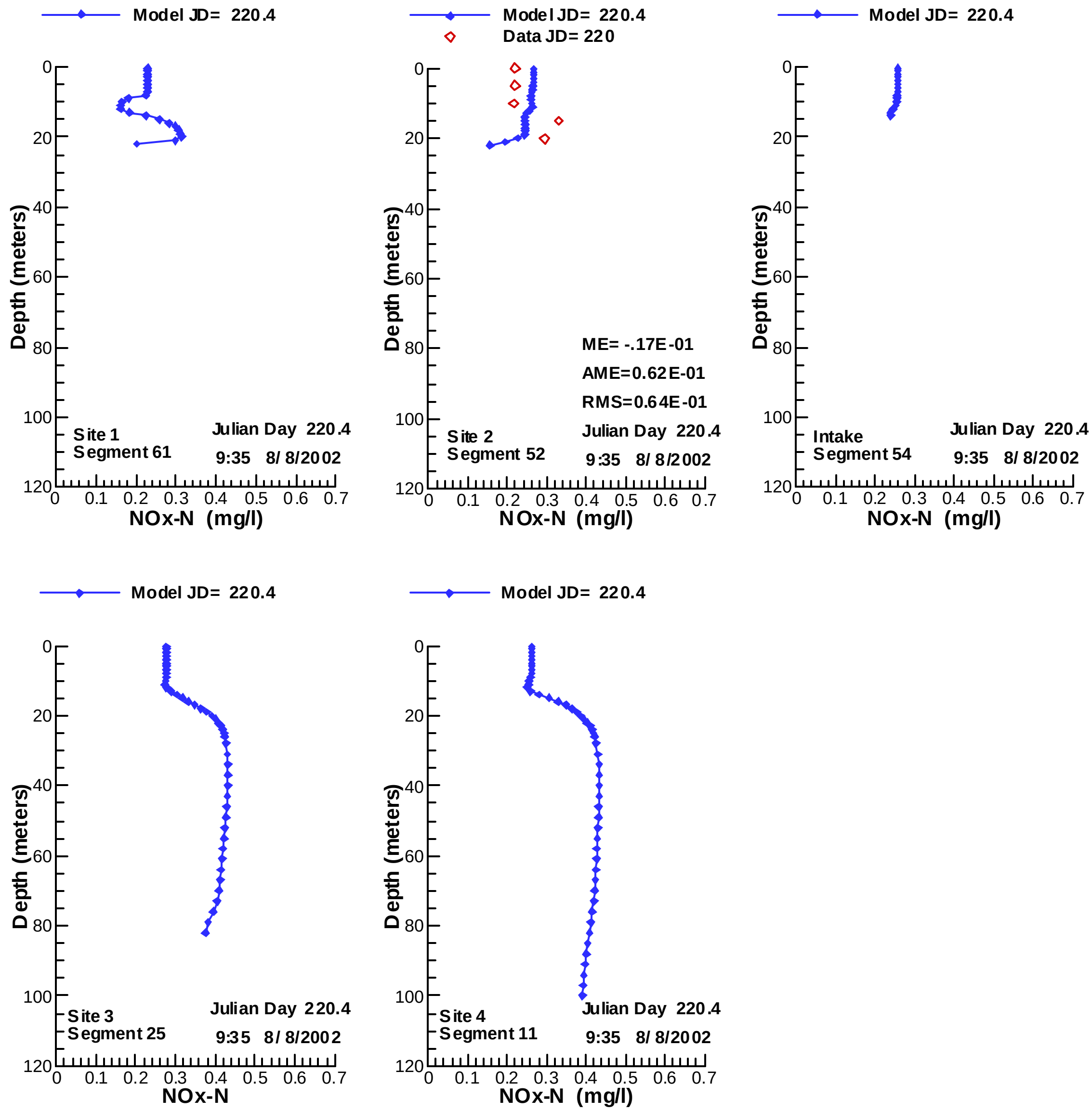

Figure 254. Vertical profiles of NOx-N compared with data for 8/ 8/2002.

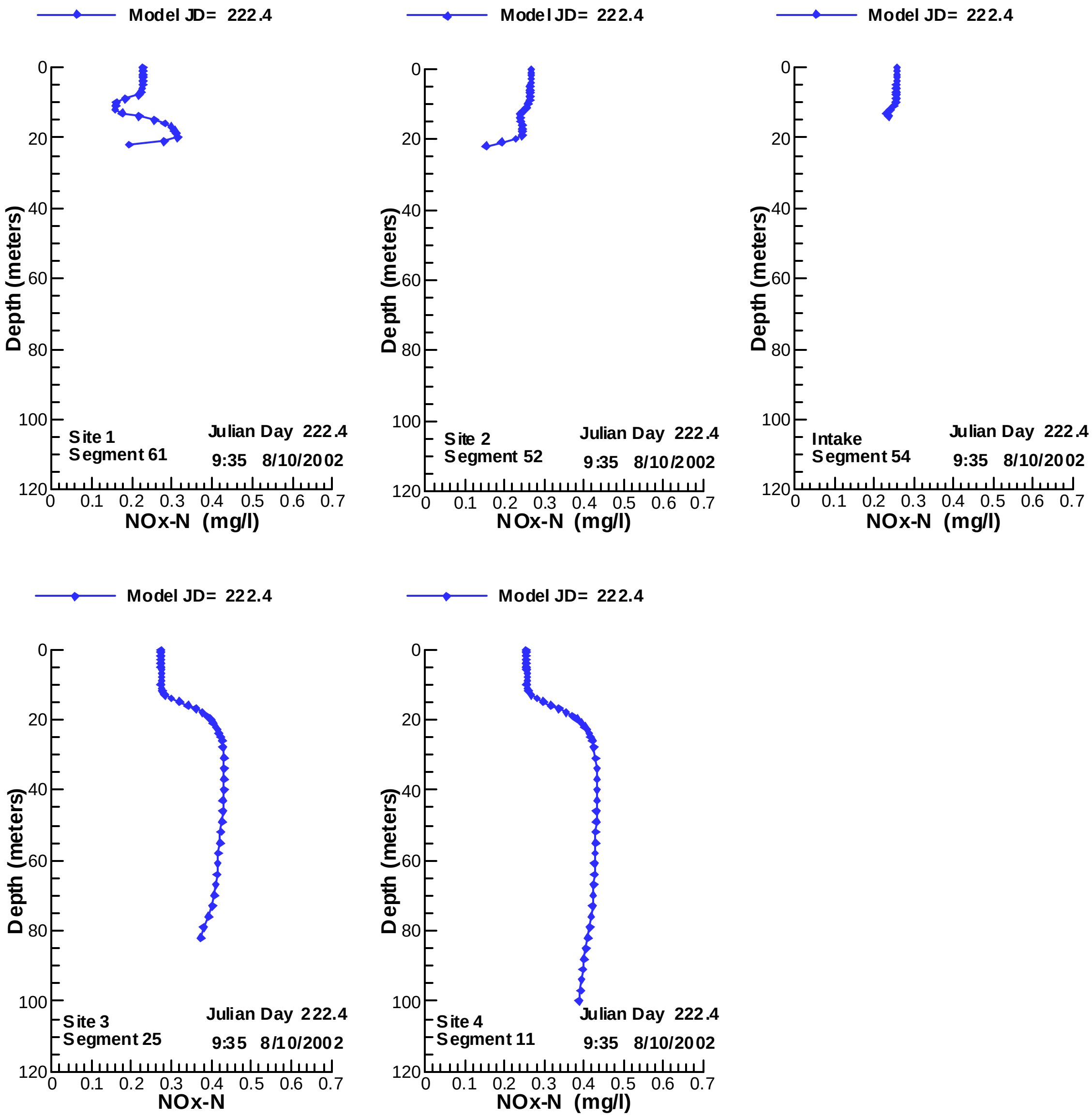

Figure 255. Vertical profiles of NOx-N compared with data for 8/10/2002.

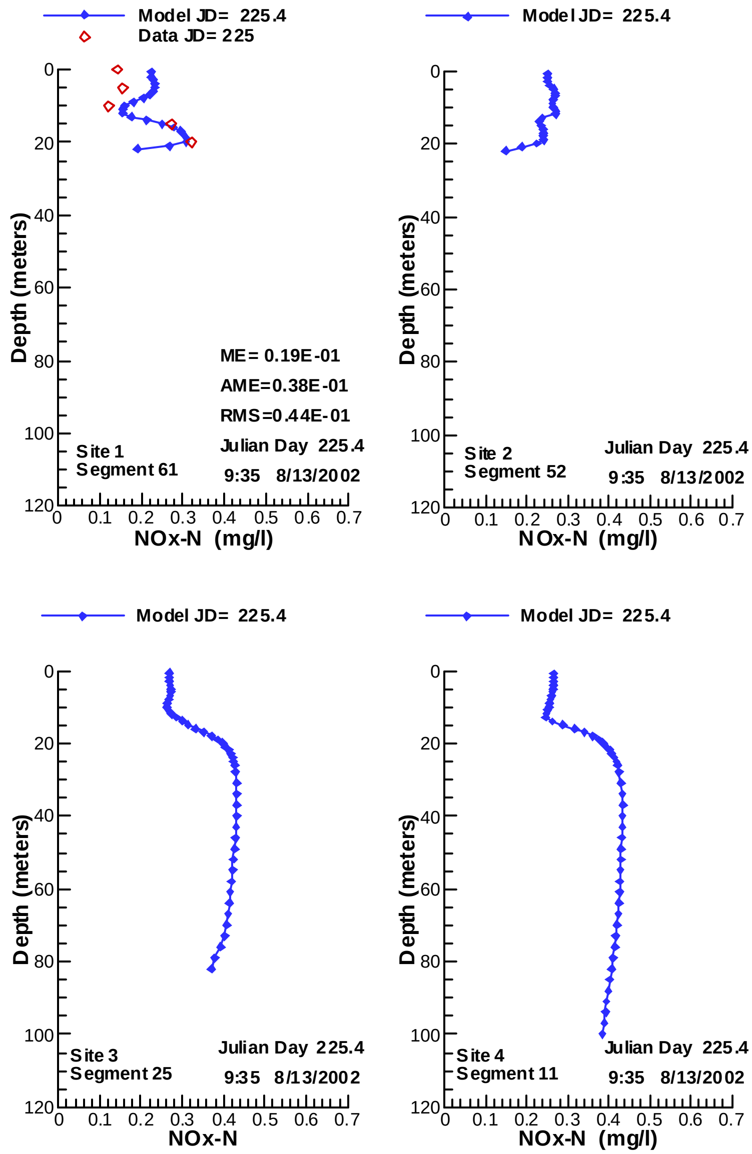

Figure 256. Vertical profiles of NOx-N compared with data for 8/13/2002.

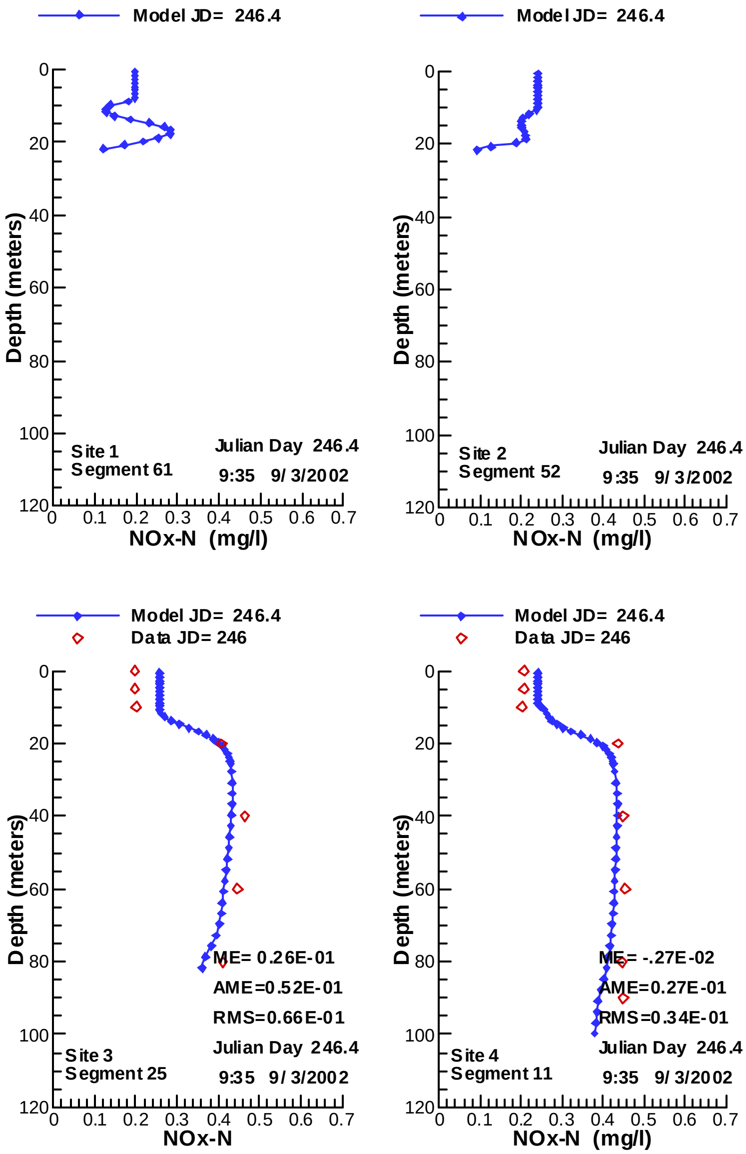

Figure 257. Vertical profiles of NOx-N compared with data for 9/ 3/2002.

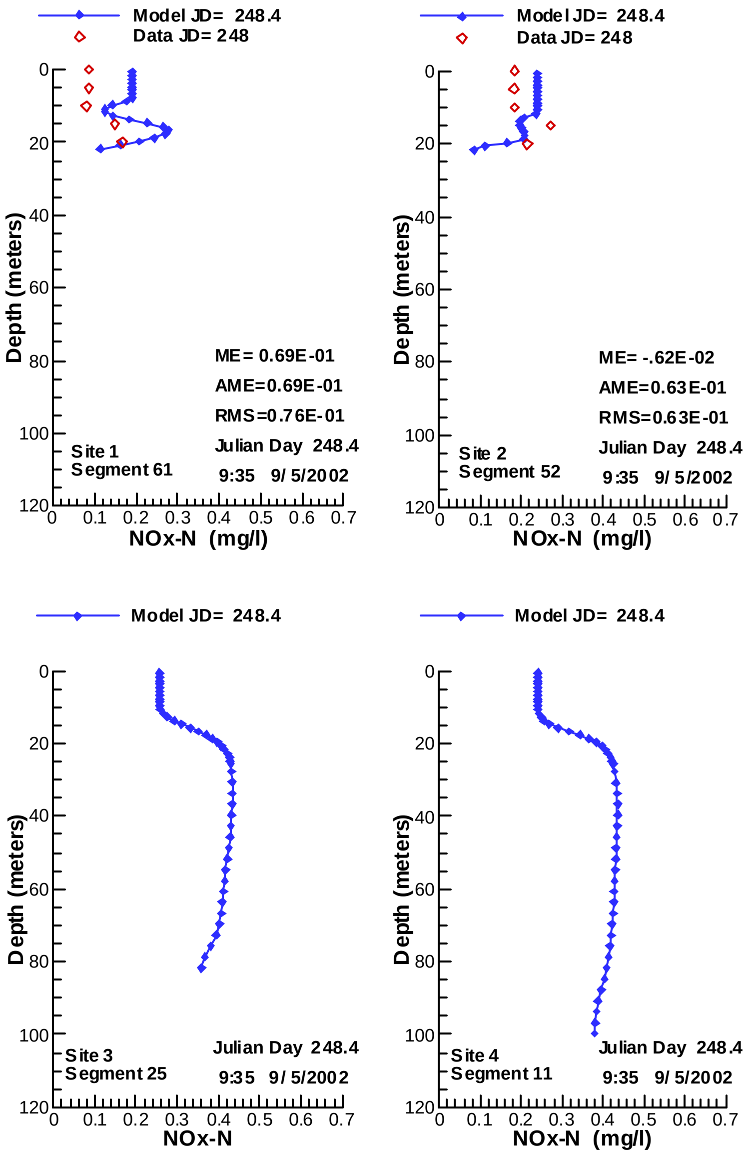

Figure 258. Vertical profiles of NOx-N compared with data for 9/ 5/2002.

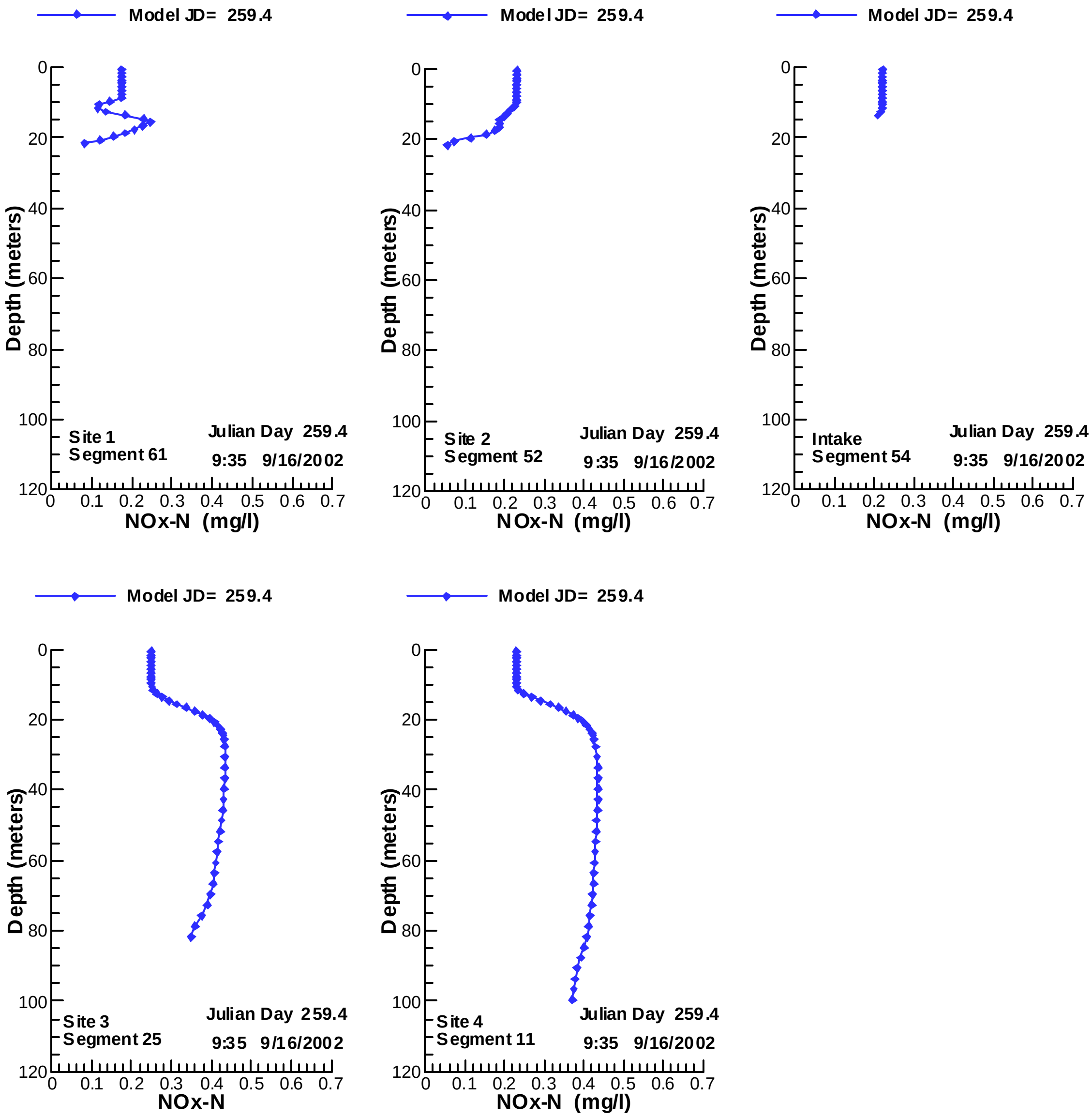

Figure 259. Vertical profiles of NOx-N compared with data for 9/16/2002.

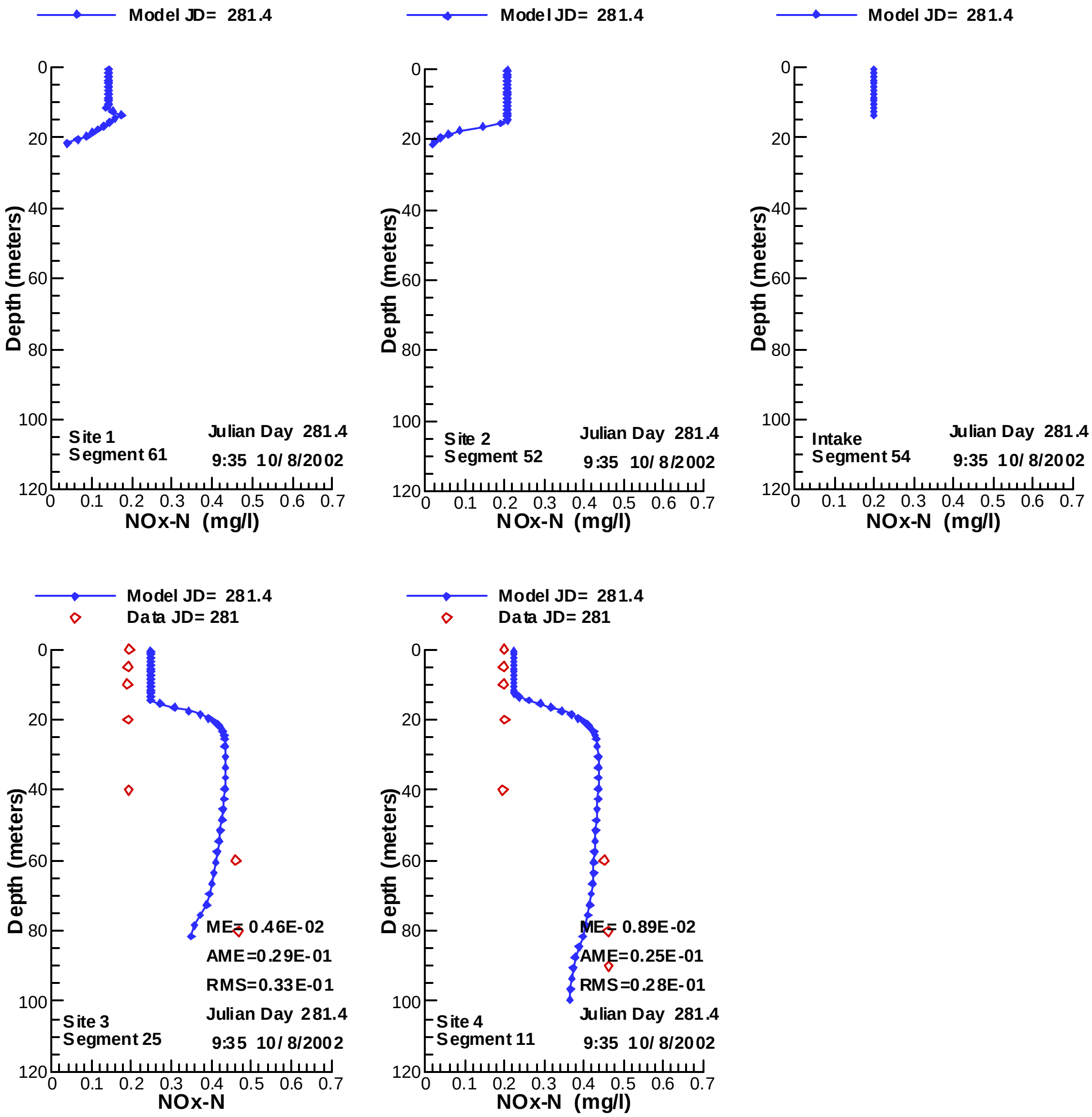

Figure 260. Vertical profiles of NOx-N compared with data for 10/ 8/2002.

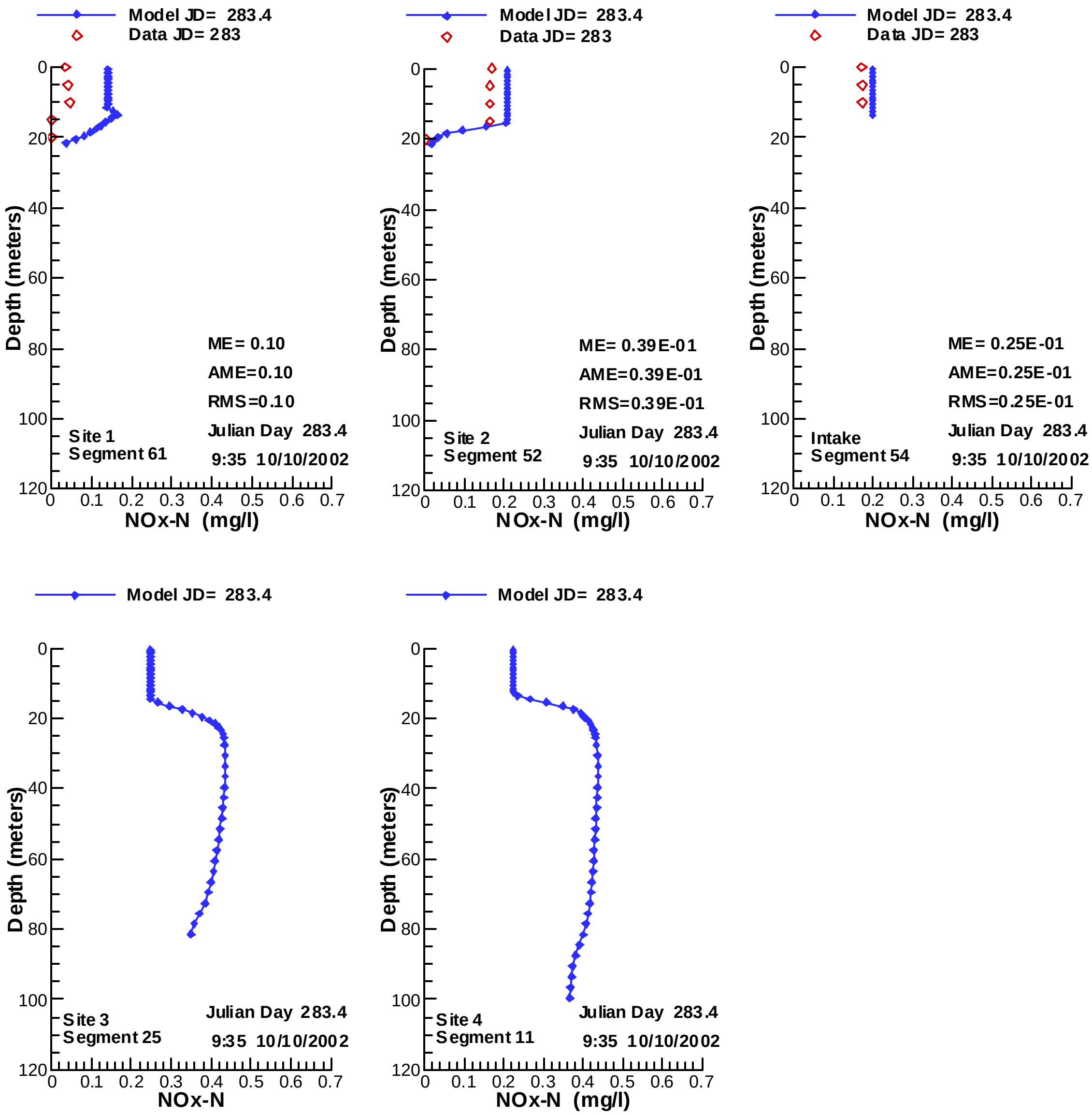

Figure 261. Vertical profiles of NOx-N compared with data for 10/10/2002.

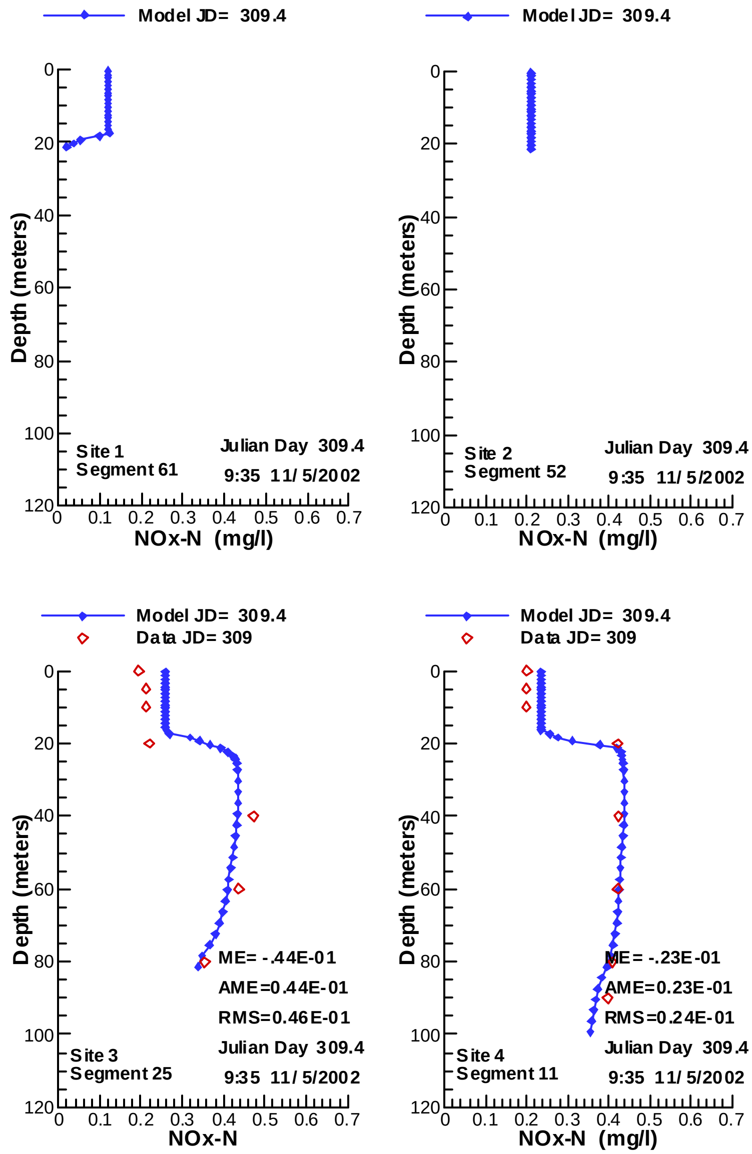

Figure 262. Vertical profiles of NOx-N compared with data for 11/ 5/2002.

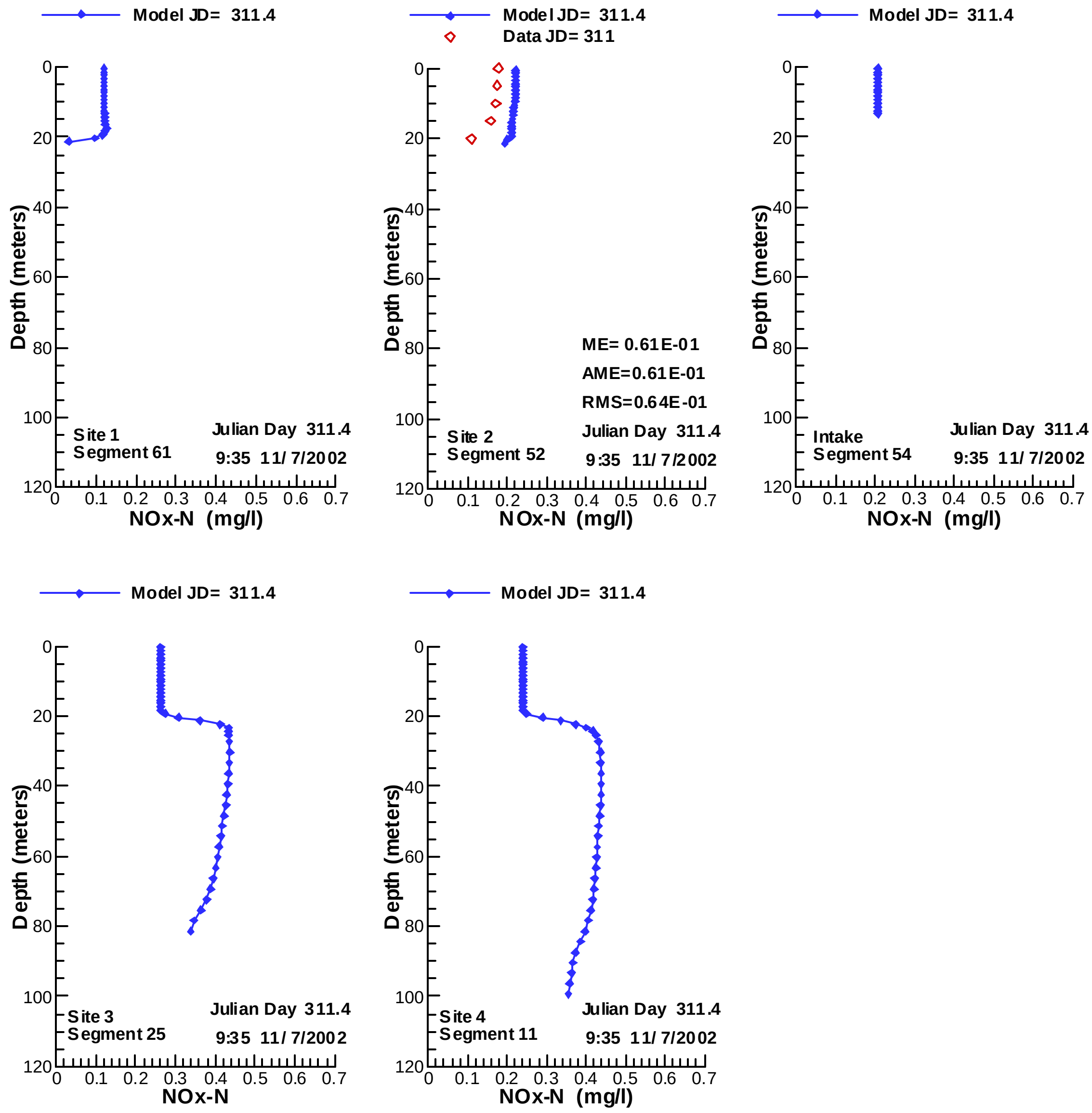

Figure 263. Vertical profiles of NOx-N compared with data for 11/ 7/2002.

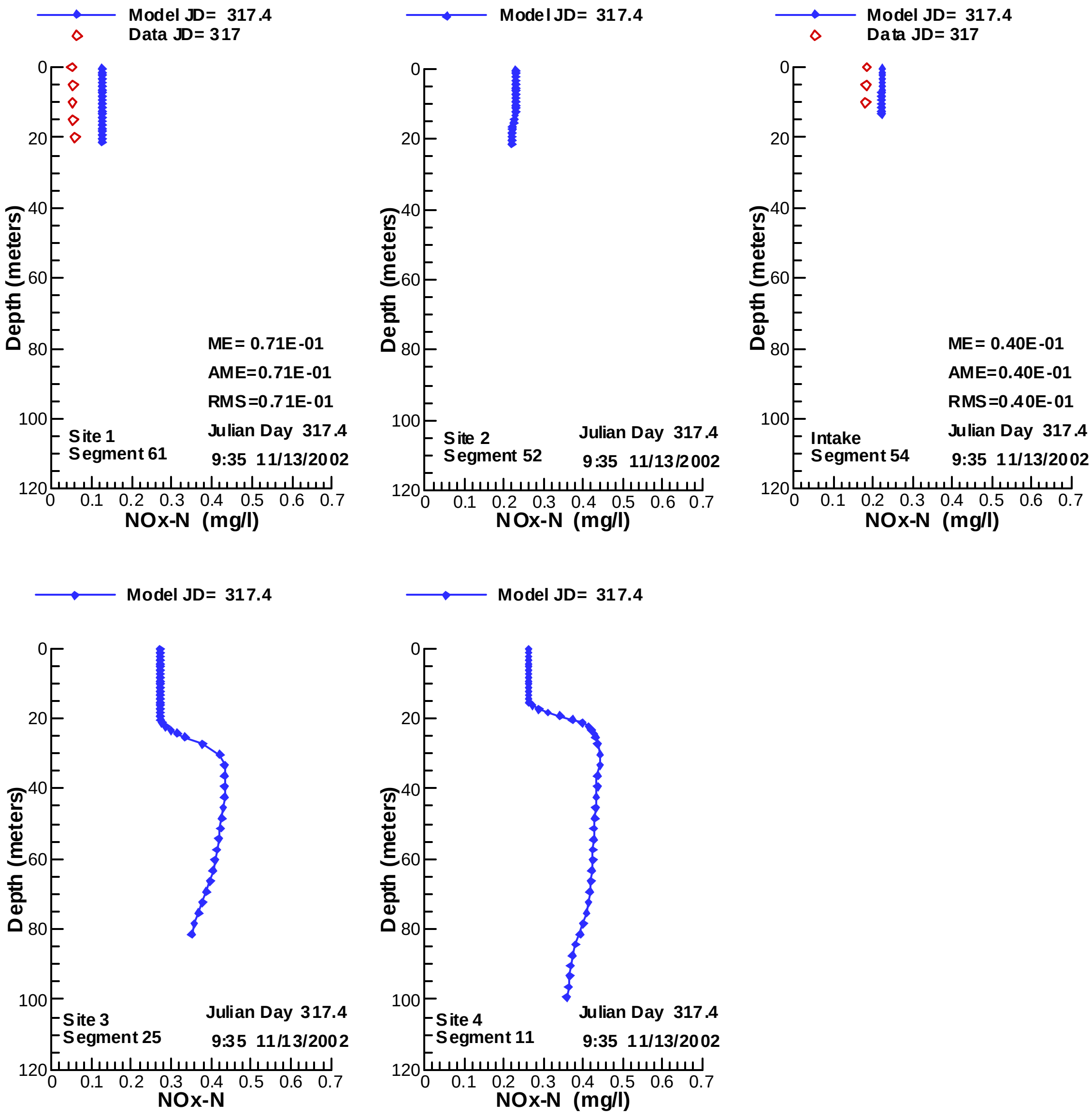

Figure 264. Vertical profiles of NOx-N compared with data for 11/13/2002.

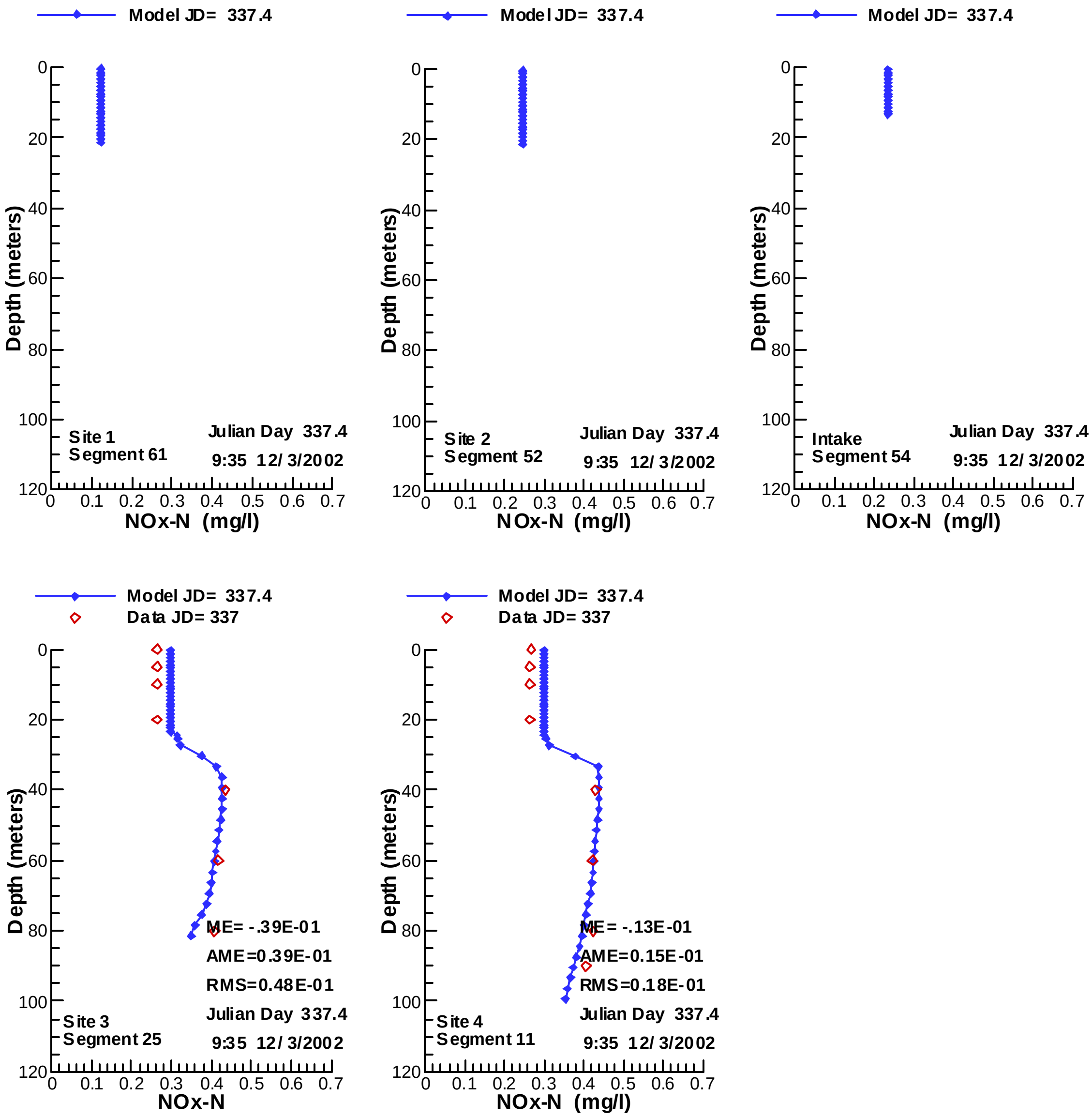

Figure 265. Vertical profiles of NOx-N compared with data for 12/ 3/2002.

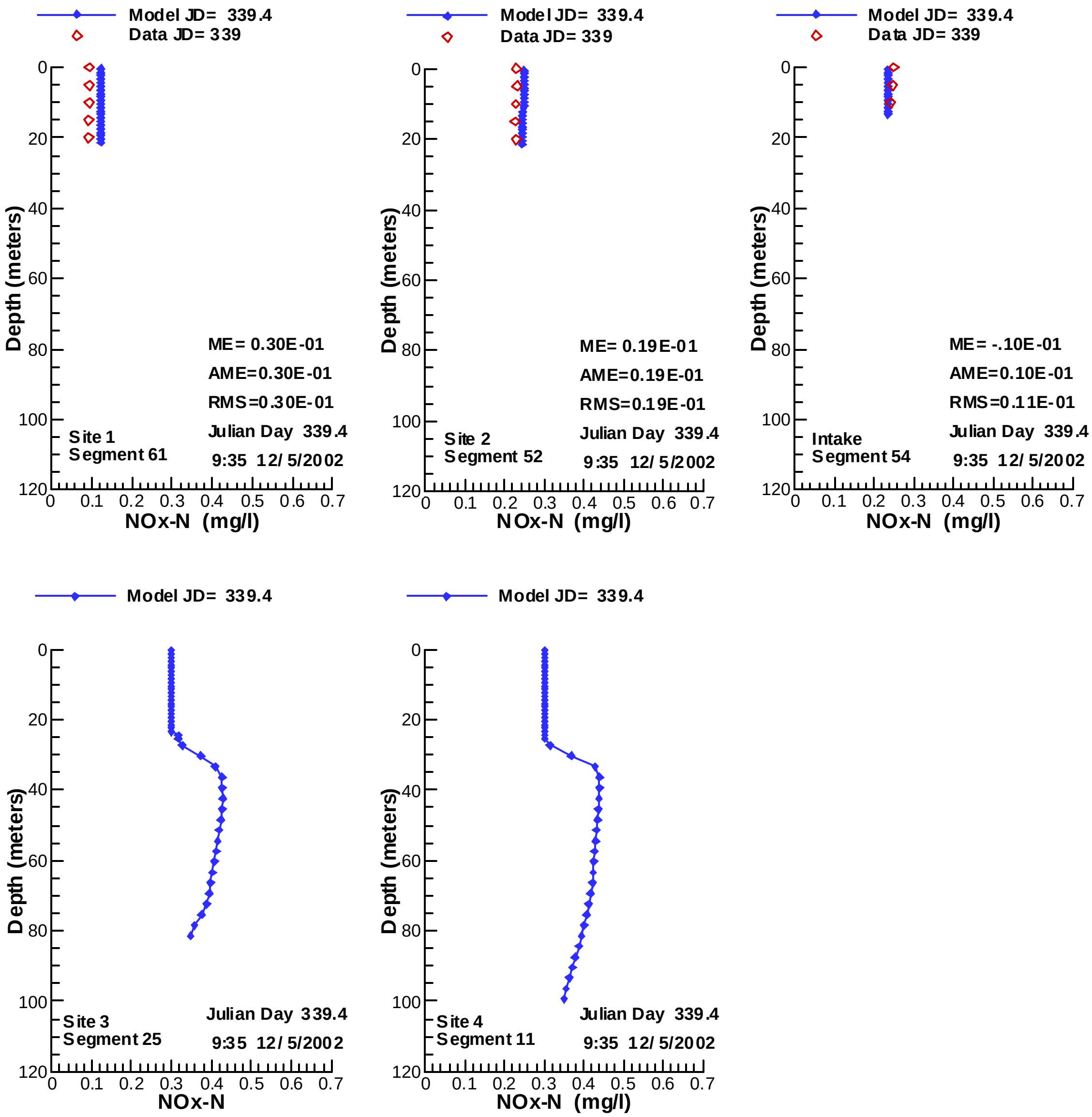

Figure 266. Vertical profiles of NOx-N compared with data for 12/ 5/2002.

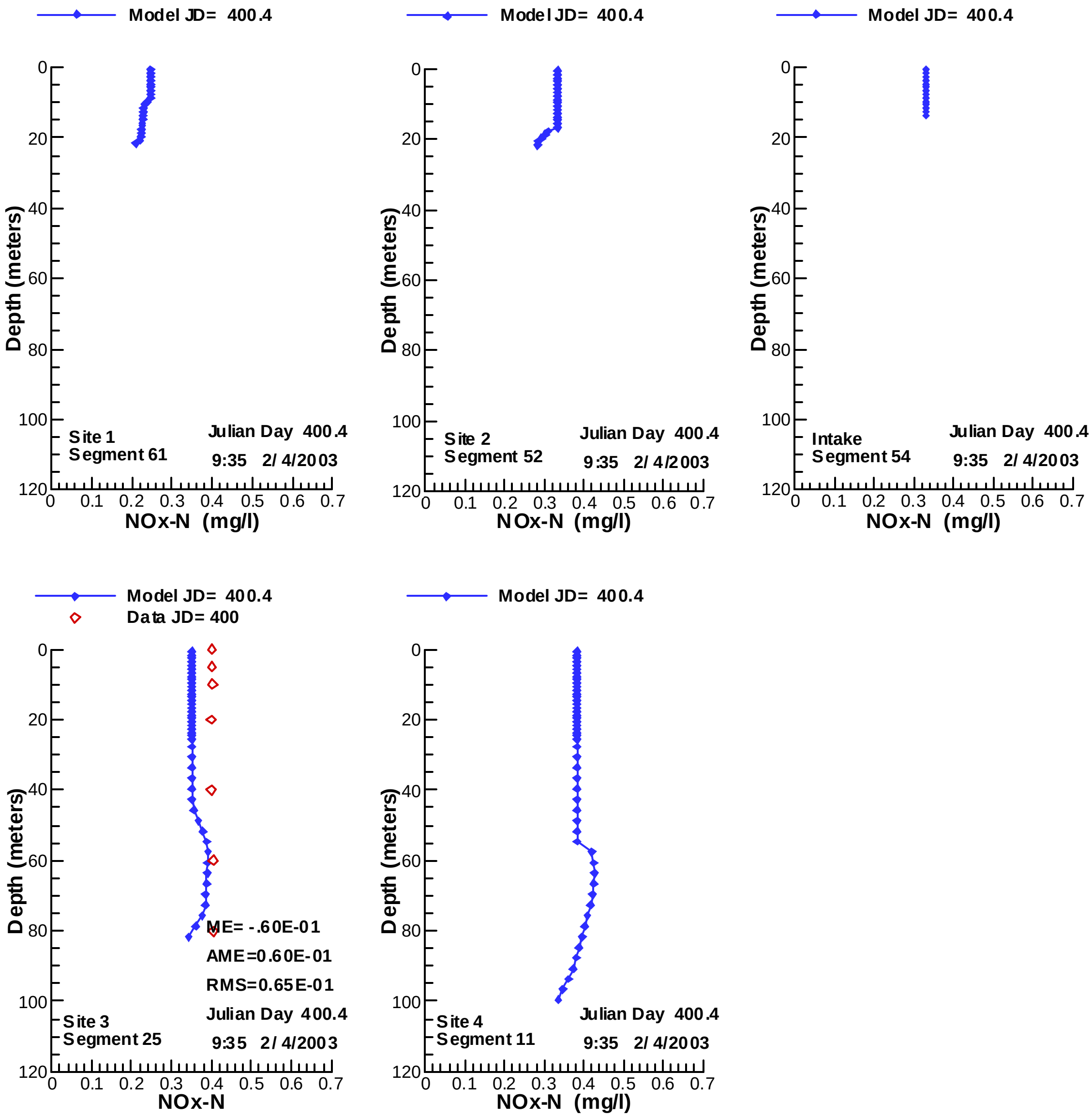

Figure 267. Vertical profiles of NOx-N compared with data for 2/ 4/2003.

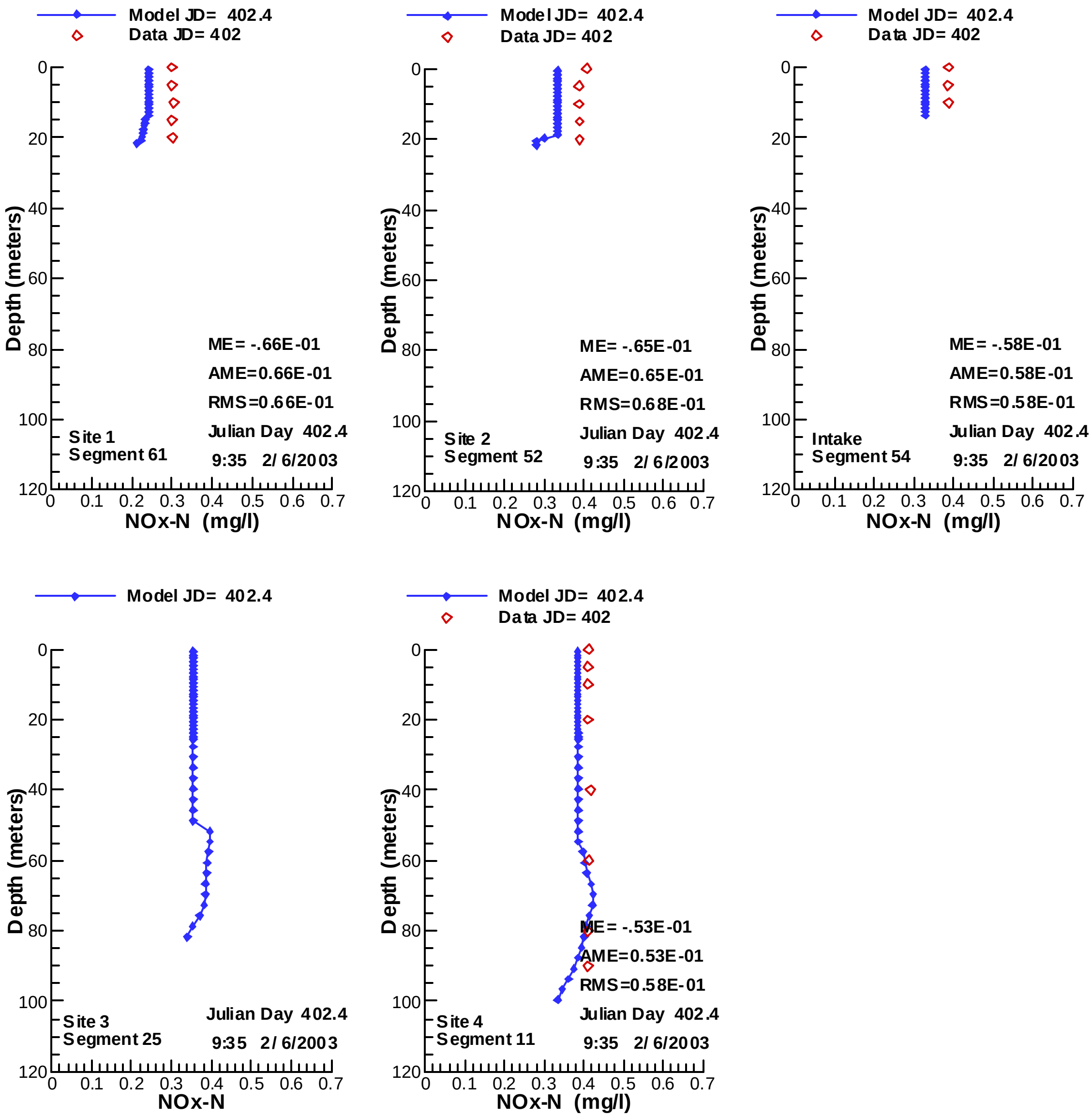

Figure 268. Vertical profiles of NOx-N compared with data for 2/ 6/2003.

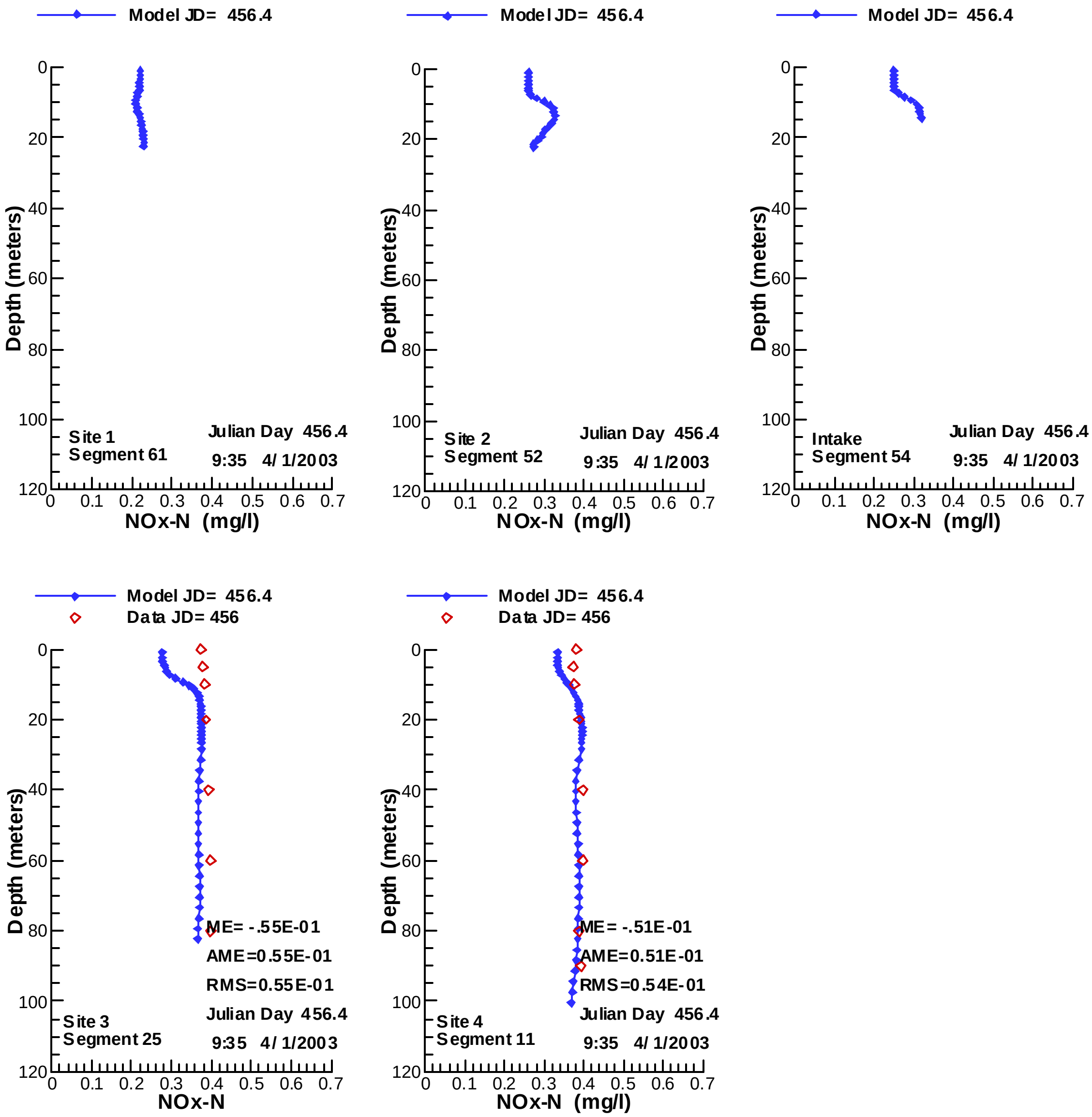

Figure 269. Vertical profiles of NOx-N compared with data for 4/ 1/2003.

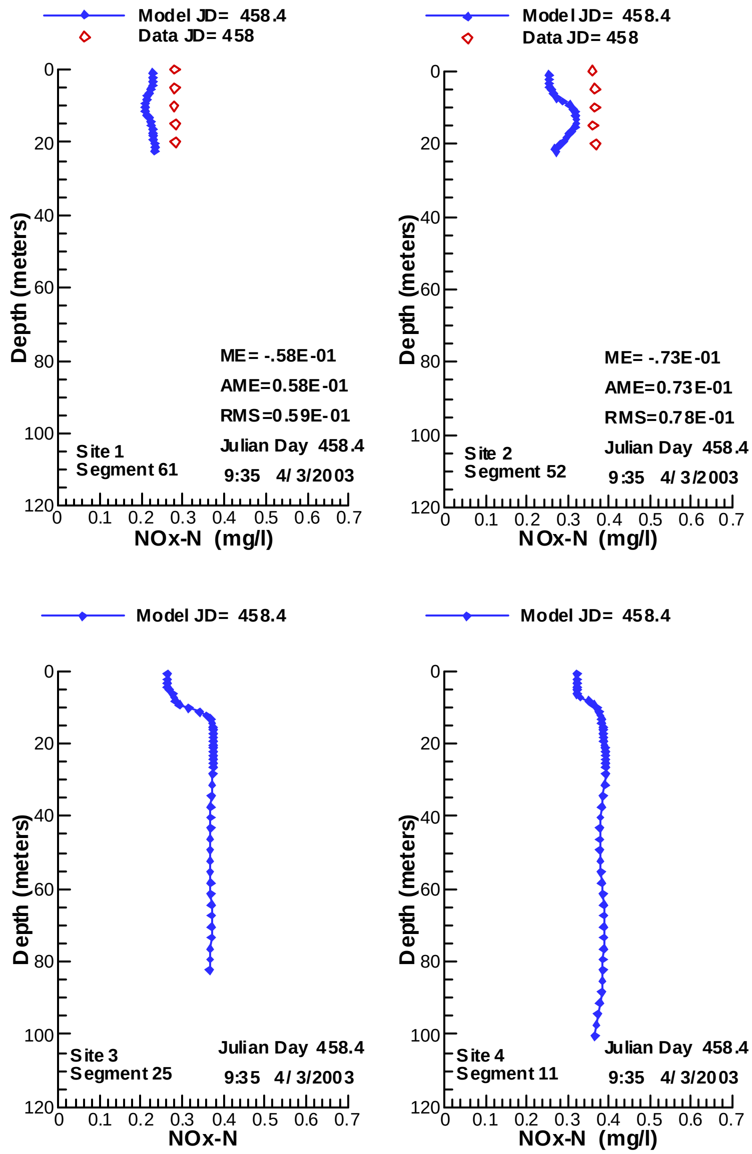

Figure 270. Vertical profiles of NOx-N compared with data for 4/ 3/2003.

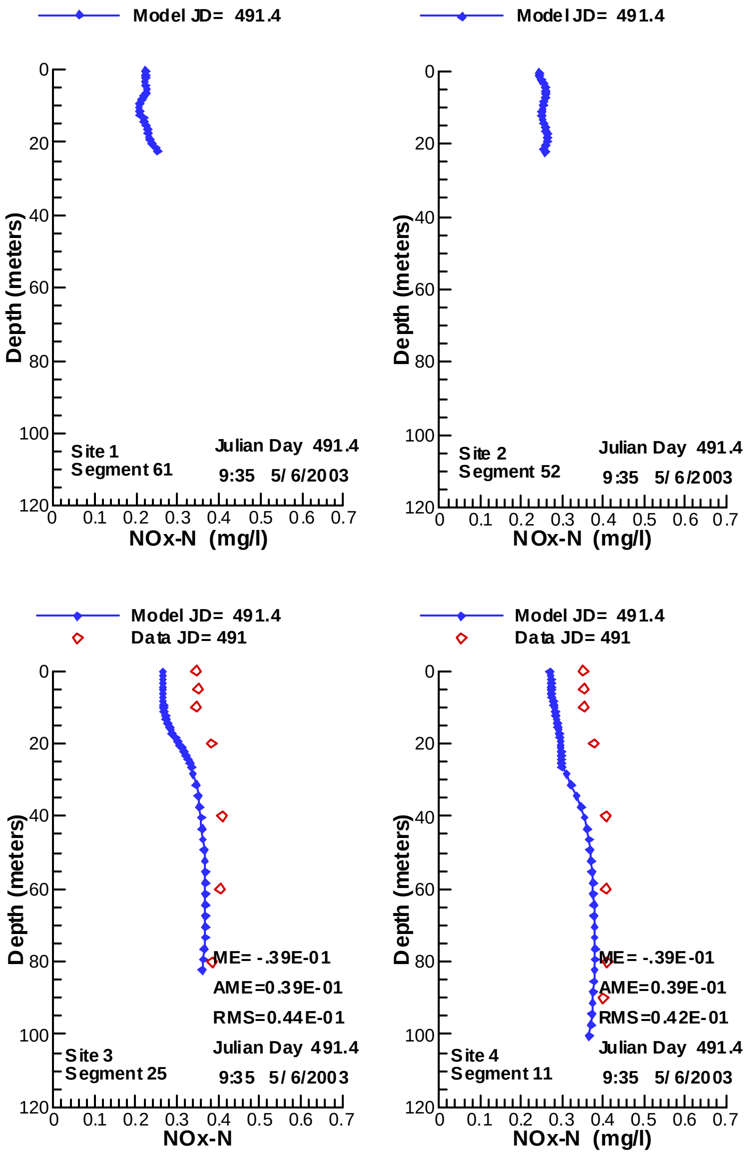

Figure 271. Vertical profiles of NOx-N compared with data for 5/ 6/2003.

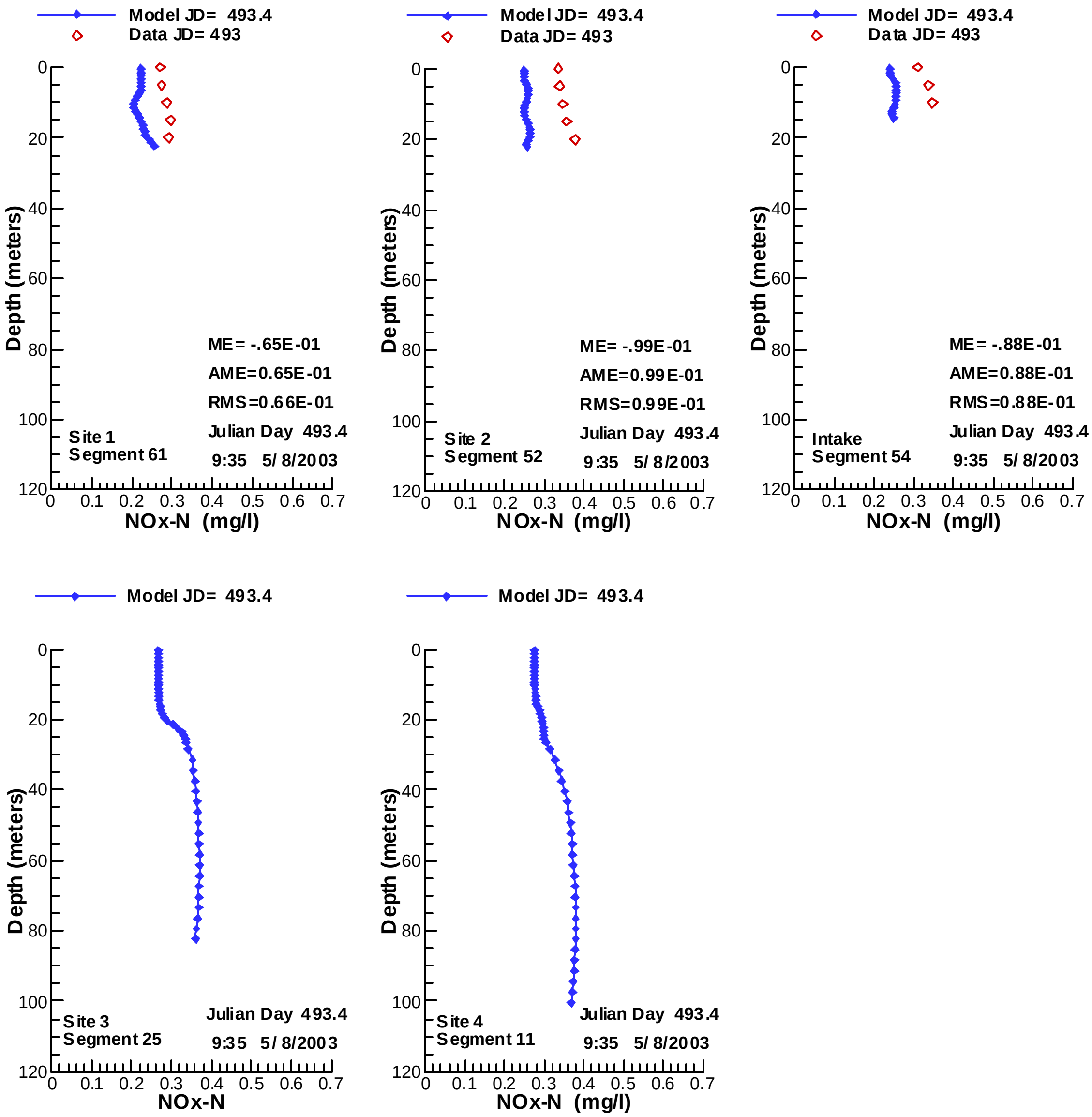

Figure 272. Vertical profiles of NOx-N compared with data for 5/ 8/2003.

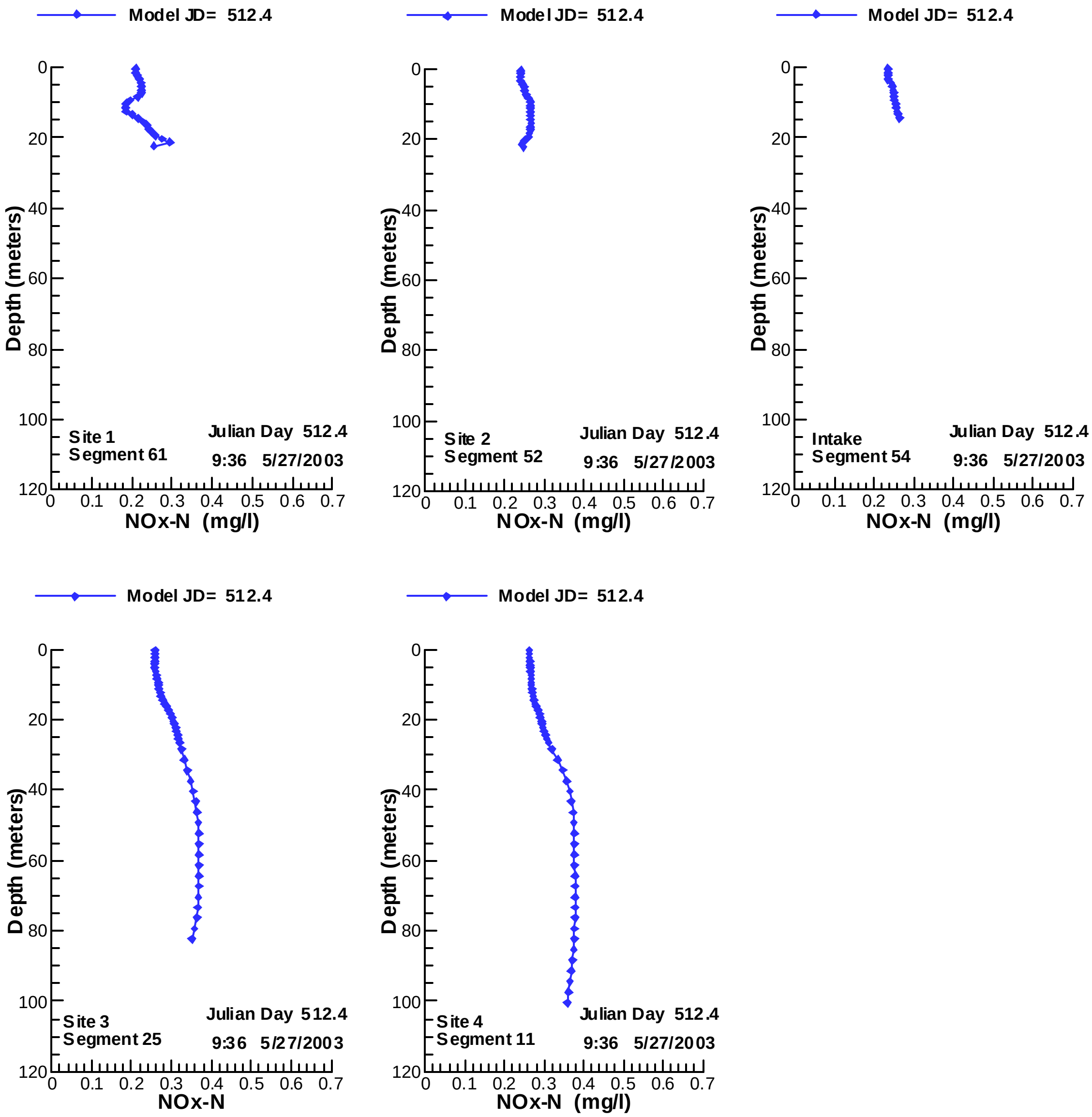

Figure 273. Vertical profiles of NOx-N compared with data for 5/27/2003.

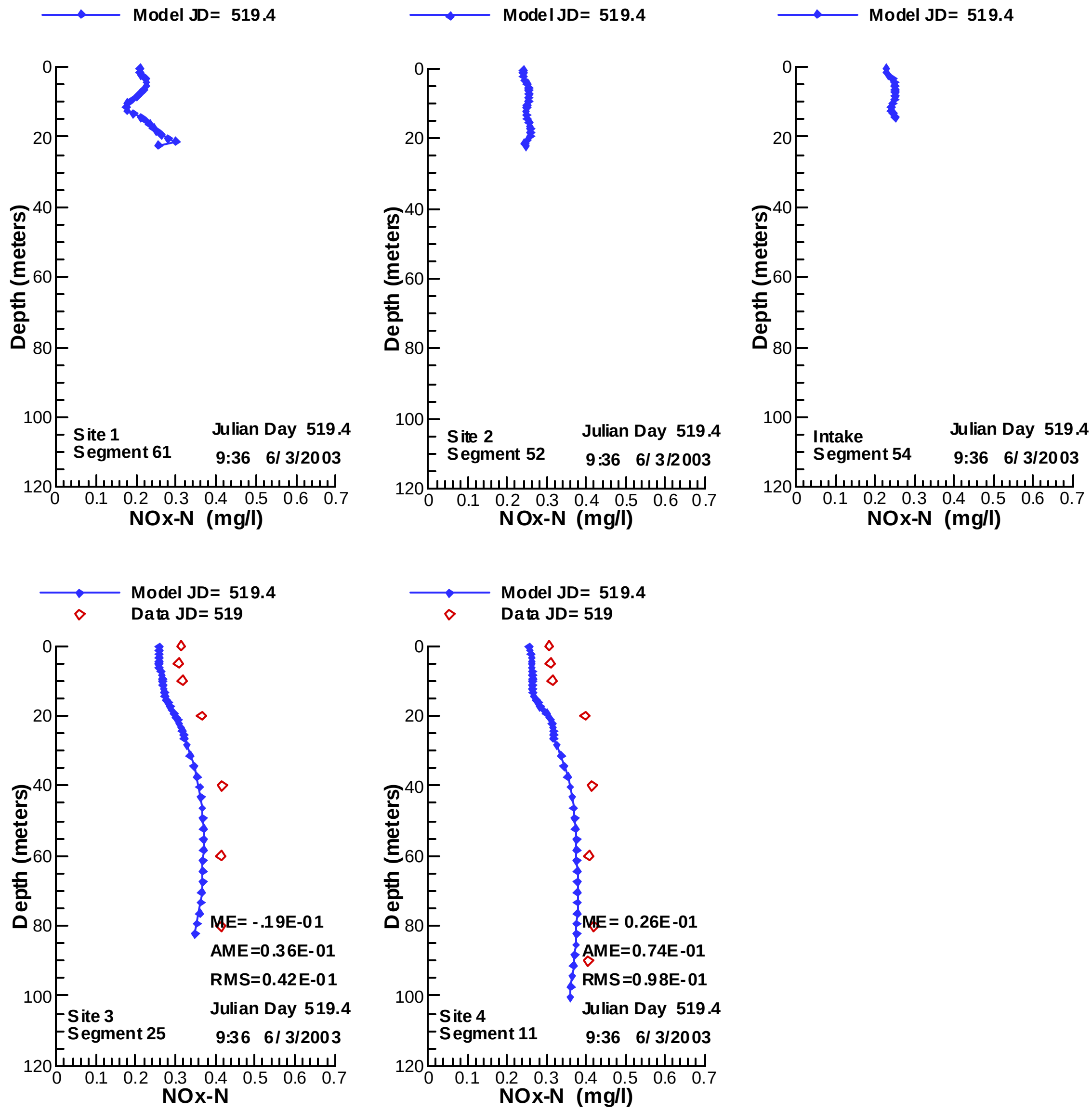

Figure 274. Vertical profiles of NOx-N compared with data for 6/ 3/2003.

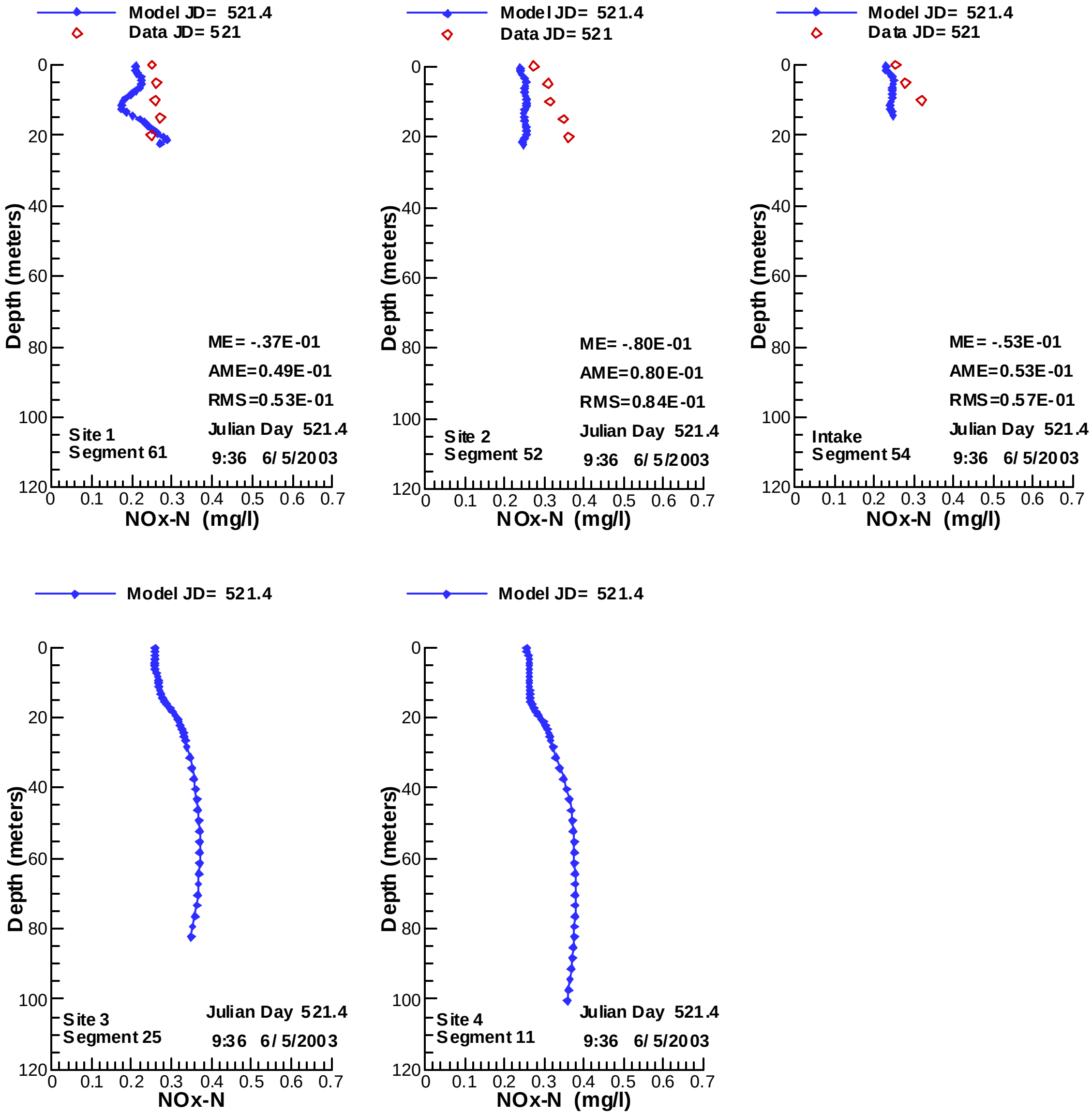

Figure 275. Vertical profiles of NOx-N compared with data for 6/ 5/2003.

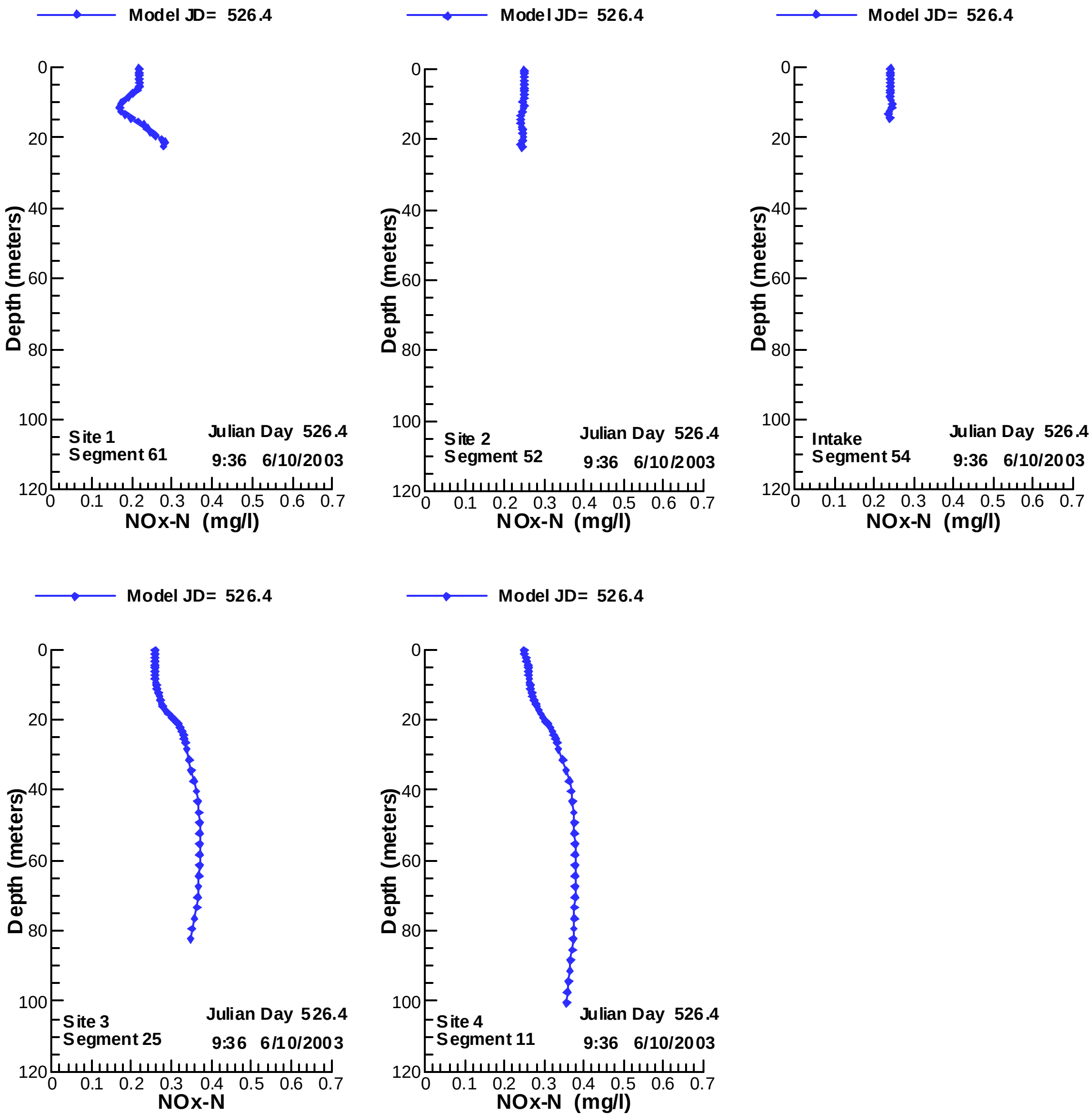

Figure 276. Vertical profiles of NOx-N compared with data for 6/10/2003.

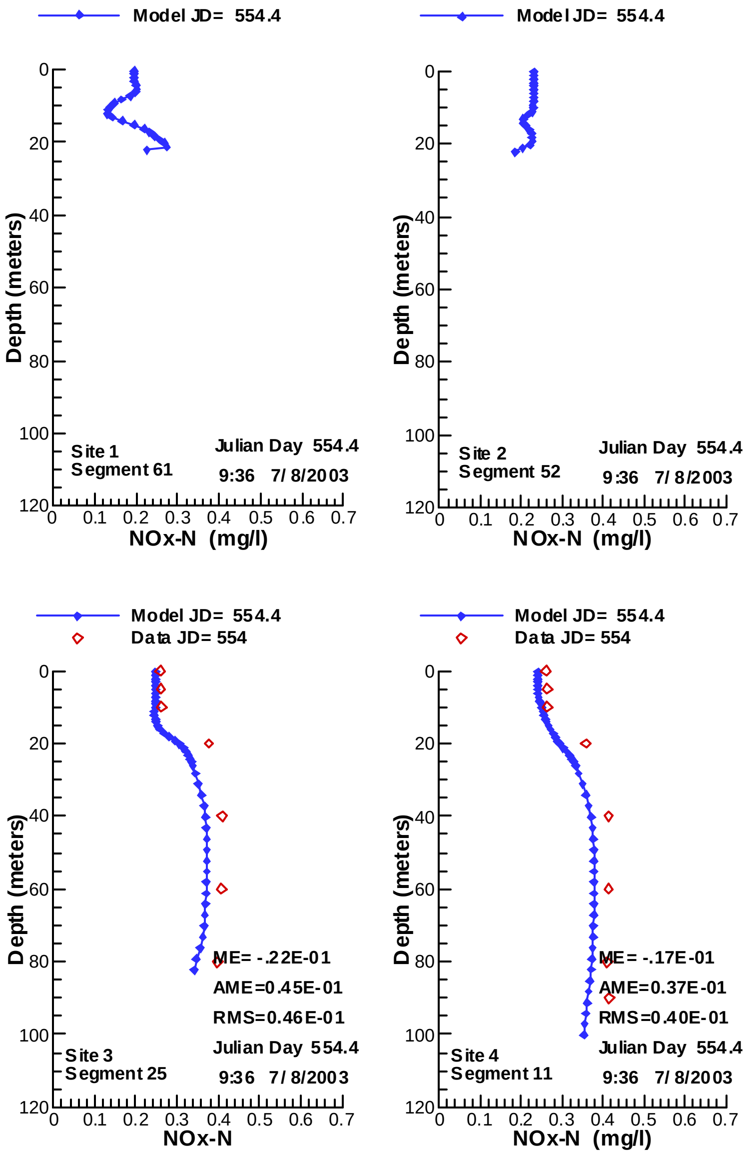

Figure 277. Vertical profiles of NOx-N compared with data for 7/ 8/2003.

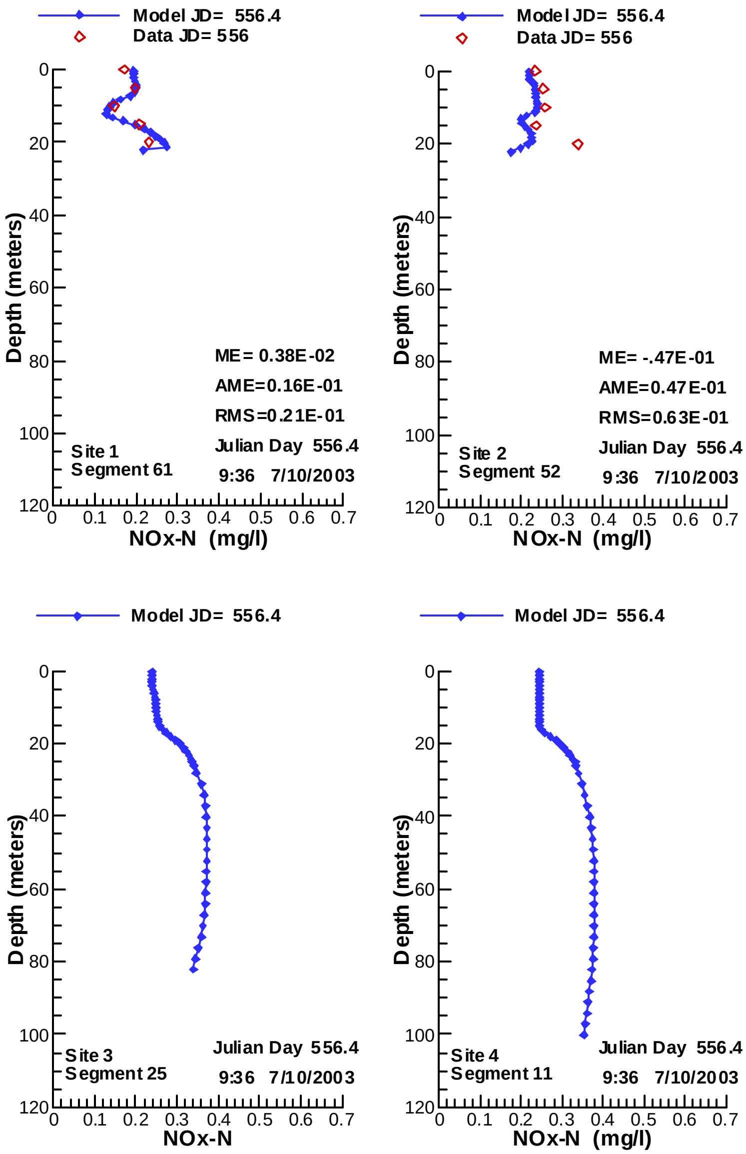

Figure 278. Vertical profiles of NOx-N compared with data for 7/10/2003.

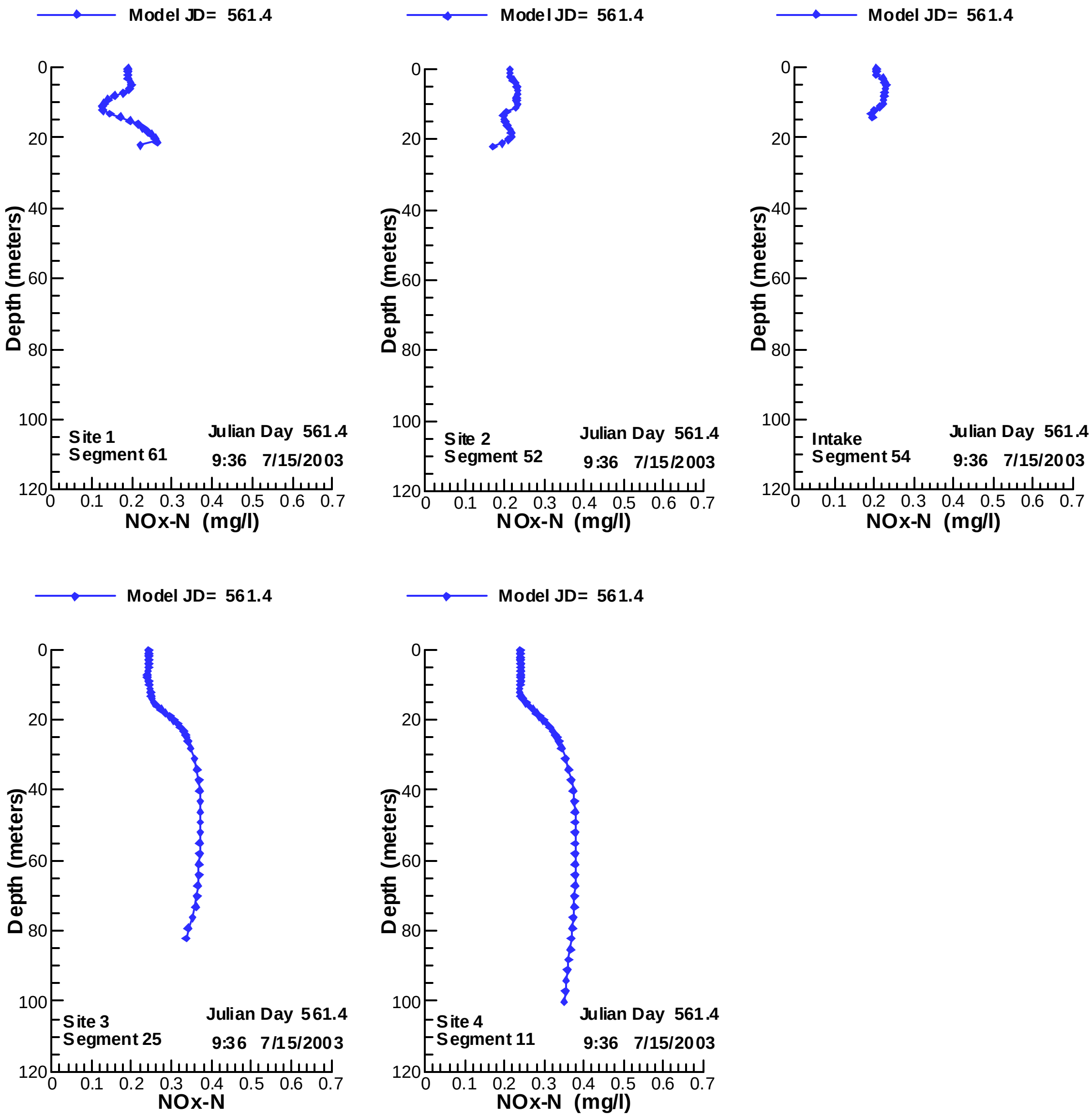

Figure 279. Vertical profiles of NOx-N compared with data for 7/15/2003.

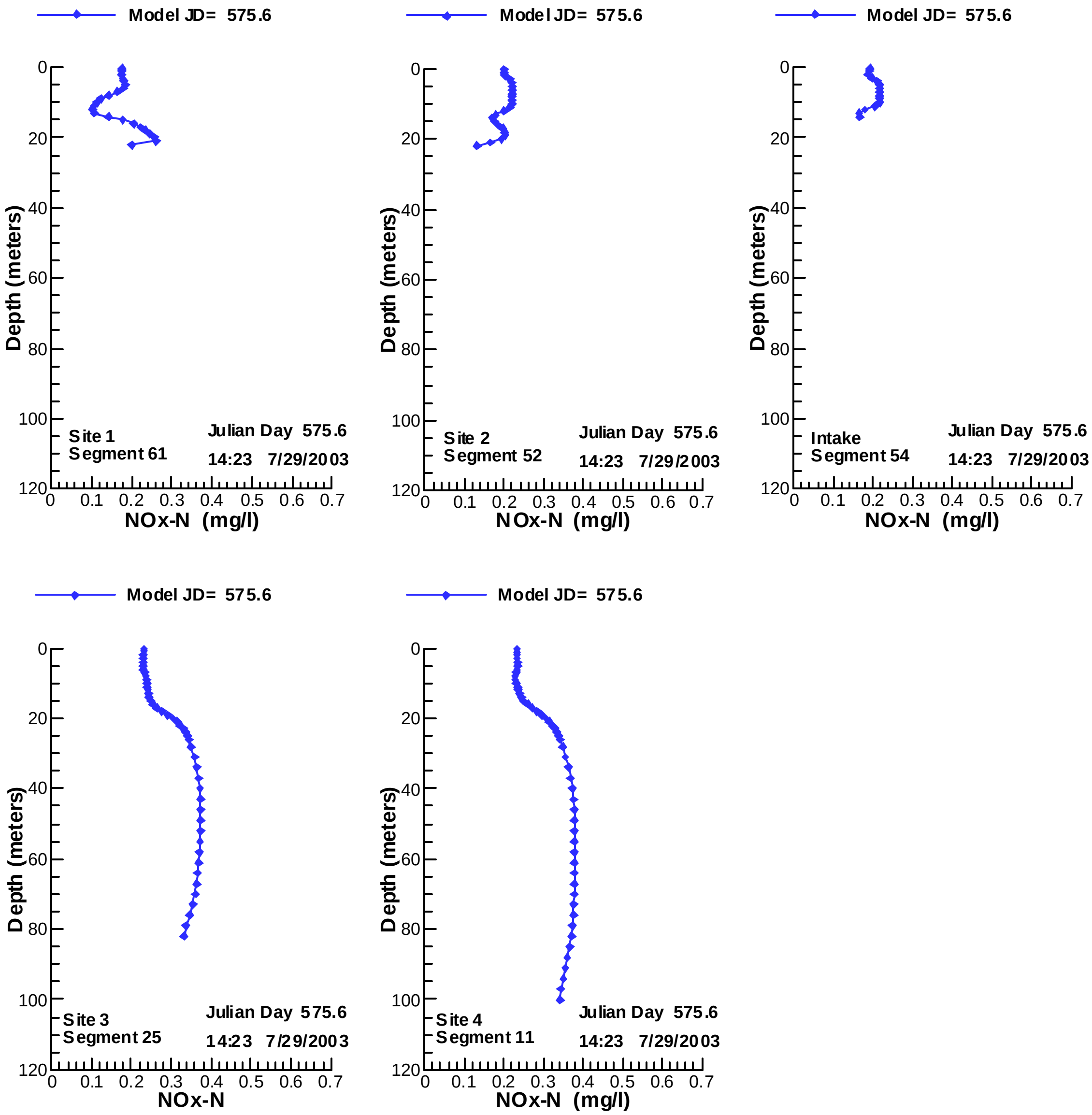

Figure 280. Vertical profiles of NOx-N compared with data for 7/29/2003.

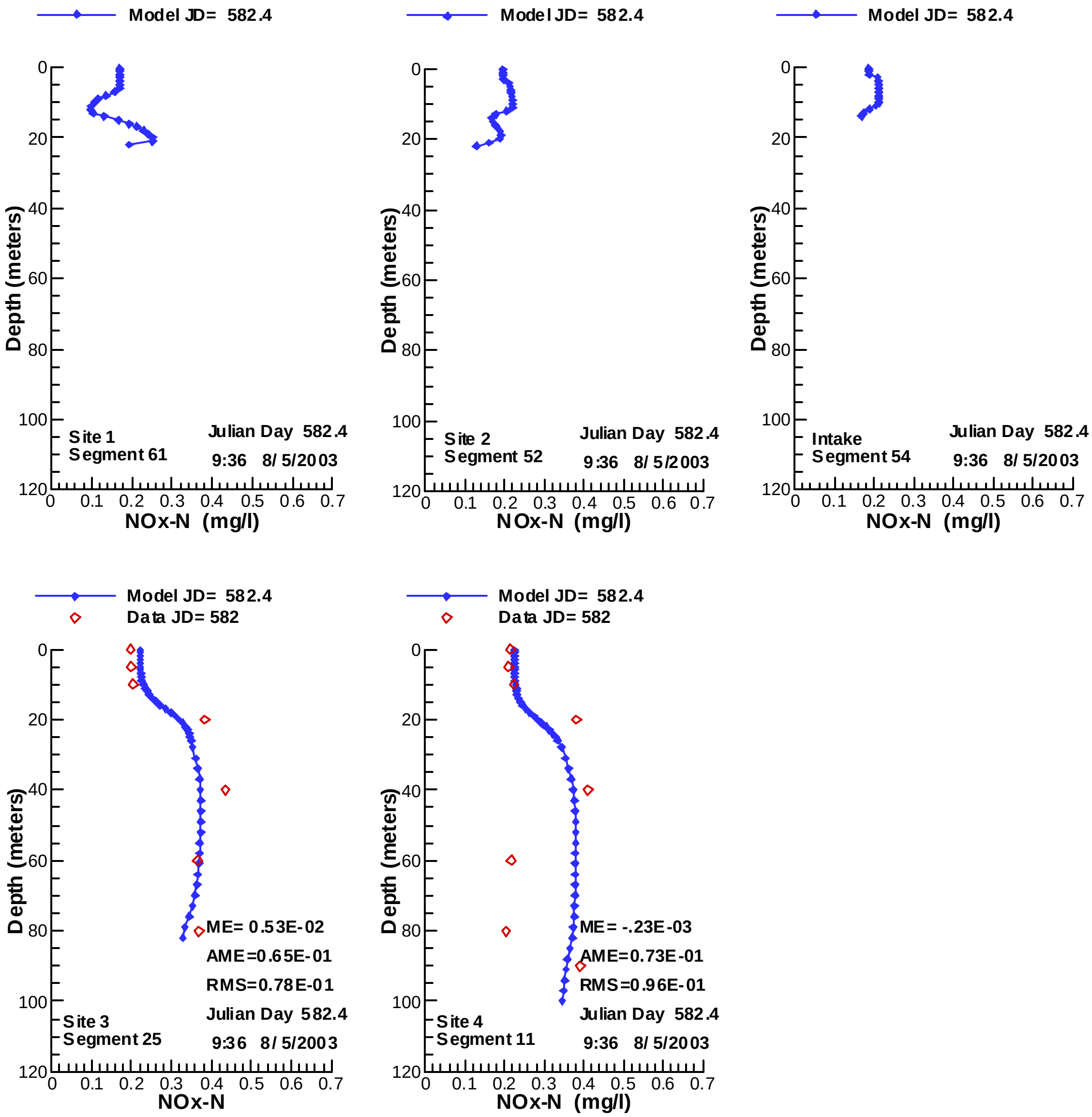

Figure 281. Vertical profiles of NOx-N compared with data for 8/ 5/2003.

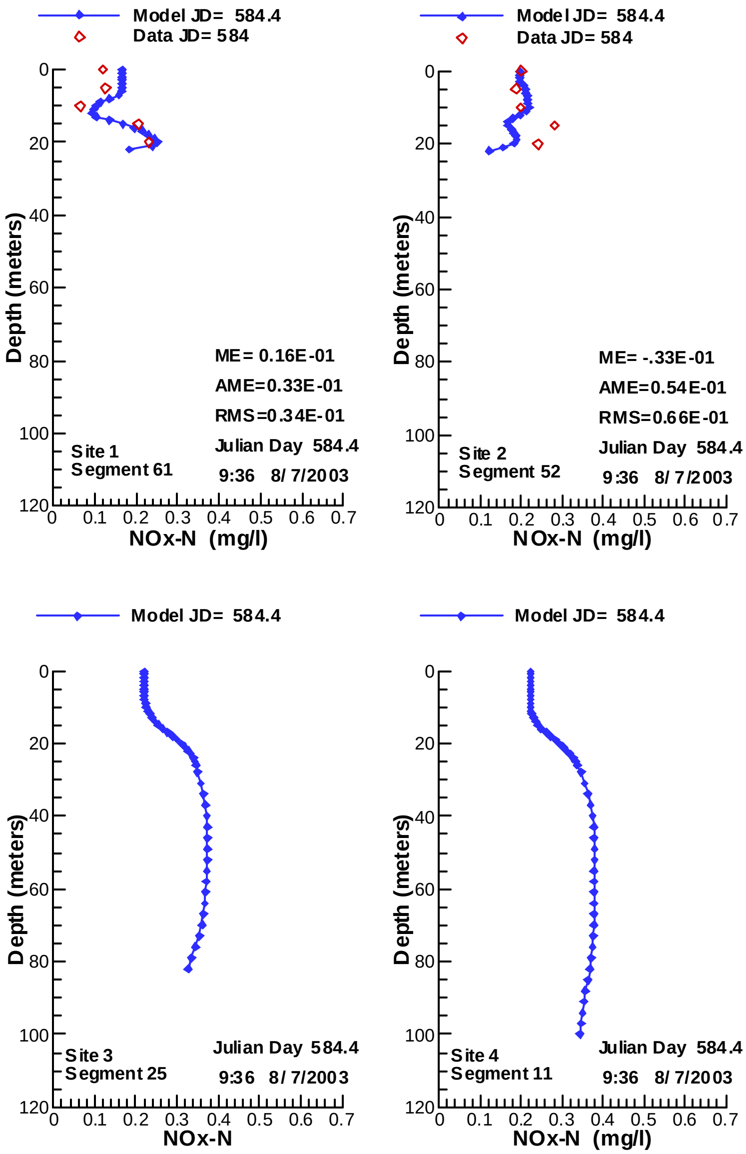

Figure 282. Vertical profiles of NOx-N compared with data for 8/ 7/2003.

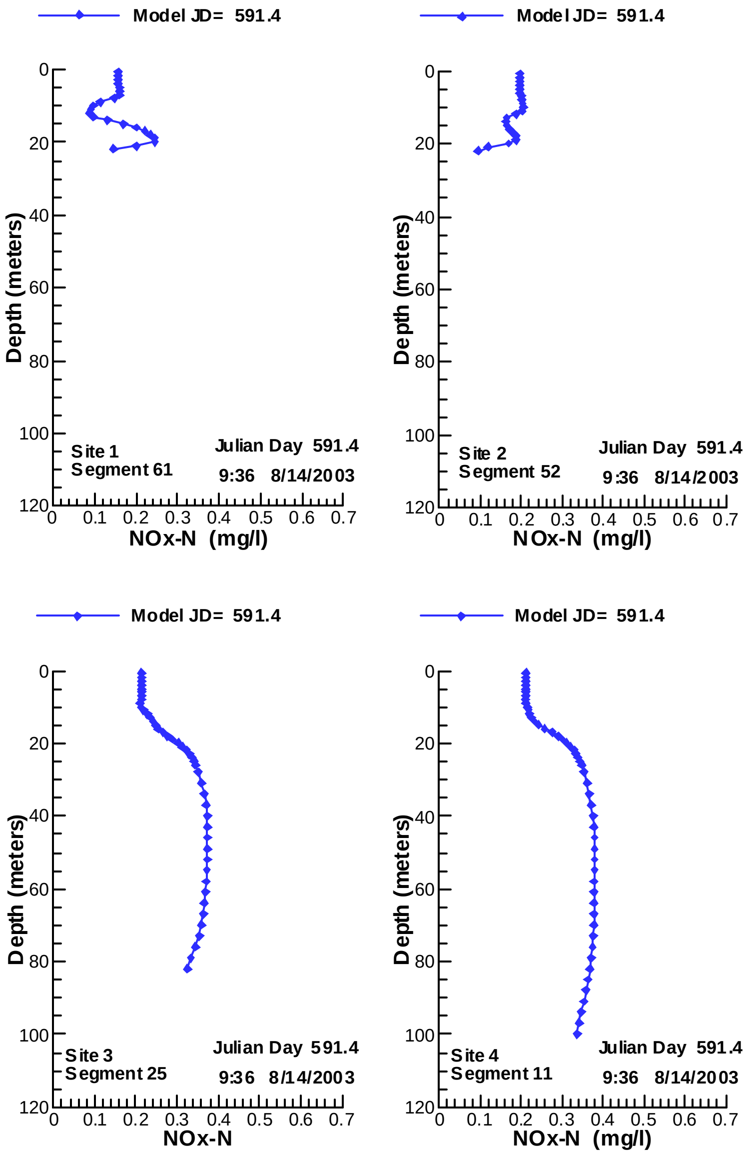

Figure 283. Vertical profiles of NOx-N compared with data for 8/14/2003.

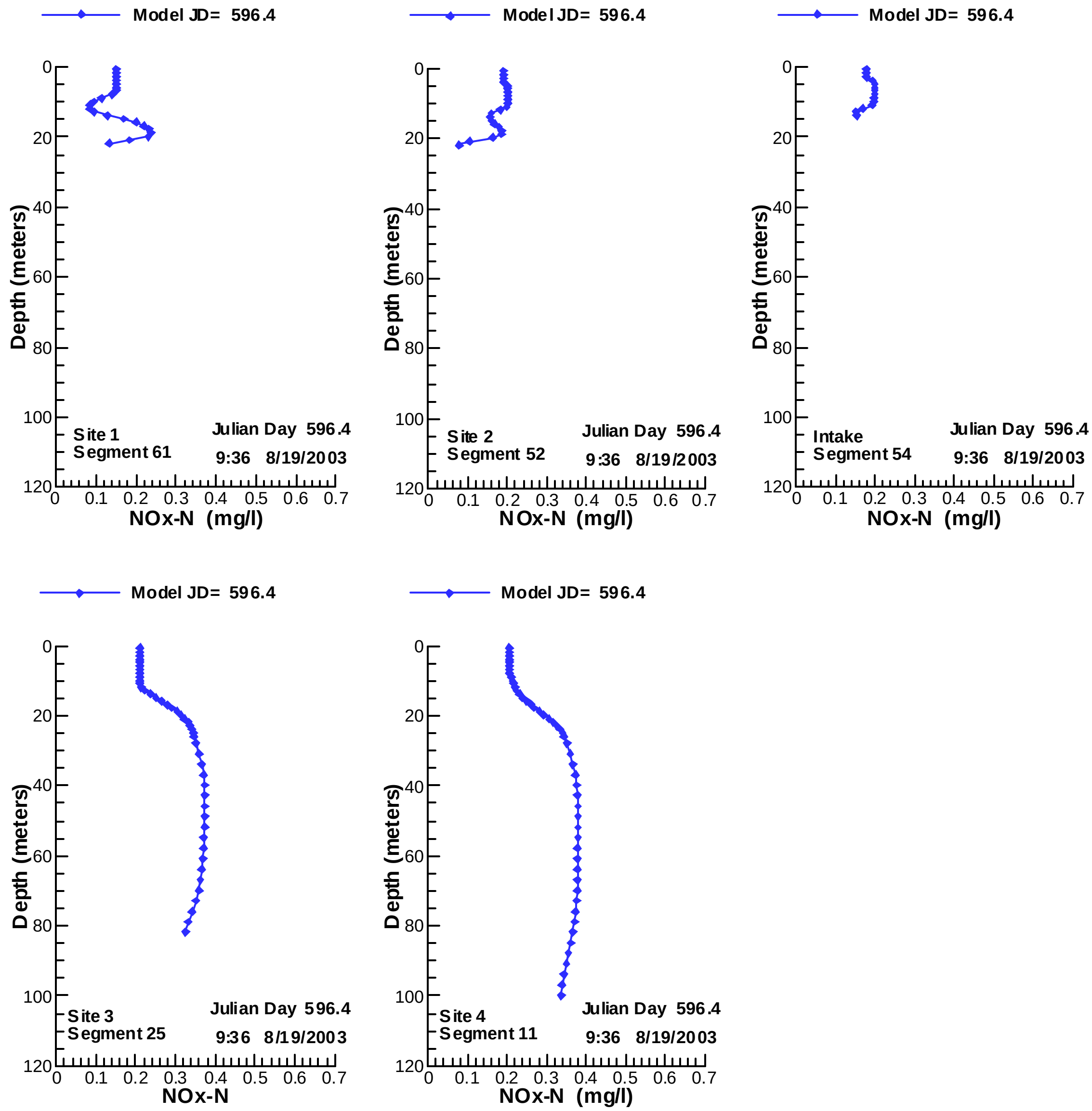

Figure 284. Vertical profiles of NOx-N compared with data for 8/19/2003.

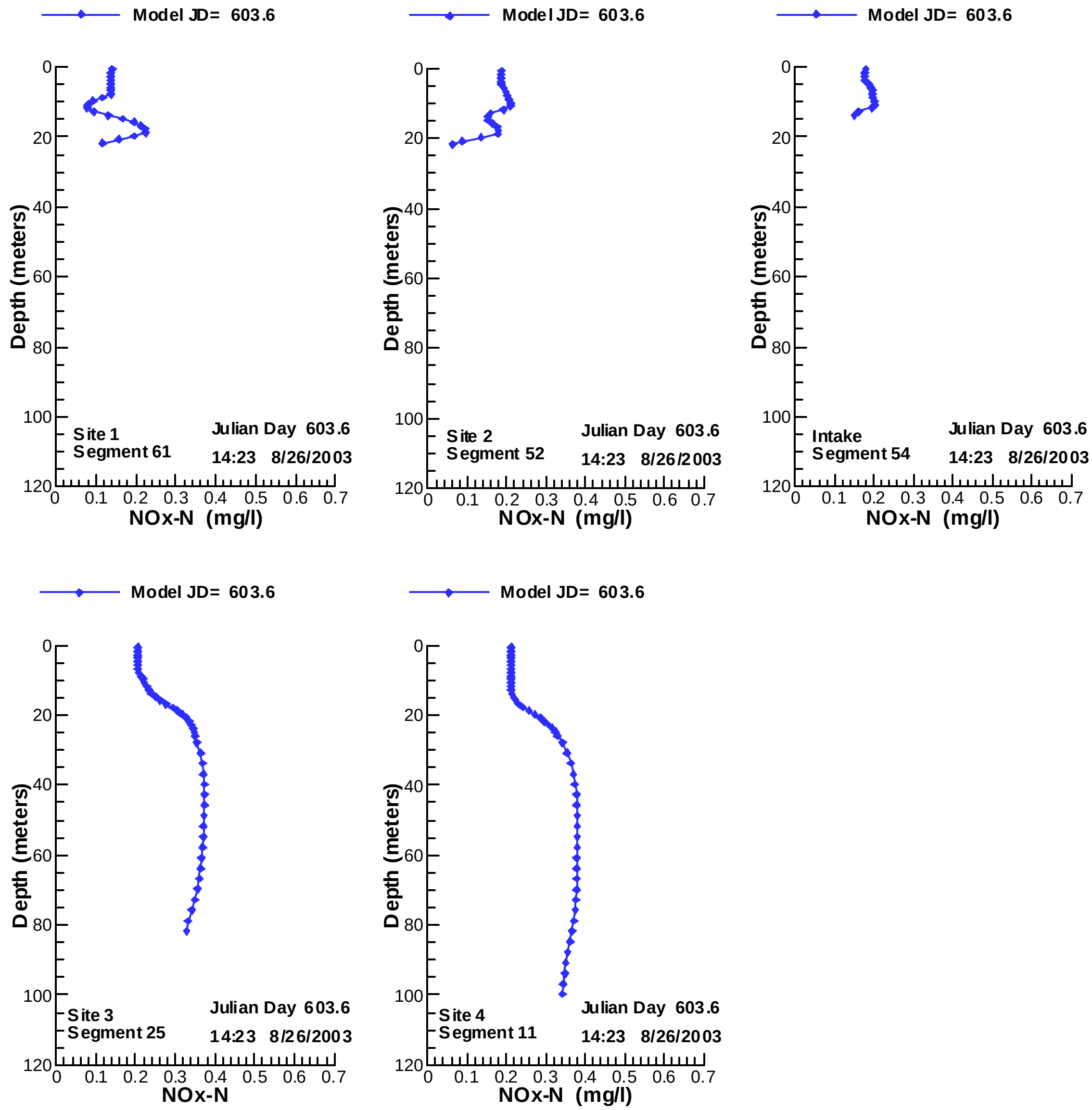

Figure 285. Vertical profiles of NOx-N compared with data for 8/26/2003.

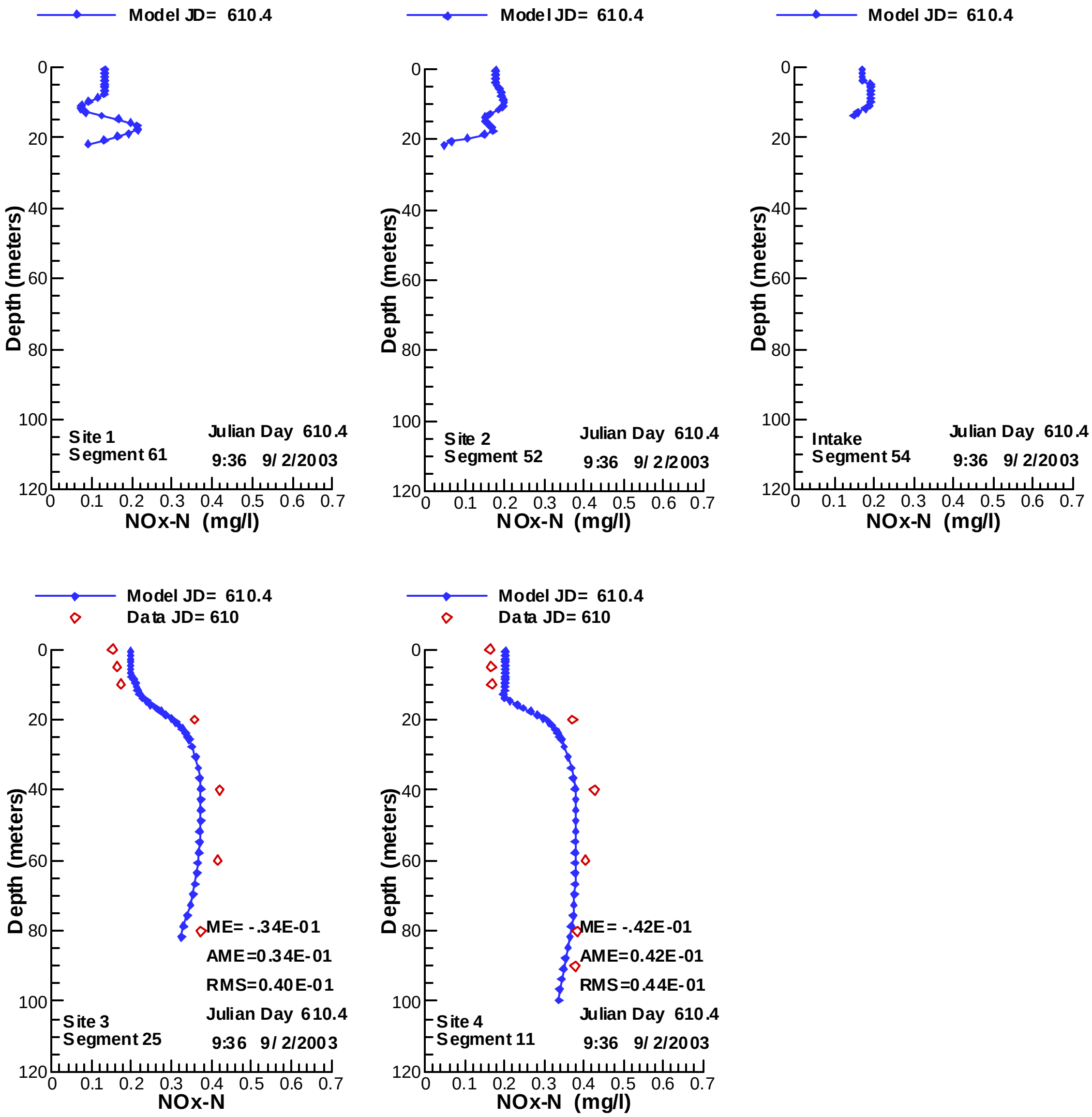

Figure 286. Vertical profiles of NOx-N compared with data for 9/ 2/2003.

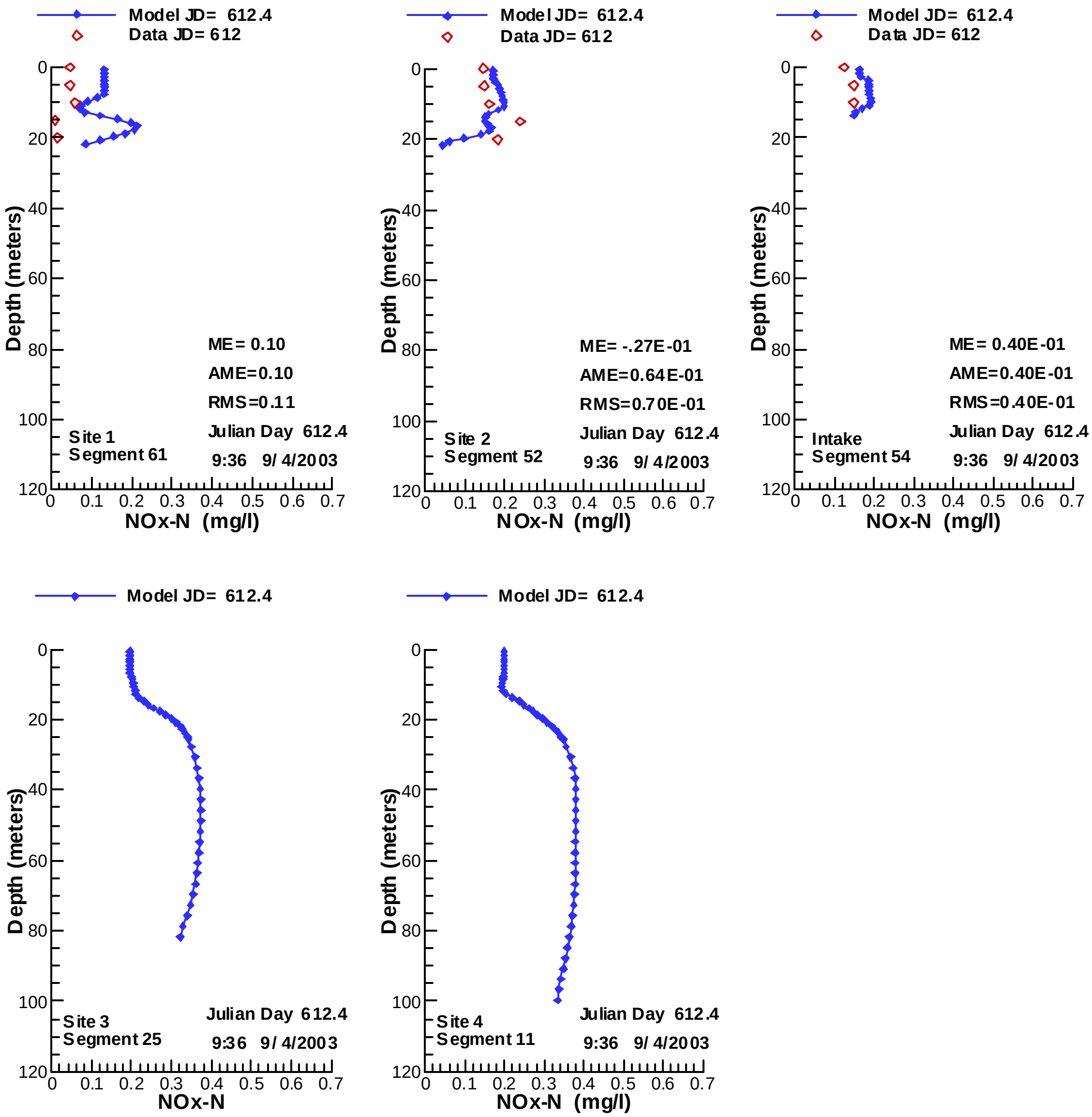

Figure 287. Vertical profiles of NOx-N compared with data for 9/ 4/2003.

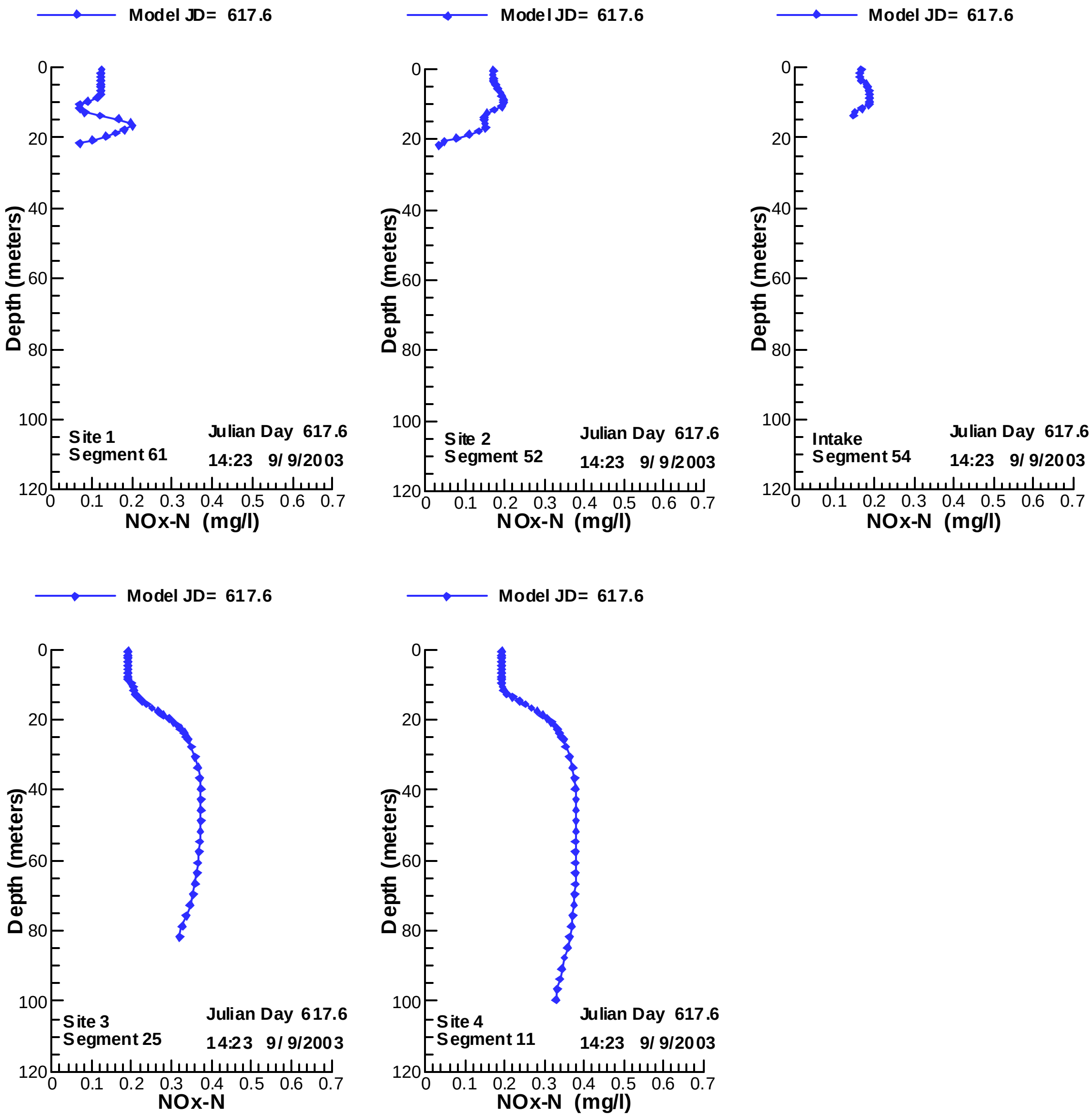

Figure 288. Vertical profiles of NOx-N compared with data for 9/ 9/2003.

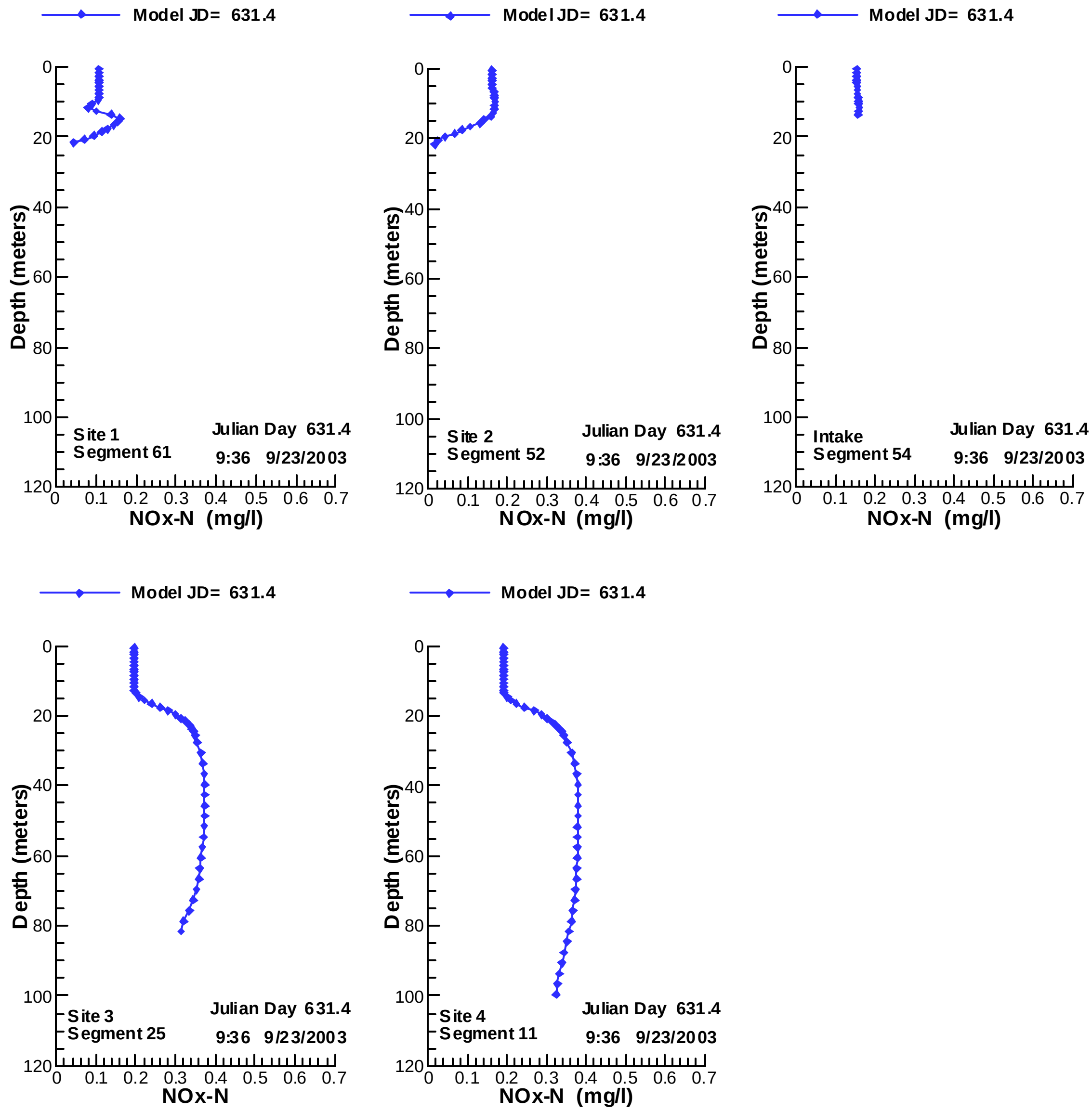

Figure 289. Vertical profiles of NOx-N compared with data for 9/23/2003.

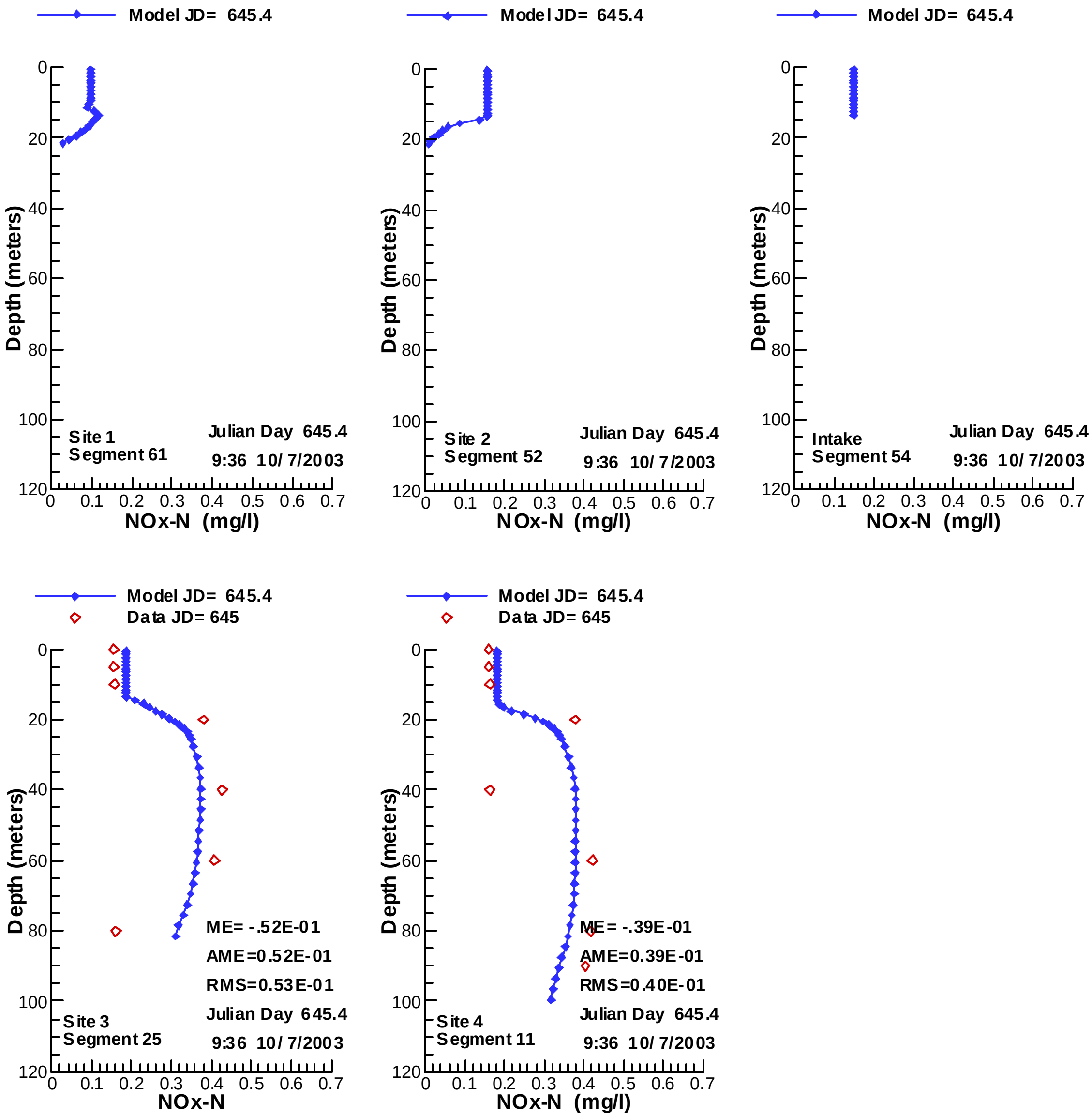

Figure 290. Vertical profiles of NOx-N compared with data for 10/ 7/2003.

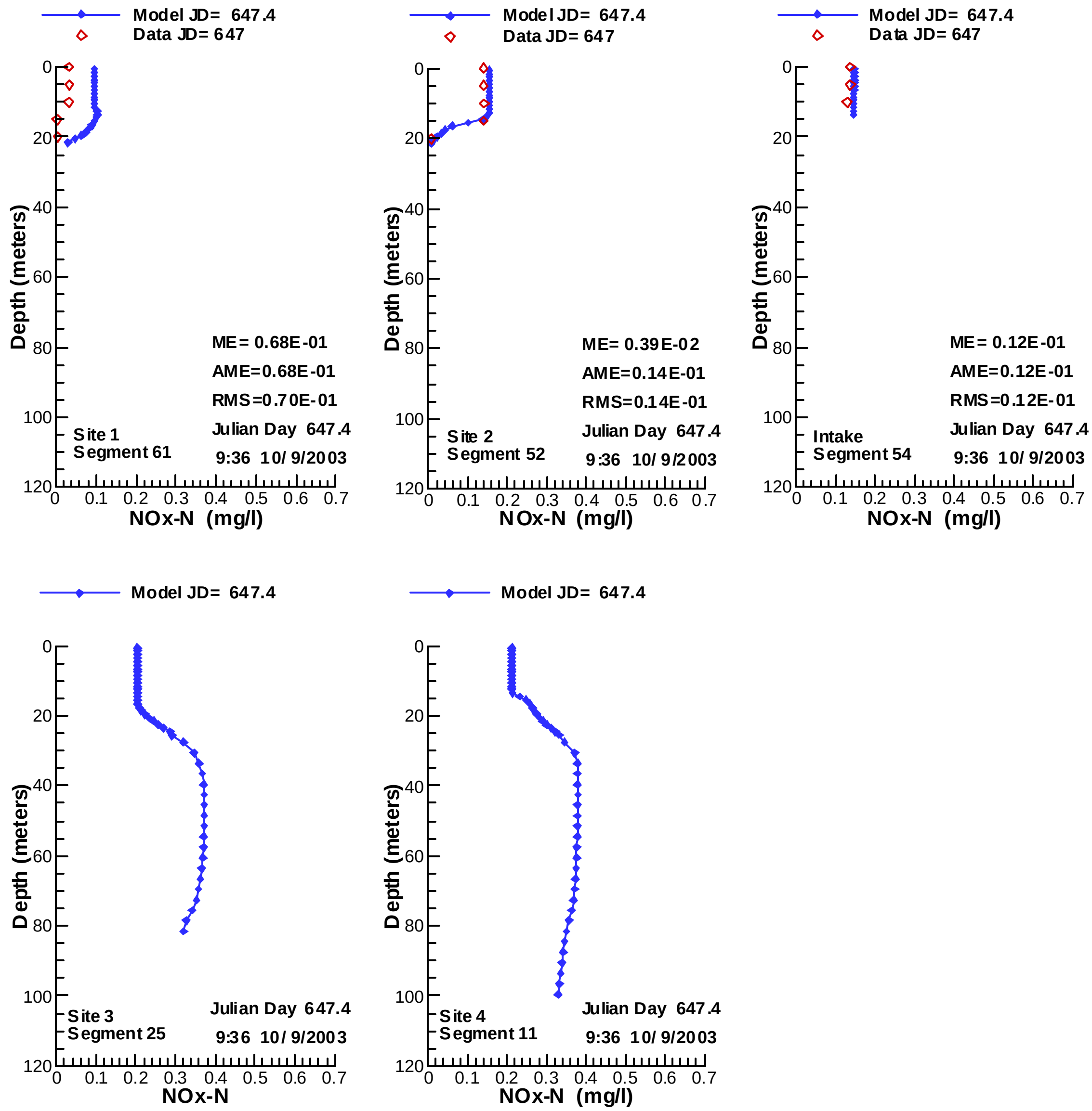

Figure 291. Vertical profiles of NOx-N compared with data for 10/ 9/2003.

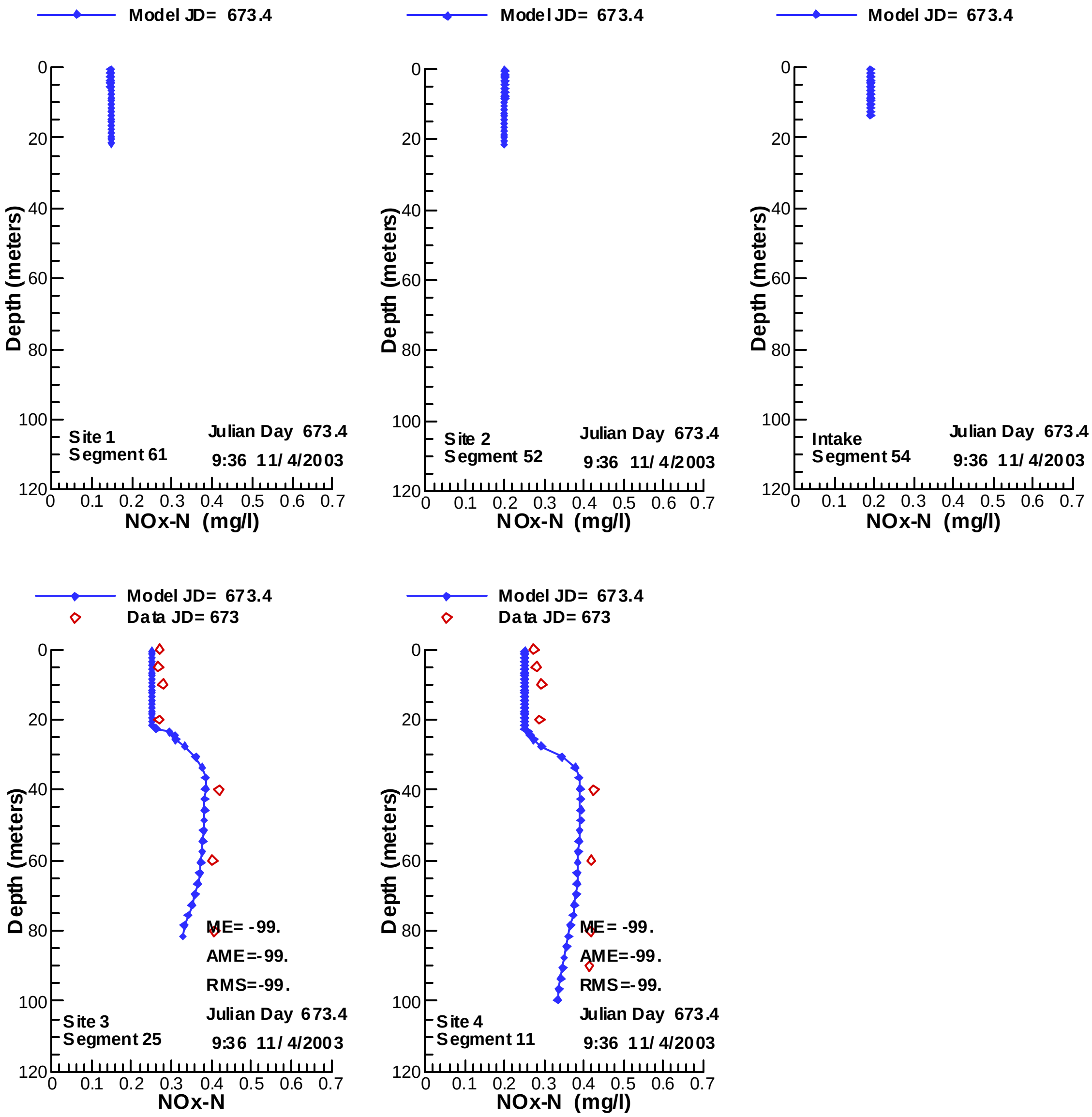

Figure 292. Vertical profiles of NOx-N compared with data for 11/ 4/2003.

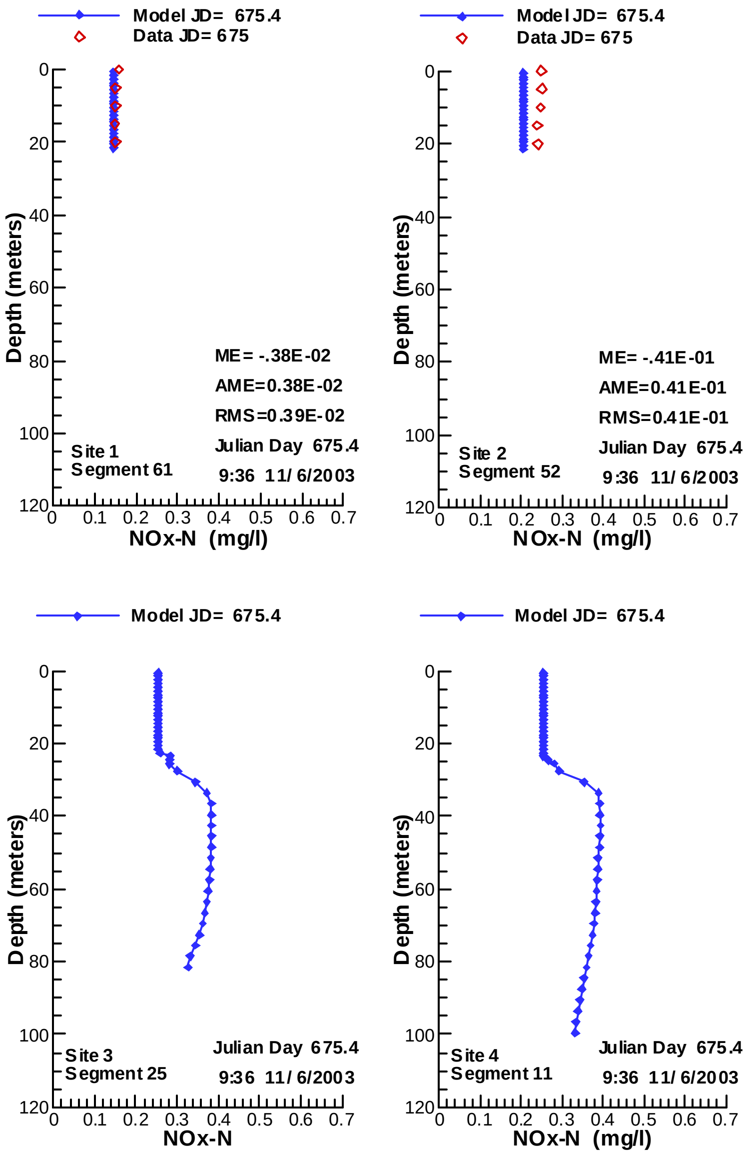

Figure 293. Vertical profiles of NOx-N compared with data for 11/ 6/2003.

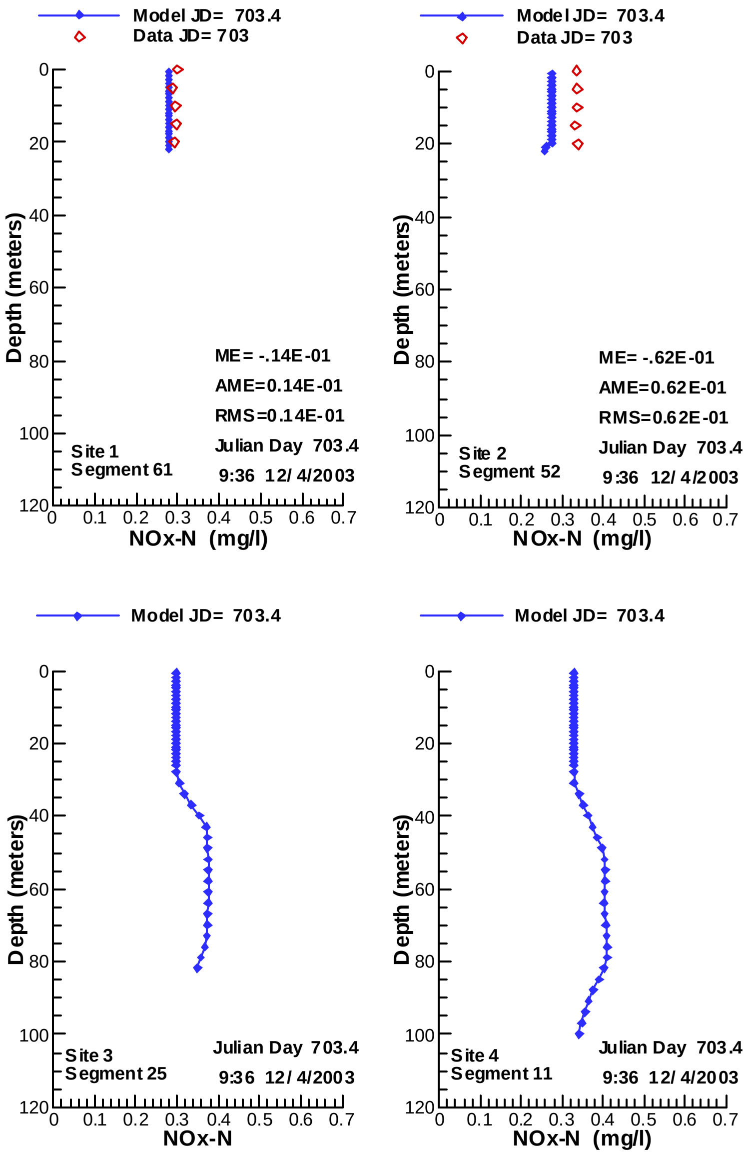

Figure 294. Vertical profiles of NOx-N compared with data for 12/ 4/2003.

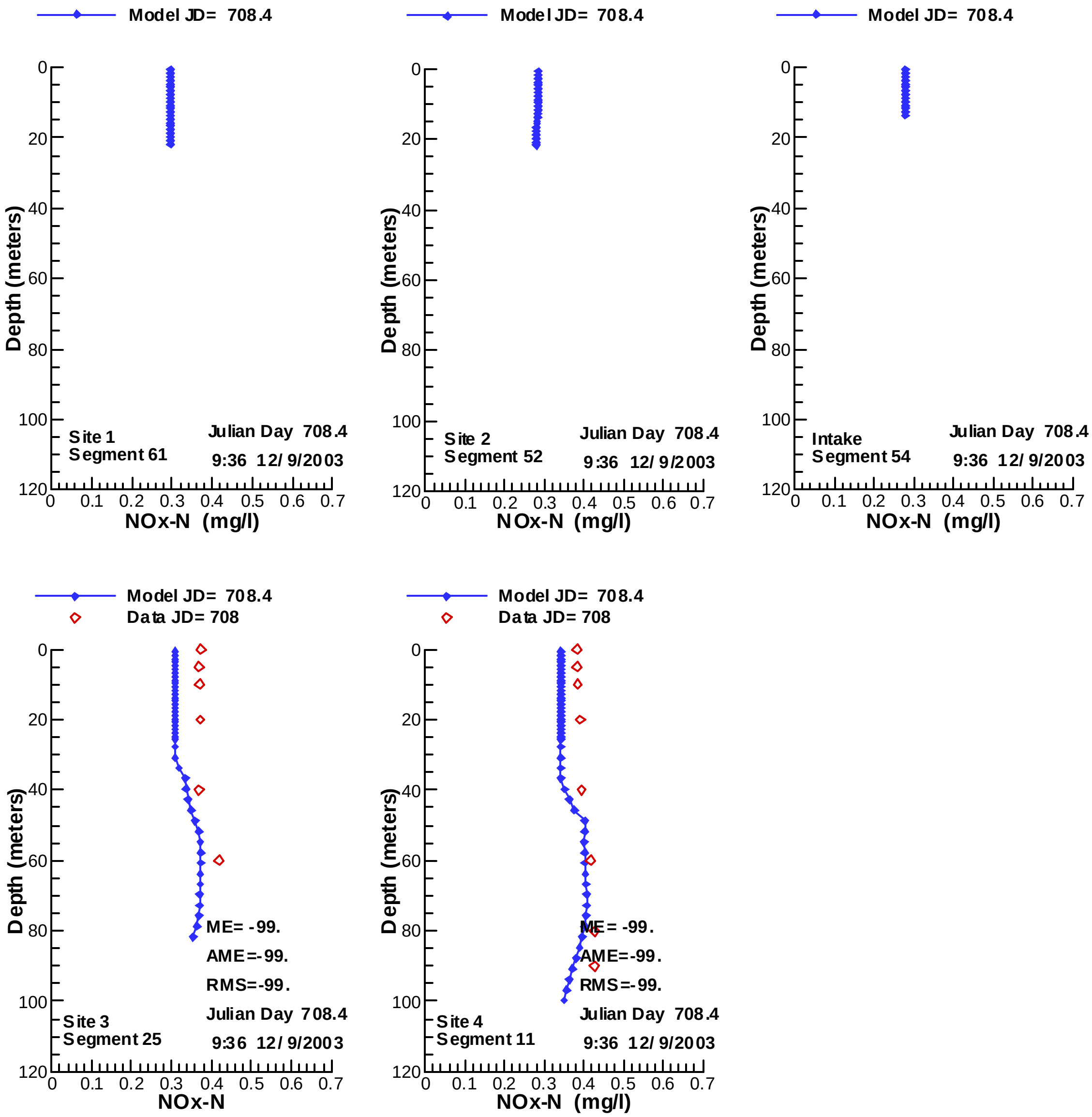

Figure 295. Vertical profiles of NOx-N compared with data for 12/ 9/2003.

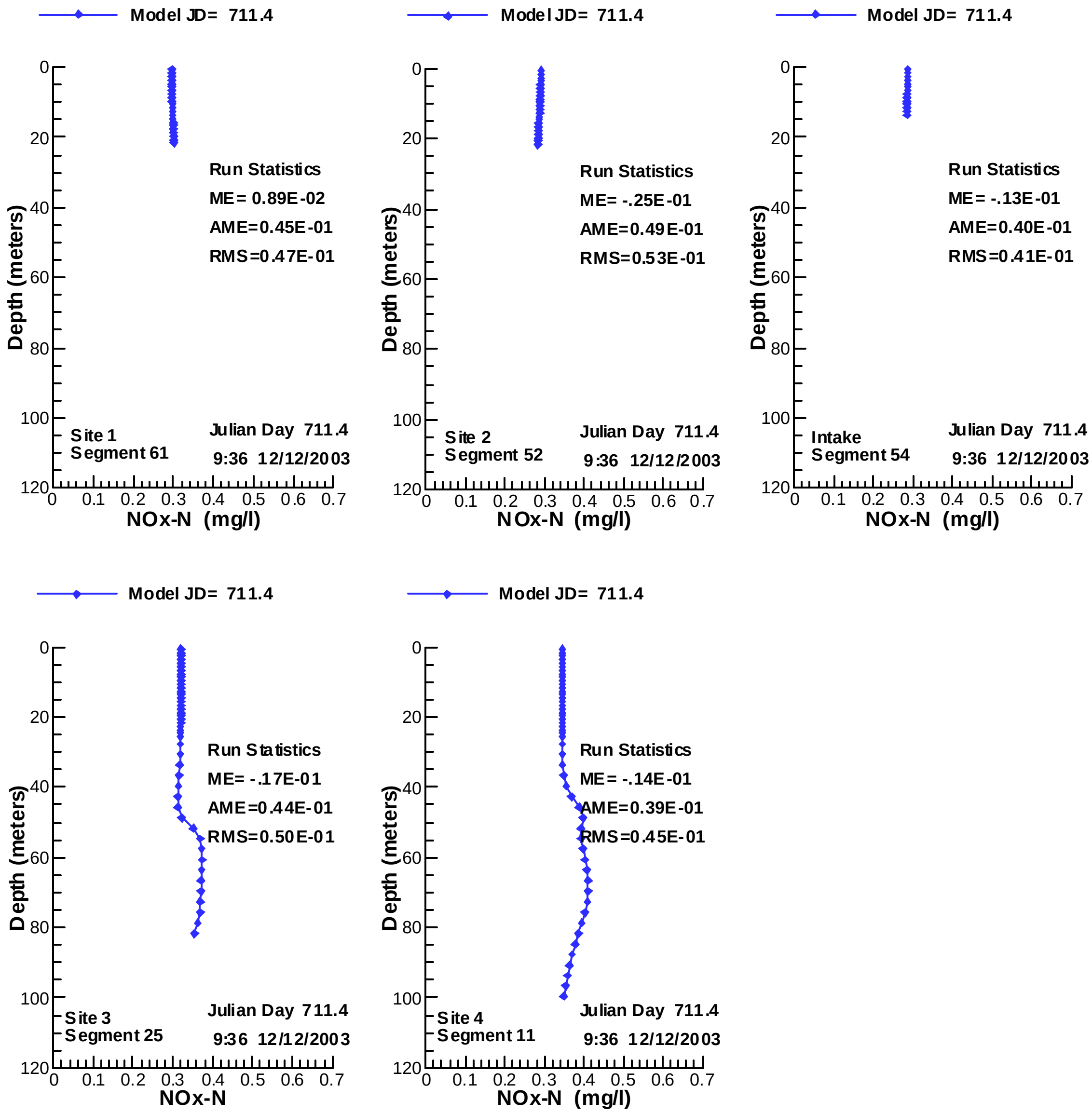

Figure 296. Vertical profiles of NOx-N compared with data for 12/12/2003.

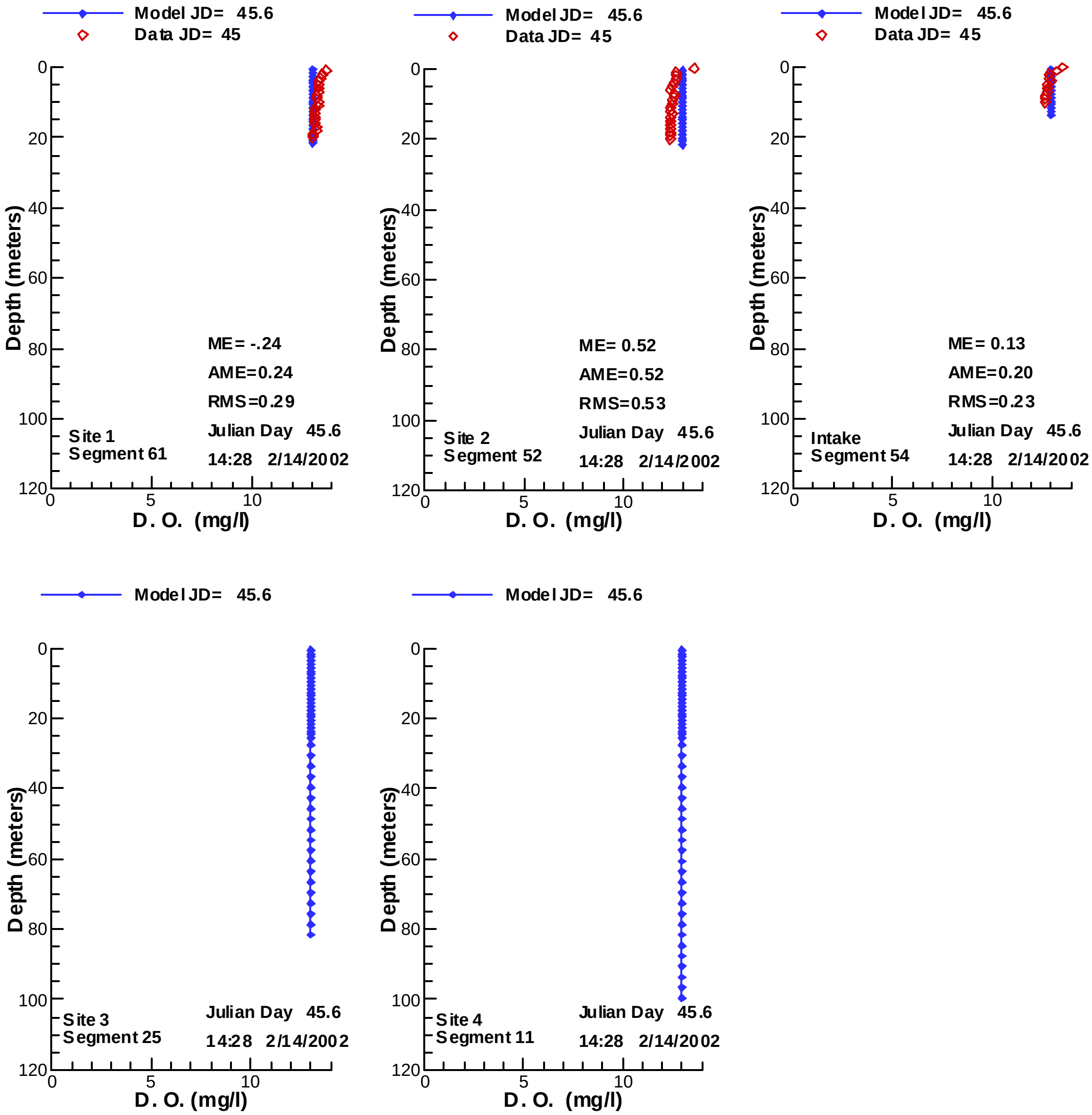

Figure 297. Vertical profiles of DISSOLVED OXYGEN compared with data for 2/14/2002.

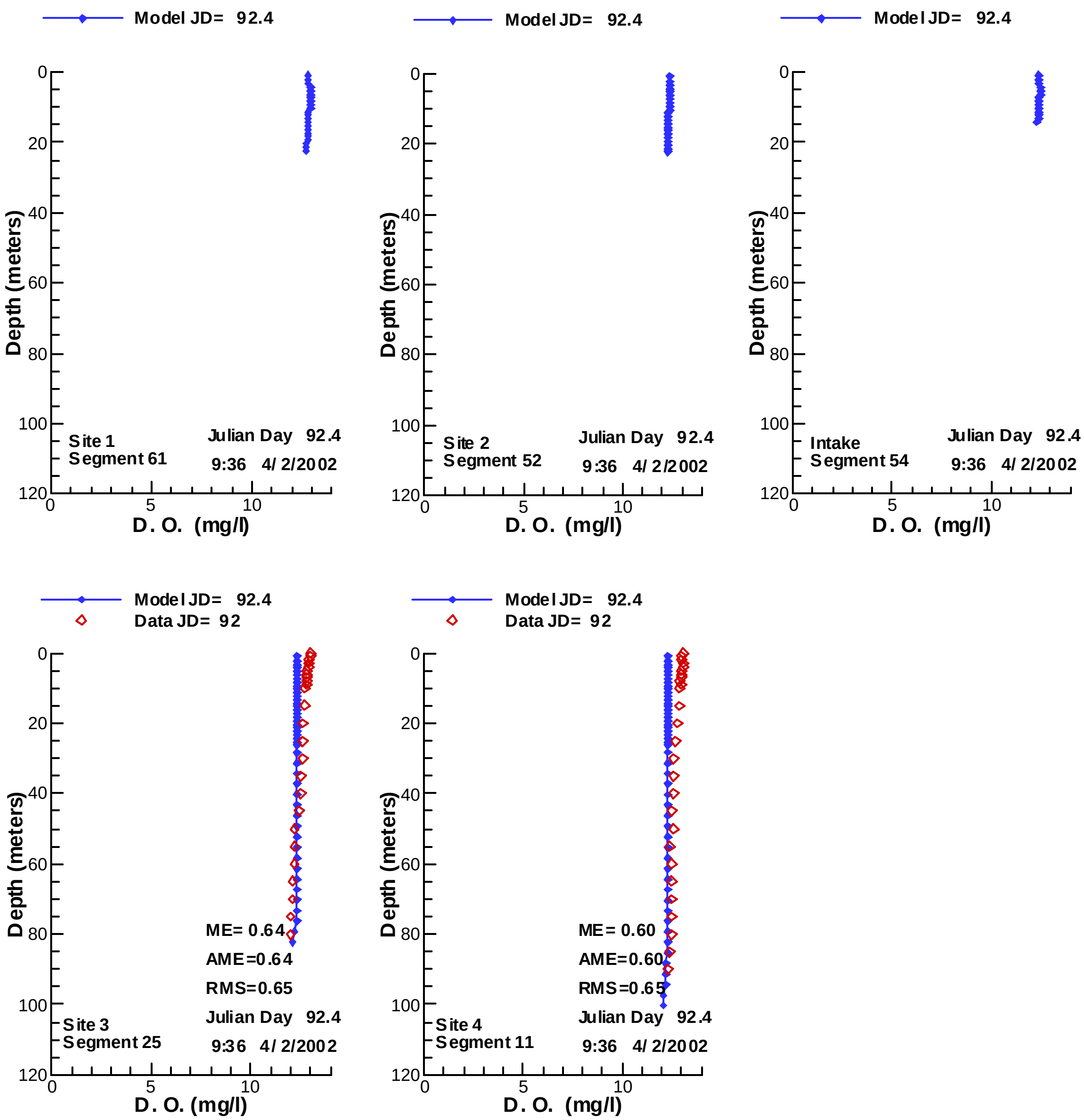

Figure 298. Vertical profiles of DISSOLVED OXYGEN compared with data for 4/ 2/2002.

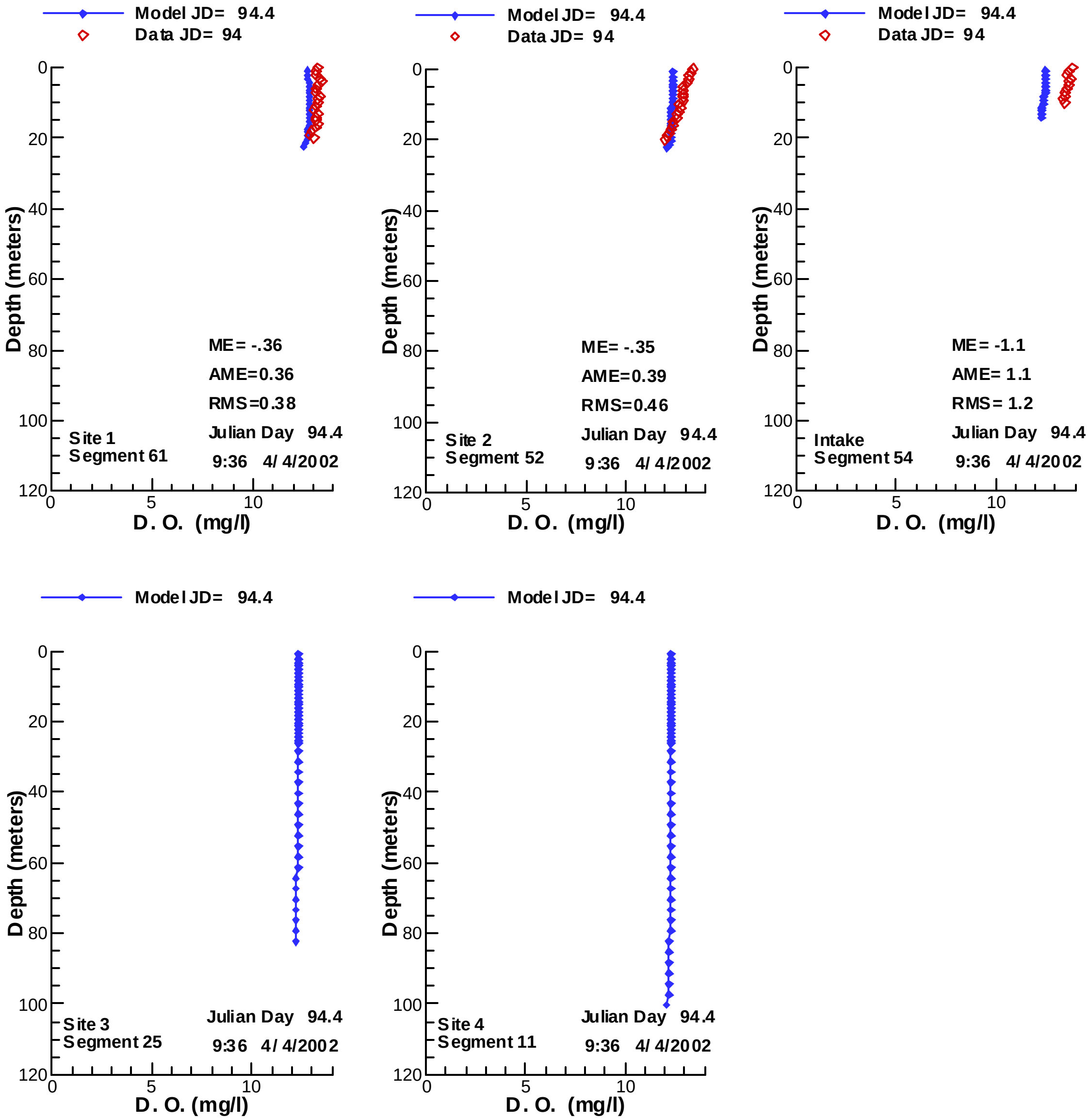

Figure 299. Vertical profiles of DISSOLVED OXYGEN compared with data for 4/ 4/2002.

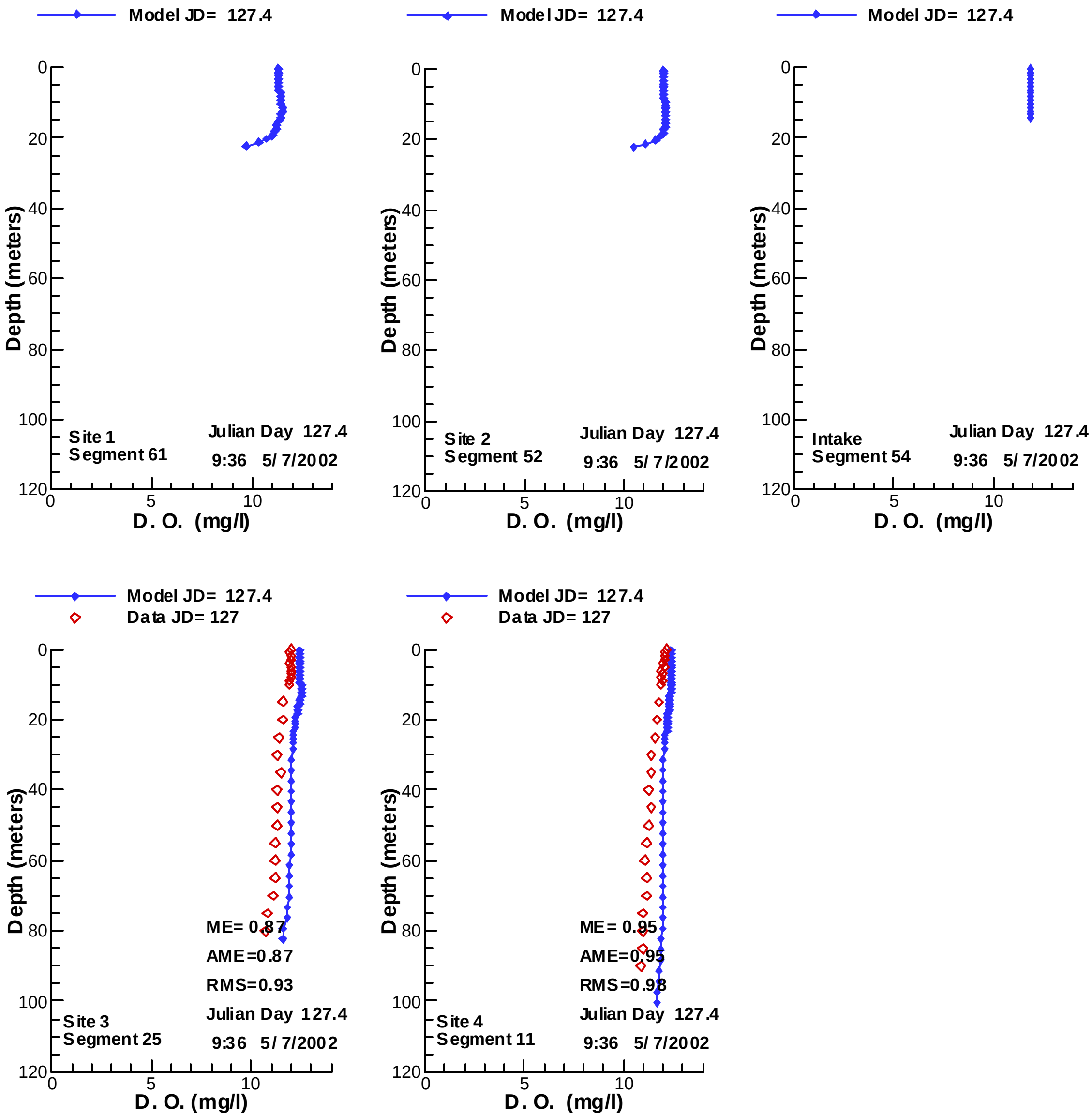

Figure 300. Vertical profiles of DISSOLVED OXYGEN compared with data for 5/ 7/2002.

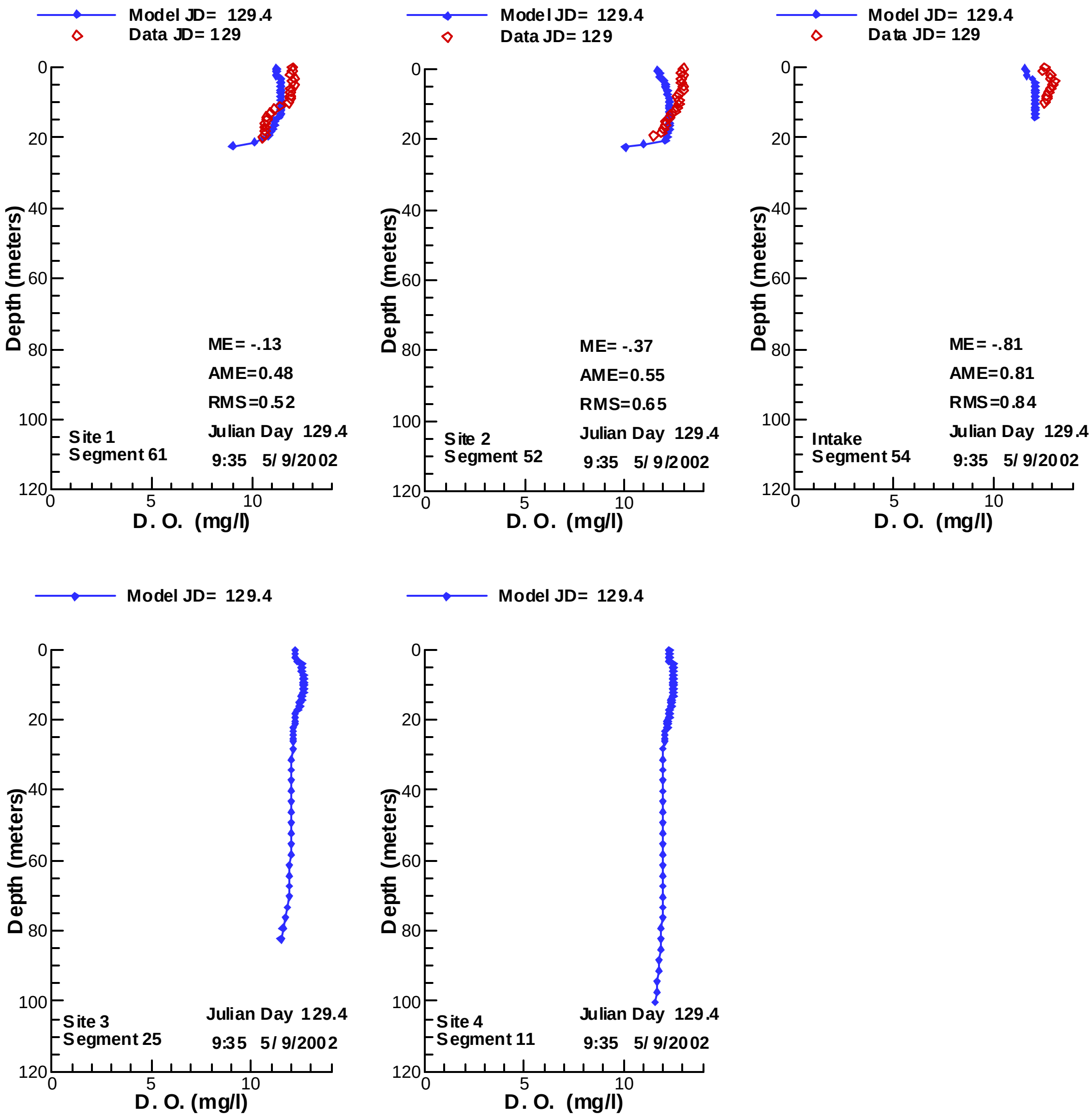

Figure 301. Vertical profiles of DISSOLVED OXYGEN compared with data for 5/ 9/2002.

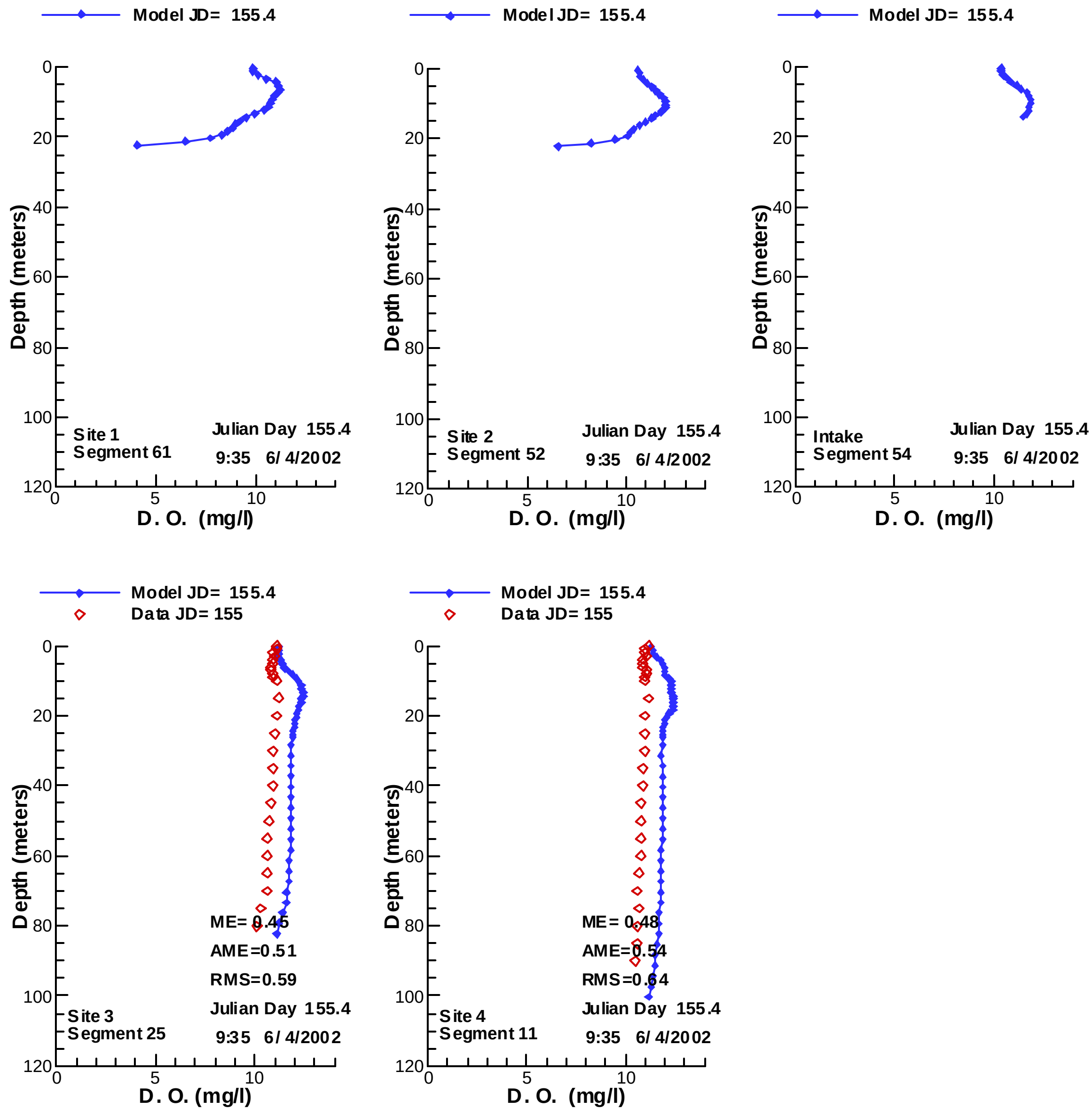

Figure 302. Vertical profiles of DISSOLVED OXYGEN compared with data for 6/ 4/2002.

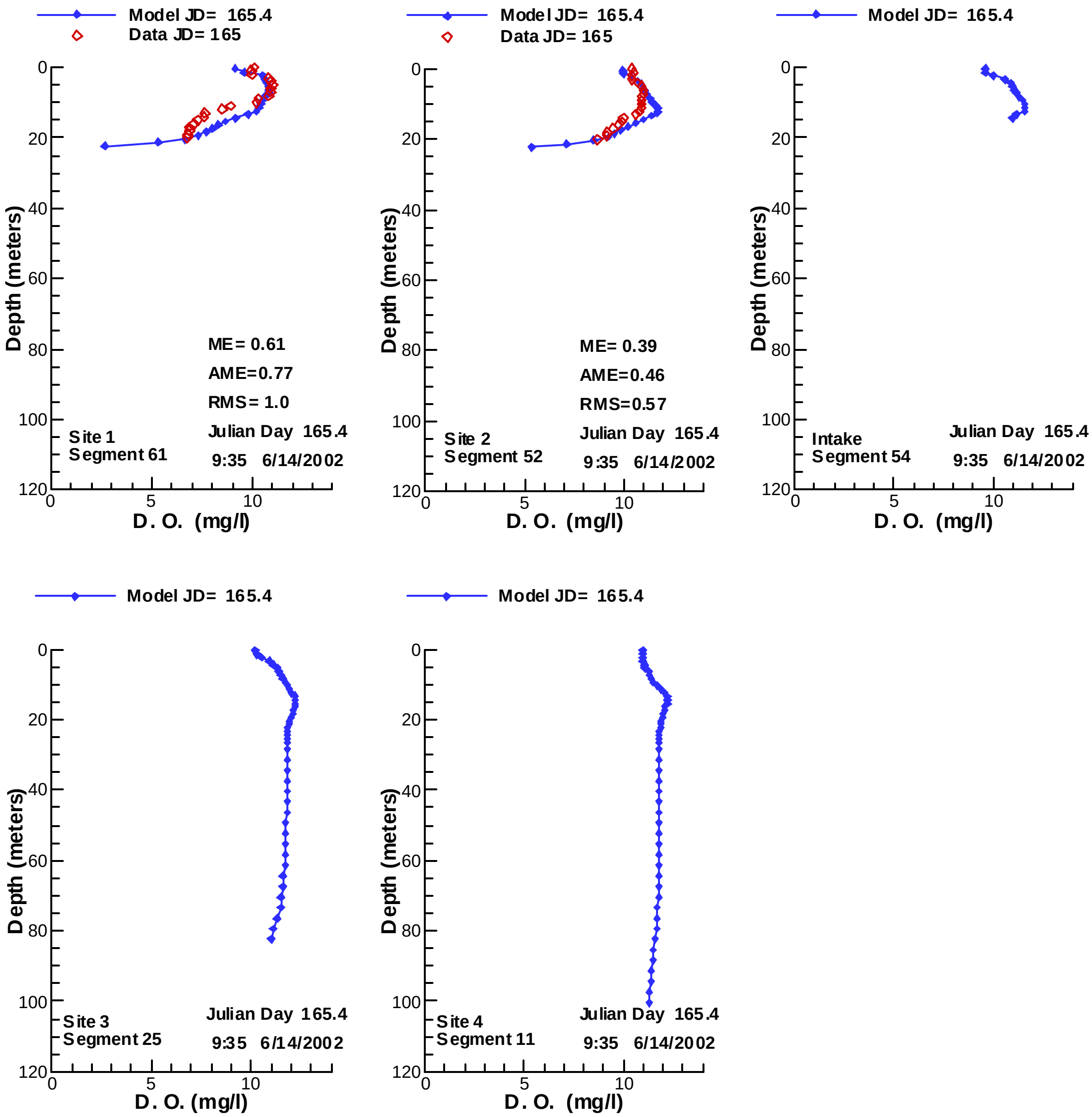

Figure 303. Vertical profiles of DISSOLVED OXYGEN compared with data for 6/14/2002.

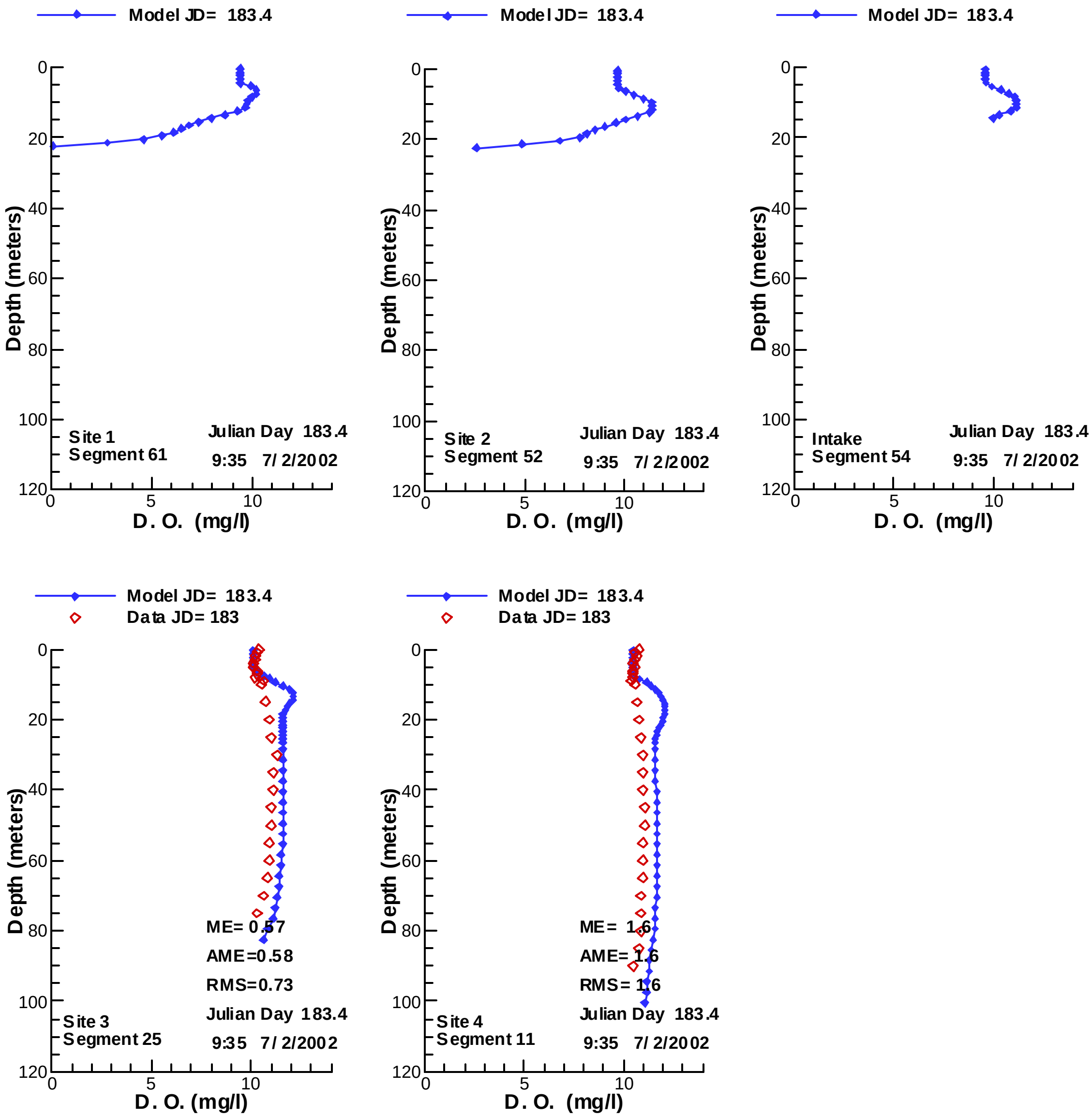

Figure 304. Vertical profiles of DISSOLVED OXYGEN compared with data for 7/ 2/2002.

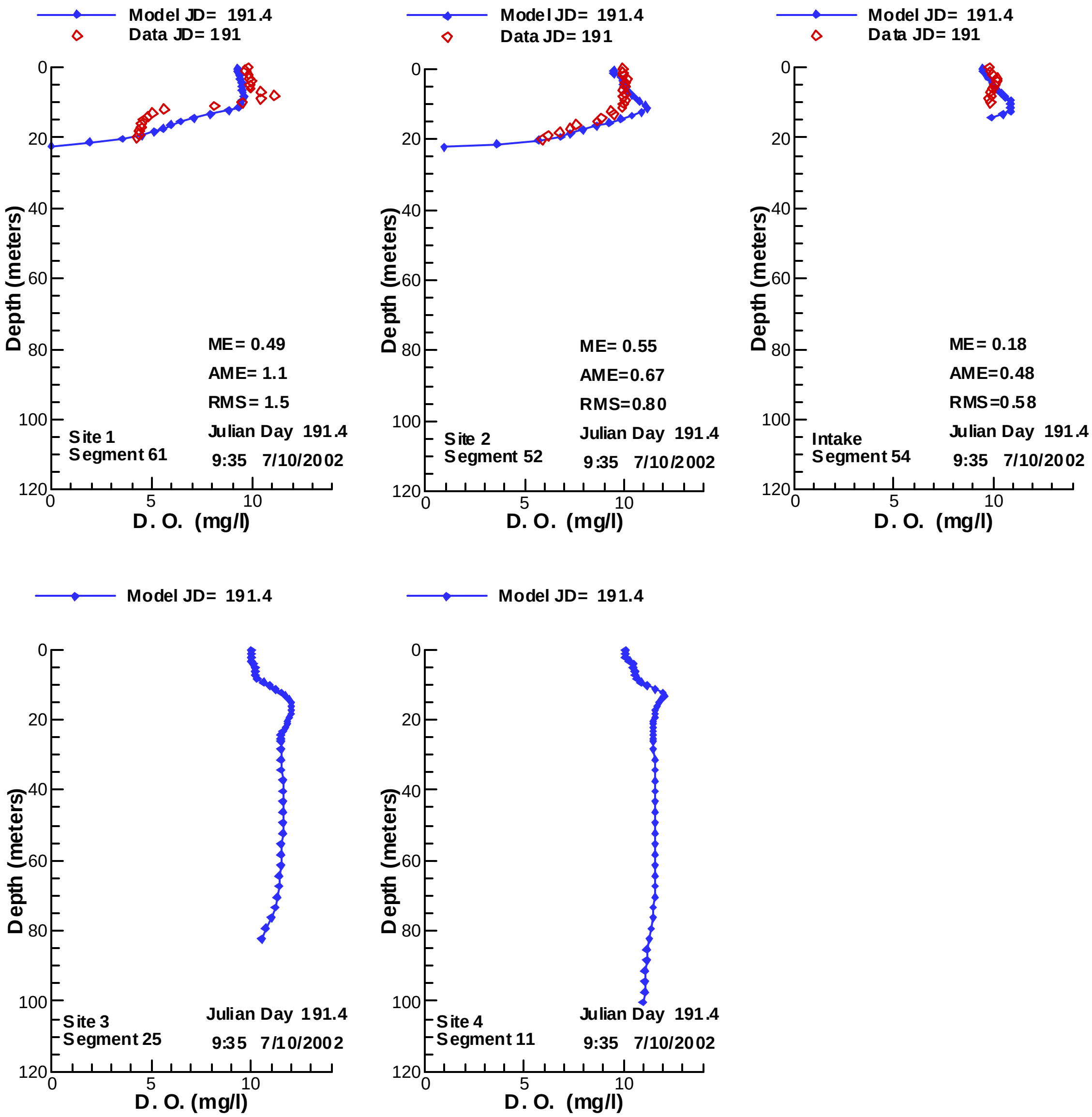

Figure 305. Vertical profiles of DISSOLVED OXYGEN compared with data for 7/10/2002.

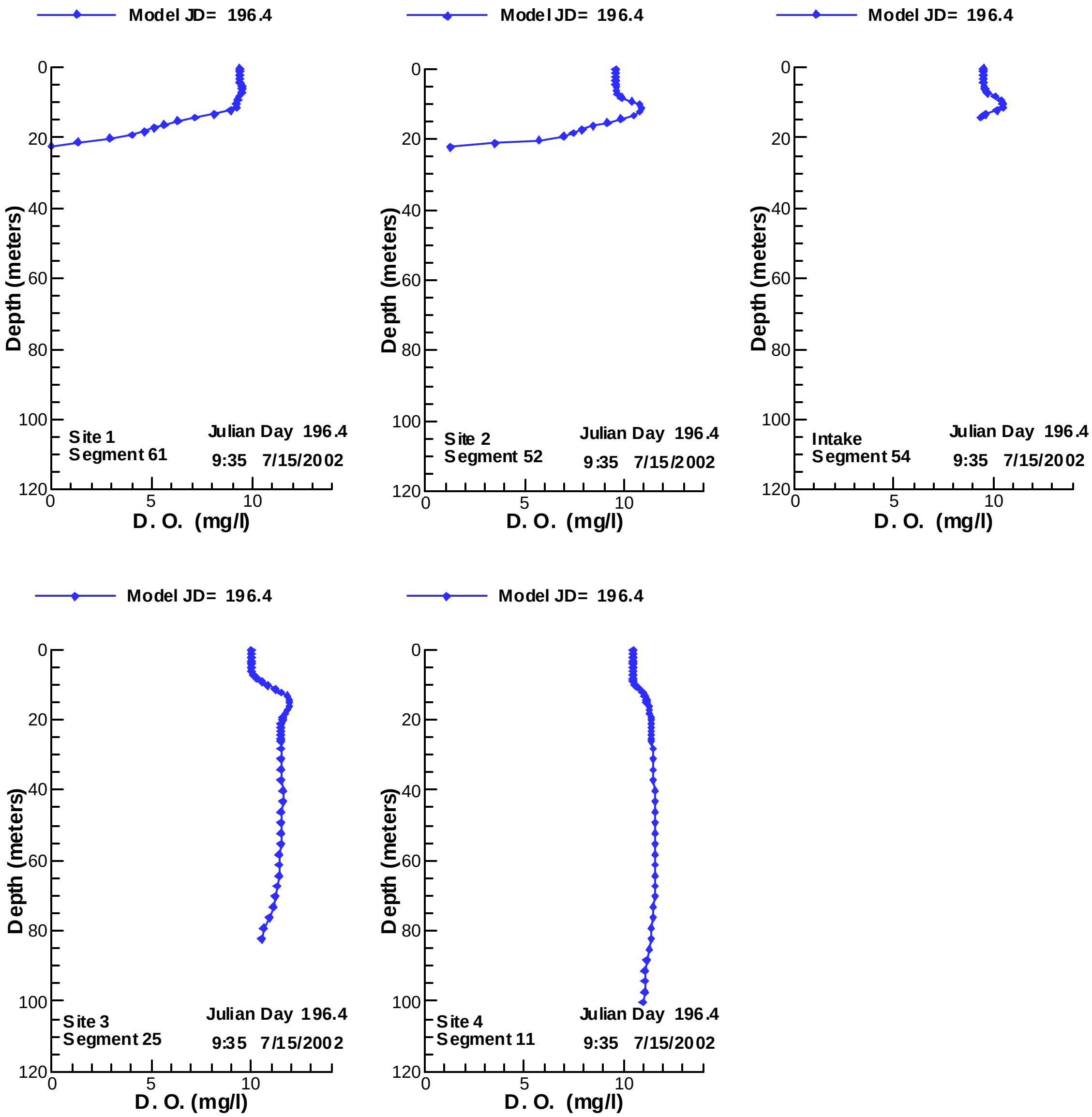

Figure 306. Vertical profiles of DISSOLVED OXYGEN compared with data for 7/15/2002.

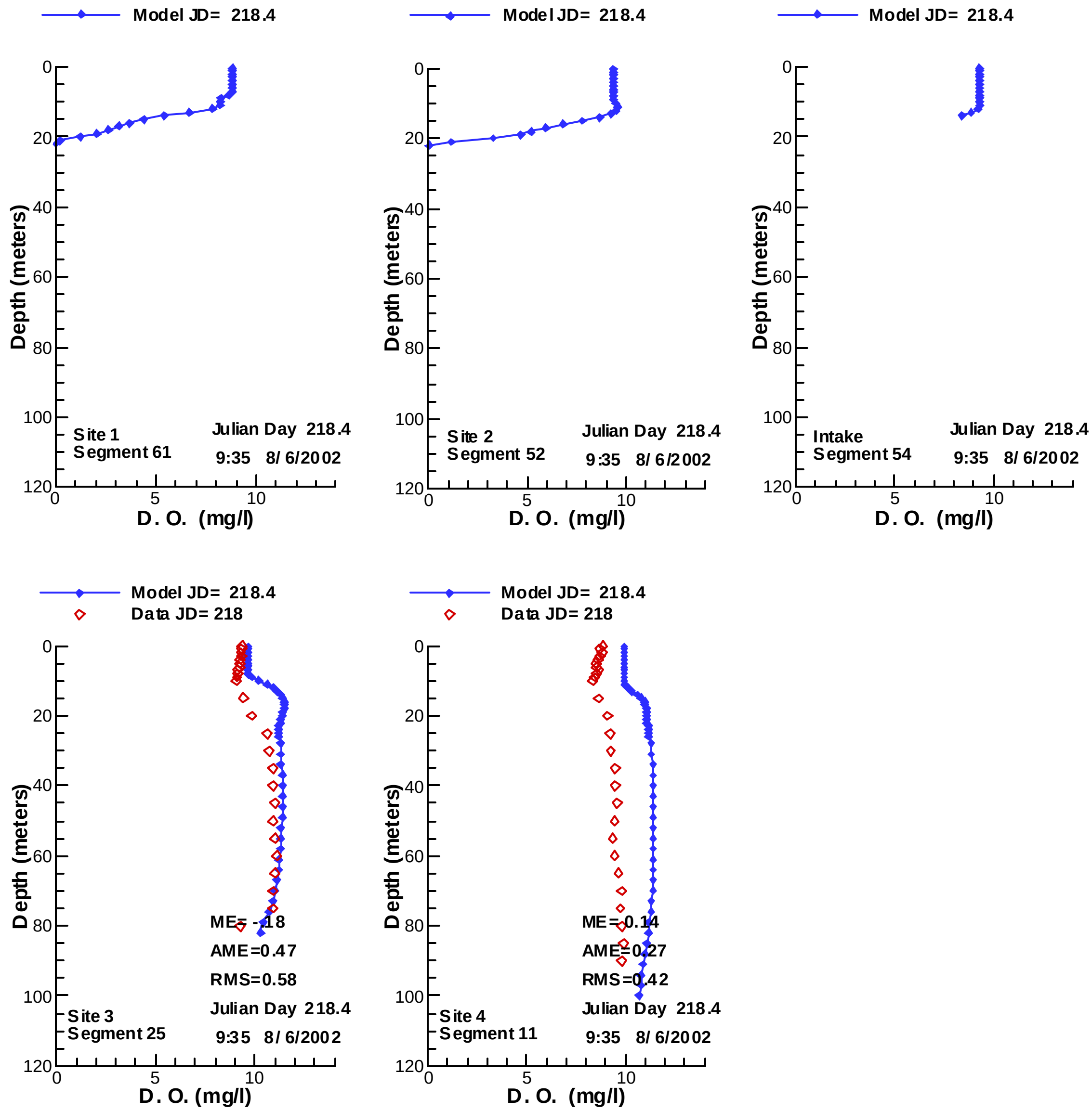

Figure 307. Vertical profiles of DISSOLVED OXYGEN compared with data for 8/ 6/2002.

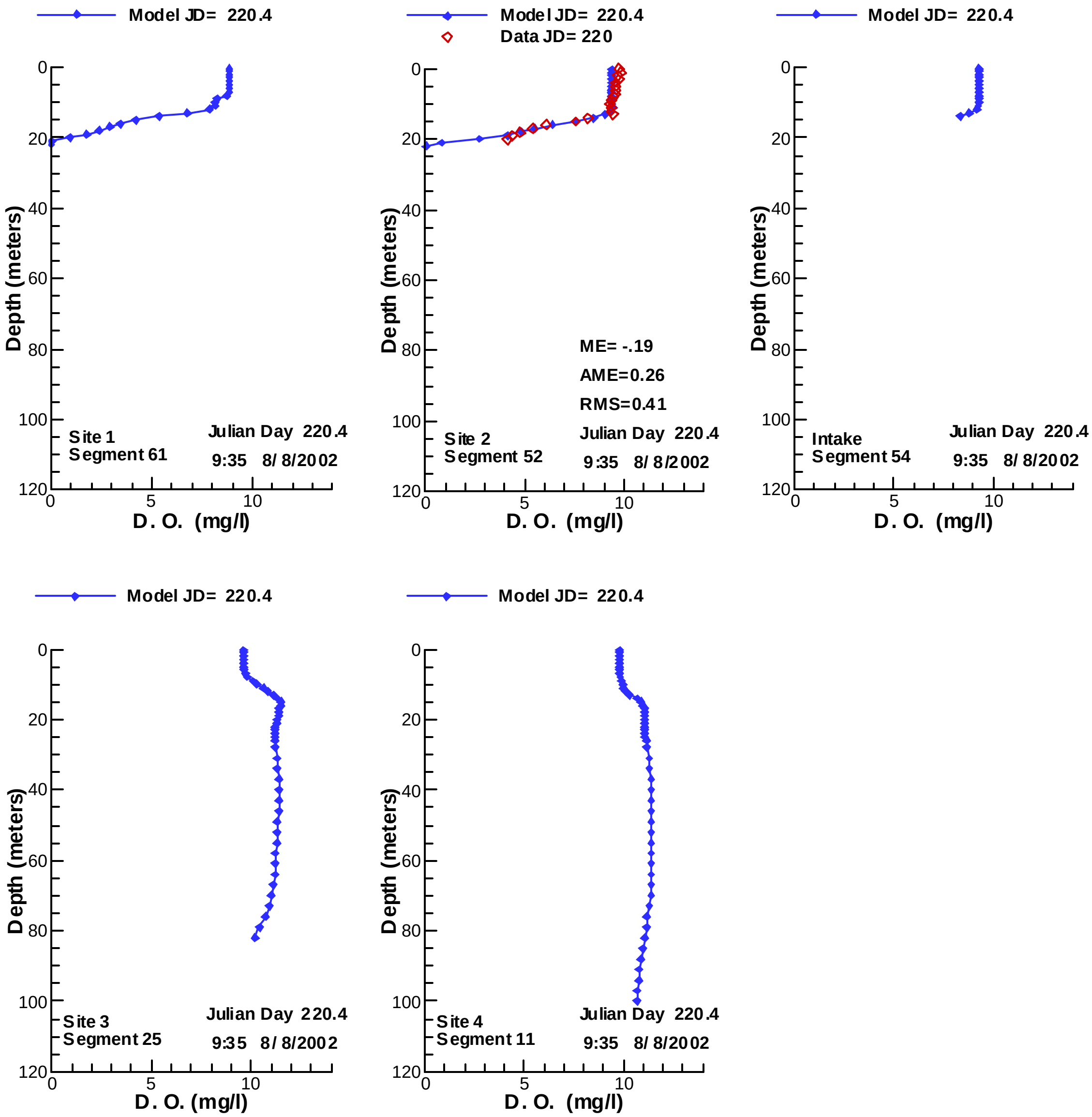

Figure 308. Vertical profiles of DISSOLVED OXYGEN compared with data for 8/ 8/2002.

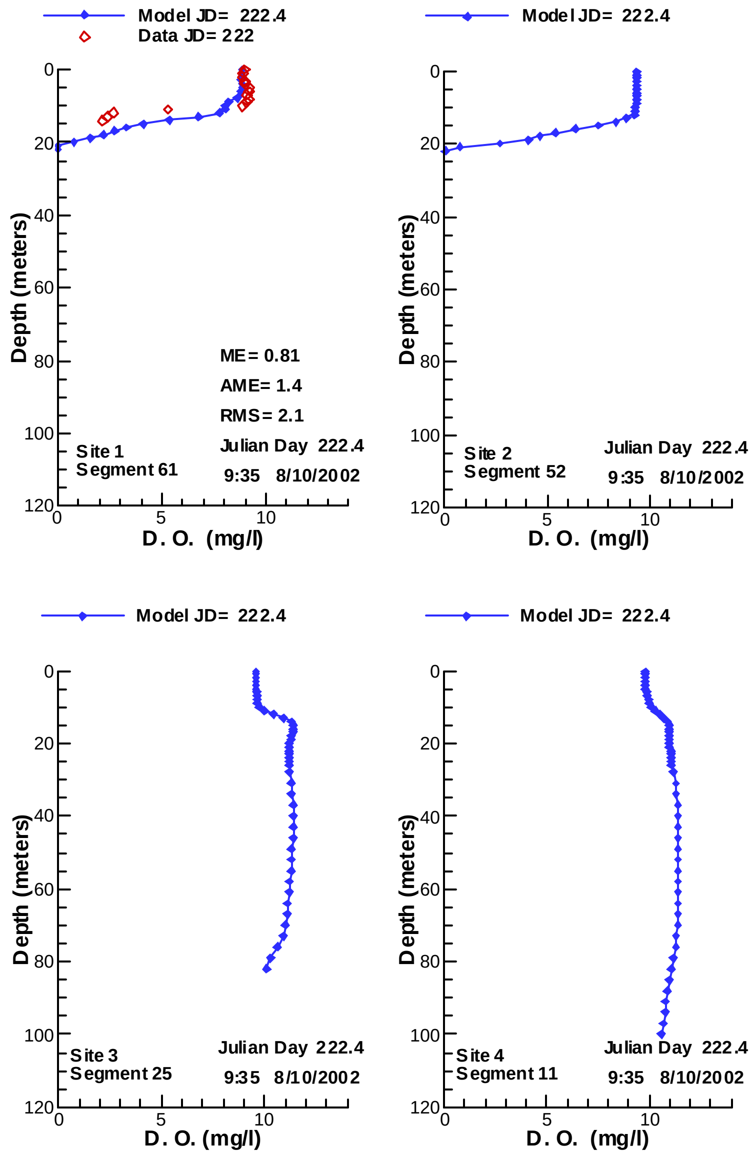

Figure 309. Vertical profiles of DISSOLVED OXYGEN compared with data for 8/10/2002.

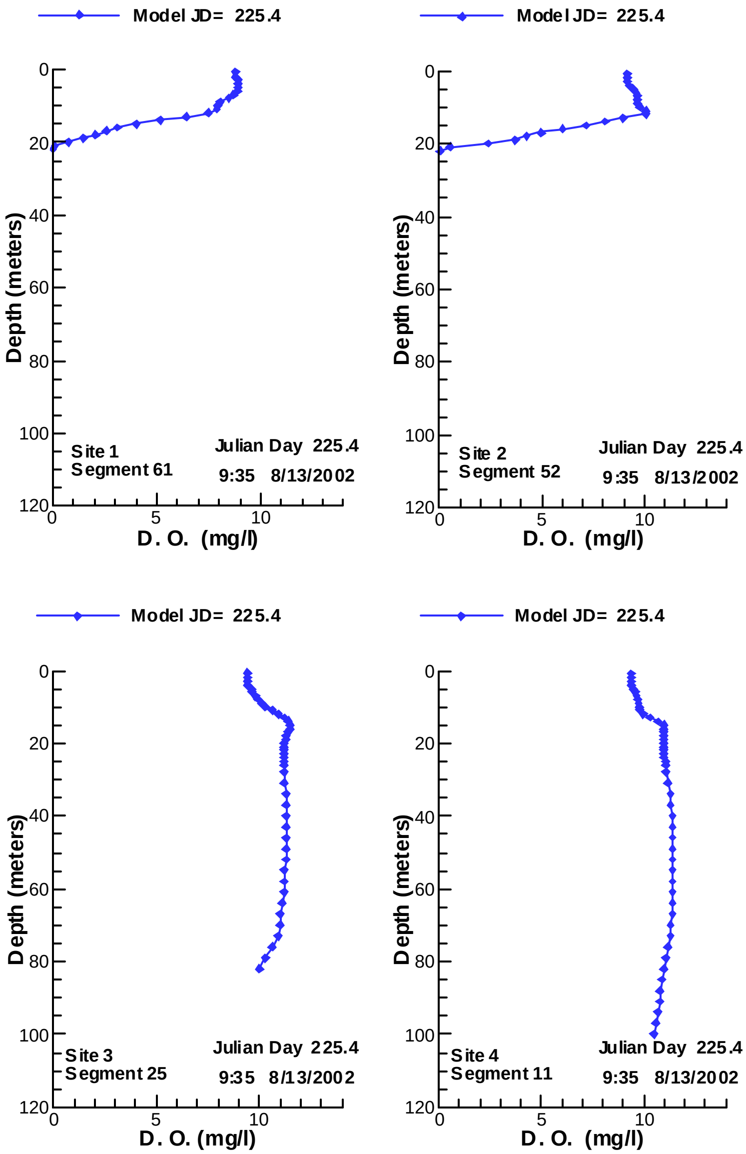

Figure 310. Vertical profiles of DISSOLVED OXYGEN compared with data for 8/13/2002.

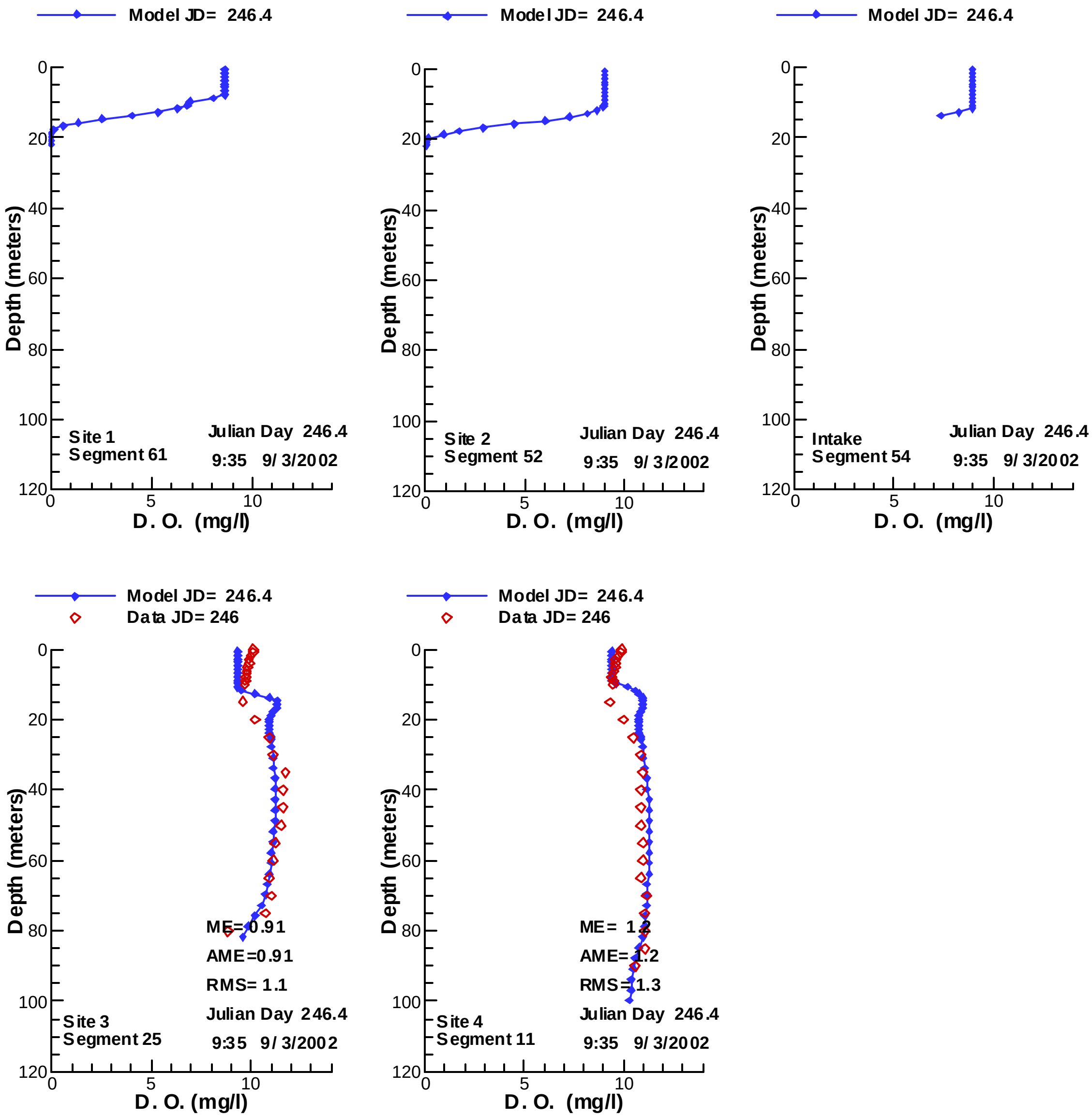

Figure 311. Vertical profiles of DISSOLVED OXYGEN compared with data for 9/ 3/2002.

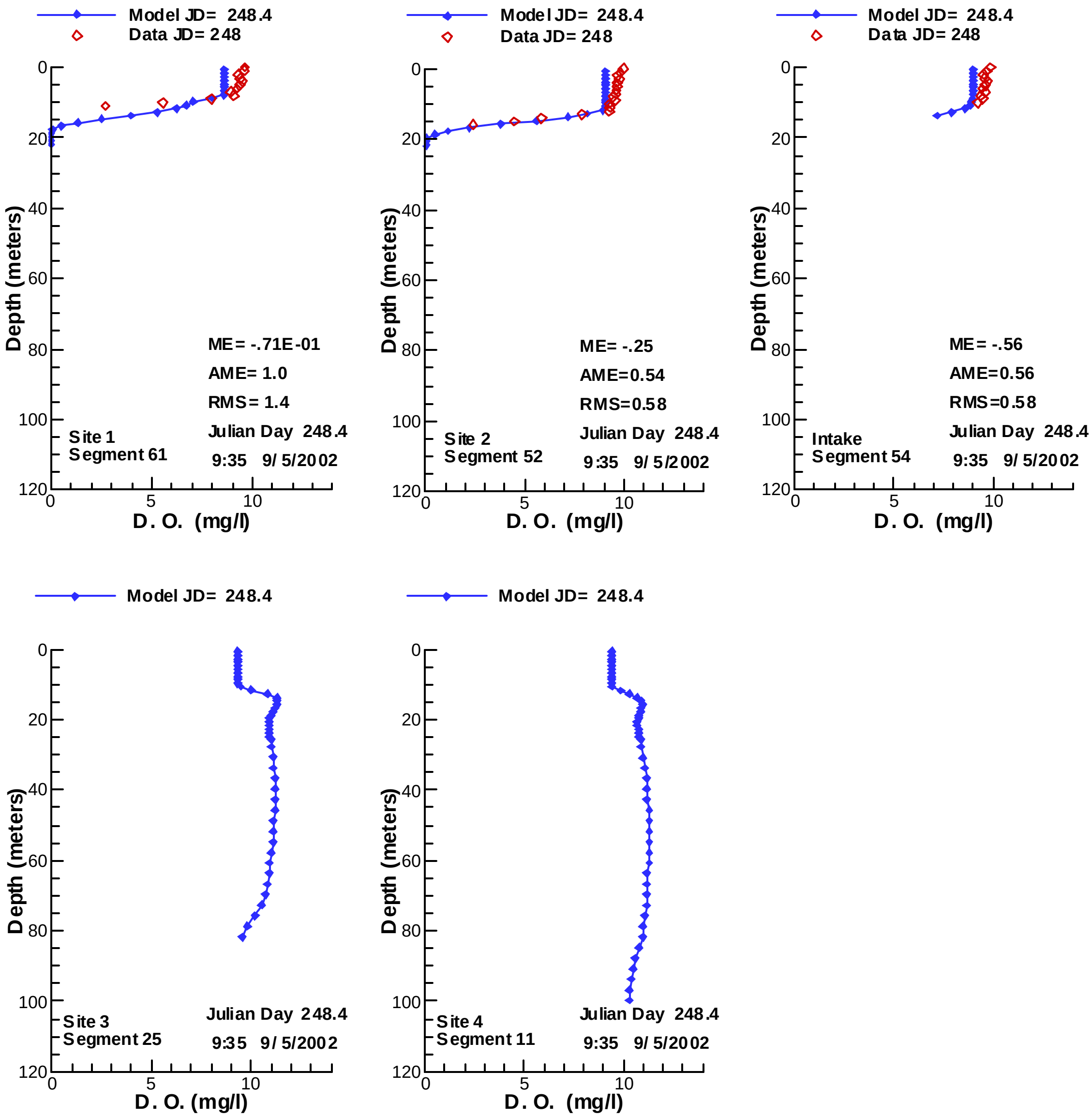

Figure 312. Vertical profiles of DISSOLVED OXYGEN compared with data for 9/ 5/2002.

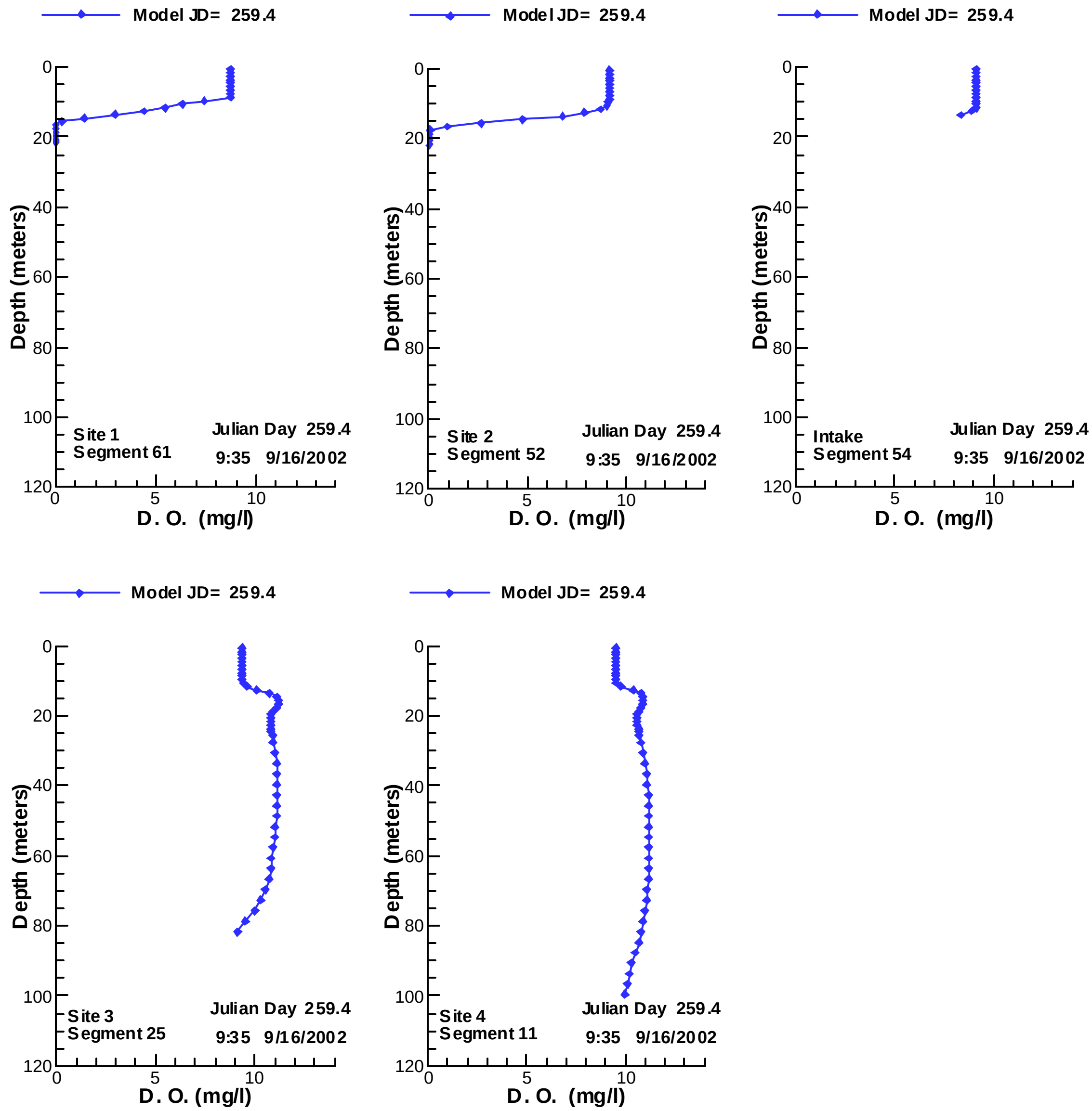

Figure 313. Vertical profiles of DISSOLVED OXYGEN compared with data for 9/16/2002.

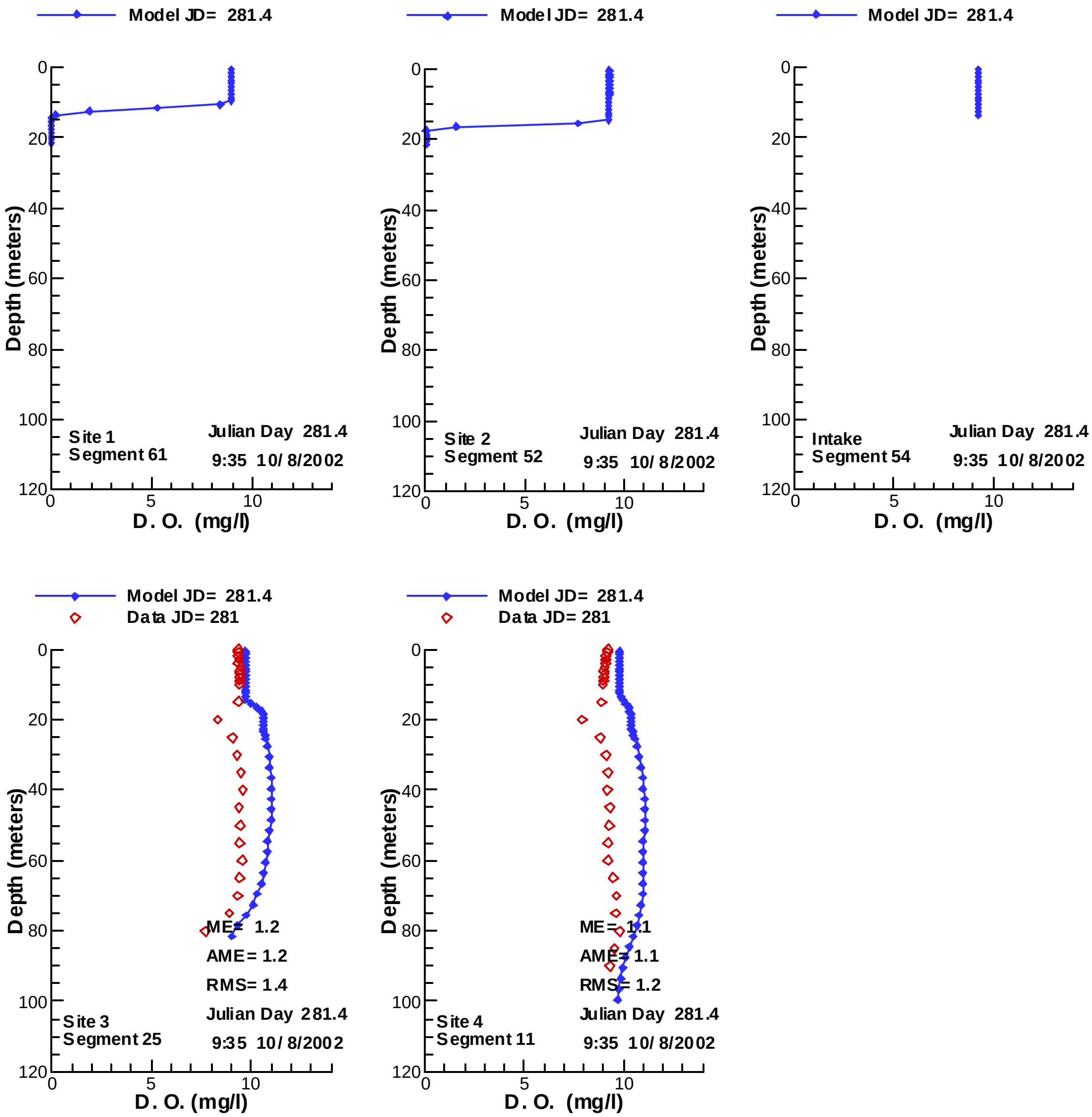

Figure 314. Vertical profiles of DISSOLVED OXYGEN compared with data for 10/ 8/2002.

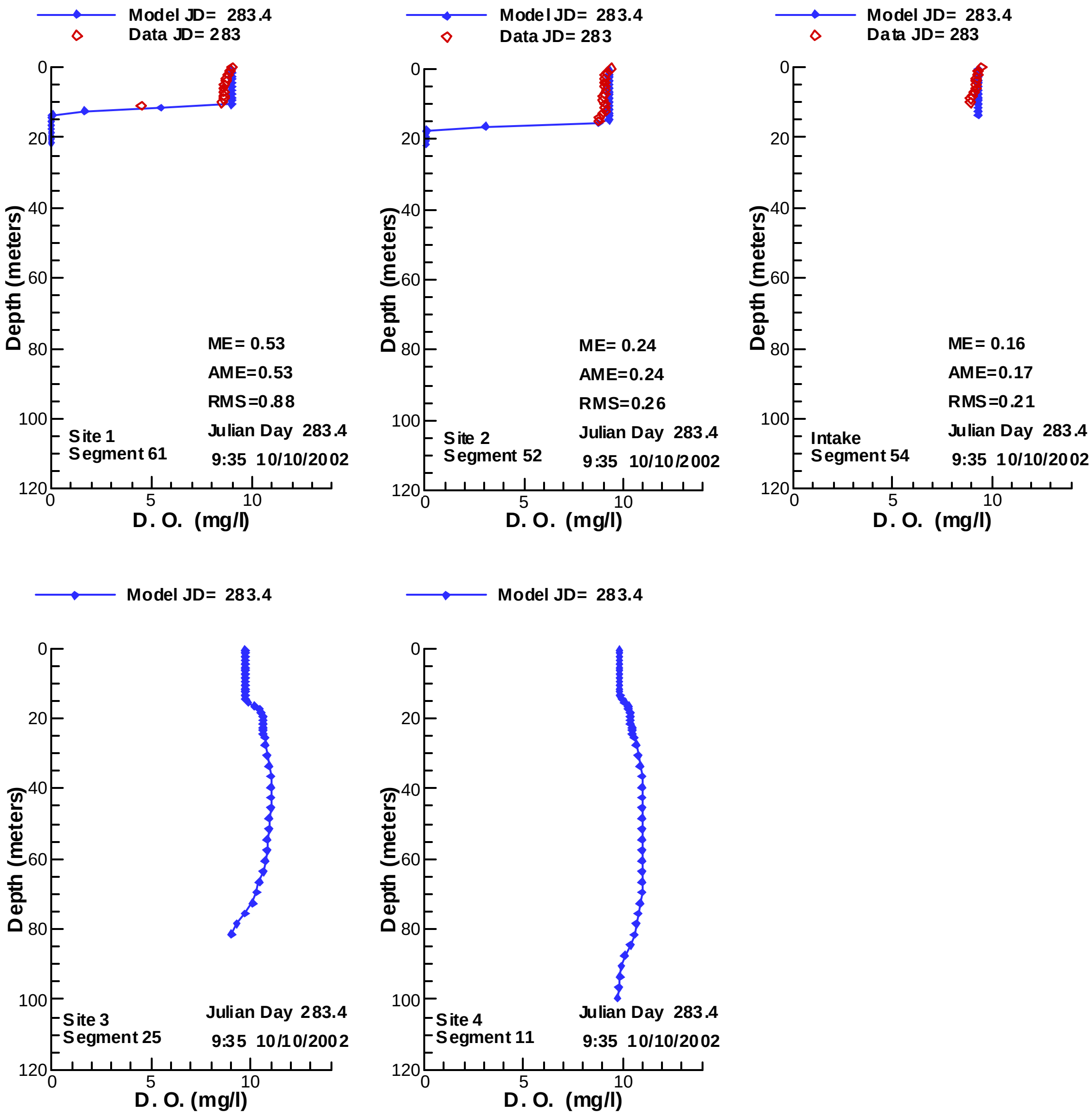

Figure 315. Vertical profiles of DISSOLVED OXYGEN compared with data for 10/10/2002.

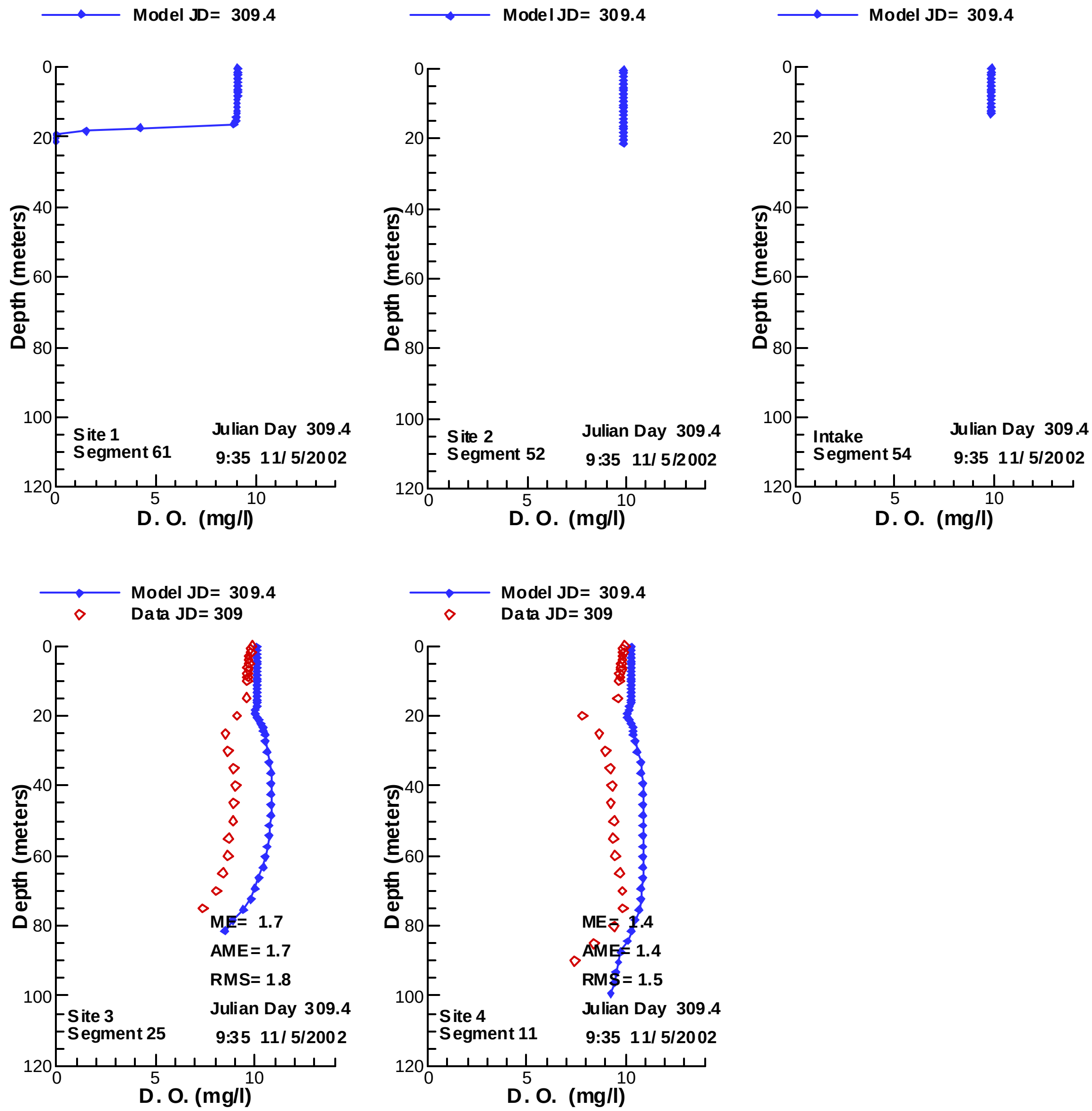

Figure 316. Vertical profiles of DISSOLVED OXYGEN compared with data for 11/ 5/2002.

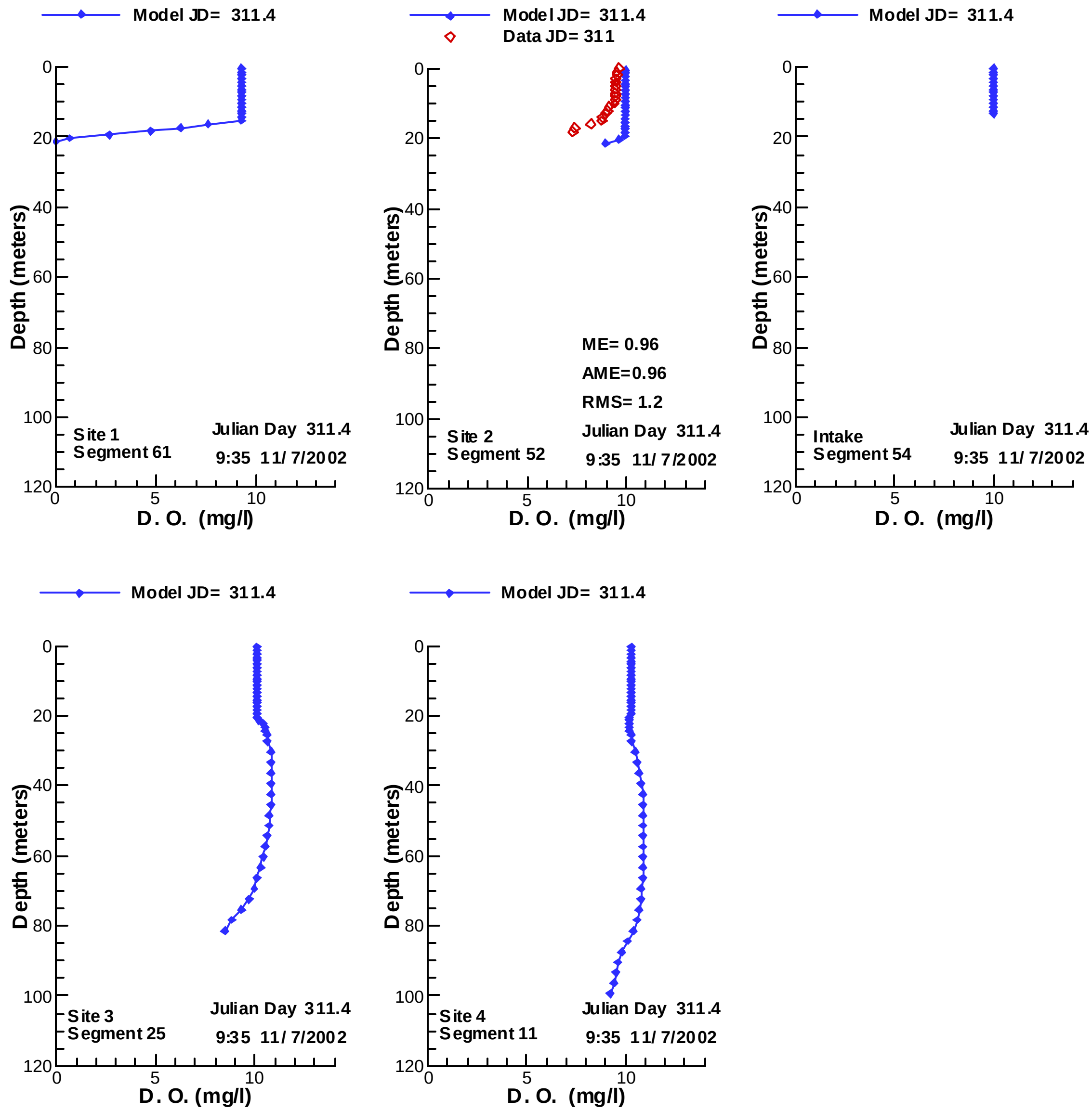

Figure 317. Vertical profiles of DISSOLVED OXYGEN compared with data for 11/ 7/2002.

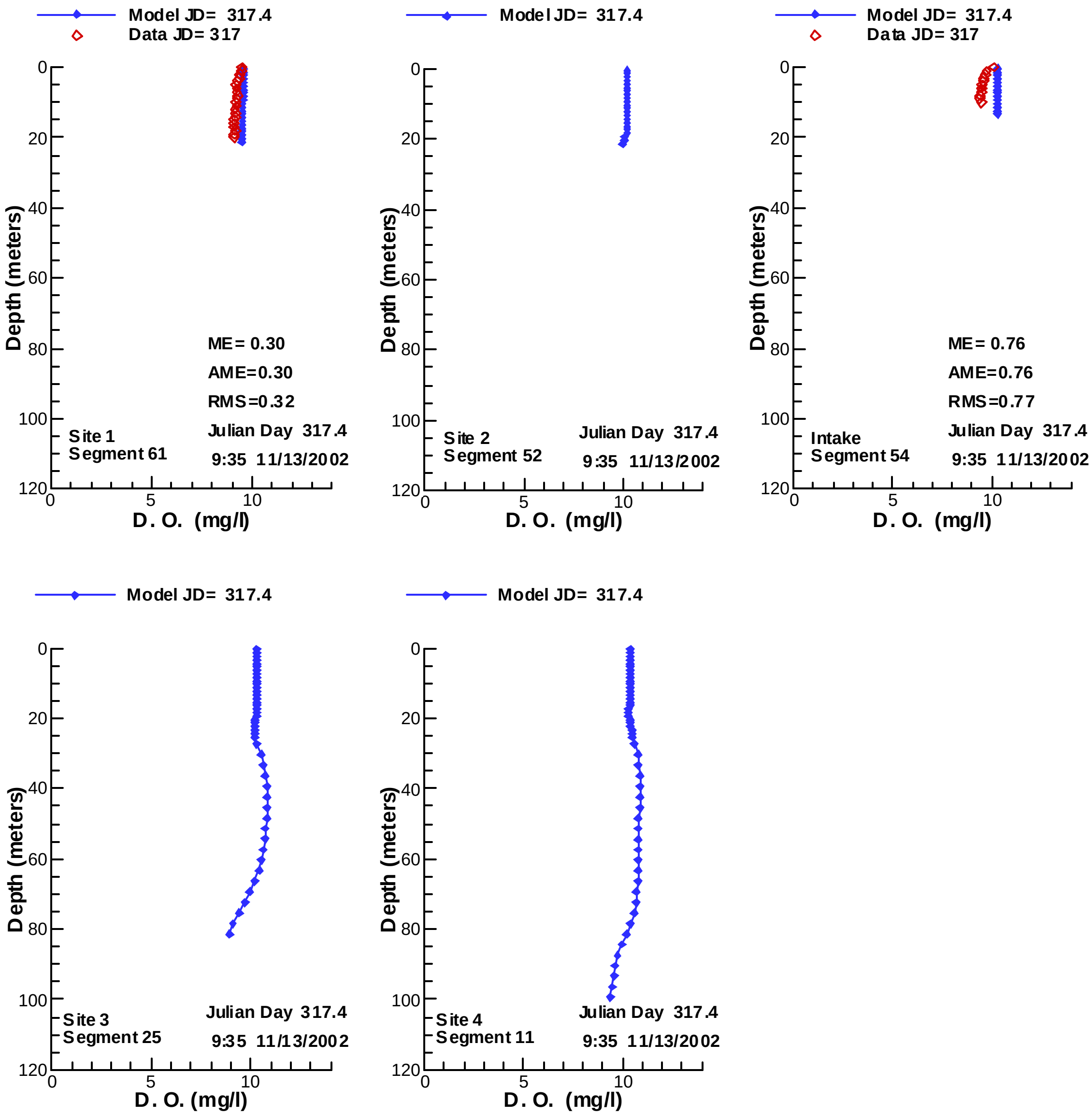

Figure 318. Vertical profiles of DISSOLVED OXYGEN compared with data for 11/13/2002.

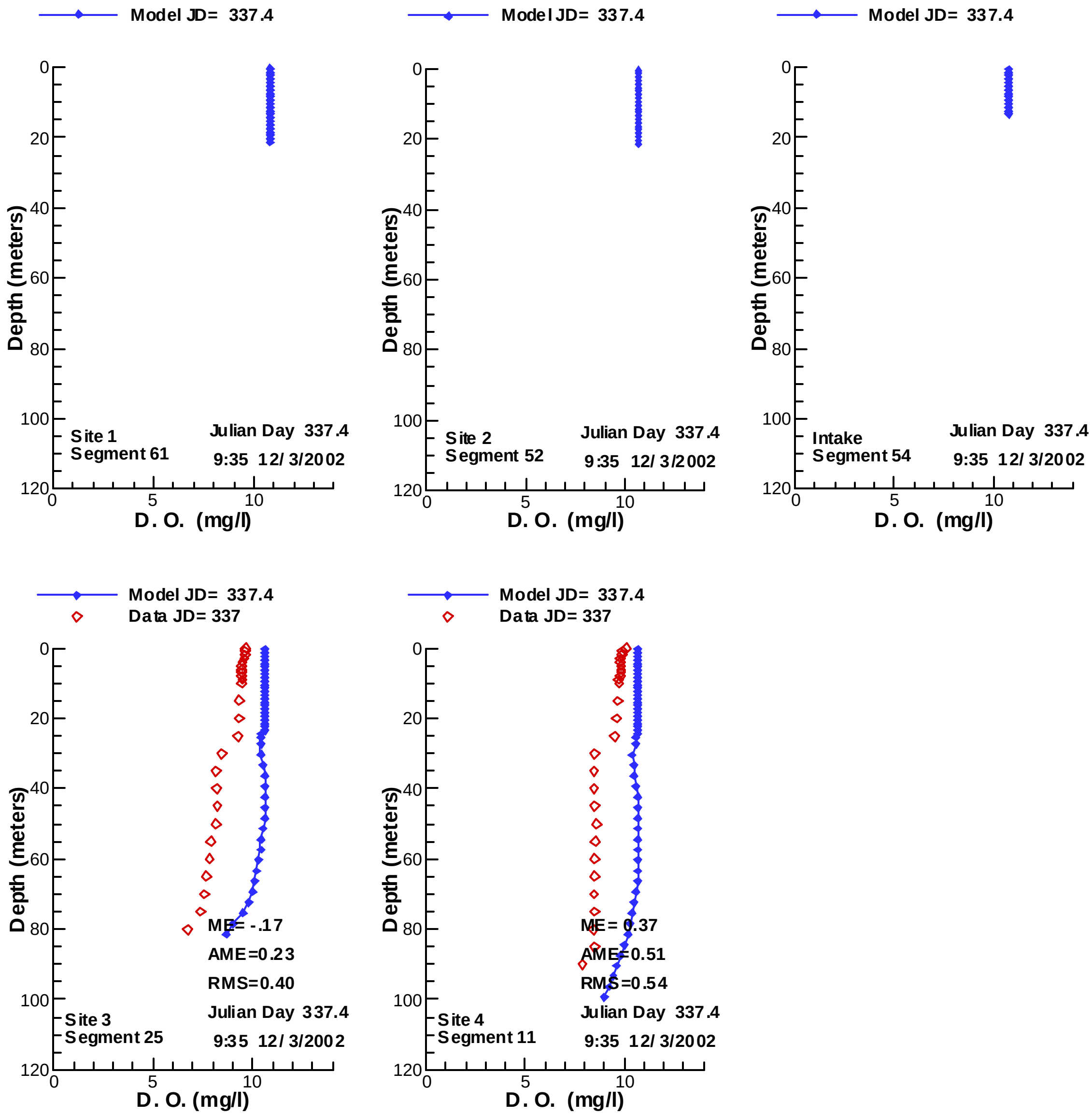

Figure 319. Vertical profiles of DISSOLVED OXYGEN compared with data for 12/ 3/2002.

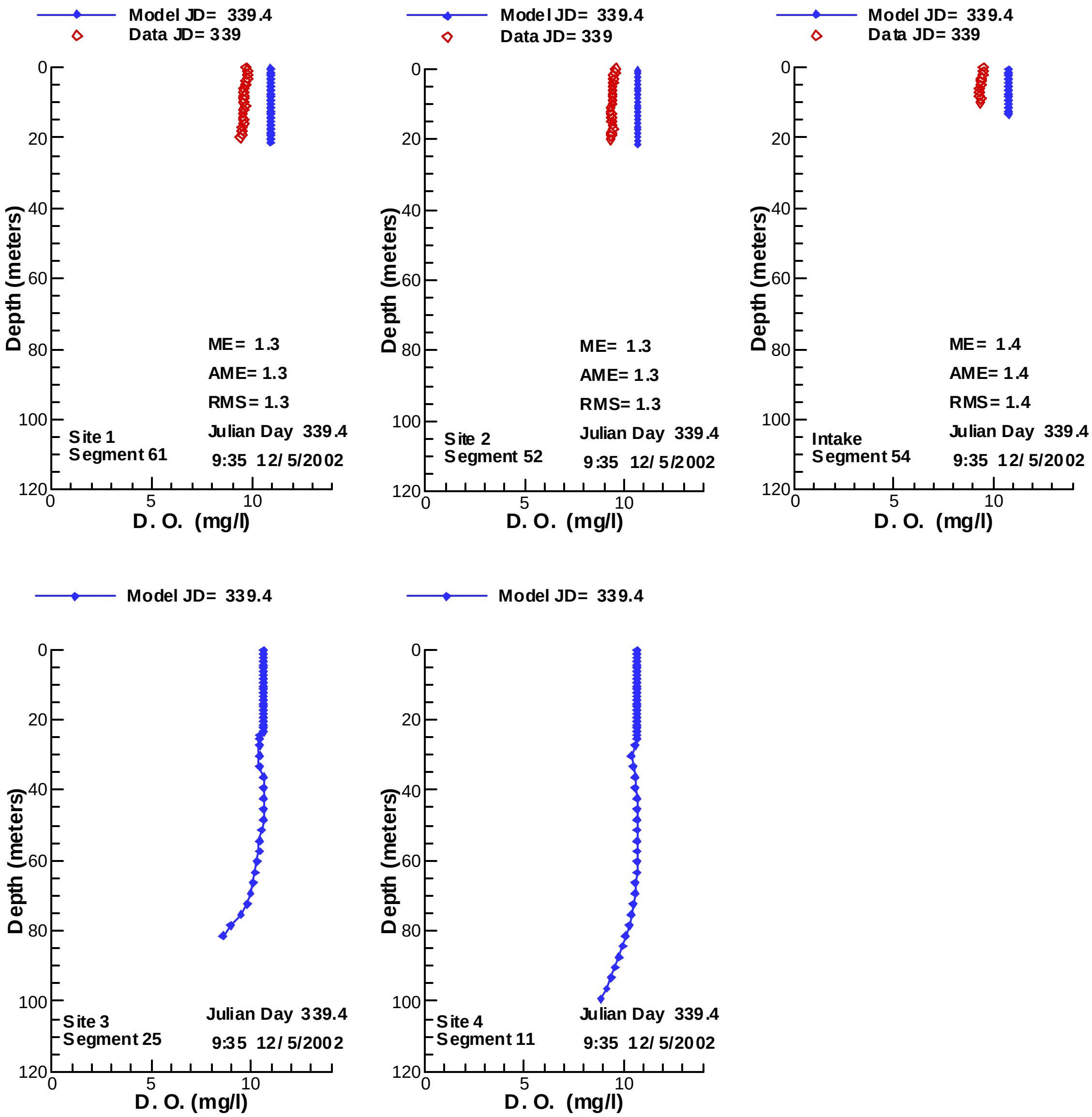

Figure 320. Vertical profiles of DISSOLVED OXYGEN compared with data for 12/ 5/2002.

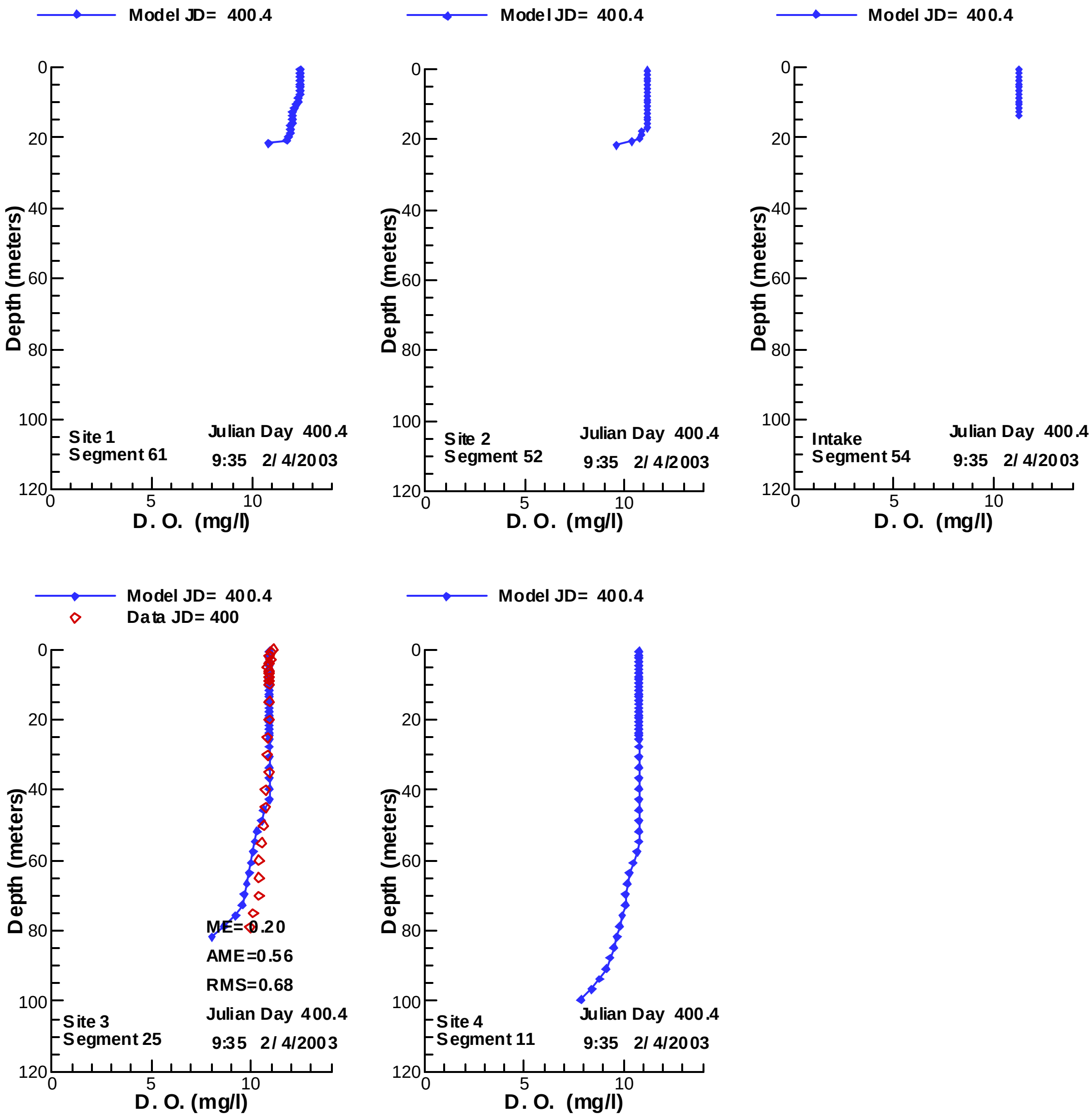

Figure 321. Vertical profiles of DISSOLVED OXYGEN compared with data for 2/ 4/2003.

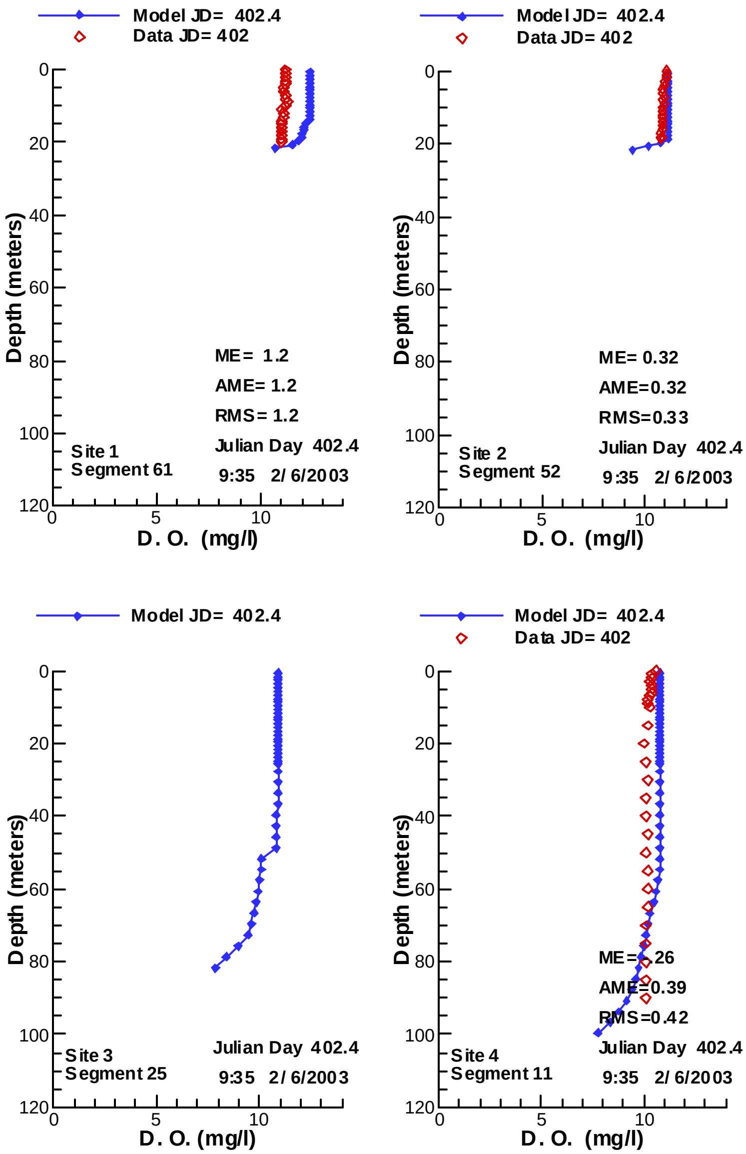

Figure 322. Vertical profiles of DISSOLVED OXYGEN compared with data for 2/ 6/2003.

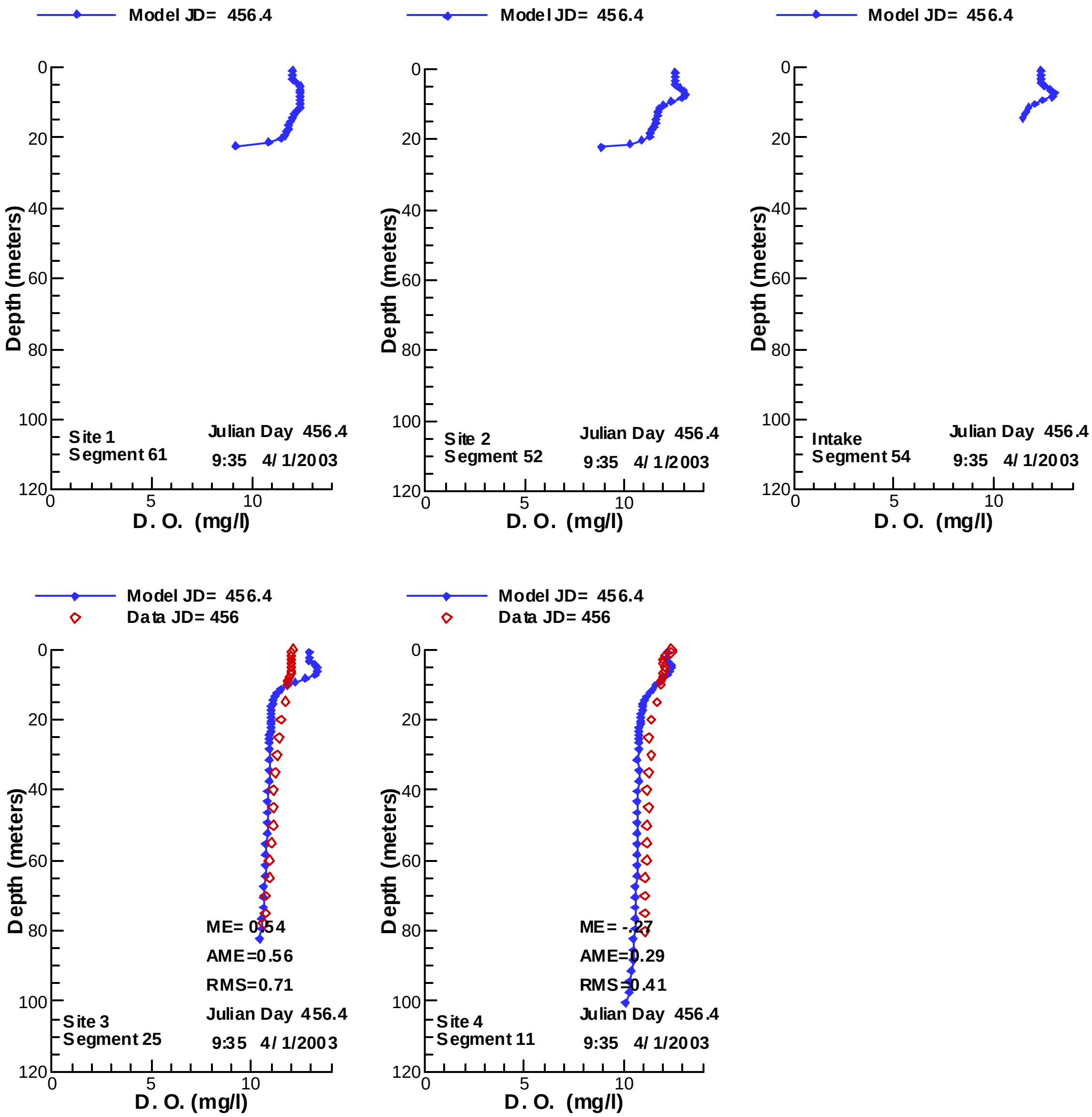

Figure 323. Vertical profiles of DISSOLVED OXYGEN compared with data for 4/ 1/2003.

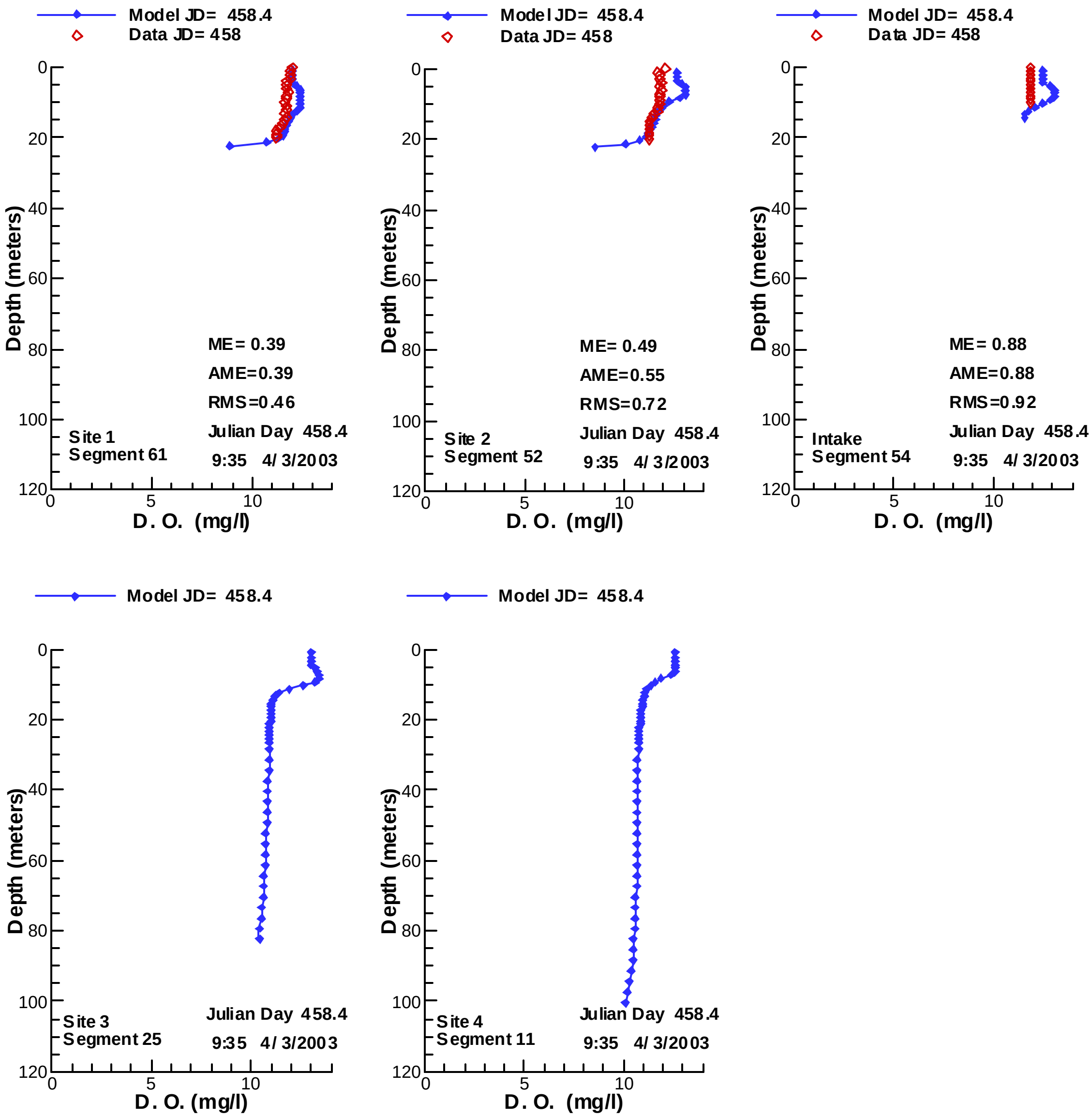

Figure 324. Vertical profiles of DISSOLVED OXYGEN compared with data for 4/ 3/2003.

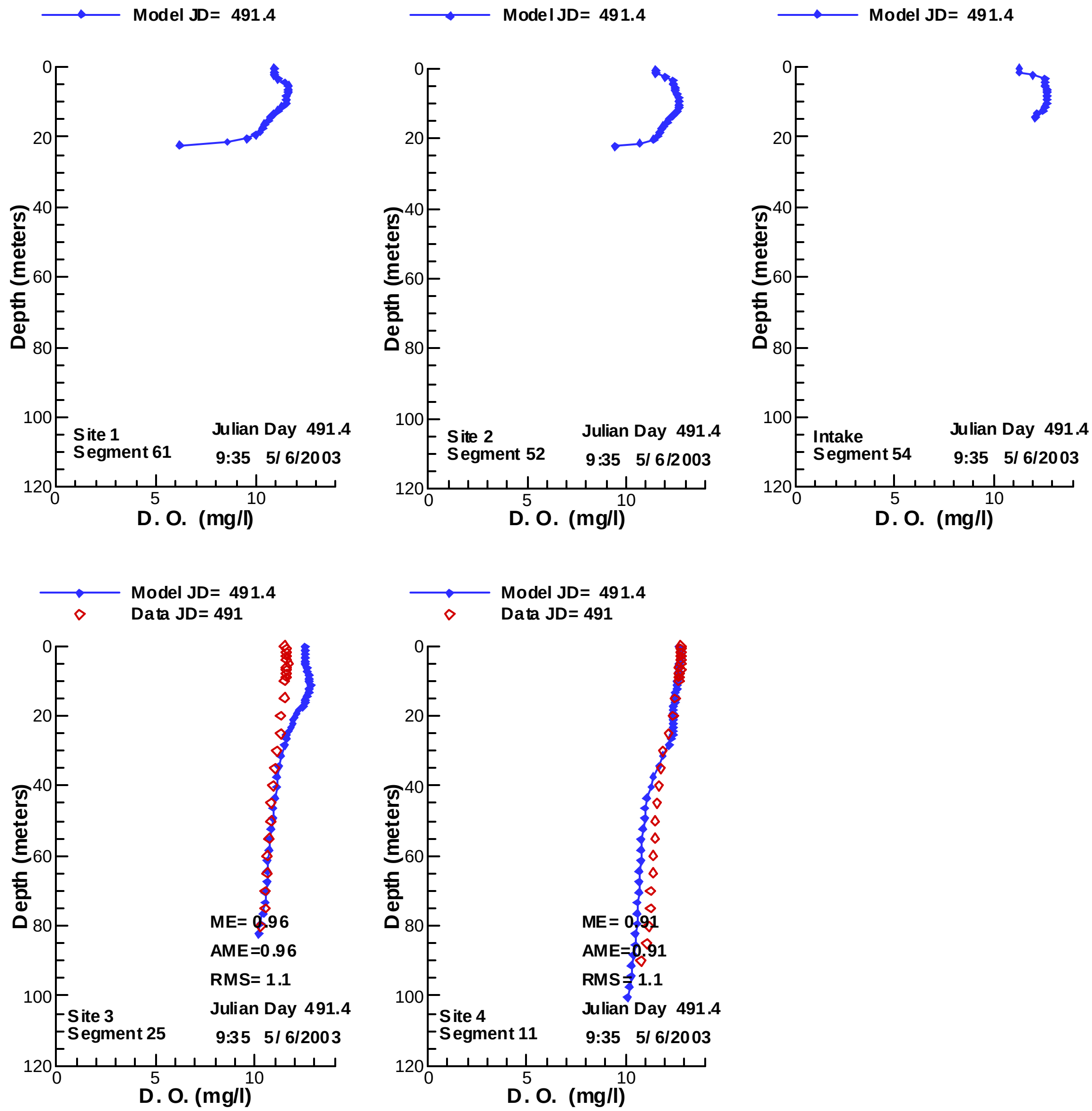

Figure 325. Vertical profiles of DISSOLVED OXYGEN compared with data for 5/ 6/2003.

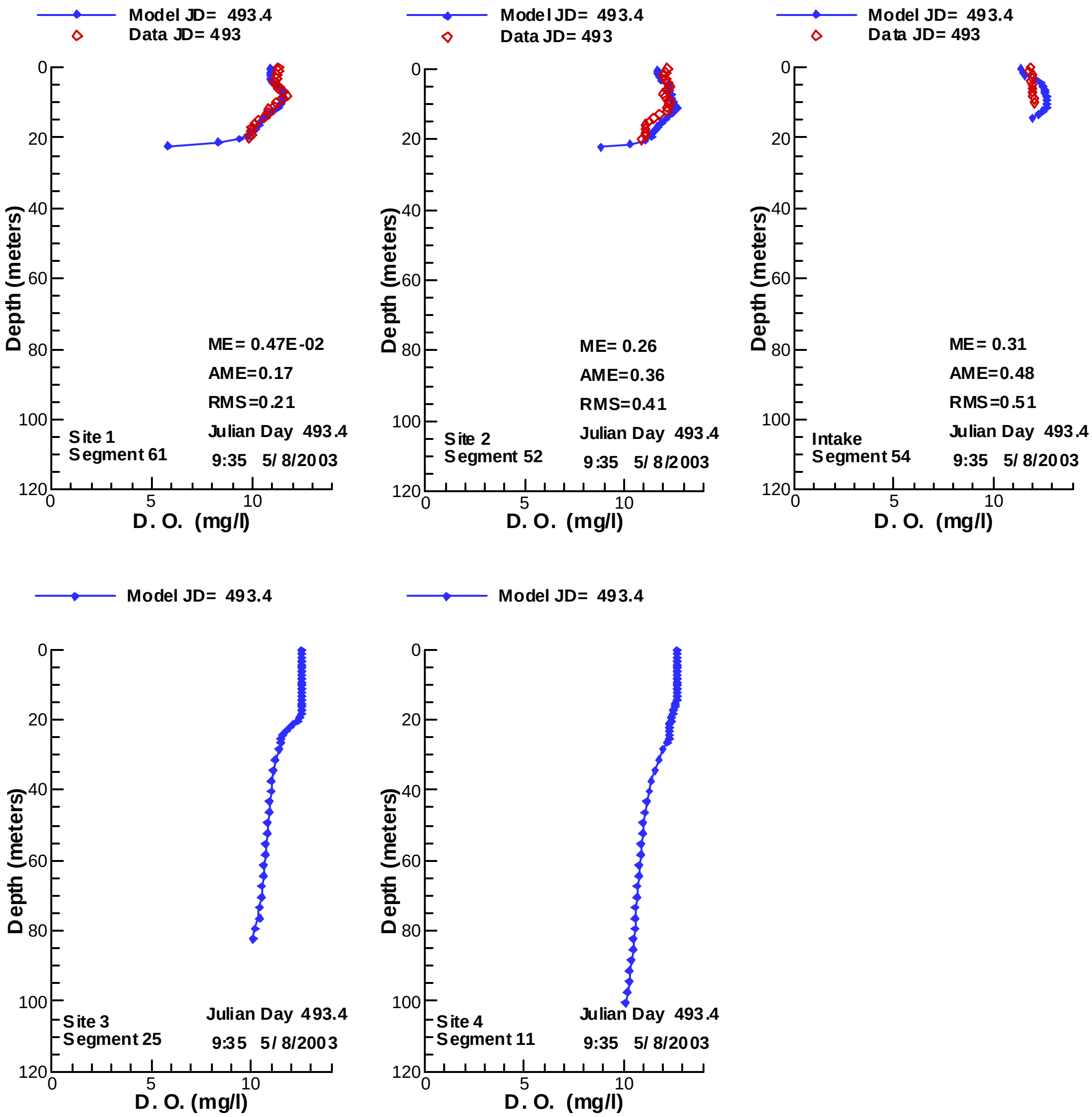

Figure 326. Vertical profiles of DISSOLVED OXYGEN compared with data for 5/ 8/2003.

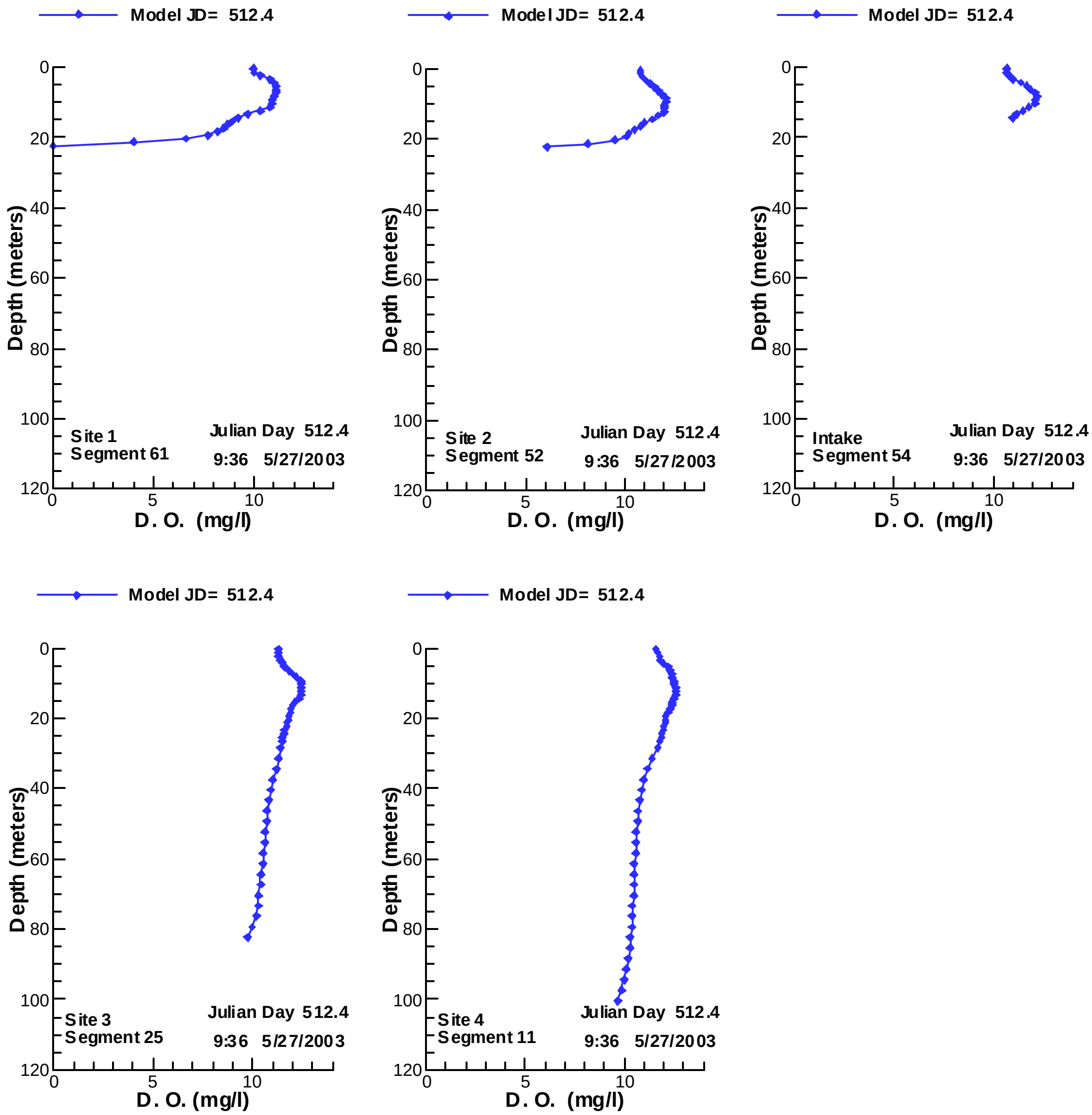

Figure 327. Vertical profiles of DISSOLVED OXYGEN compared with data for 5/27/2003.

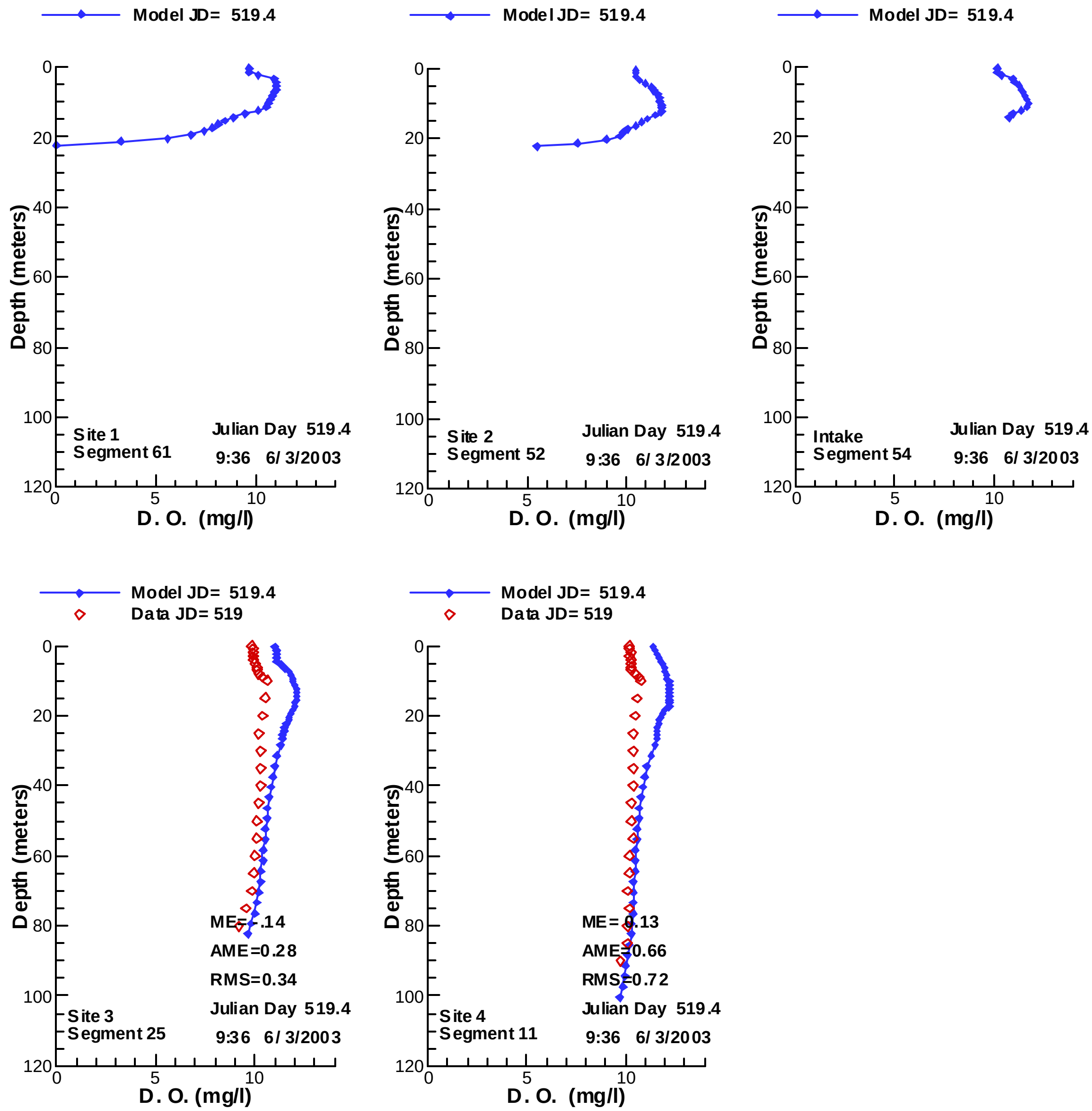

Figure 328. Vertical profiles of DISSOLVED OXYGEN compared with data for 6/ 3/2003.

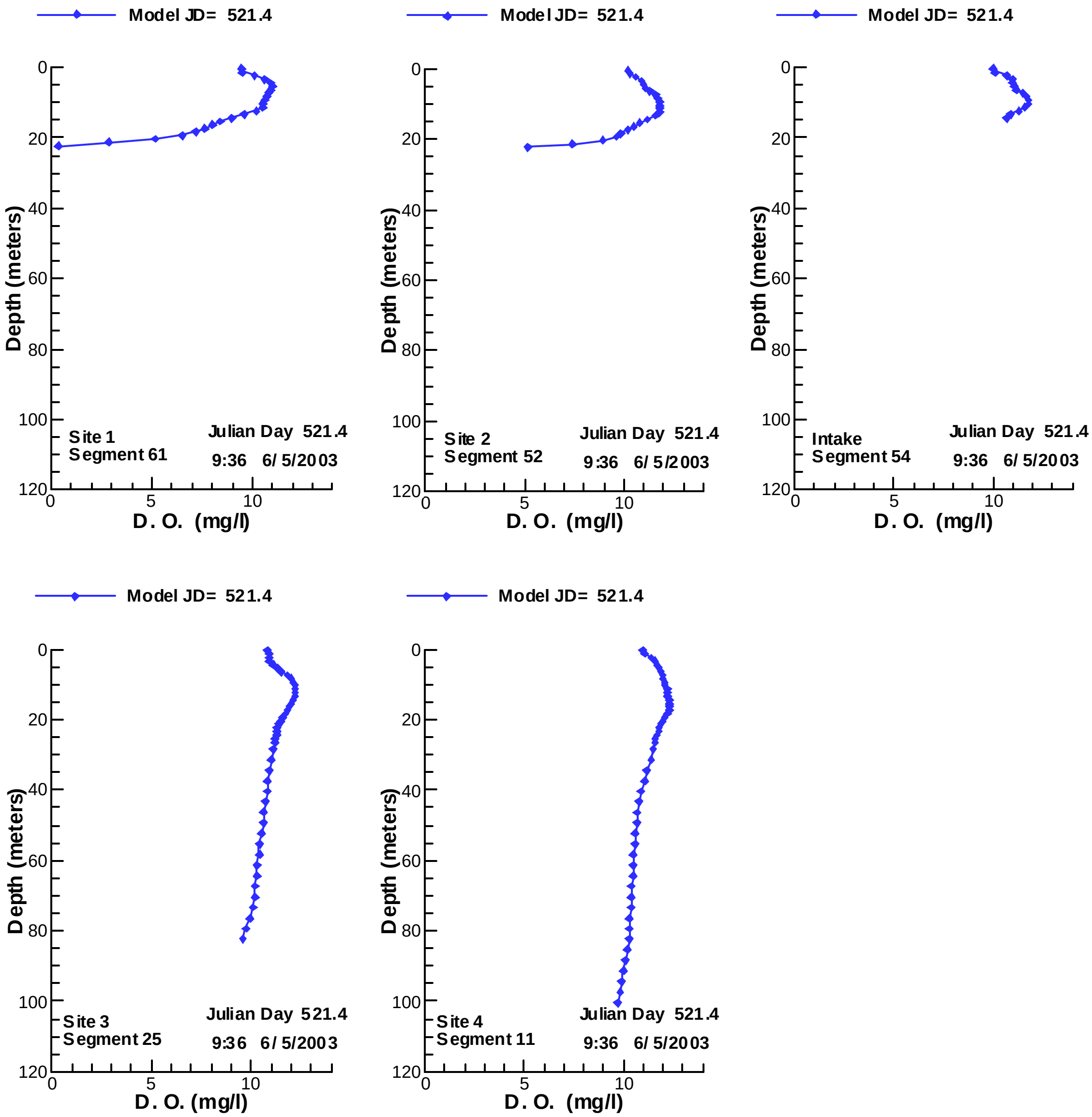

Figure 329. Vertical profiles of DISSOLVED OXYGEN compared with data for 6/ 5/2003.

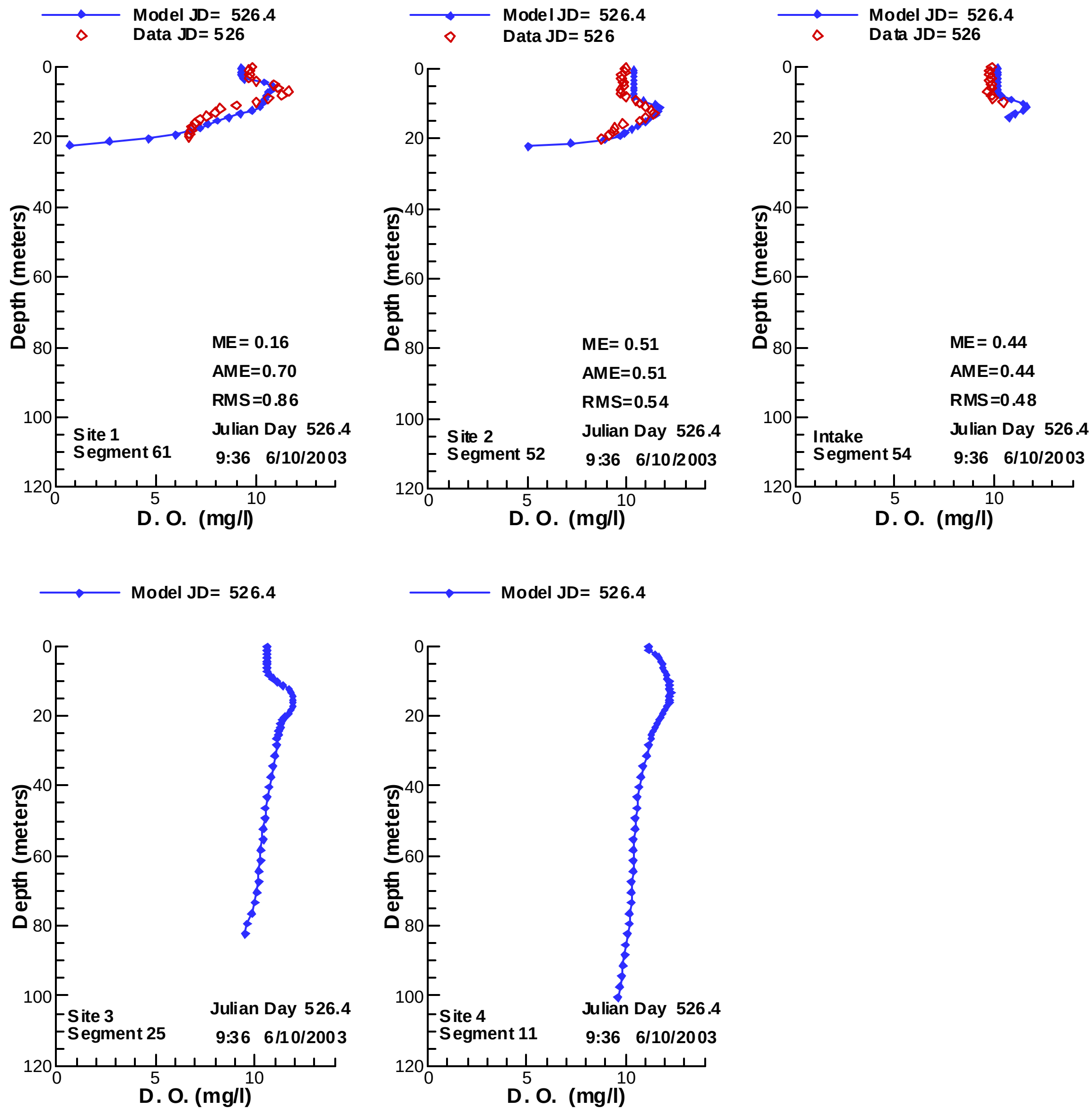

Figure 330. Vertical profiles of DISSOLVED OXYGEN compared with data for 6/10/2003.

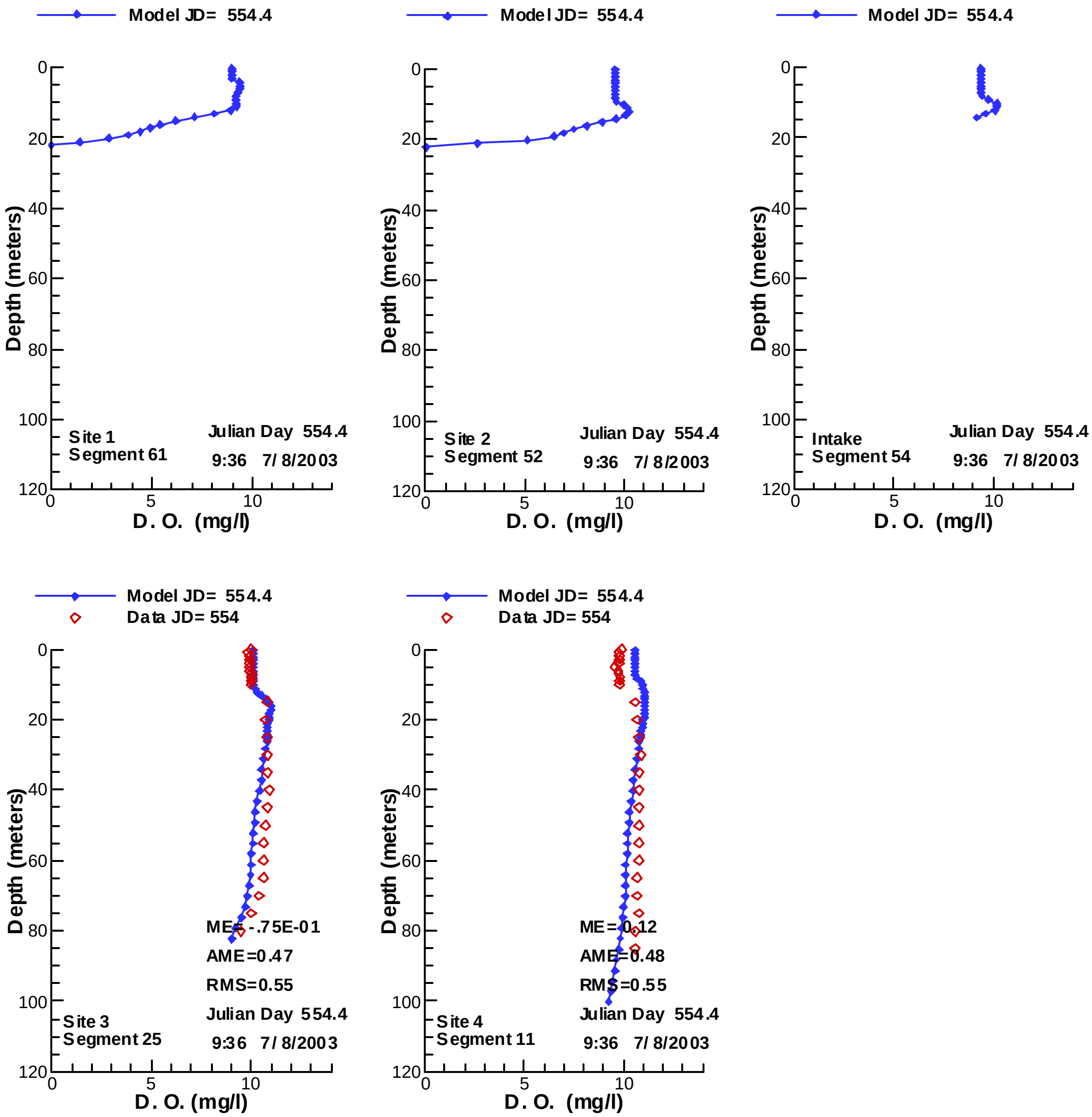

Figure 331. Vertical profiles of DISSOLVED OXYGEN compared with data for 7/ 8/2003.

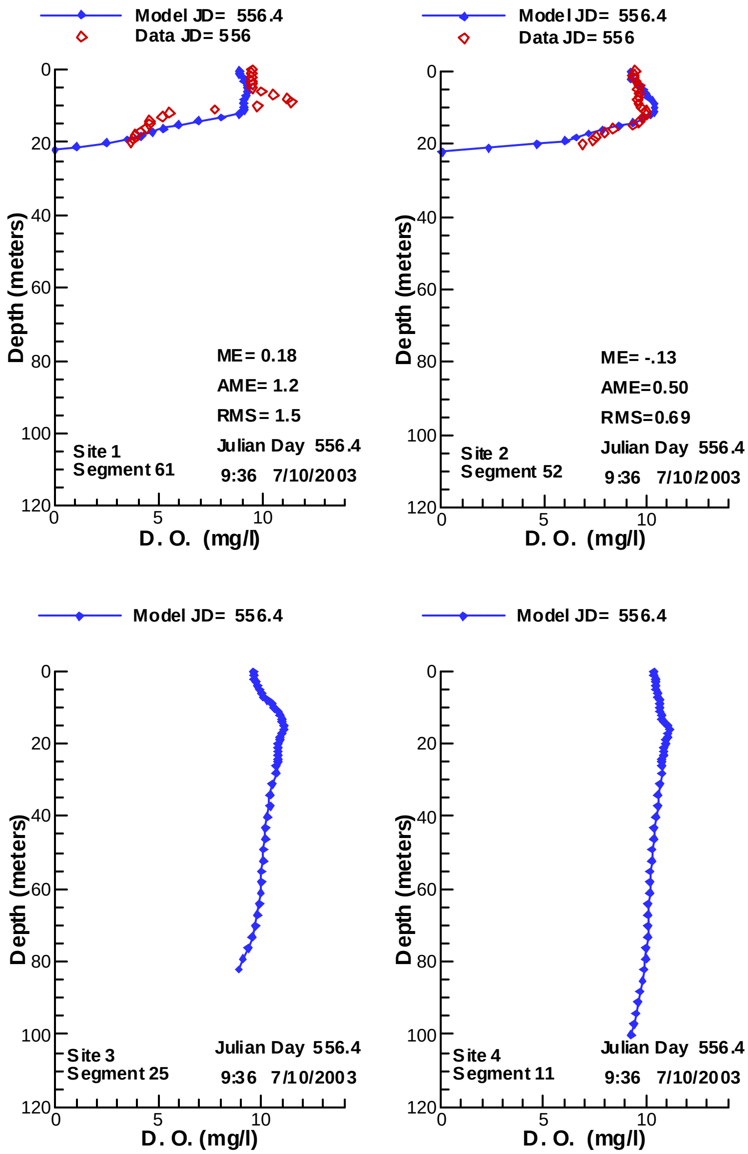

Figure 332. Vertical profiles of DISSOLVED OXYGEN compared with data for 7/10/2003.

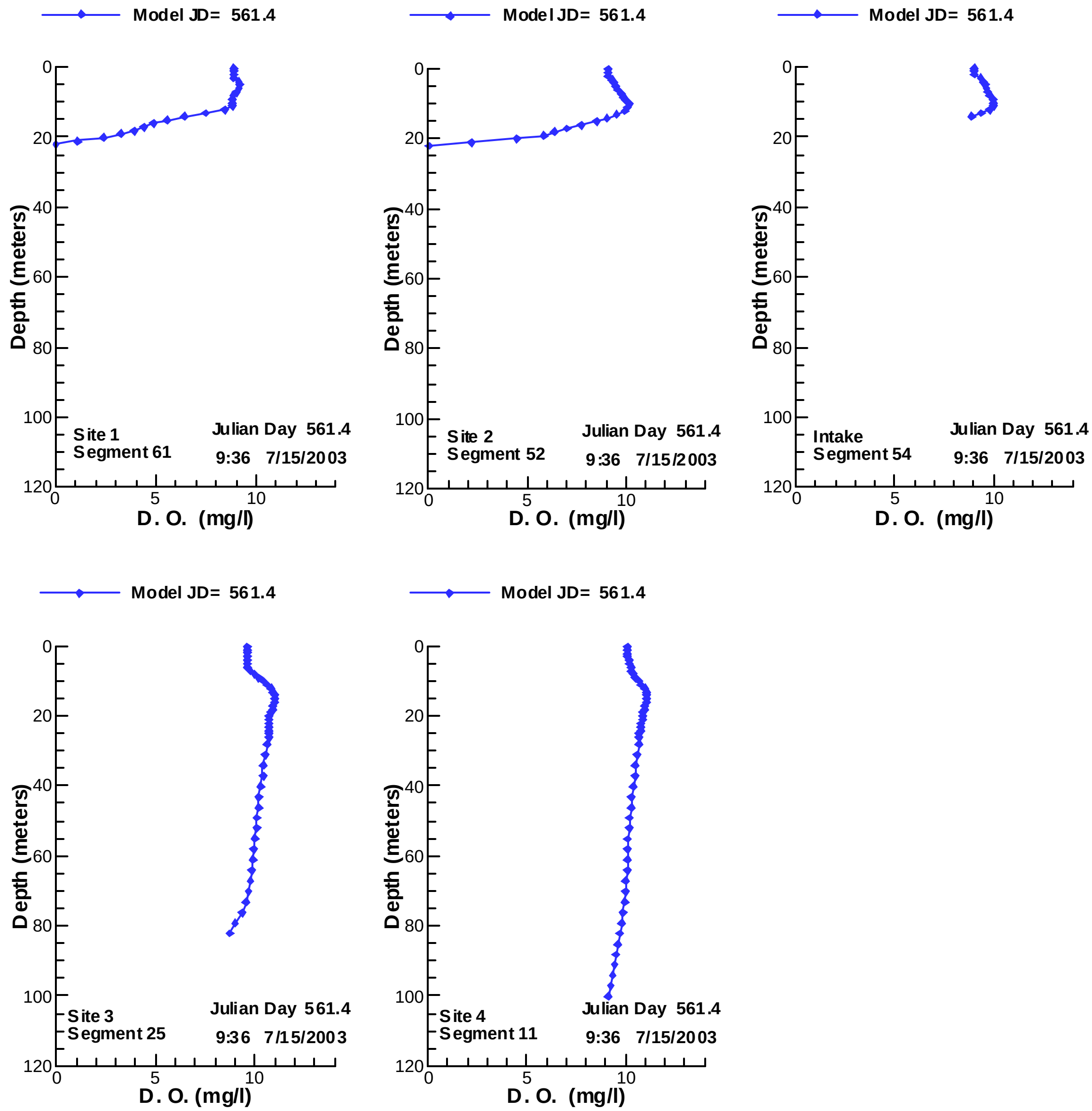

Figure 333. Vertical profiles of DISSOLVED OXYGEN compared with data for 7/15/2003.

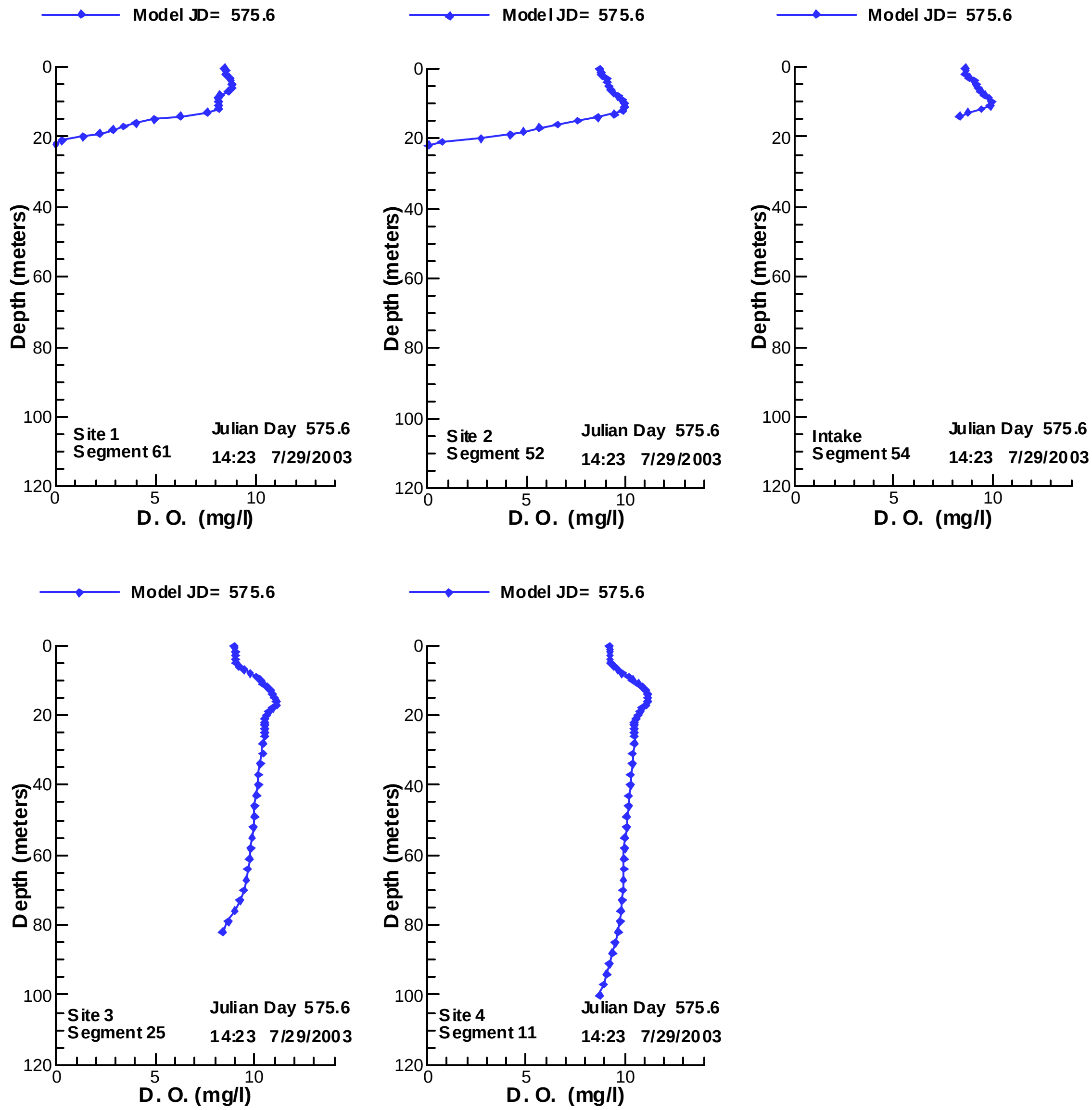

Figure 334. Vertical profiles of DISSOLVED OXYGEN compared with data for 7/29/2003.

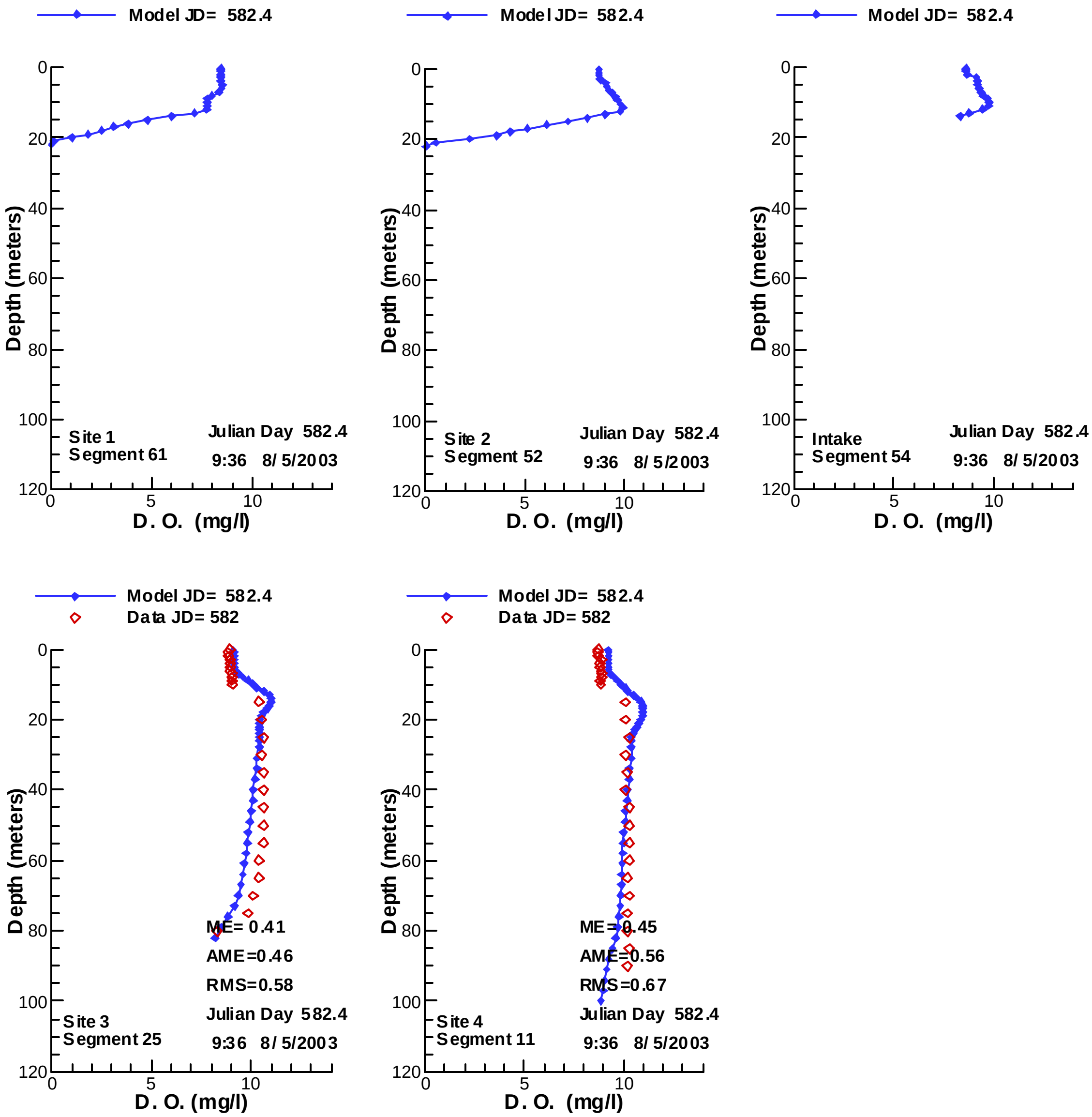

Figure 335. Vertical profiles of DISSOLVED OXYGEN compared with data for 8/ 5/2003.

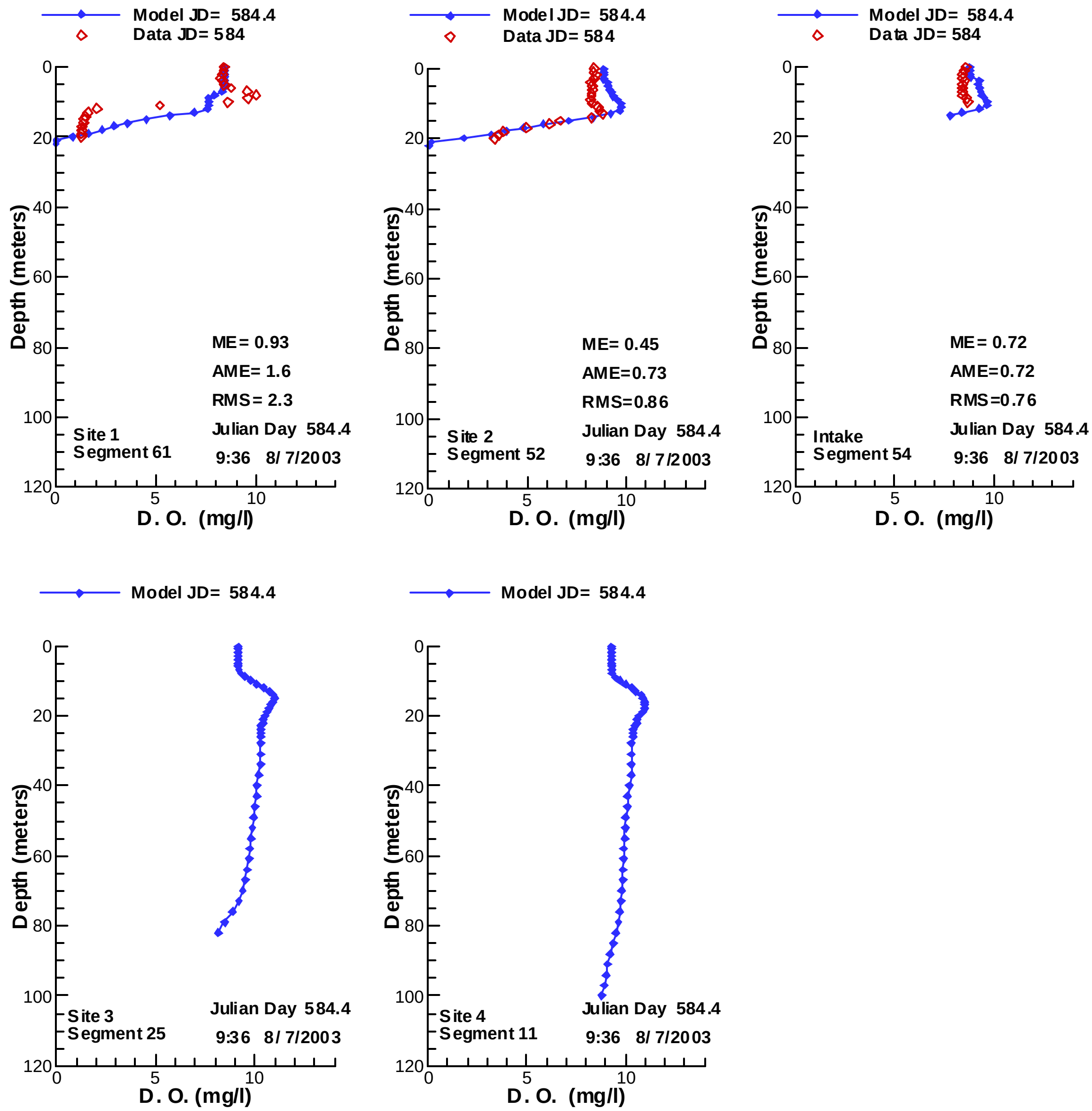

Figure 336. Vertical profiles of DISSOLVED OXYGEN compared with data for 8/ 7/2003.

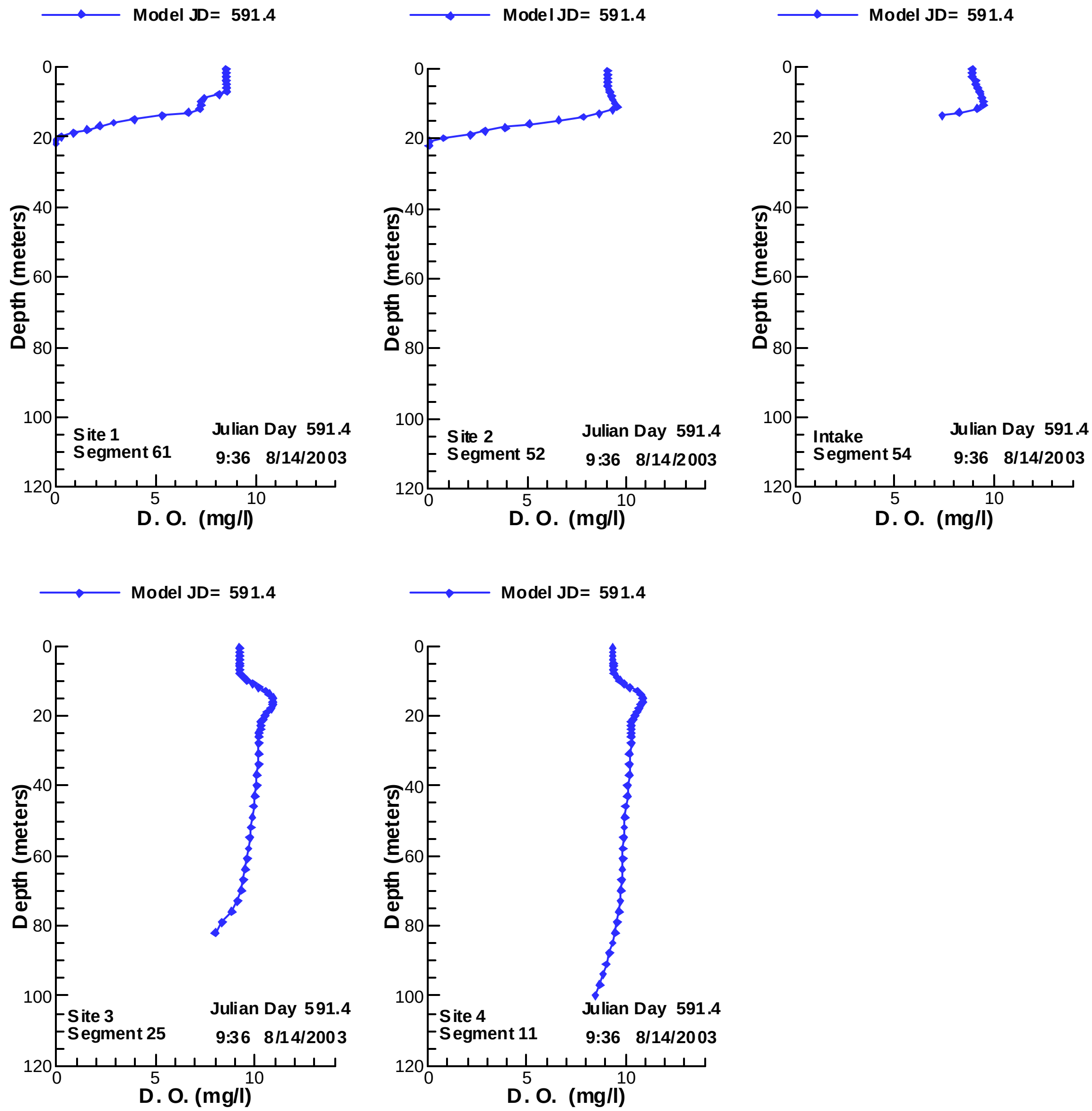

Figure 337. Vertical profiles of DISSOLVED OXYGEN compared with data for 8/14/2003.

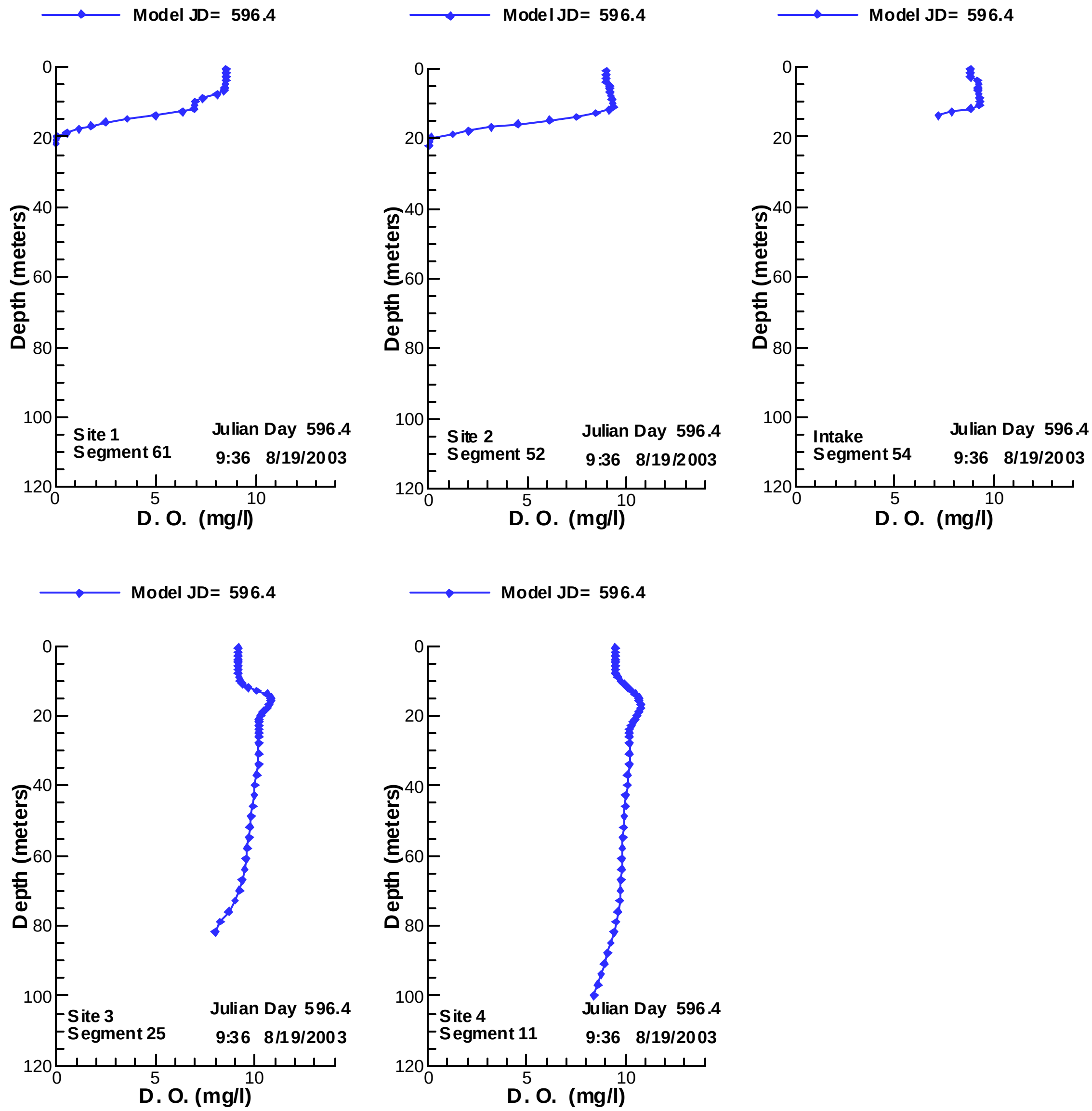

Figure 338. Vertical profiles of DISSOLVED OXYGEN compared with data for 8/19/2003.

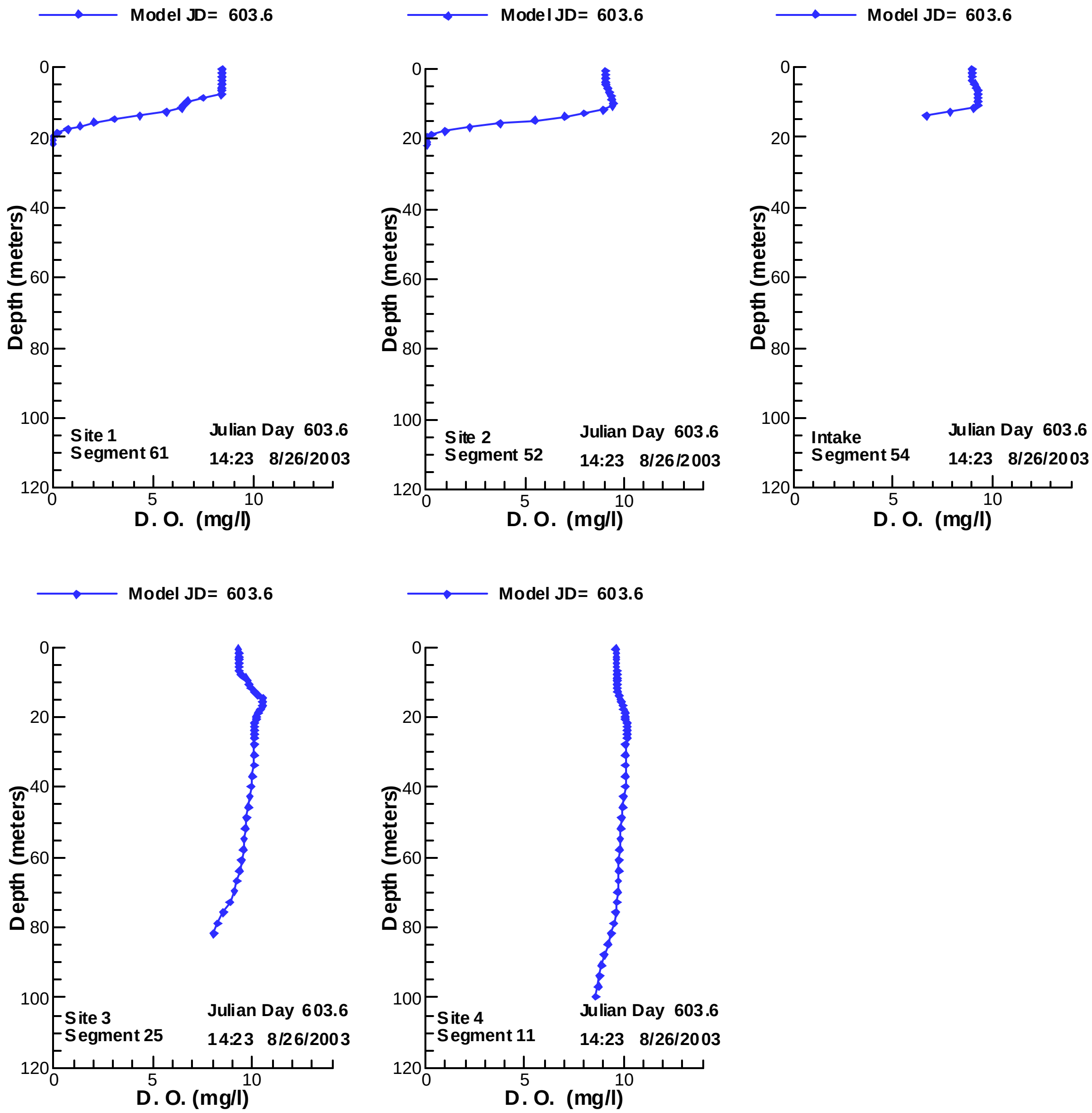

Figure 339. Vertical profiles of DISSOLVED OXYGEN compared with data for 8/26/2003.

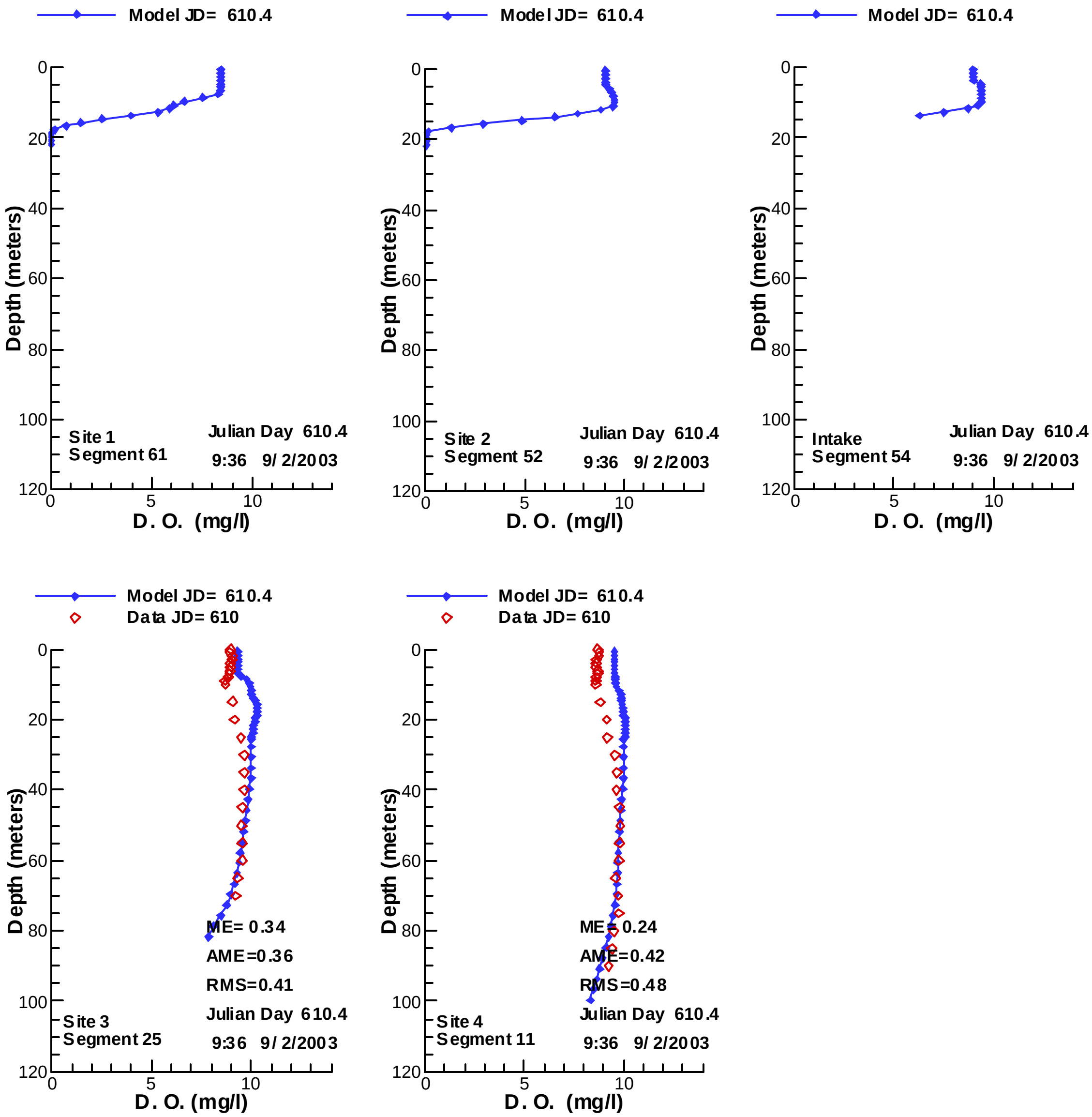

Figure 340. Vertical profiles of DISSOLVED OXYGEN compared with data for 9/ 2/2003.

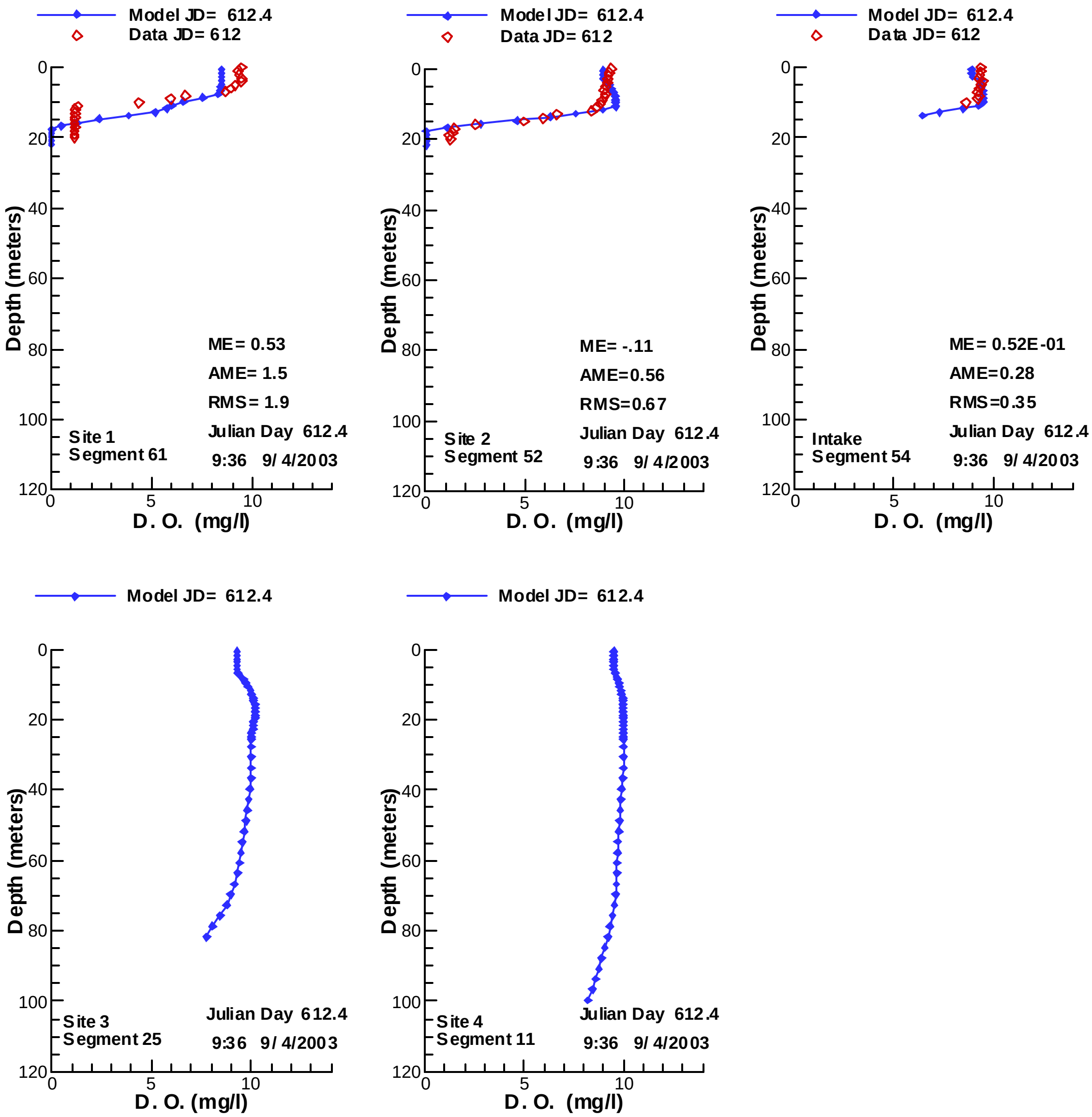

Figure 341. Vertical profiles of DISSOLVED OXYGEN compared with data for 9/ 4/2003.

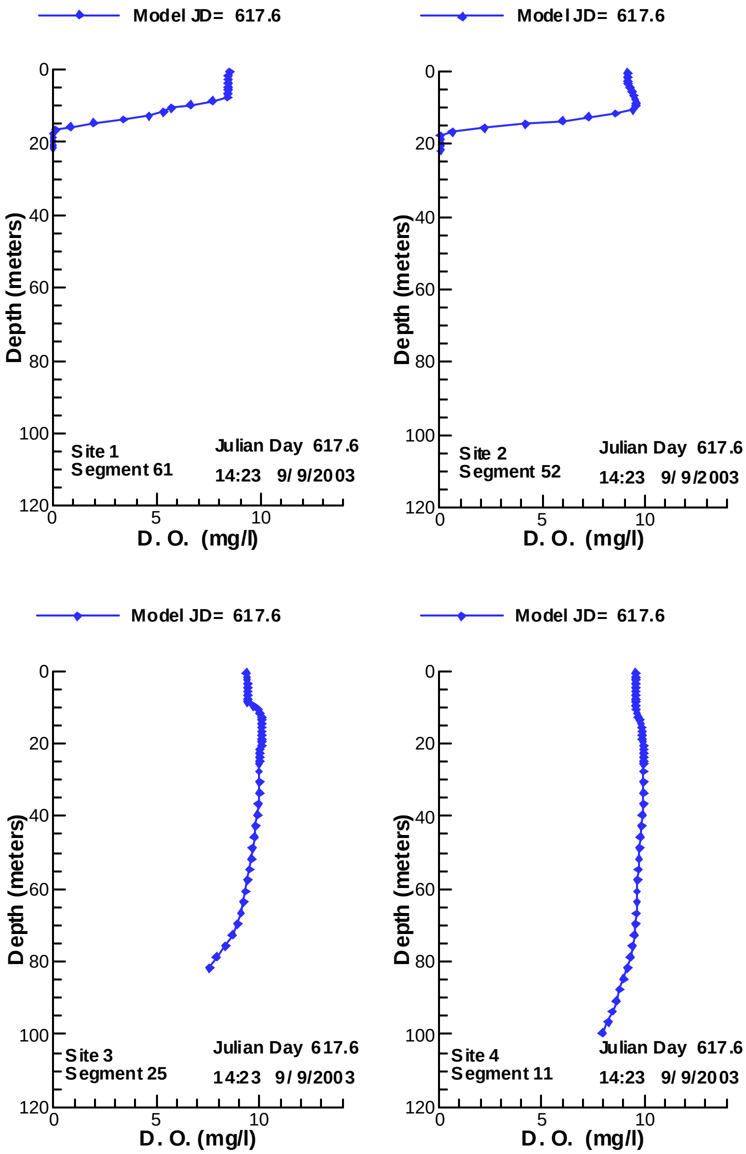

Figure 342. Vertical profiles of DISSOLVED OXYGEN compared with data for 9/ 9/2003.

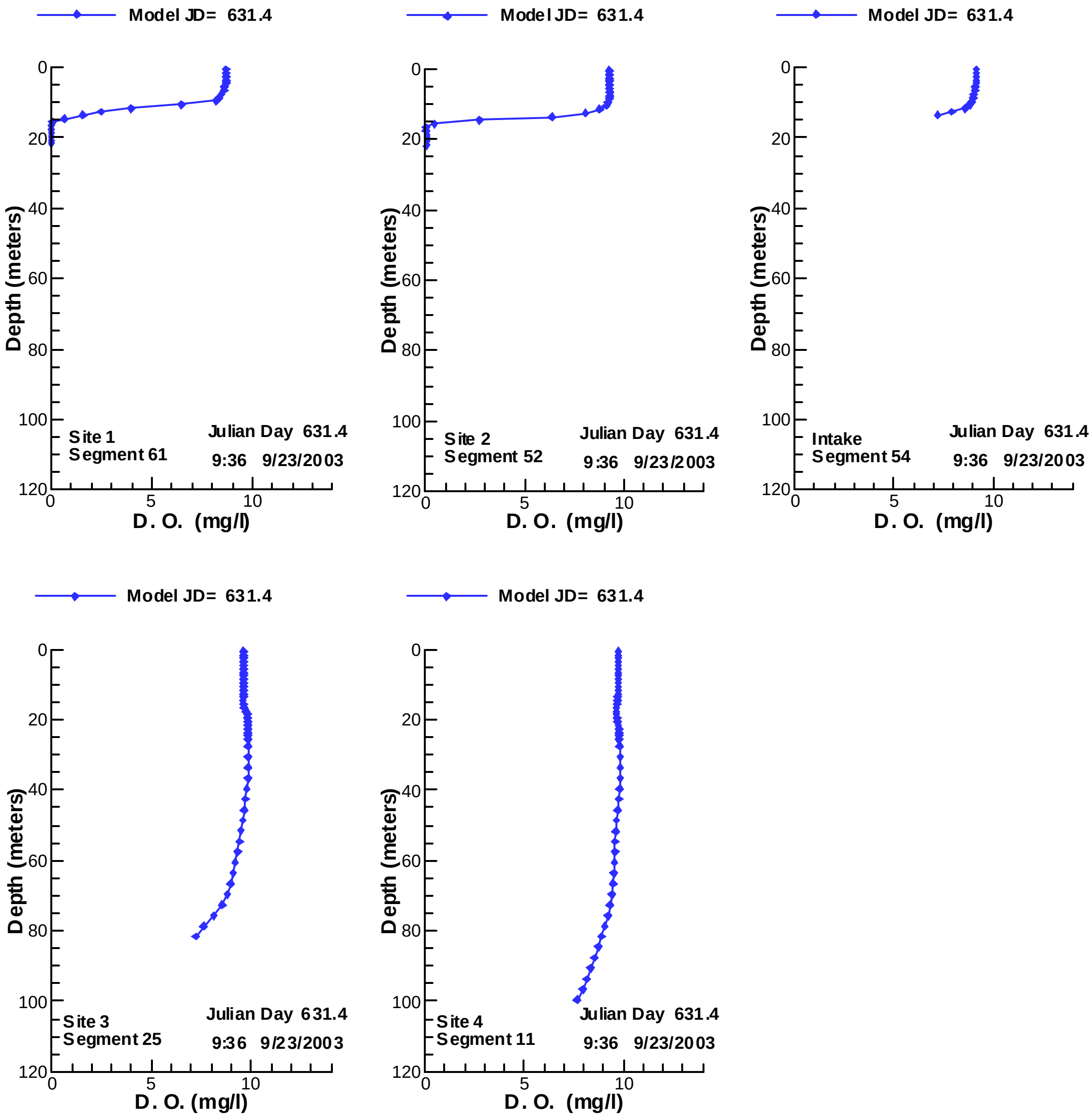

Figure 343. Vertical profiles of DISSOLVED OXYGEN compared with data for 9/23/2003.

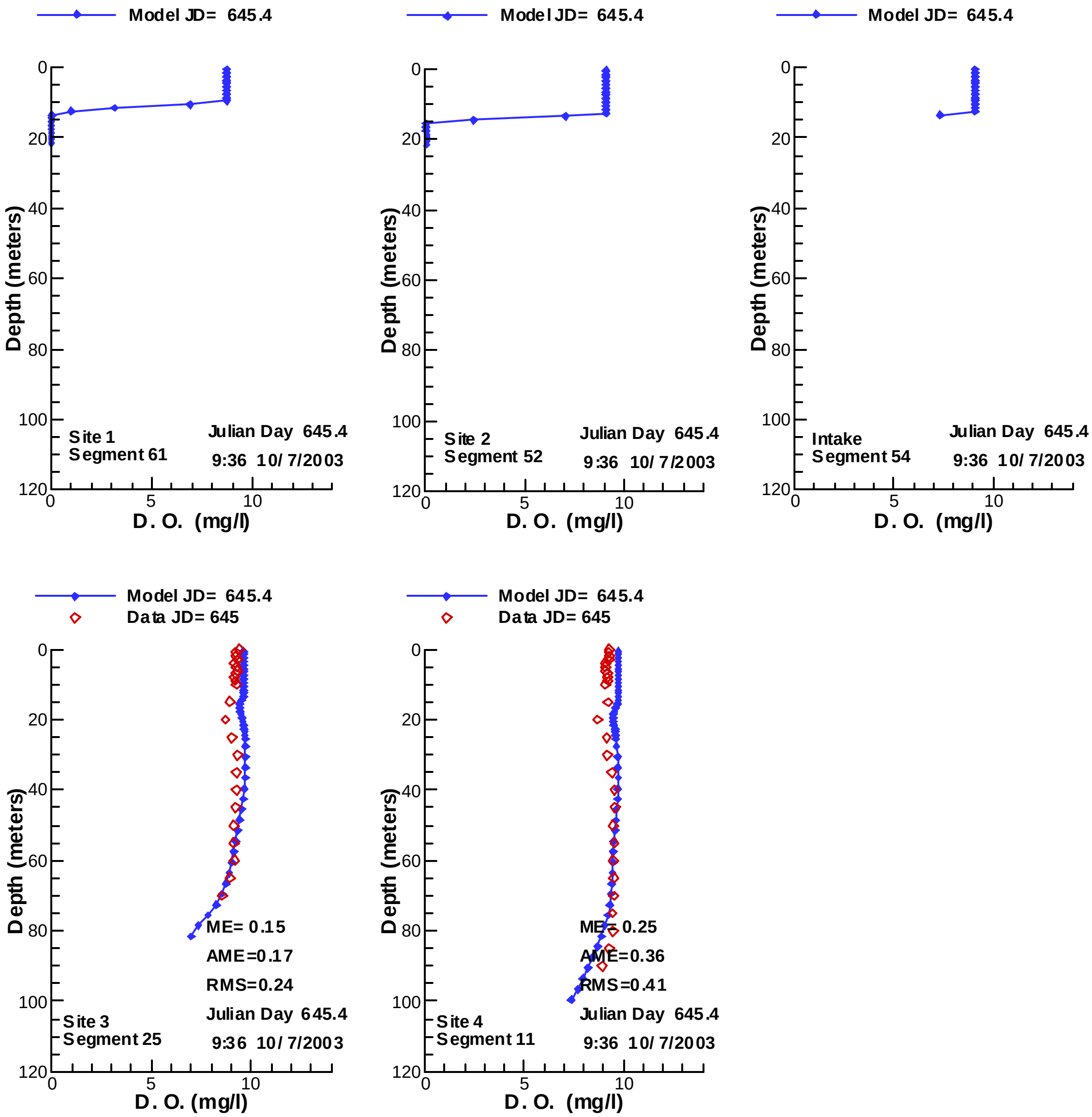

Figure 344. Vertical profiles of DISSOLVED OXYGEN compared with data for 10/ 7/2003.

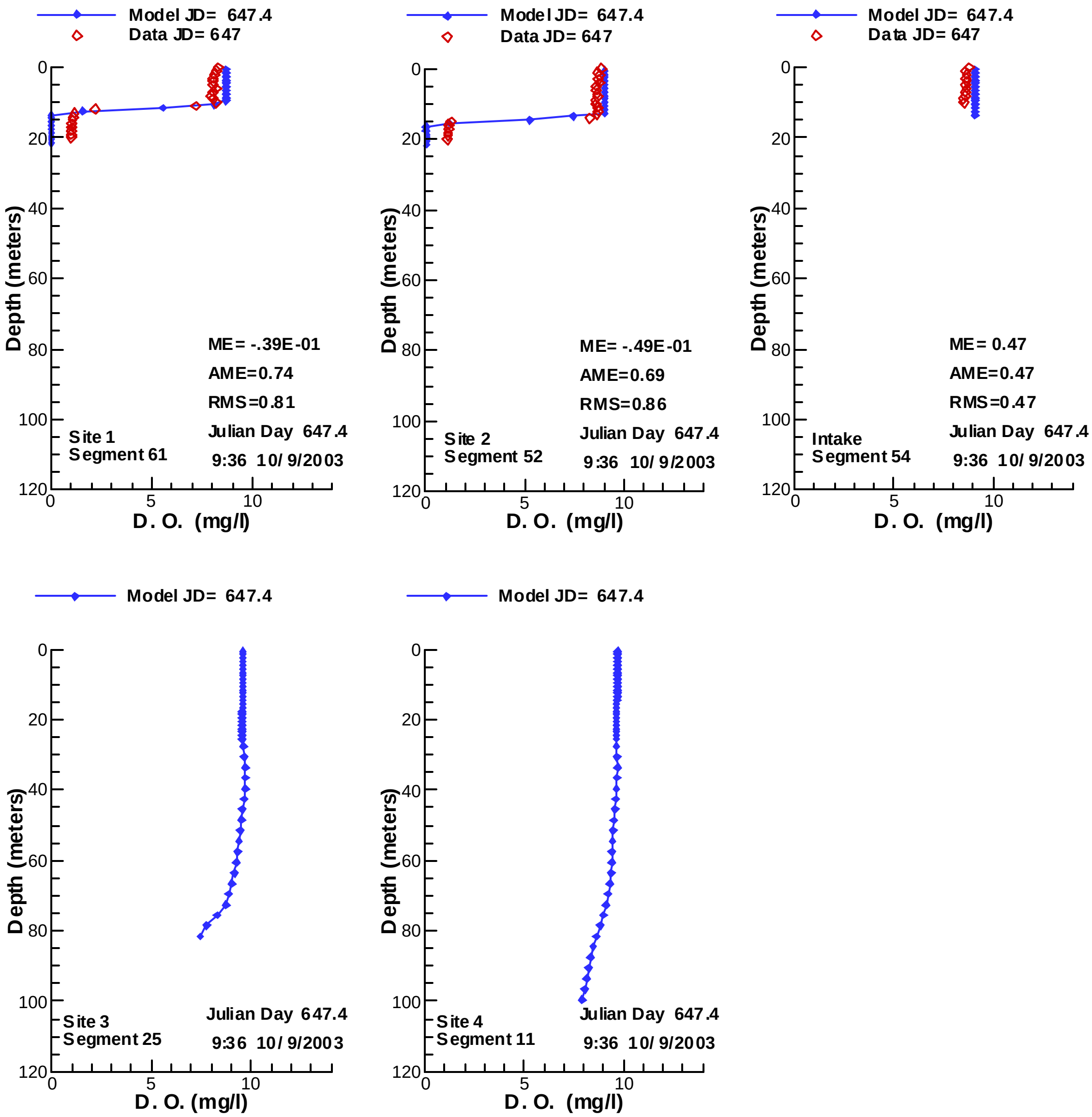

Figure 345. Vertical profiles of DISSOLVED OXYGEN compared with data for 10/ 9/2003.

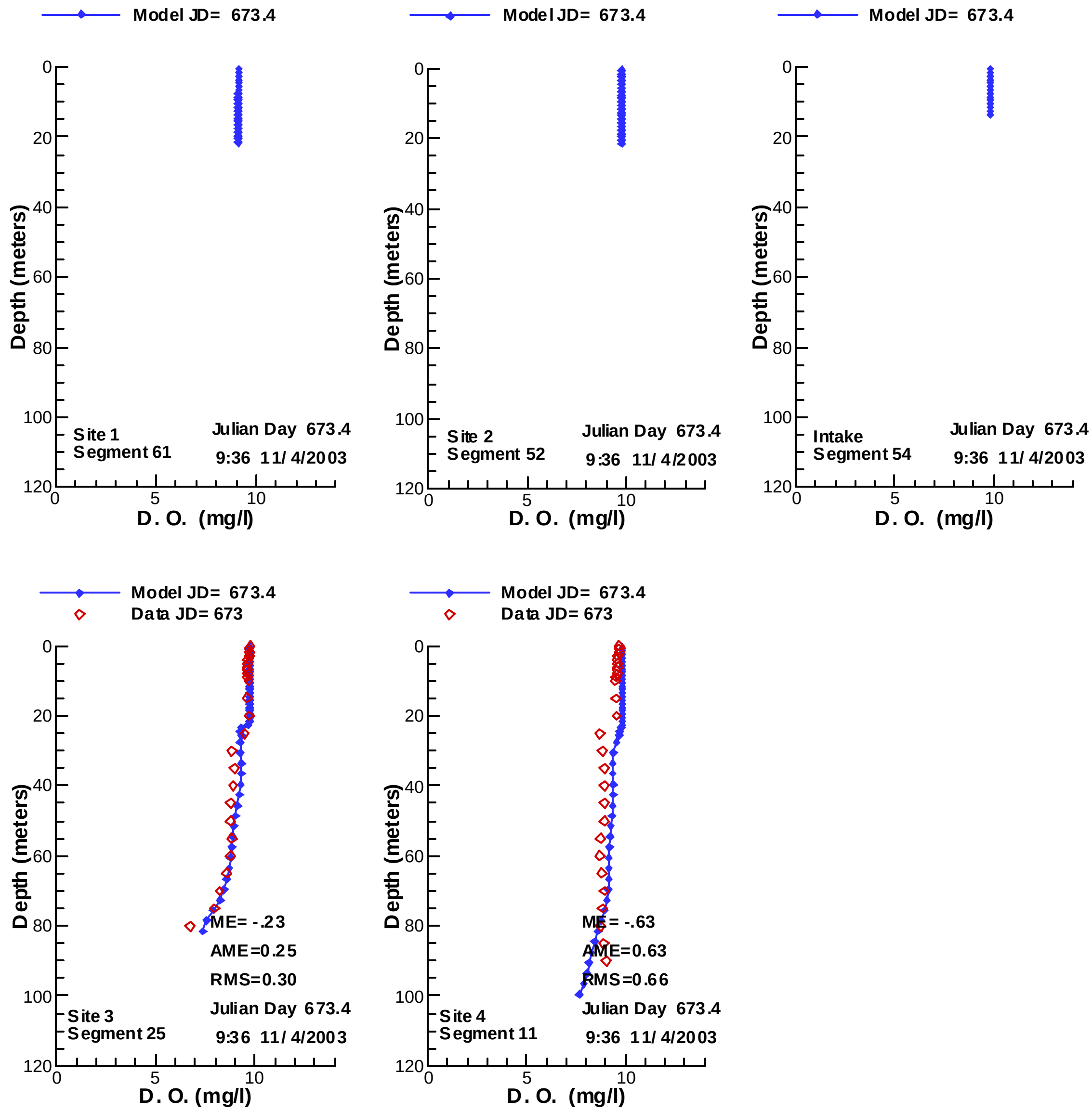

Figure 346. Vertical profiles of DISSOLVED OXYGEN compared with data for 11/ 4/2003.

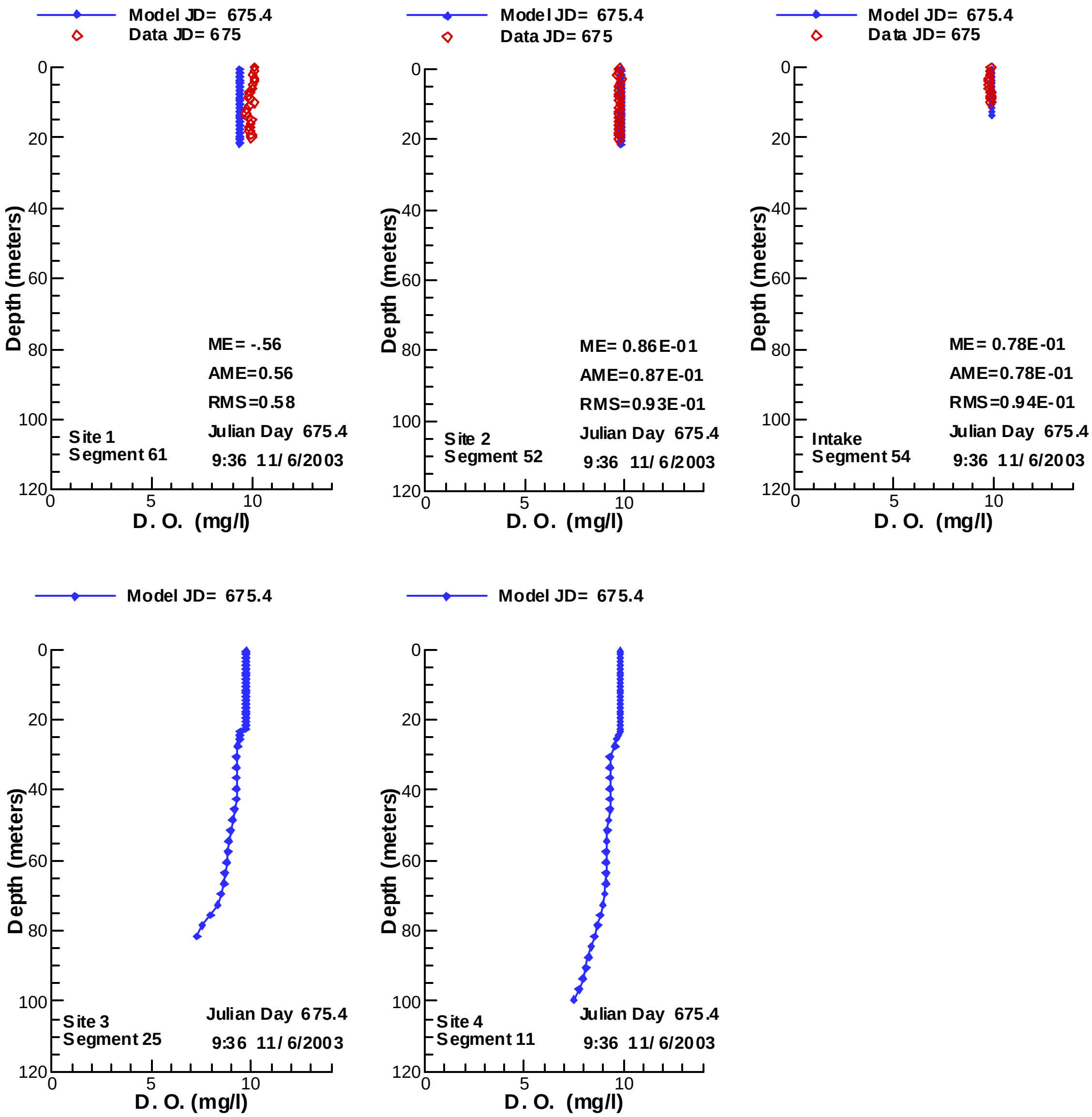

Figure 347. Vertical profiles of DISSOLVED OXYGEN compared with data for 11/ 6/2003.

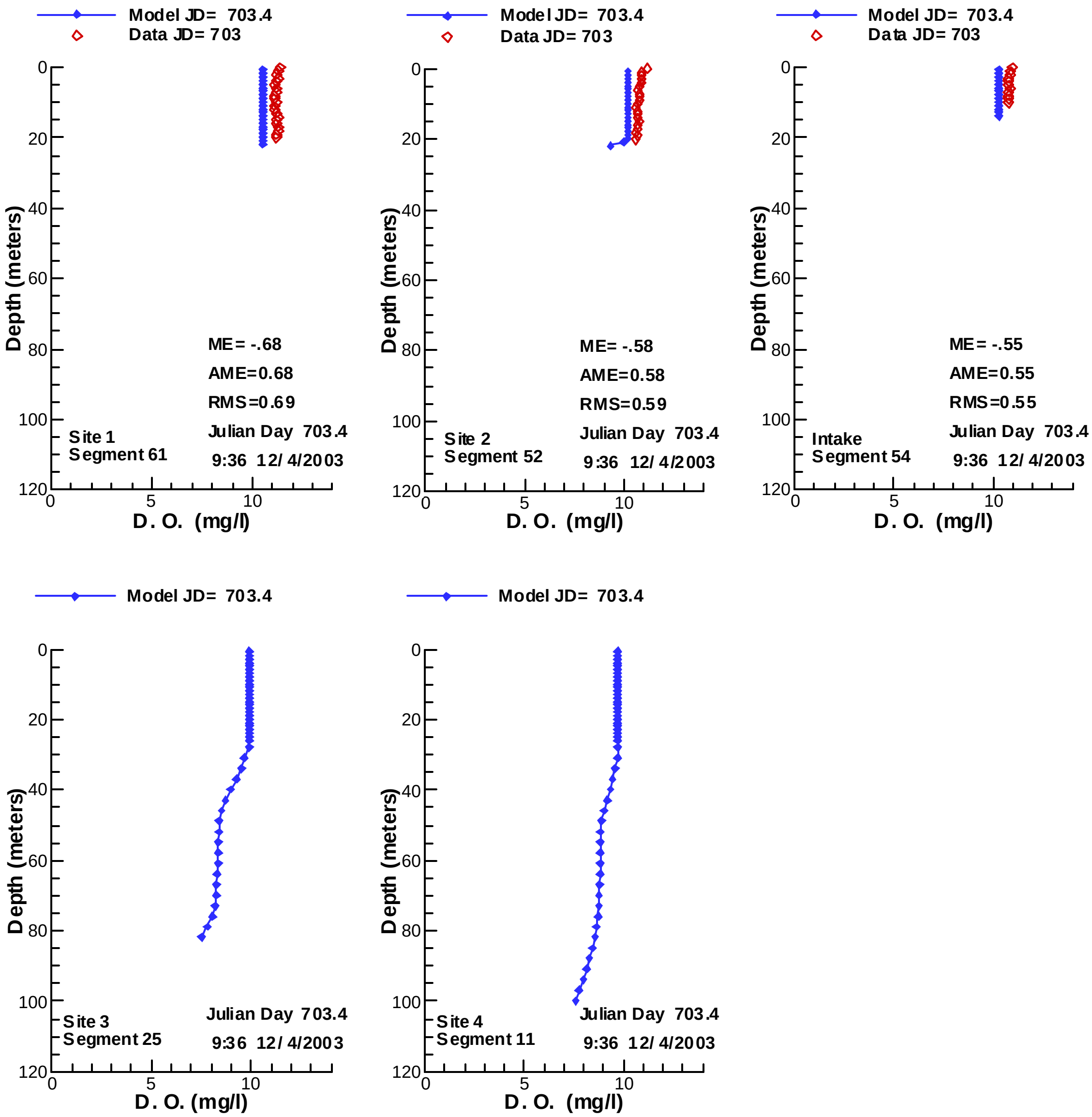

Figure 348. Vertical profiles of DISSOLVED OXYGEN compared with data for 12/ 4/2003.

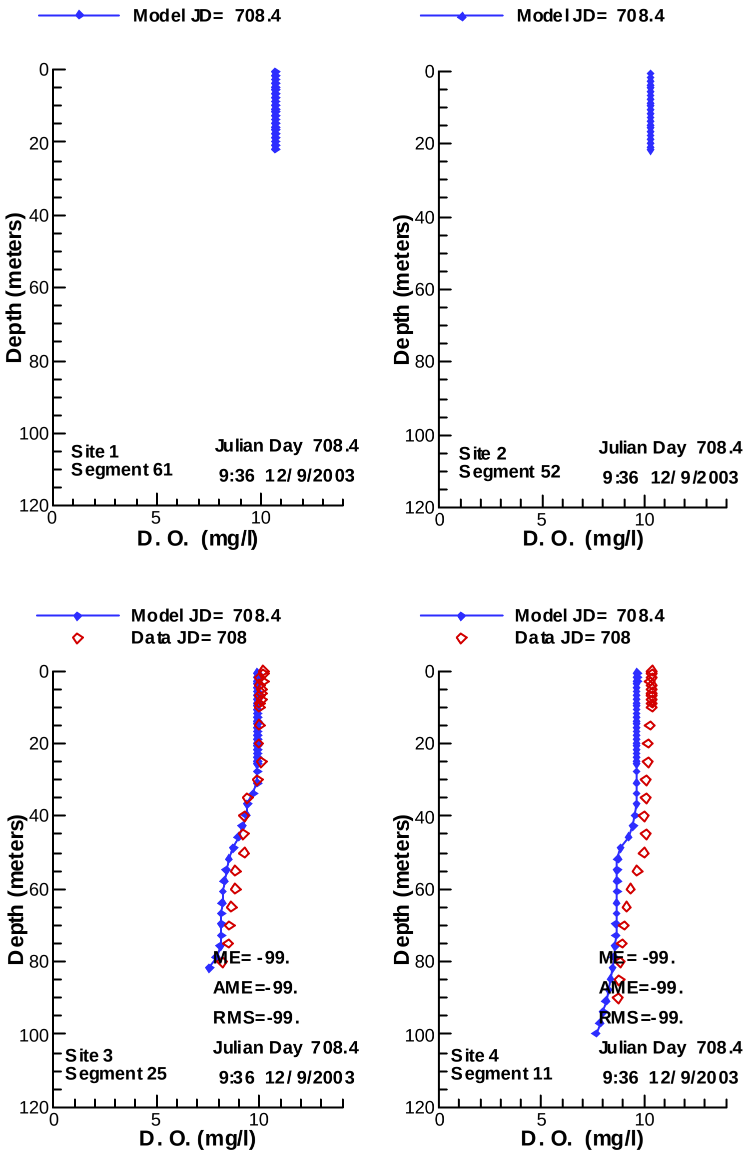

Figure 349. Vertical profiles of DISSOLVED OXYGEN compared with data for 12/ 9/2003.

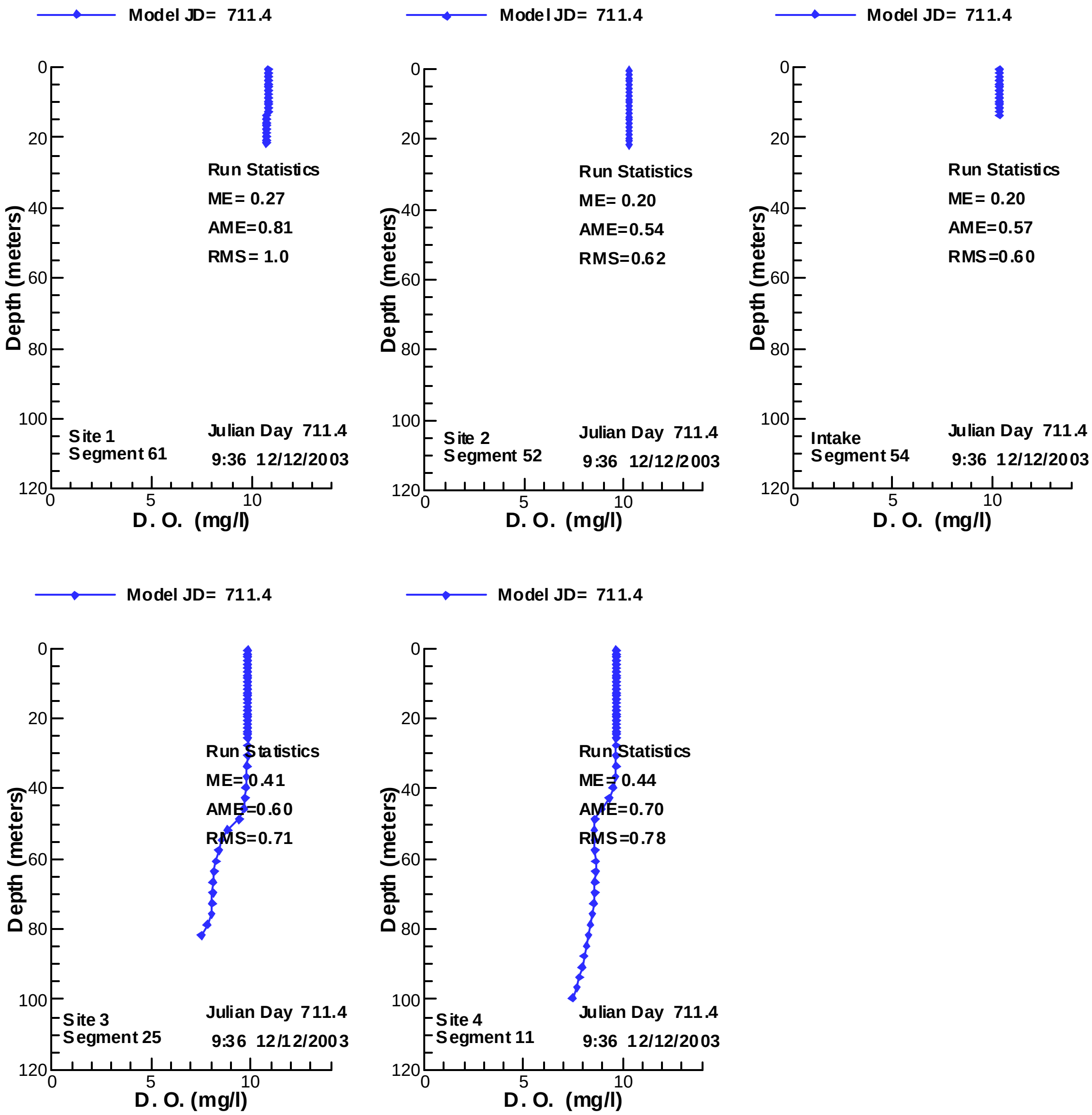

Figure 350. Vertical profiles of DISSOLVED OXYGEN compared with data for 12/12/2003.

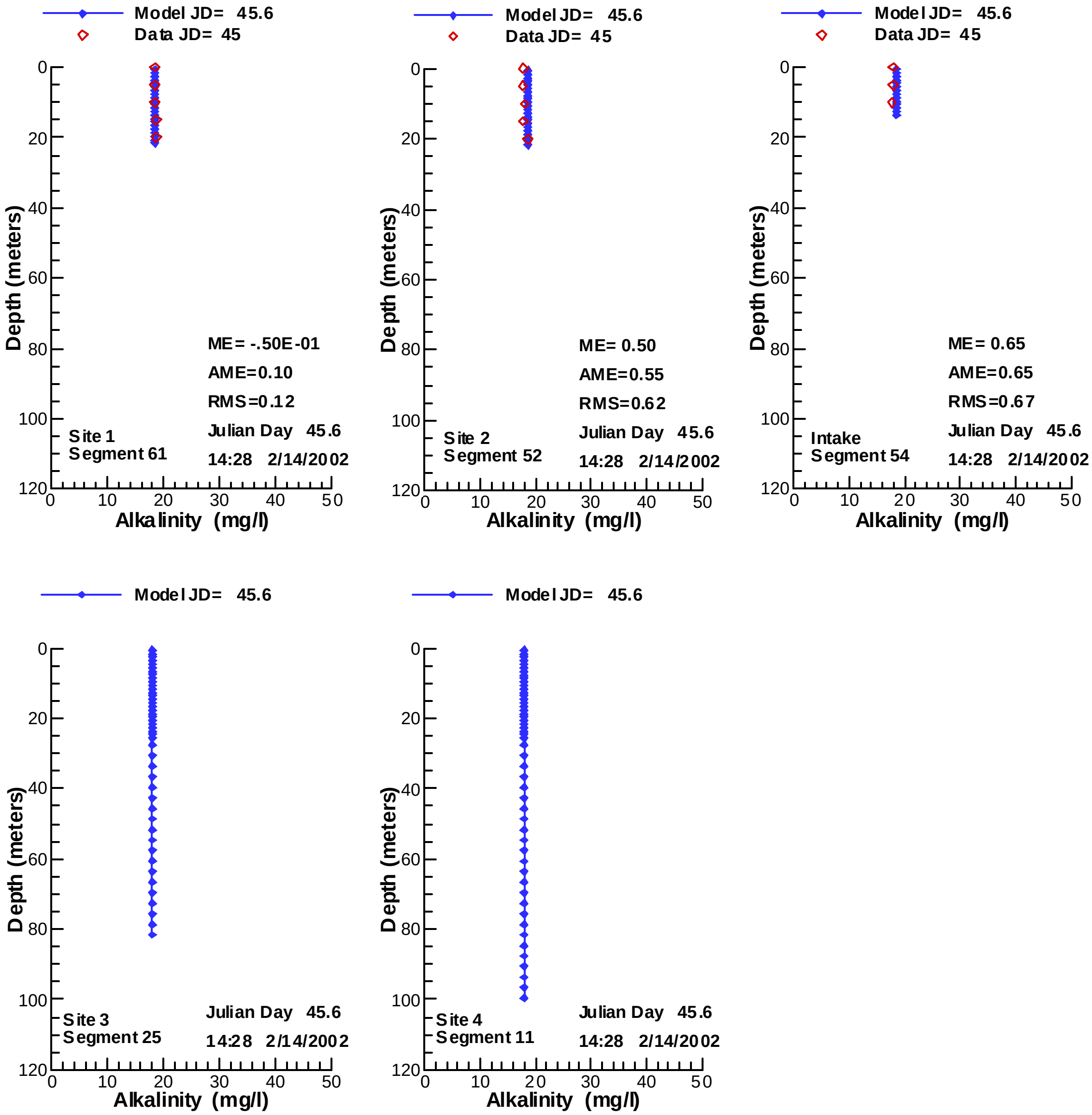

Figure 351. Vertical profiles of Alkalinity compared with data for 2/14/2002.

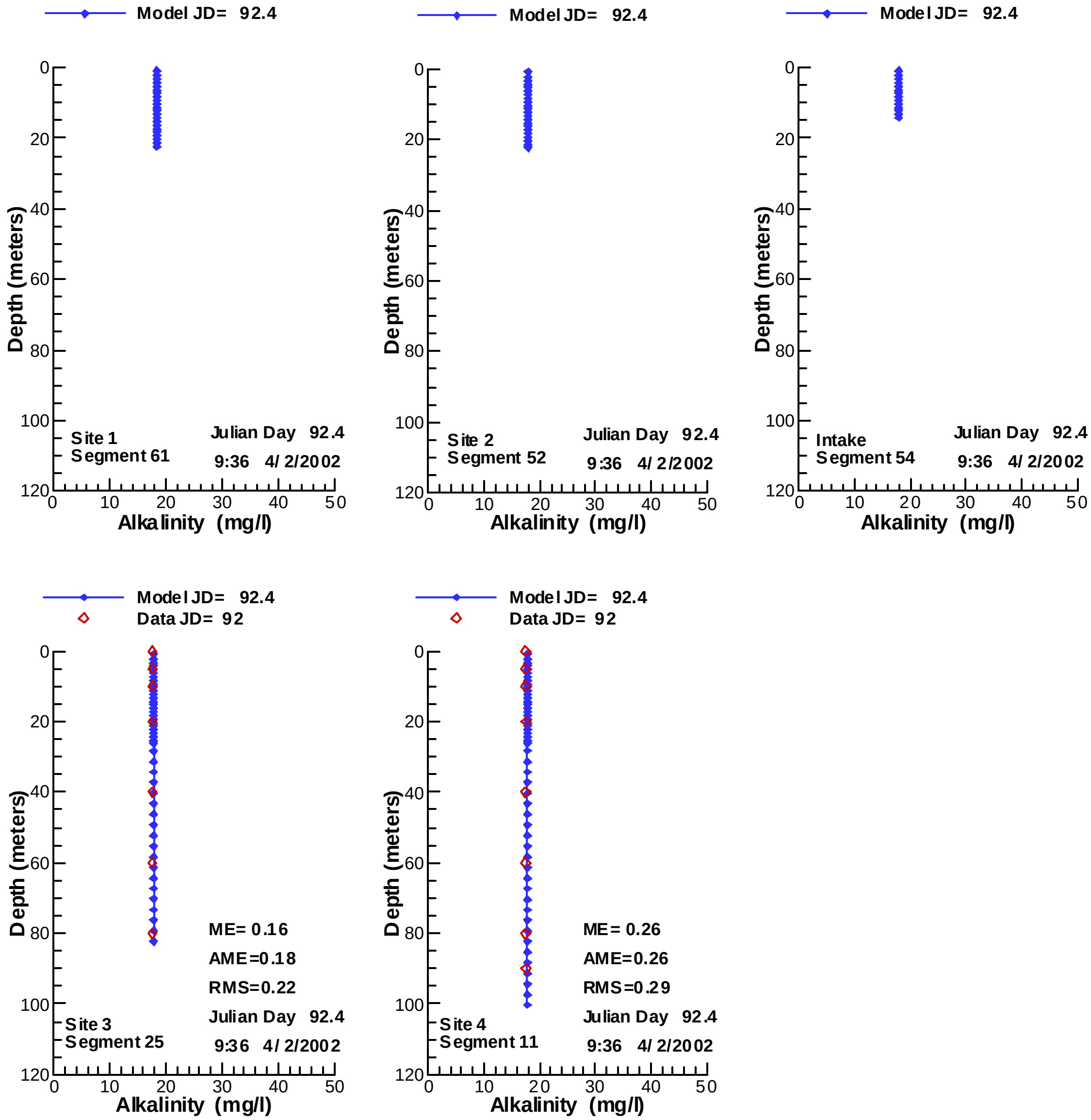

Figure 352. Vertical profiles of Alkalinity compared with data for 4/ 2/2002.

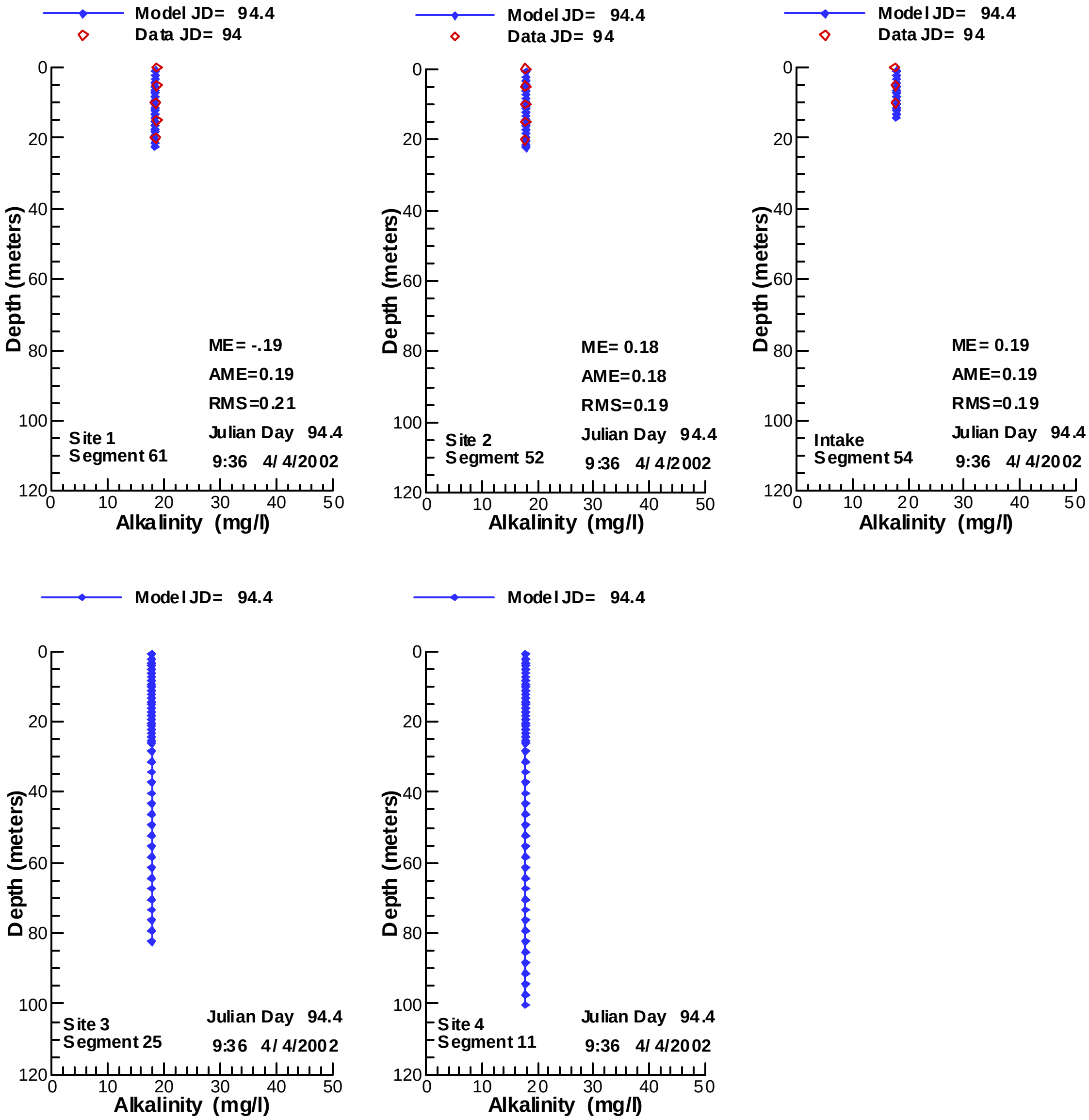

Figure 353. Vertical profiles of Alkalinity compared with data for 4/ 4/2002.

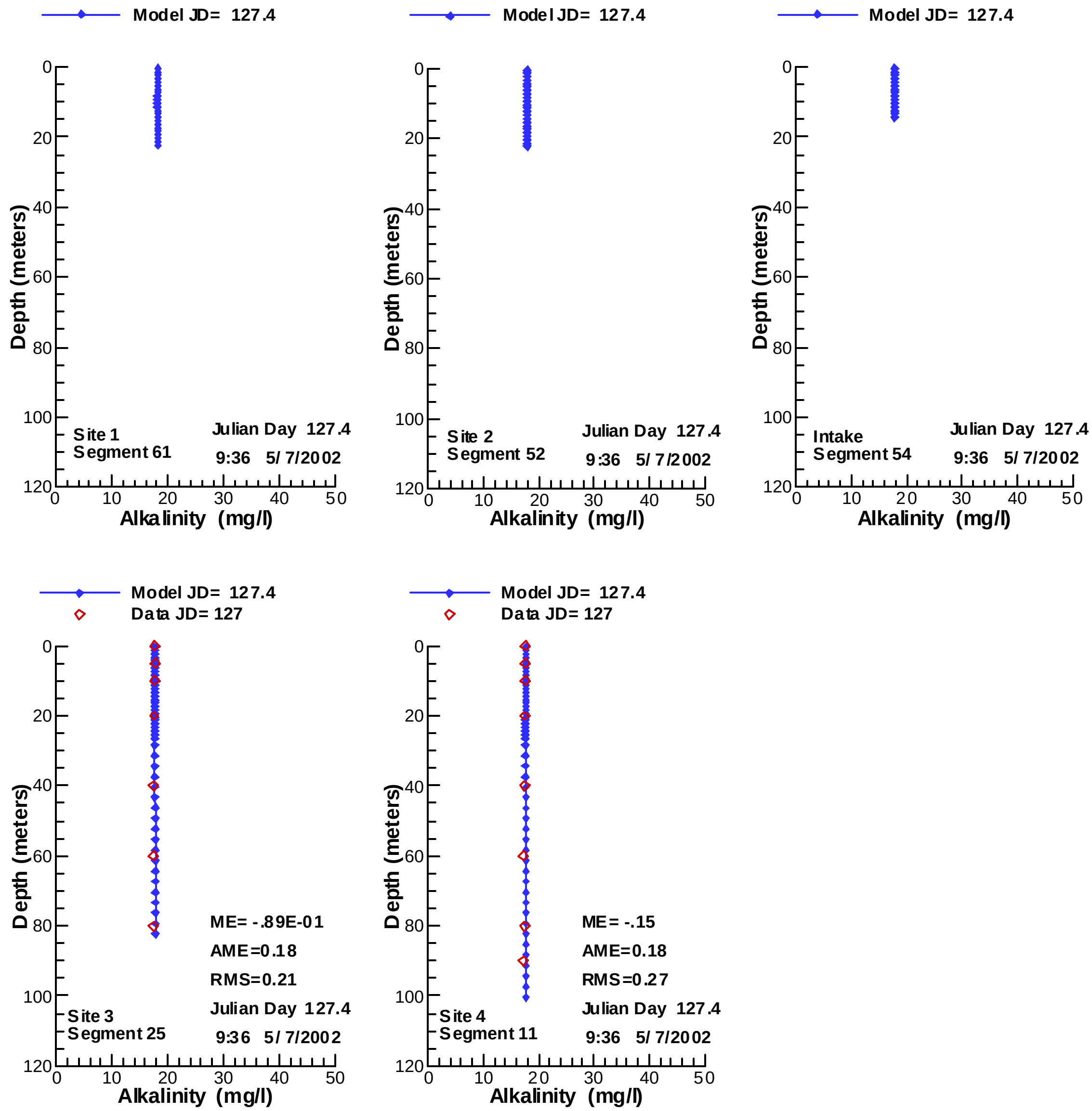

Figure 354. Vertical profiles of Alkalinity compared with data for 5/ 7/2002.

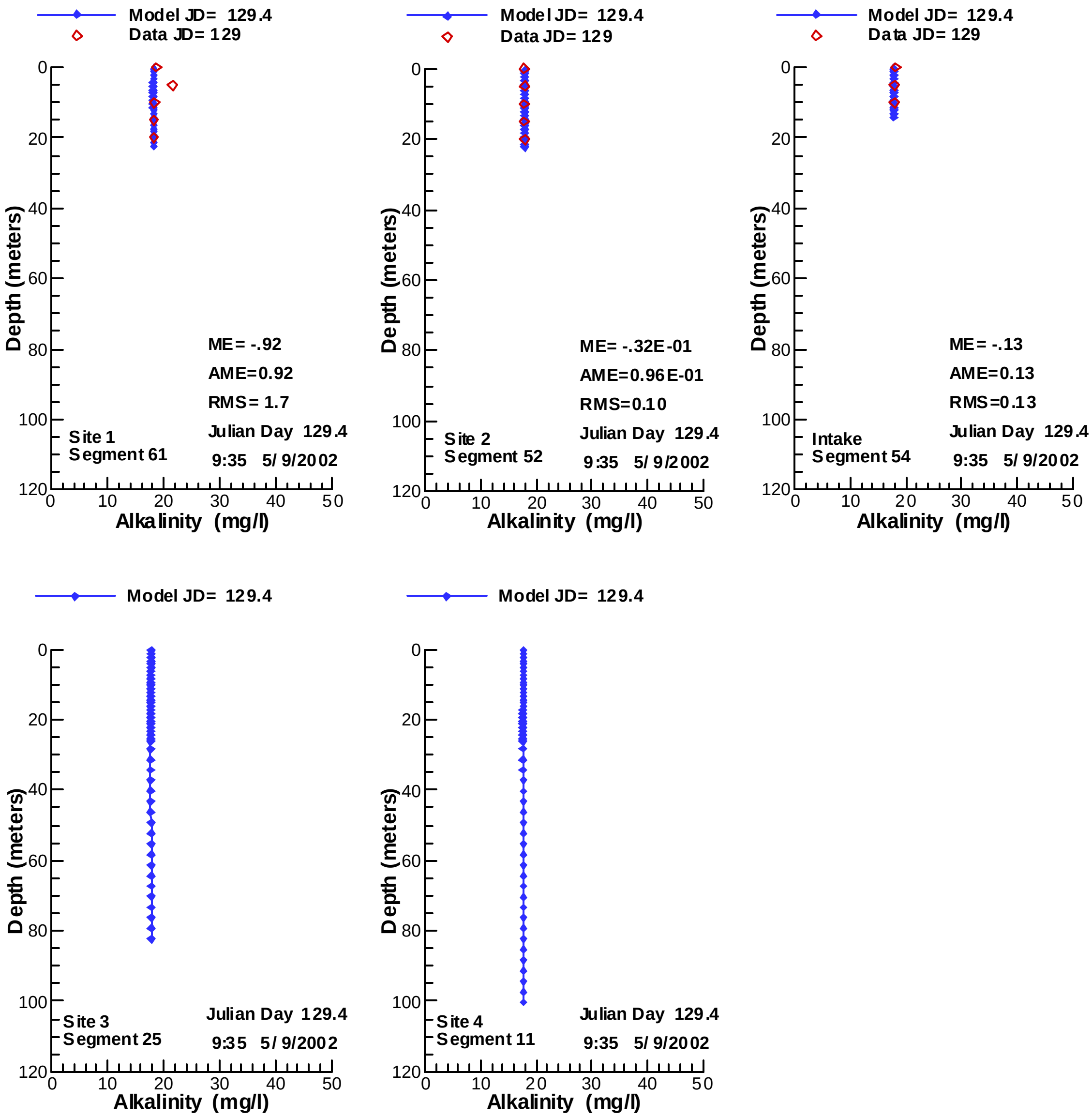

Figure 355. Vertical profiles of Alkalinity compared with data for 5/ 9/2002.

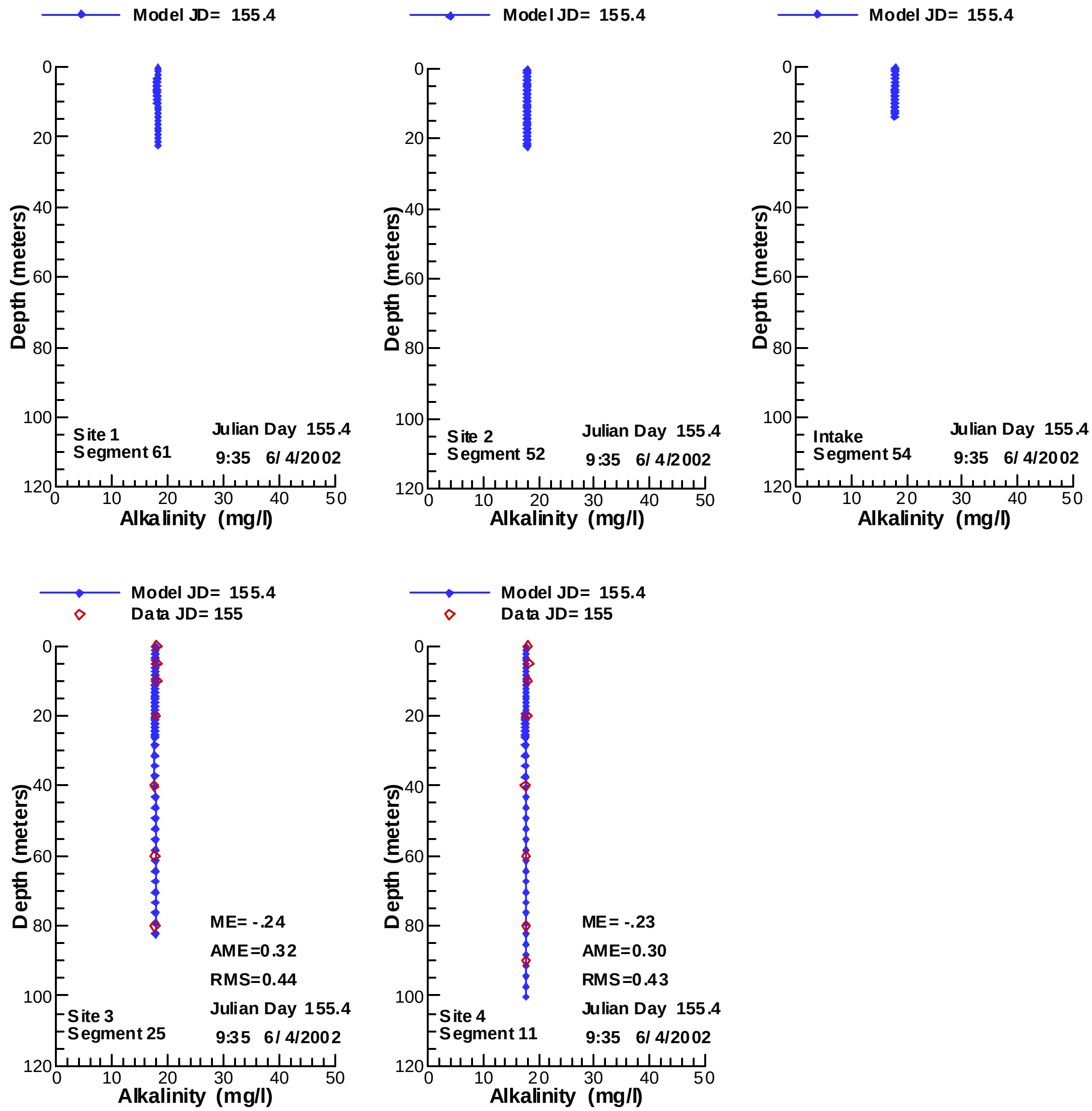

Figure 356. Vertical profiles of Alkalinity compared with data for 6/ 4/2002.

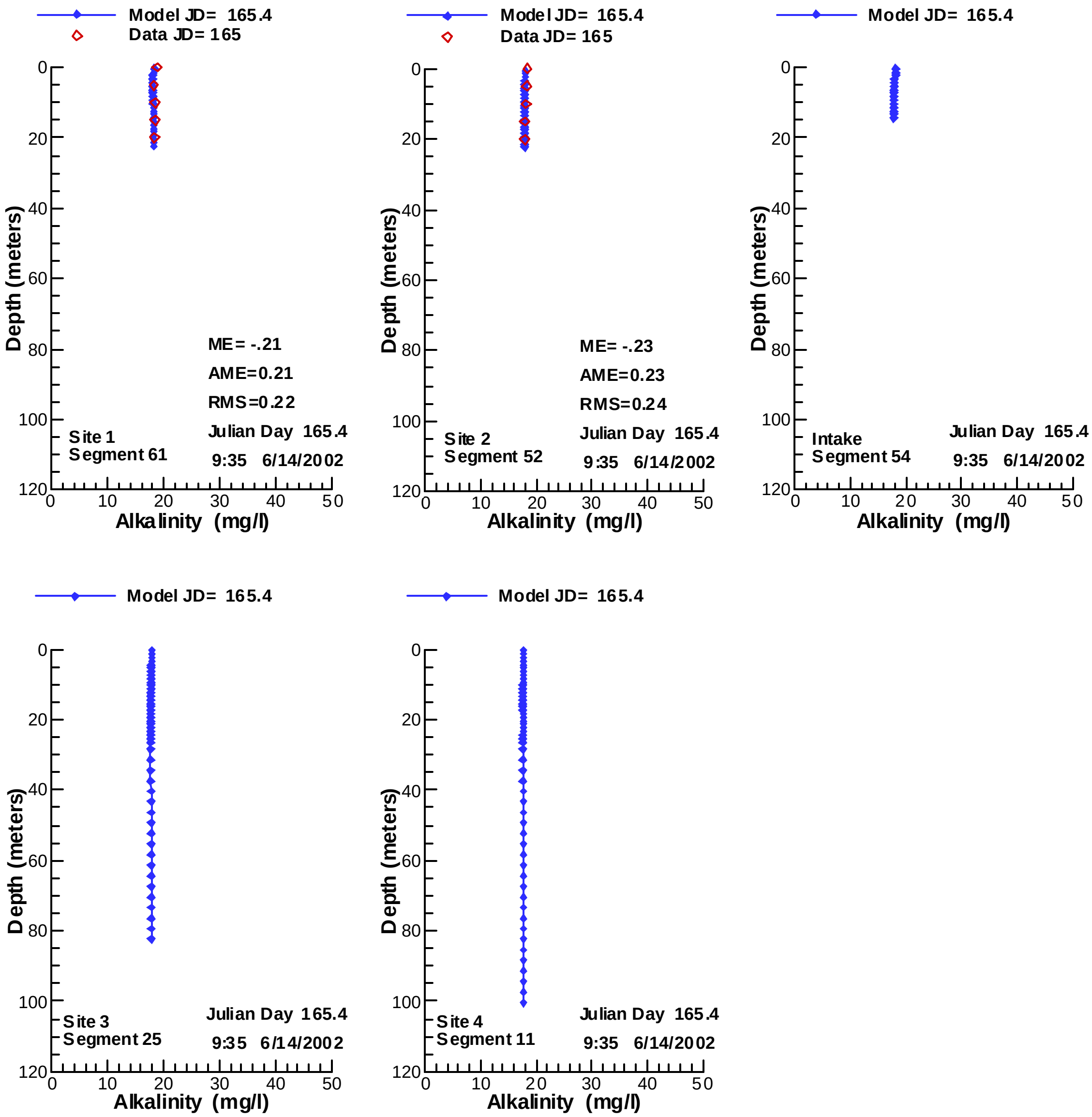

Figure 357. Vertical profiles of Alkalinity compared with data for 6/14/2002.

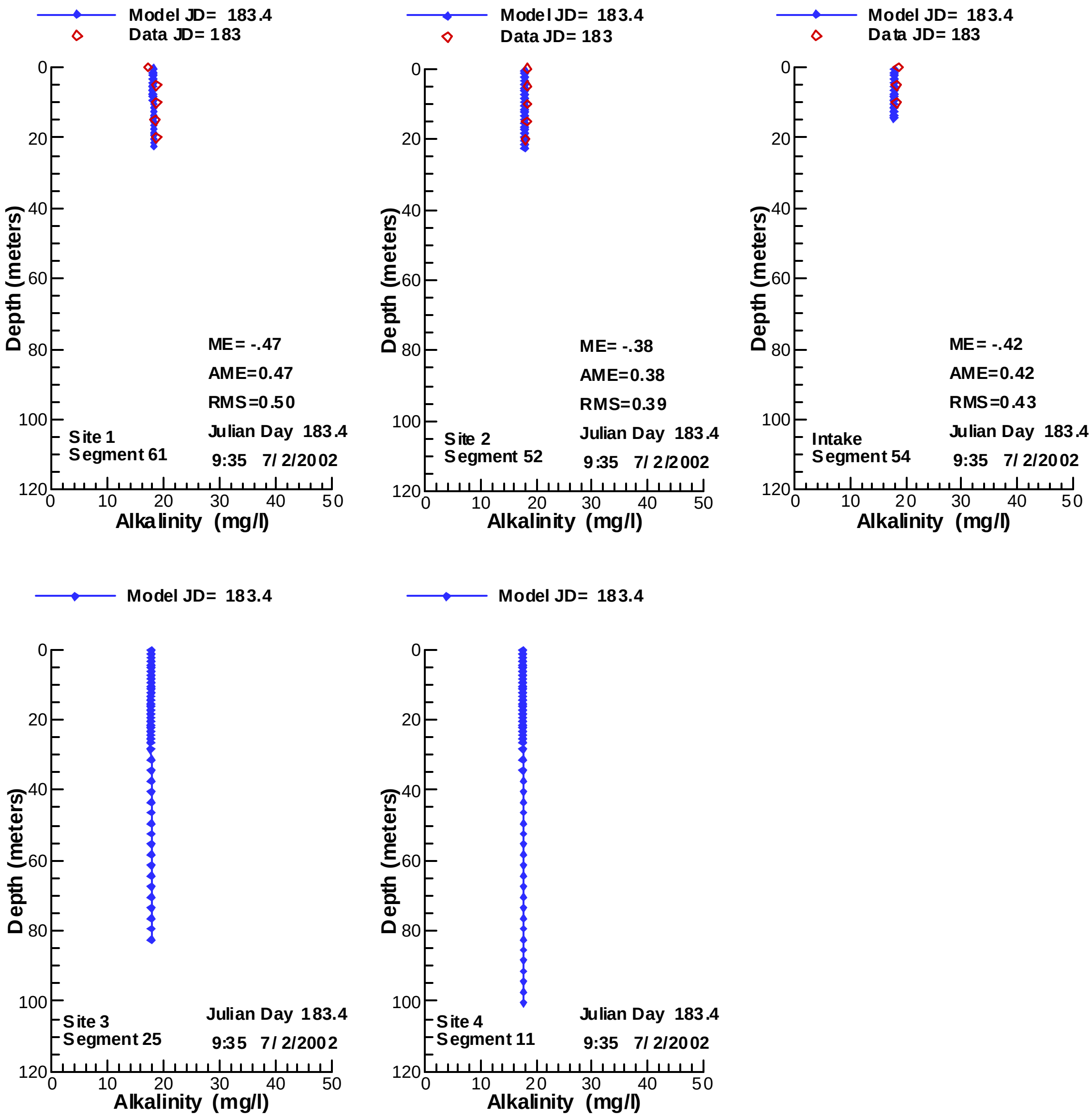

Figure 358. Vertical profiles of Alkalinity compared with data for 7/ 2/2002.

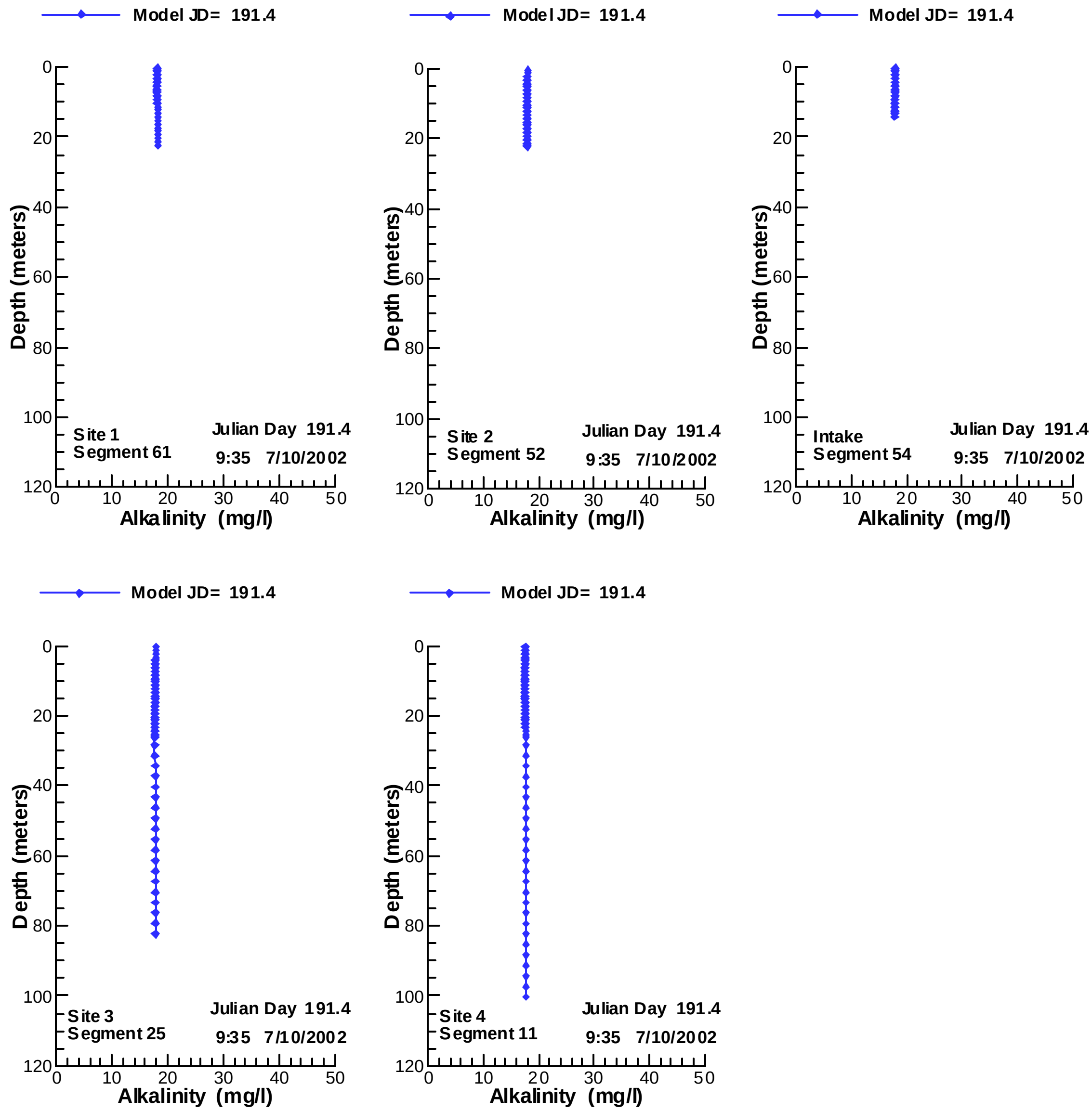

Figure 359. Vertical profiles of Alkalinity compared with data for 7/10/2002.

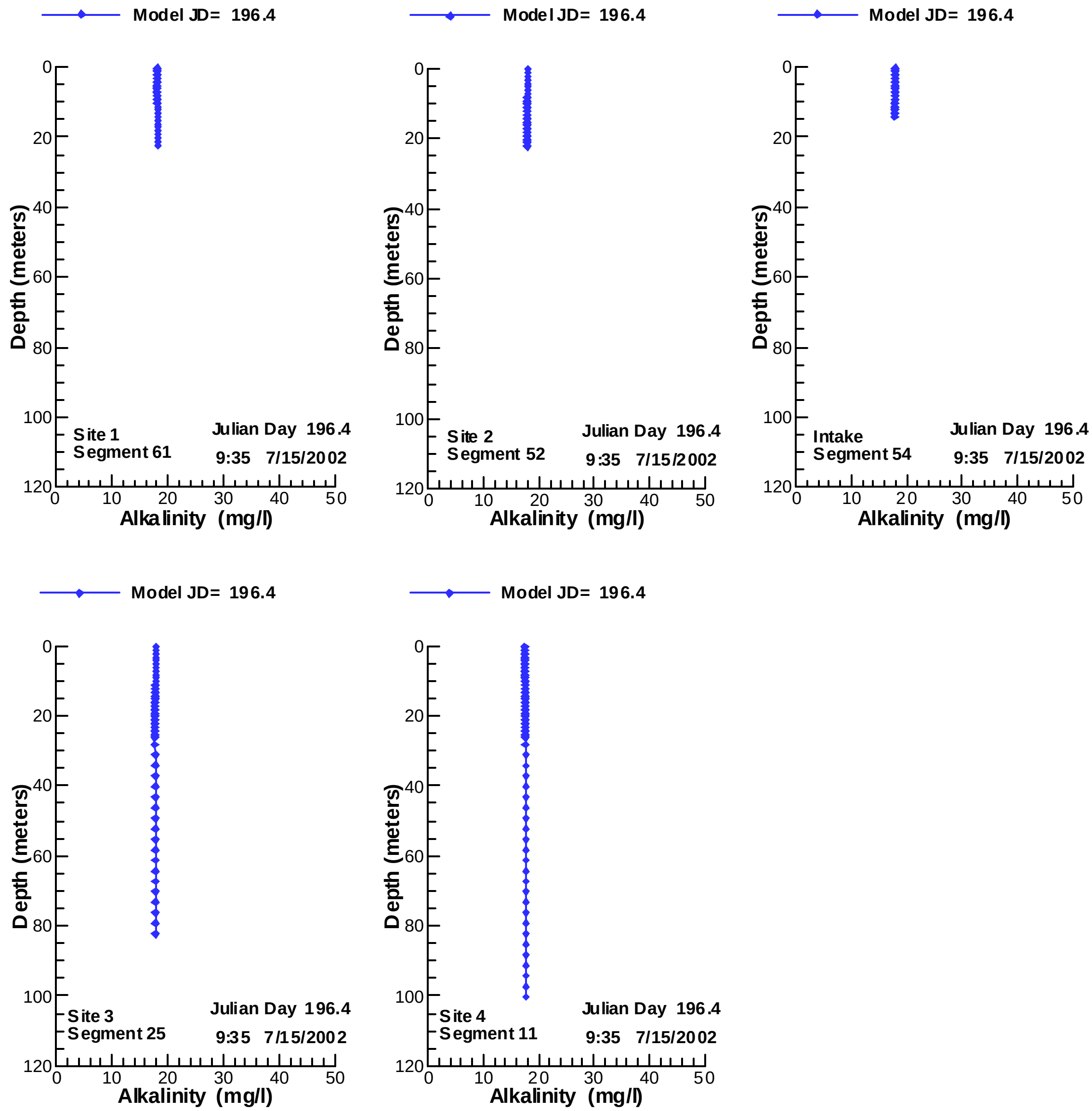

Figure 360. Vertical profiles of Alkalinity compared with data for 7/15/2002.

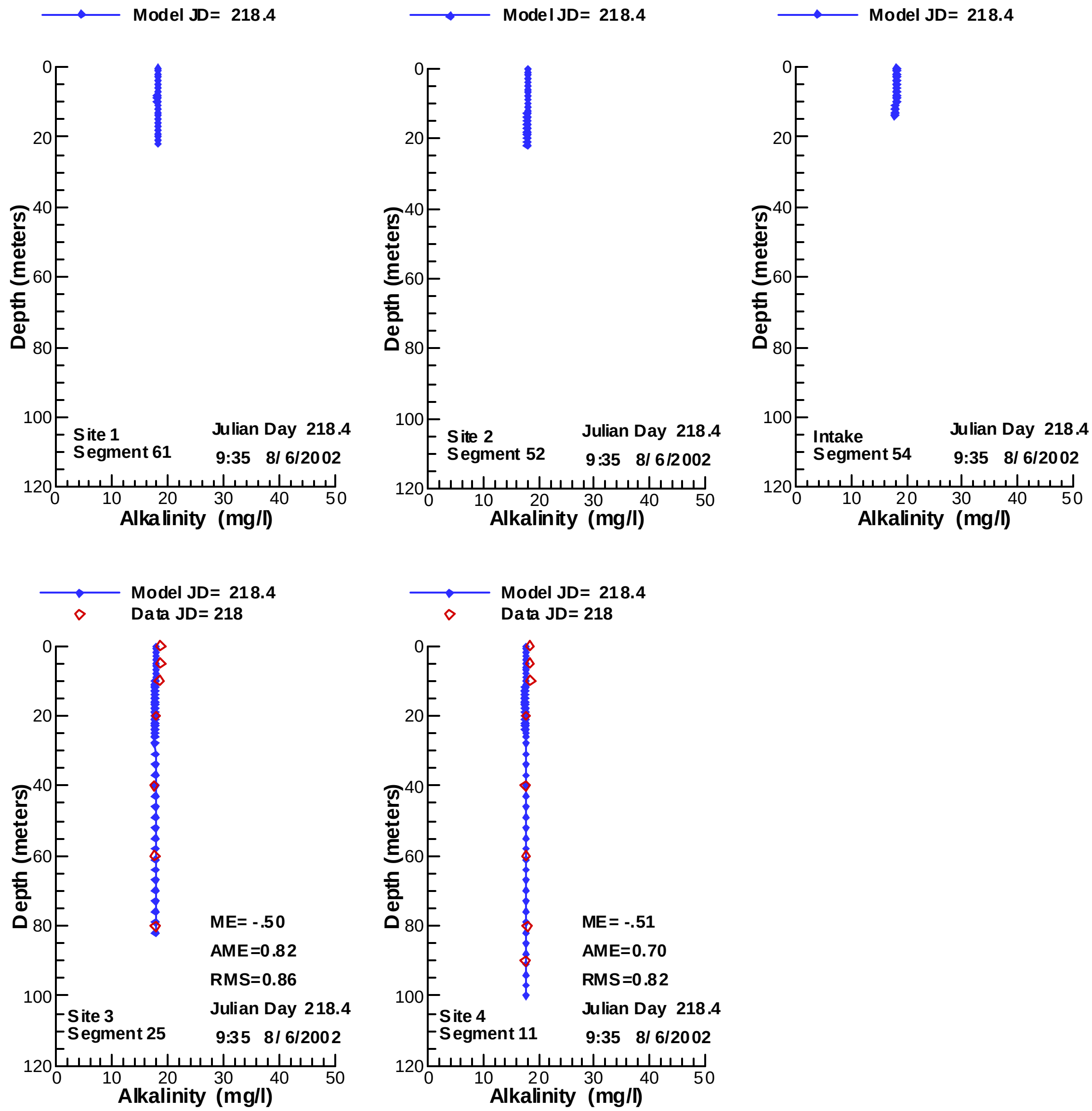

Figure 361. Vertical profiles of Alkalinity compared with data for 8/ 6/2002.

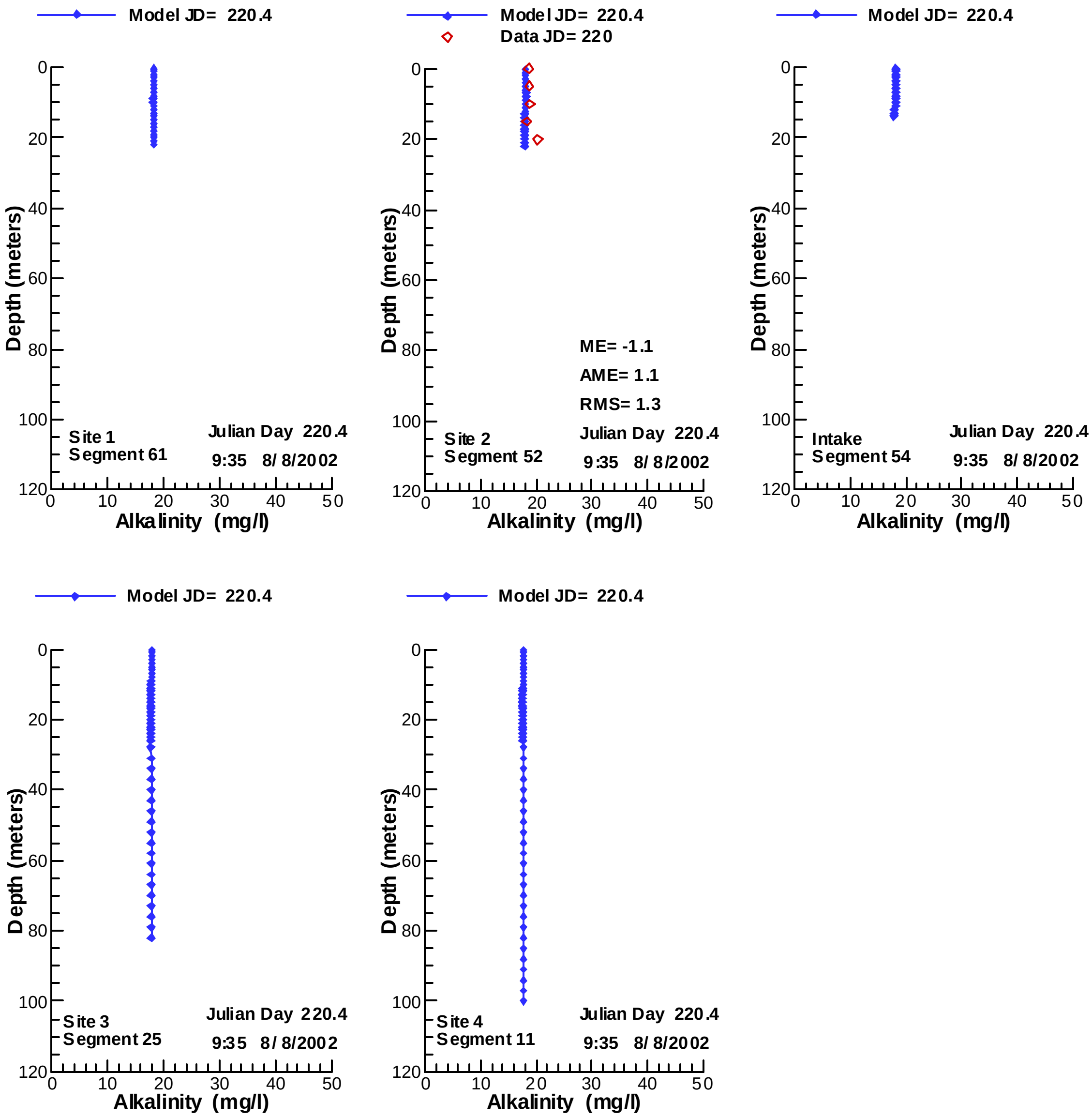

Figure 362. Vertical profiles of Alkalinity compared with data for 8/ 8/2002.

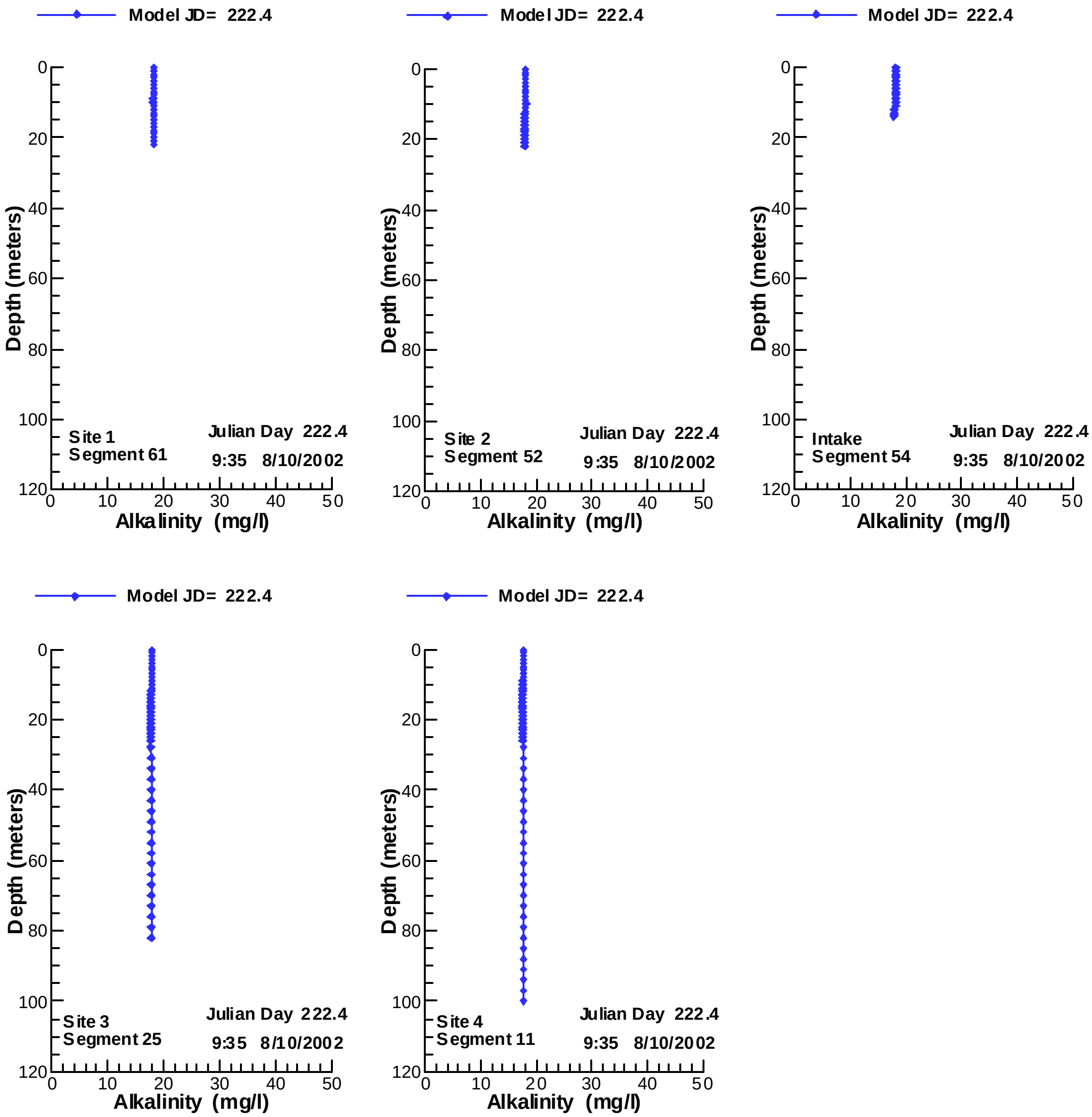

Figure 363. Vertical profiles of Alkalinity compared with data for 8/10/2002.

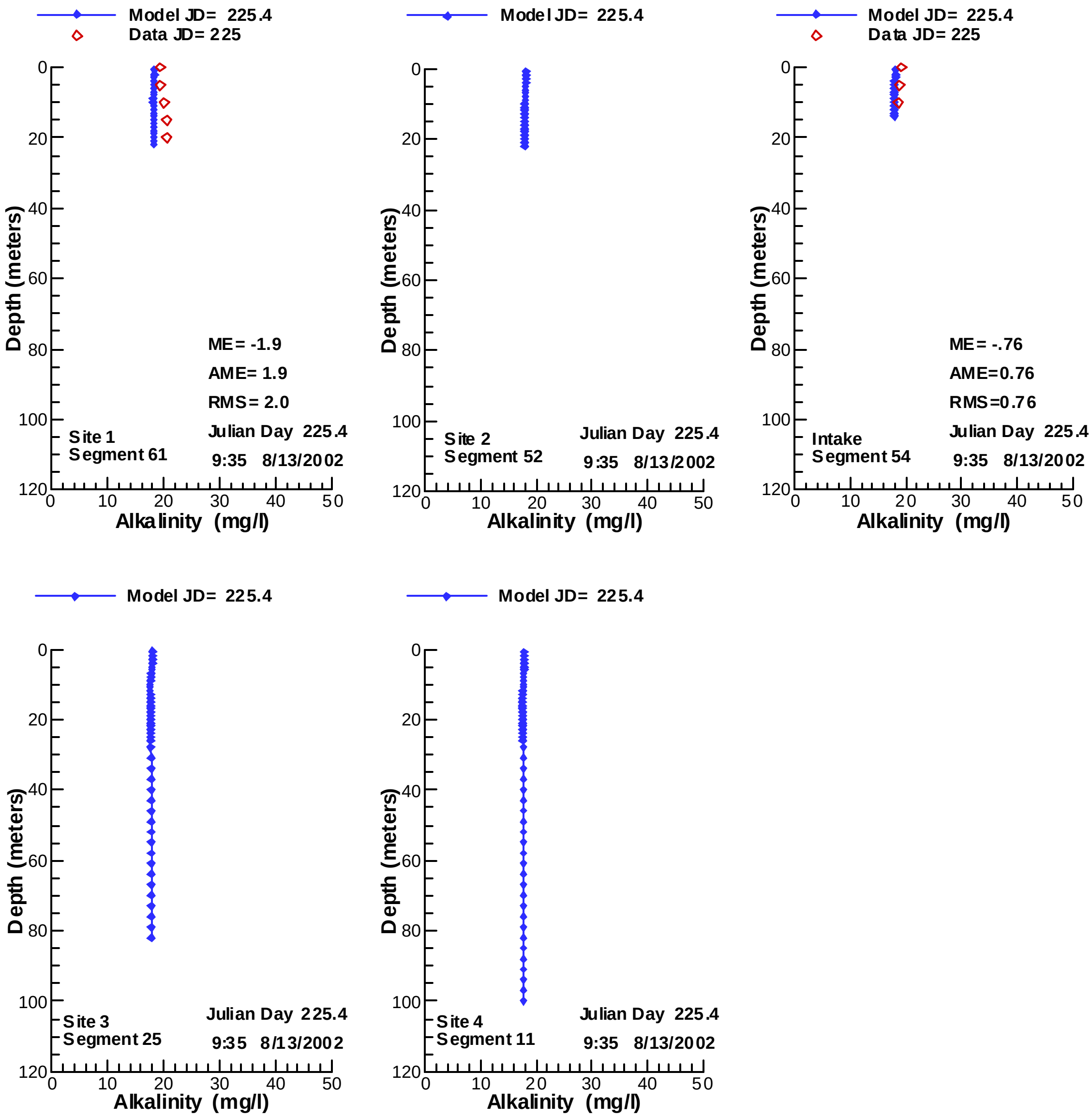

Figure 364. Vertical profiles of Alkalinity compared with data for 8/13/2002.

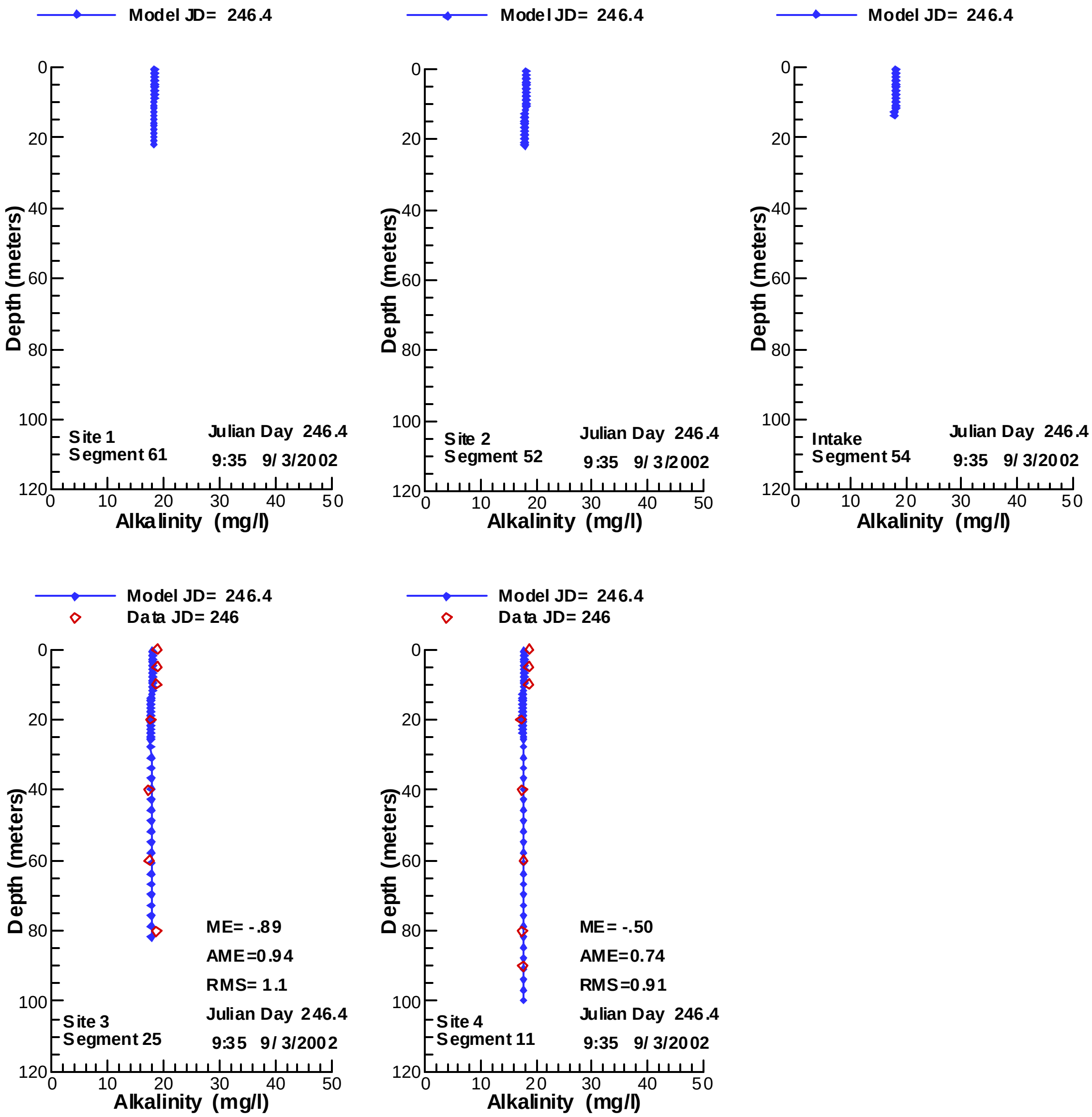

Figure 365. Vertical profiles of Alkalinity compared with data for 9/ 3/2002.

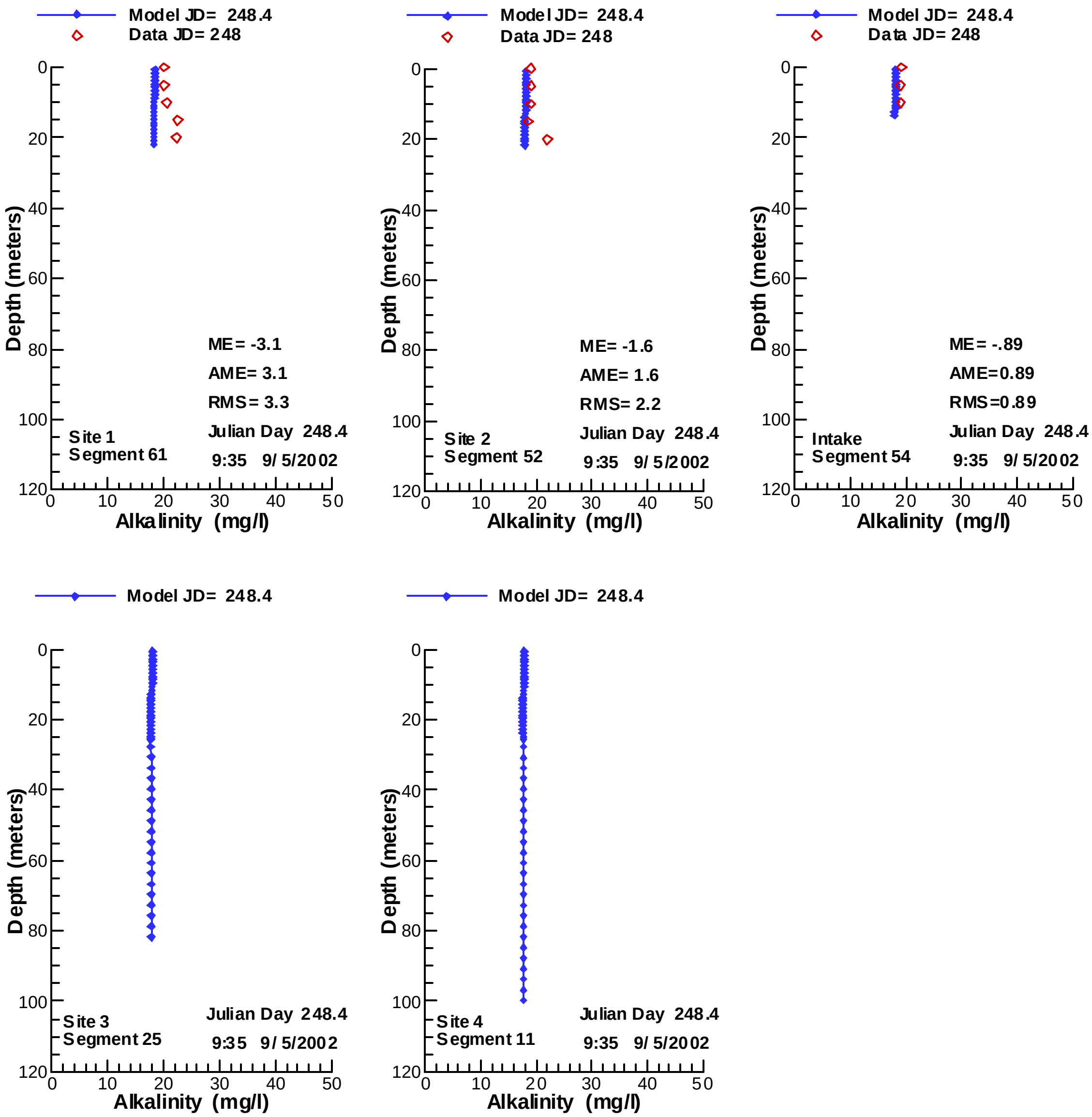

Figure 366. Vertical profiles of Alkalinity compared with data for 9/ 5/2002.

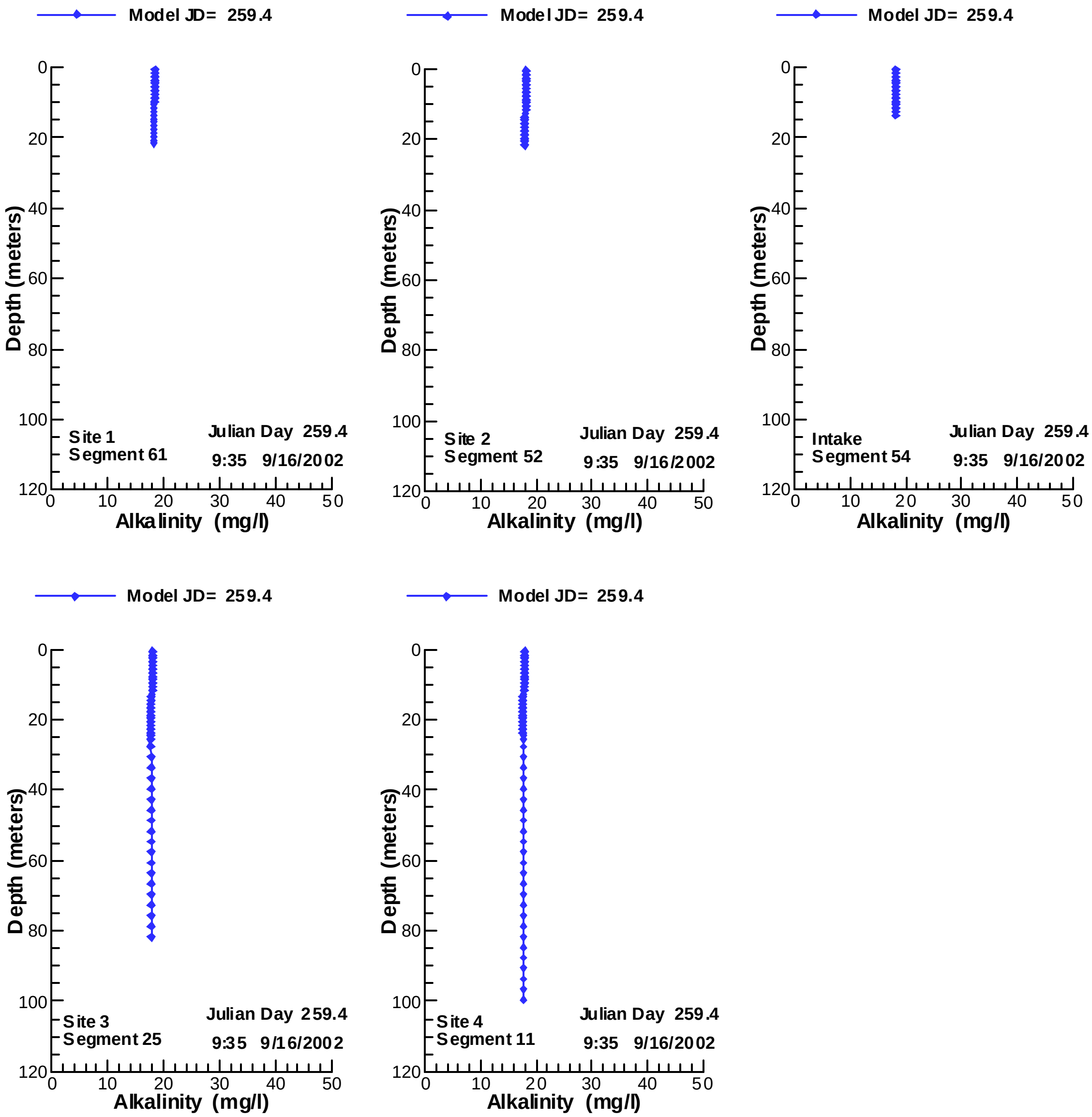

Figure 367. Vertical profiles of Alkalinity compared with data for 9/16/2002.

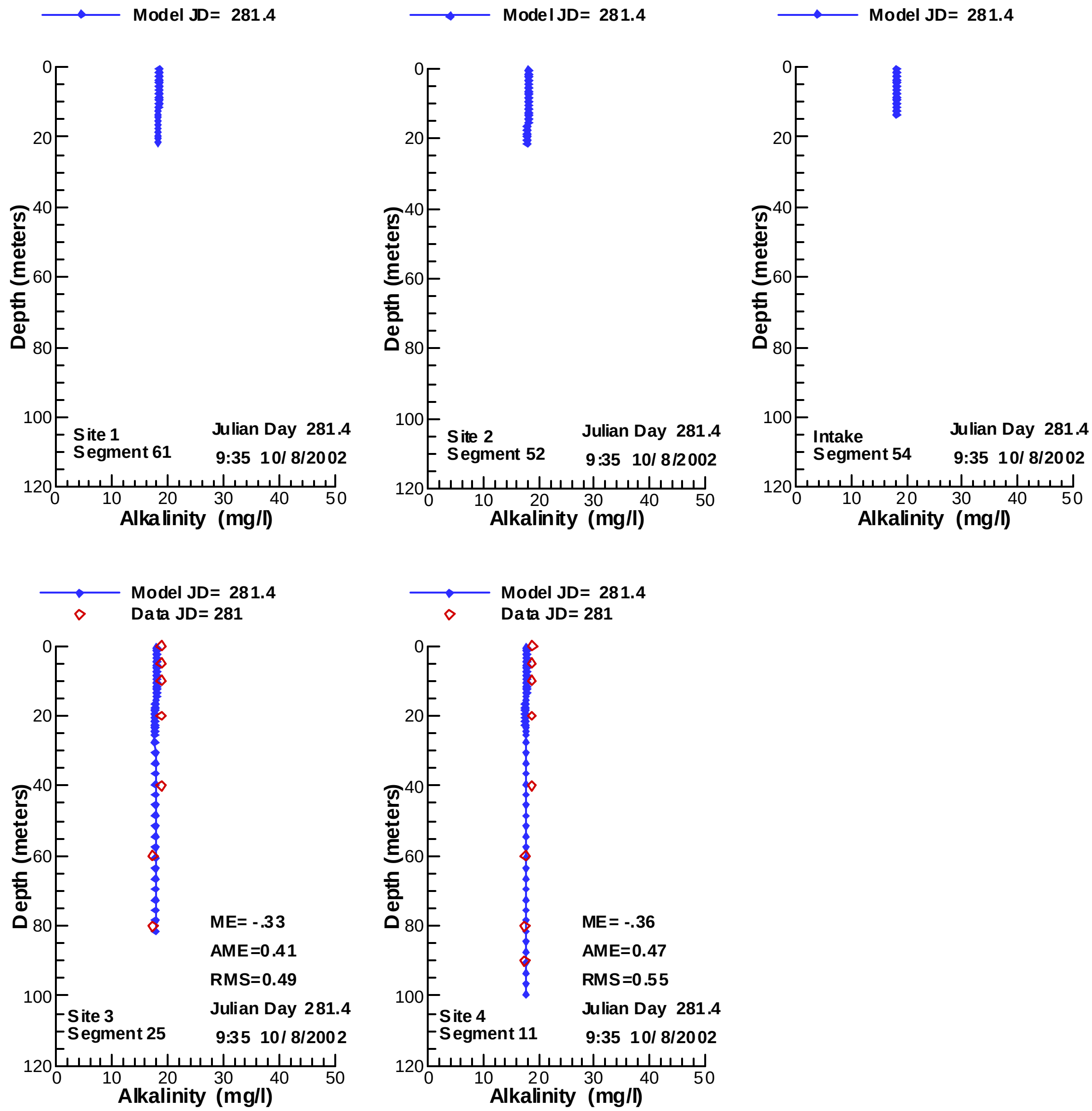

Figure 368. Vertical profiles of Alkalinity compared with data for 10/ 8/2002.

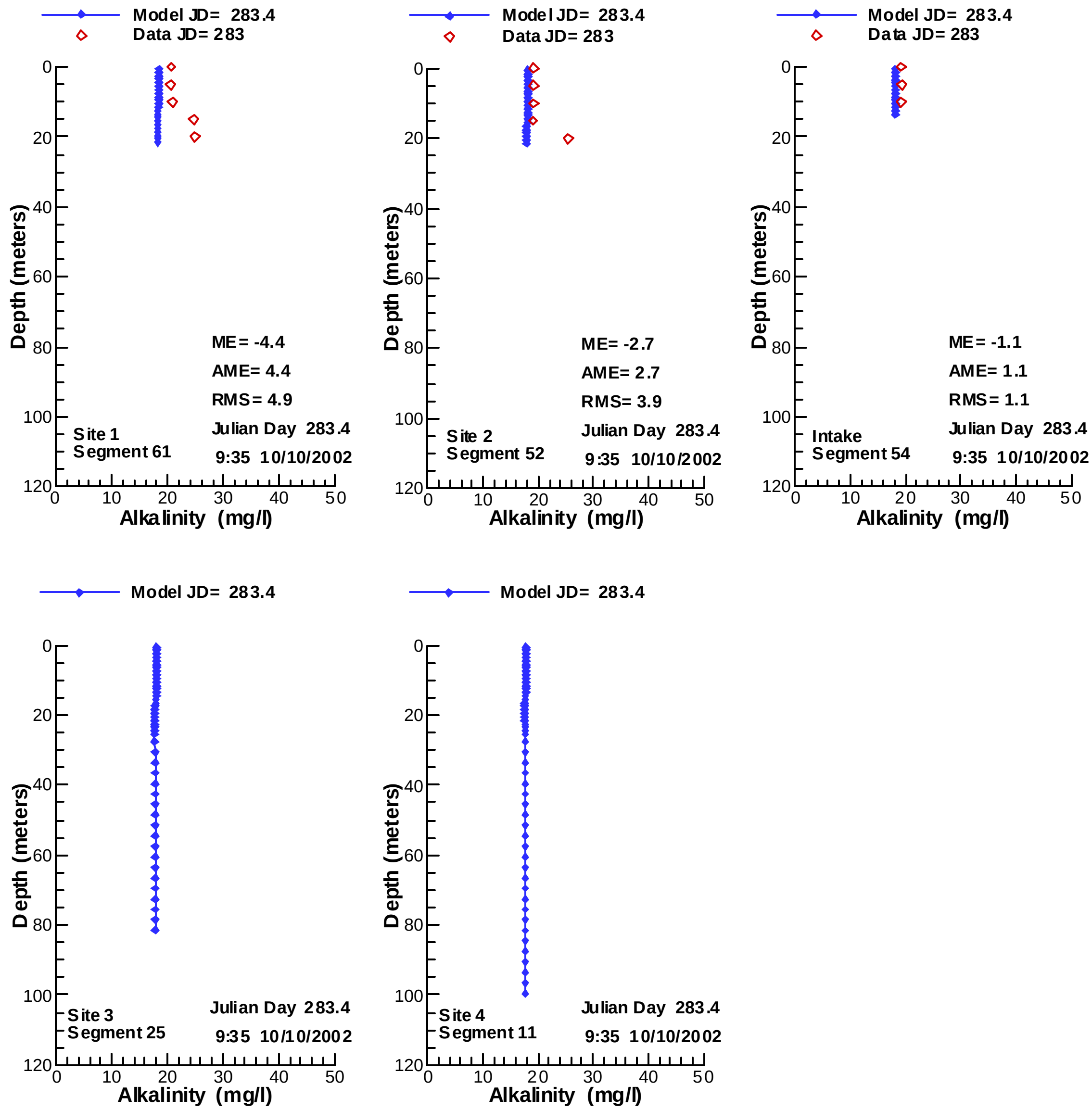

Figure 369. Vertical profiles of Alkalinity compared with data for 10/10/2002.

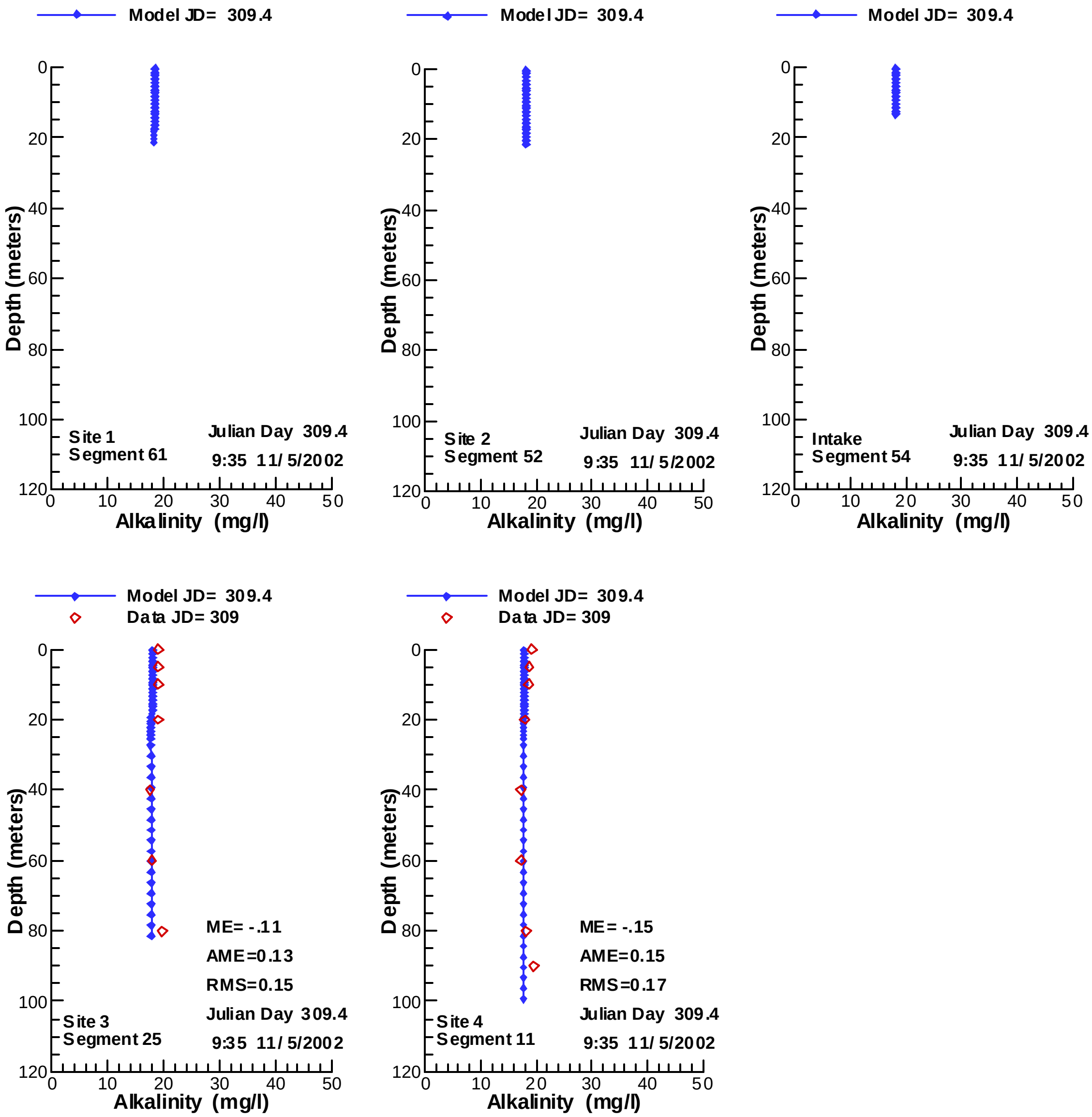

Figure 370. Vertical profiles of Alkalinity compared with data for 11/ 5/2002.

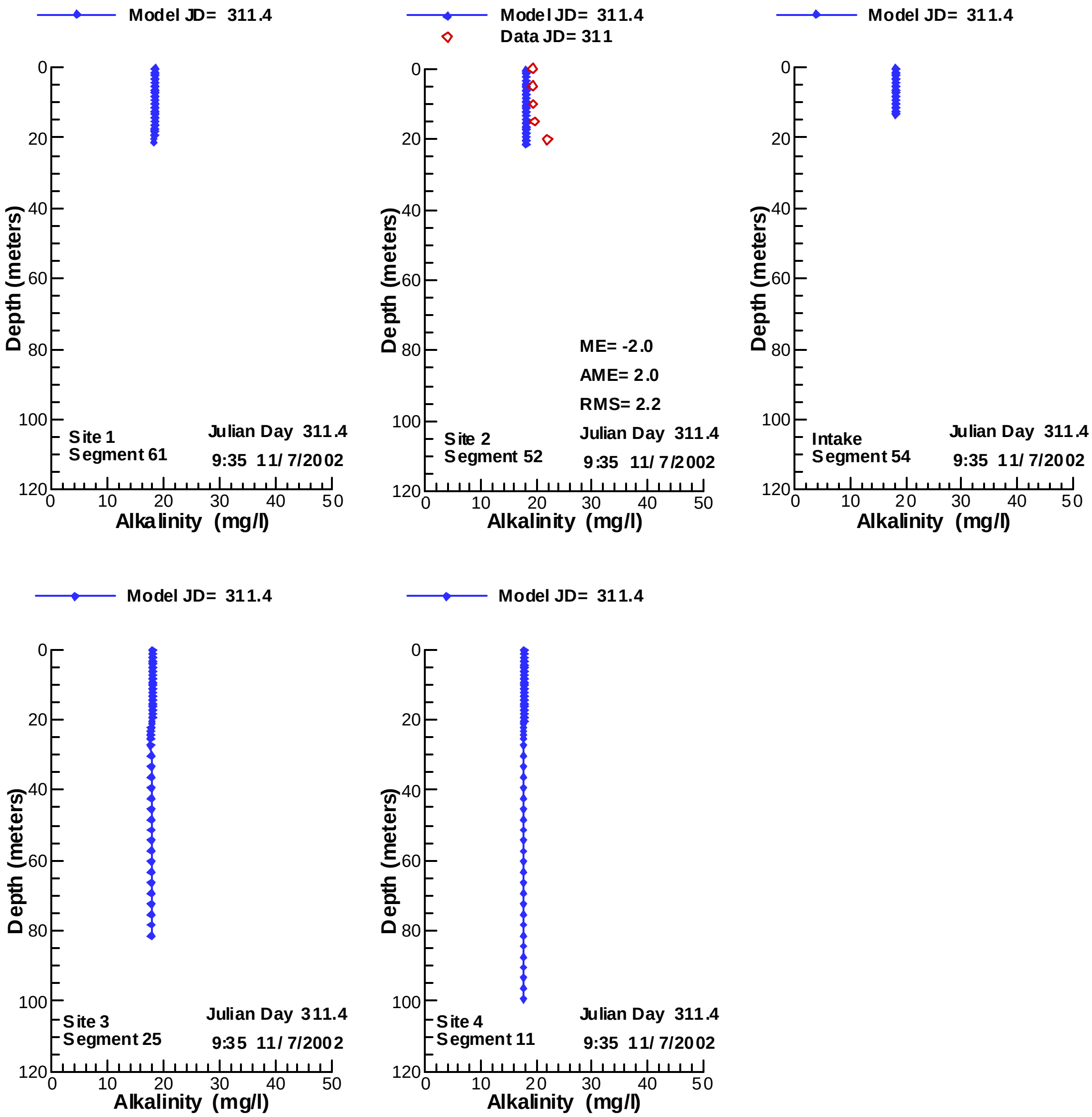

Figure 371. Vertical profiles of Alkalinity compared with data for 11/ 7/2002.

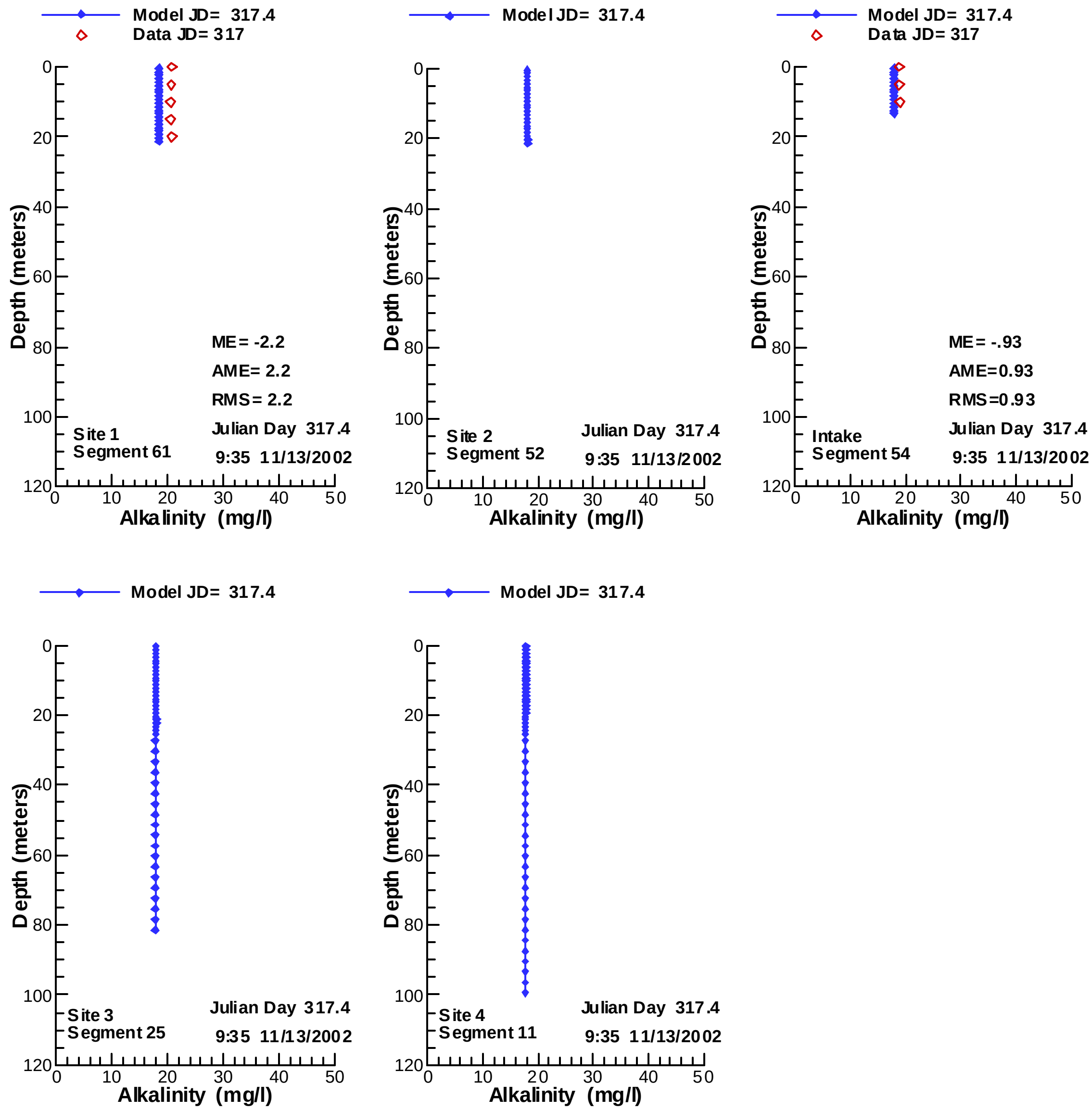

Figure 372. Vertical profiles of Alkalinity compared with data for 11/13/2002.

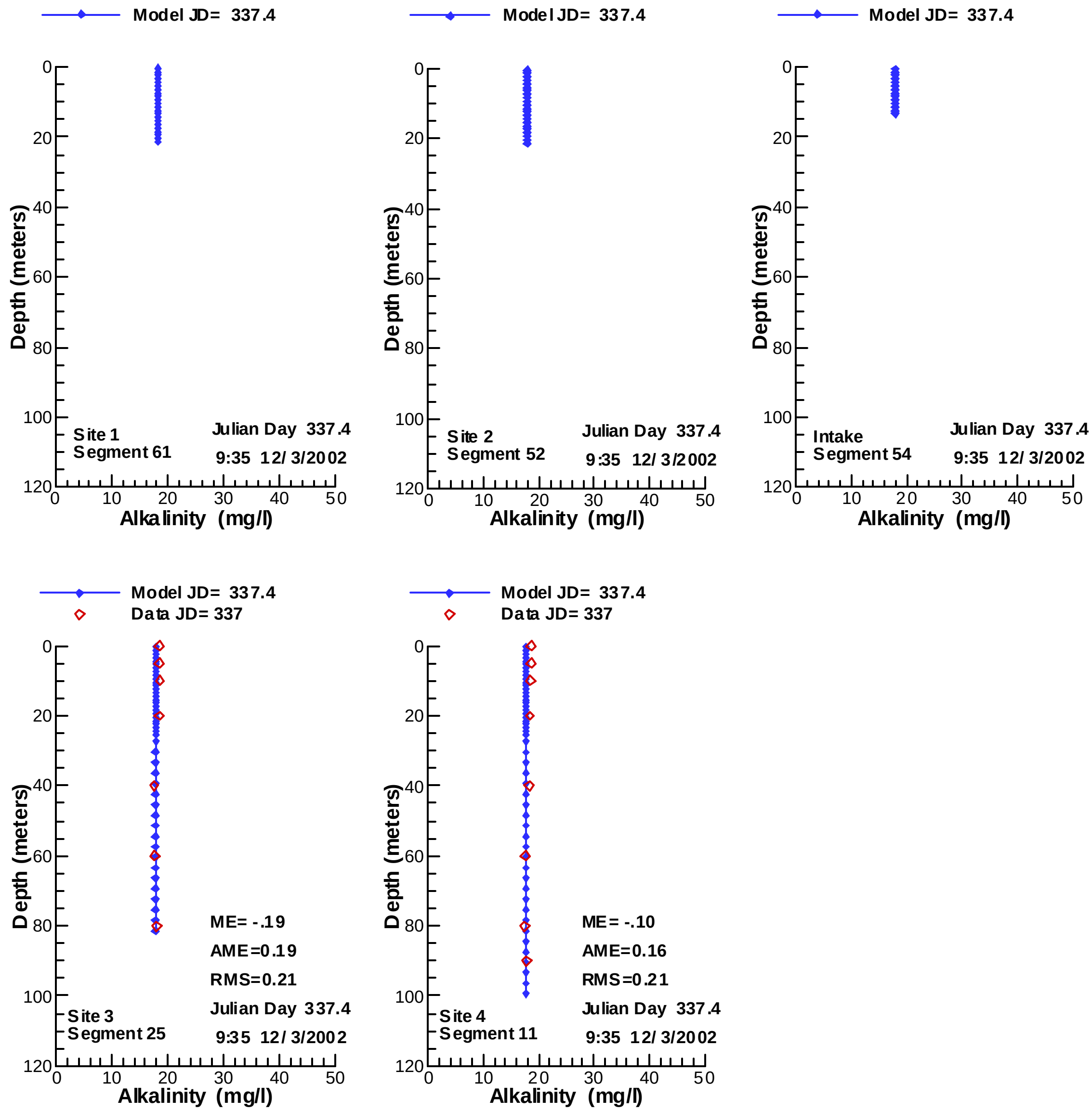

Figure 373. Vertical profiles of Alkalinity compared with data for 12/ 3/2002.

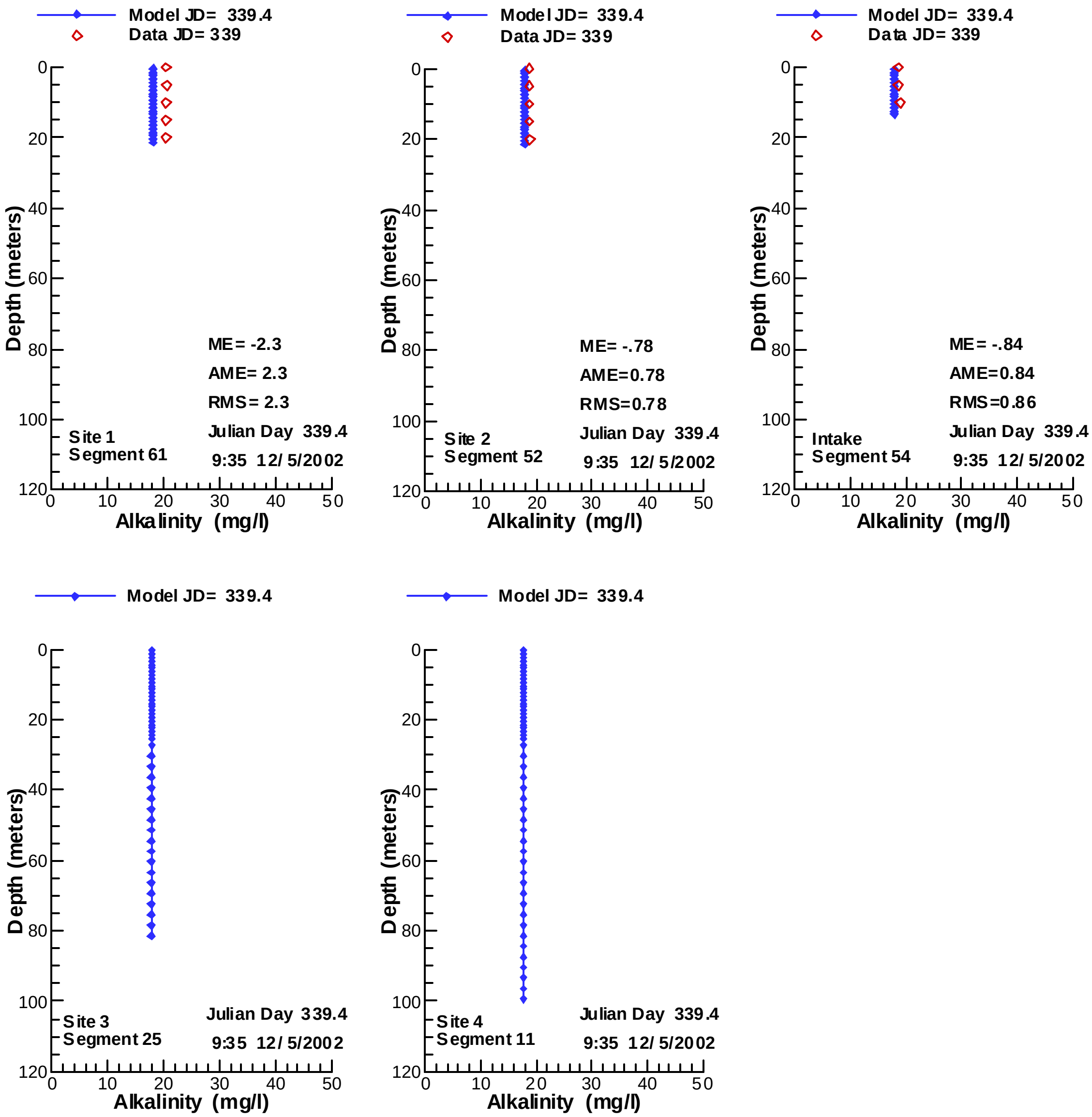

Figure 374. Vertical profiles of Alkalinity compared with data for 12/ 5/2002.

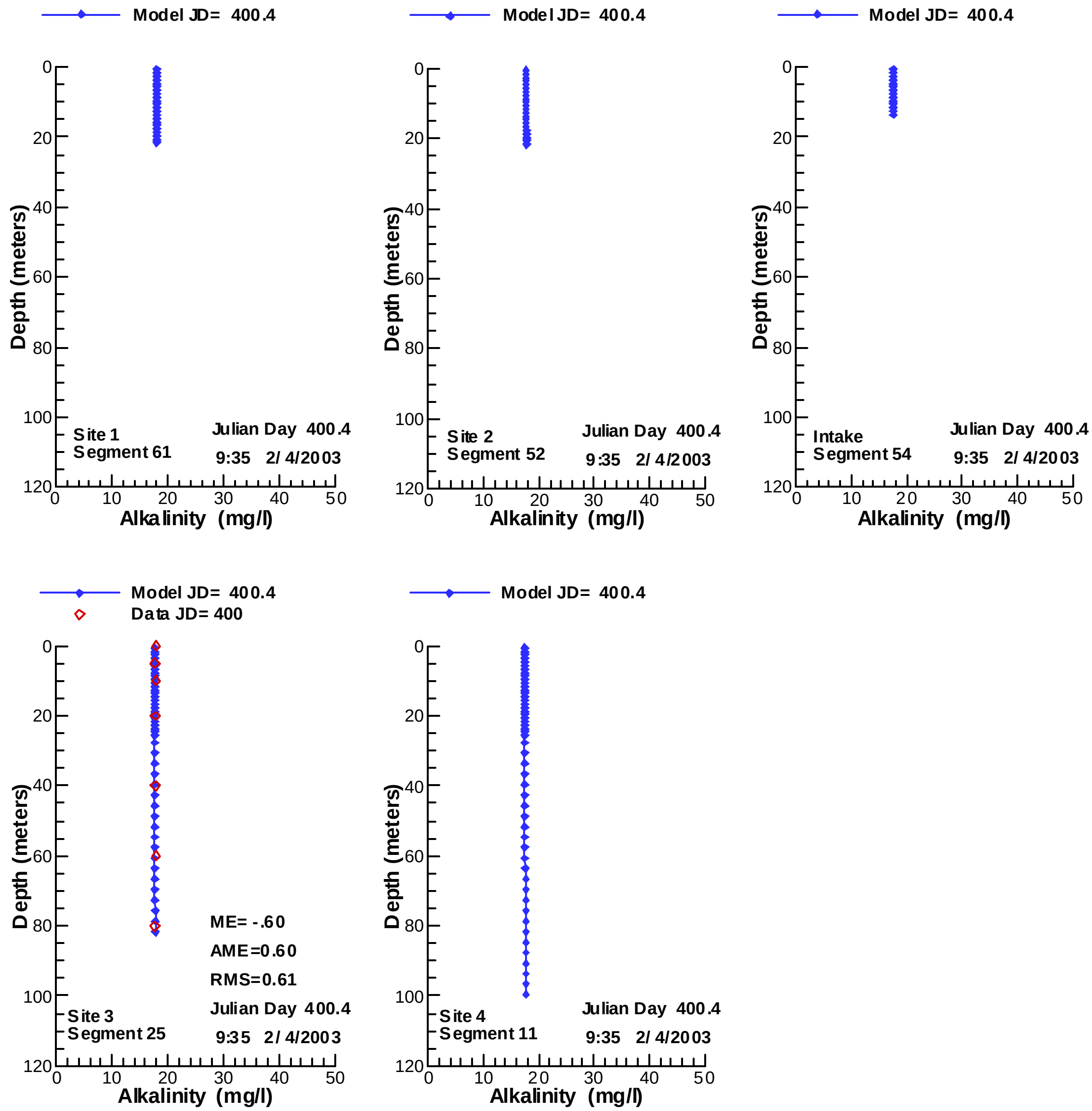

Figure 375. Vertical profiles of Alkalinity compared with data for 2/ 4/2003.

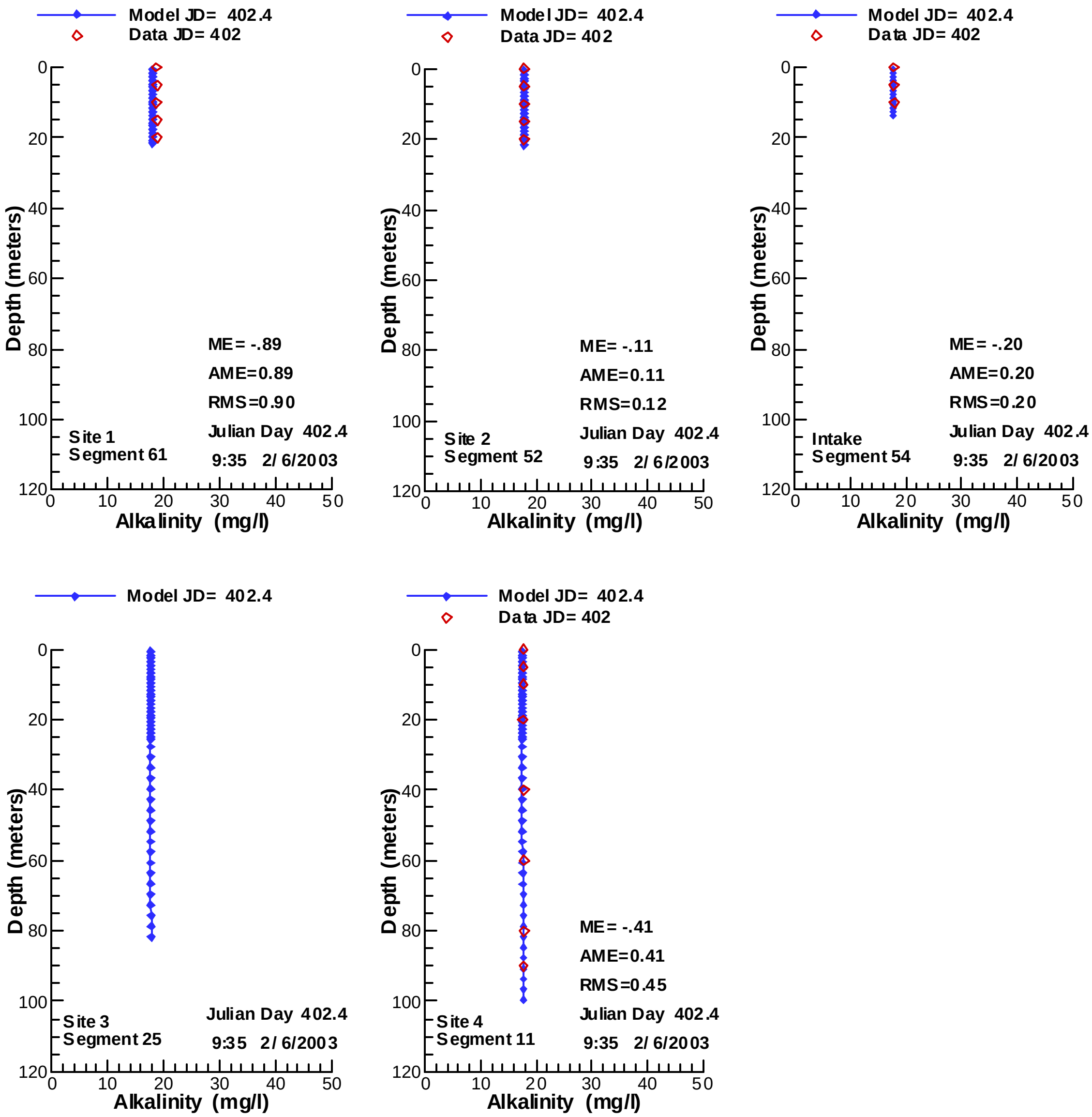

Figure 376. Vertical profiles of Alkalinity compared with data for 2/ 6/2003.

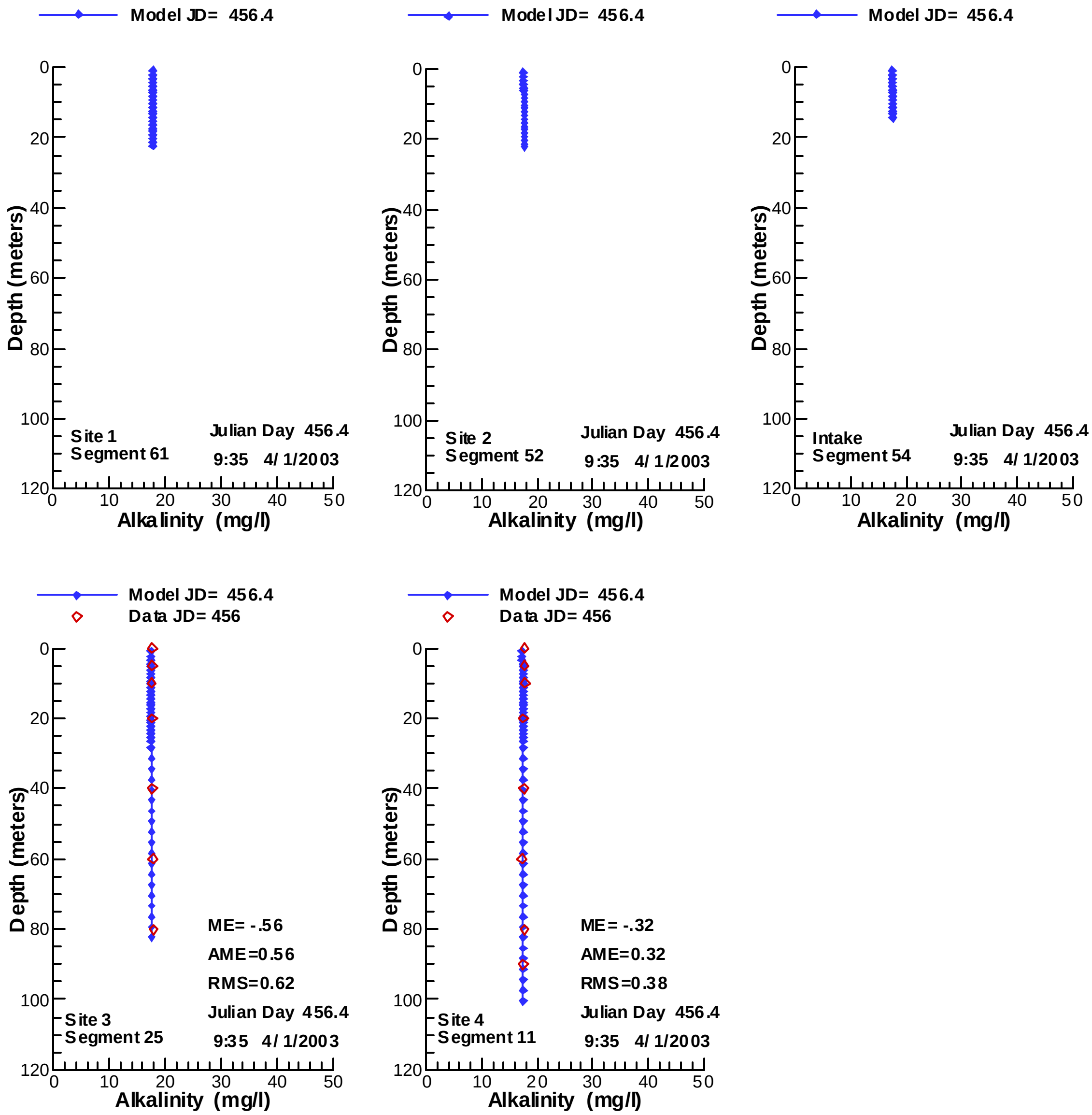

Figure 377. Vertical profiles of Alkalinity compared with data for 4/ 1/2003.

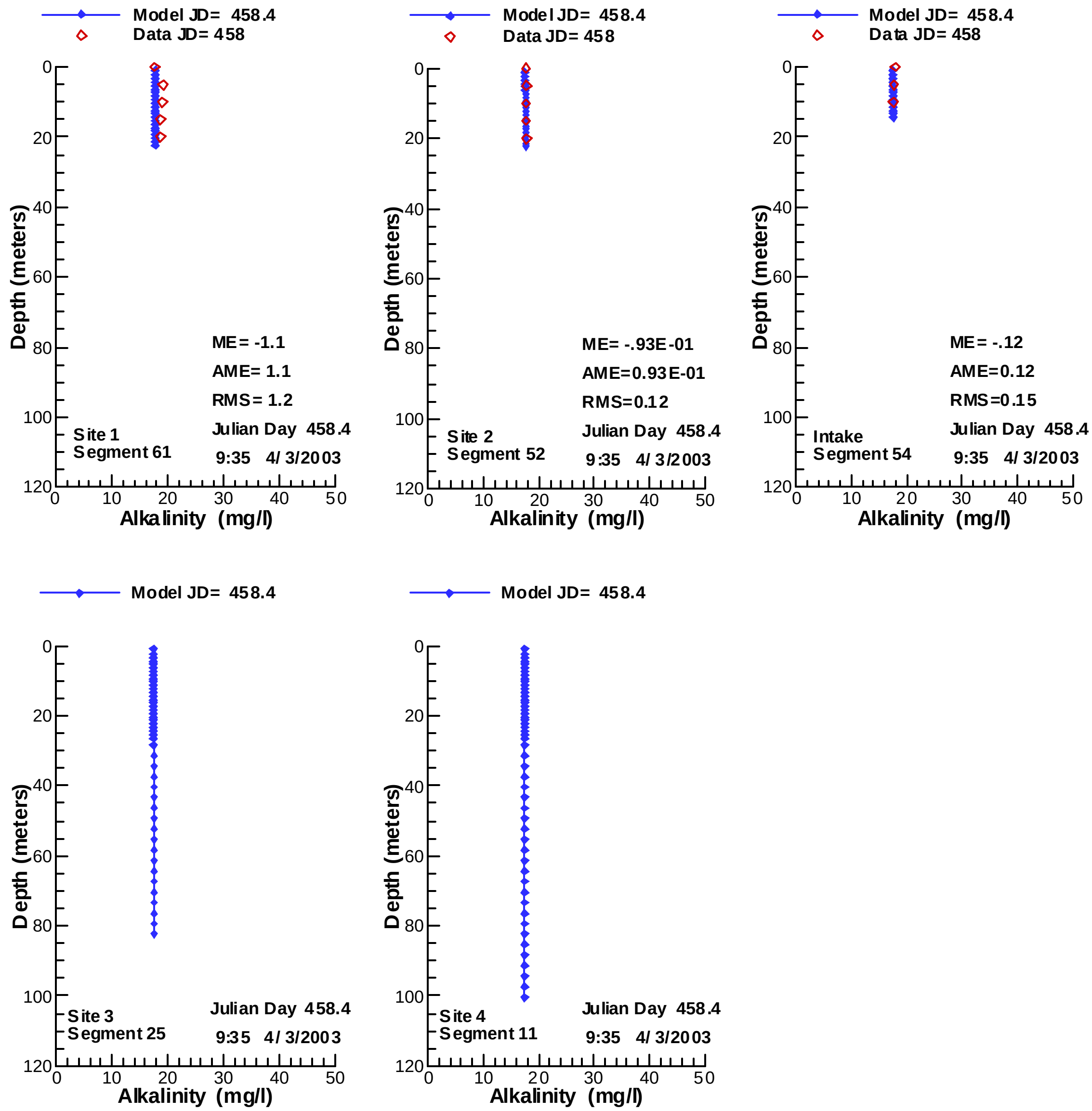

Figure 378. Vertical profiles of Alkalinity compared with data for 4/ 3/2003.

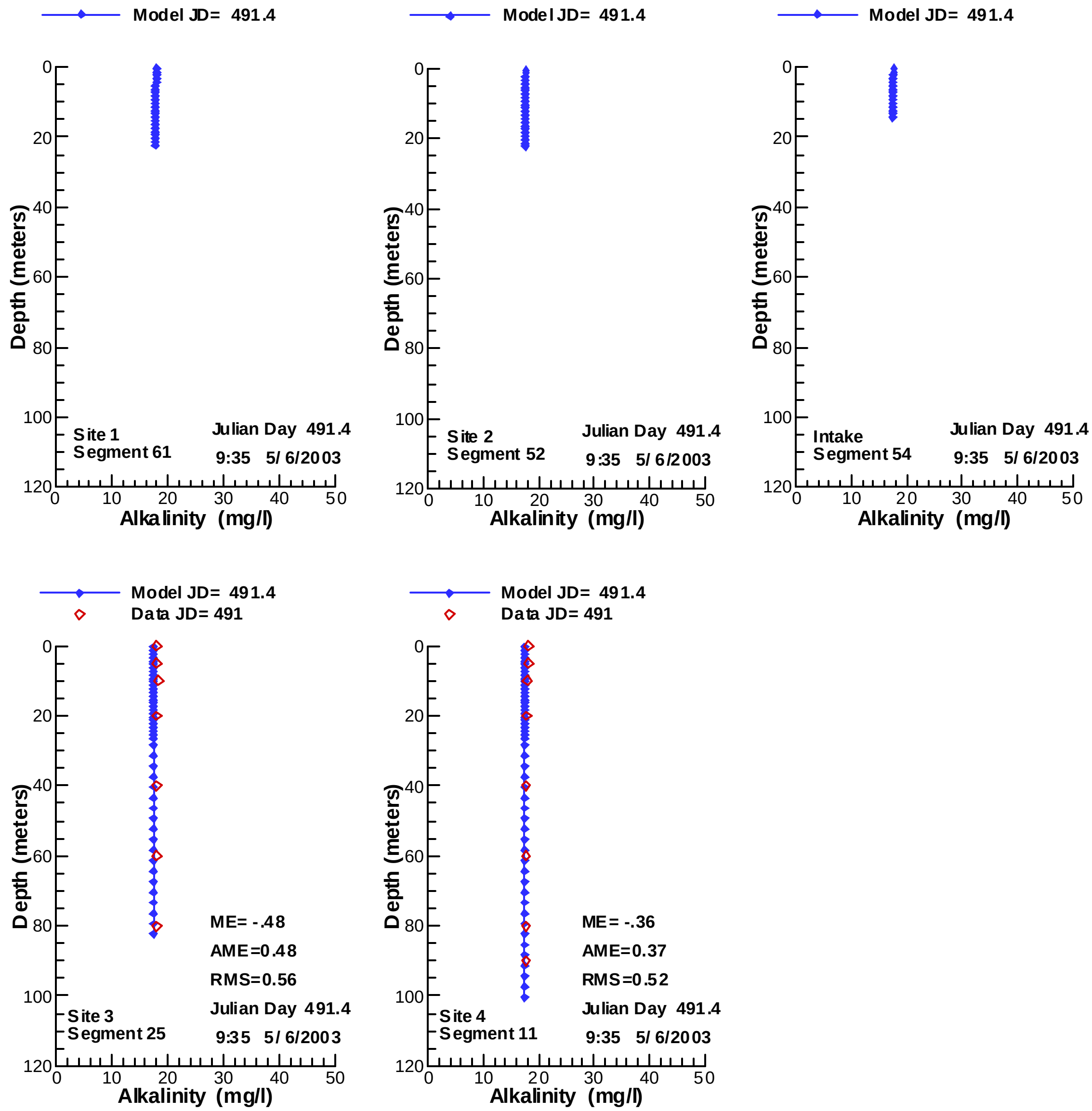

Figure 379. Vertical profiles of Alkalinity compared with data for 5/ 6/2003.

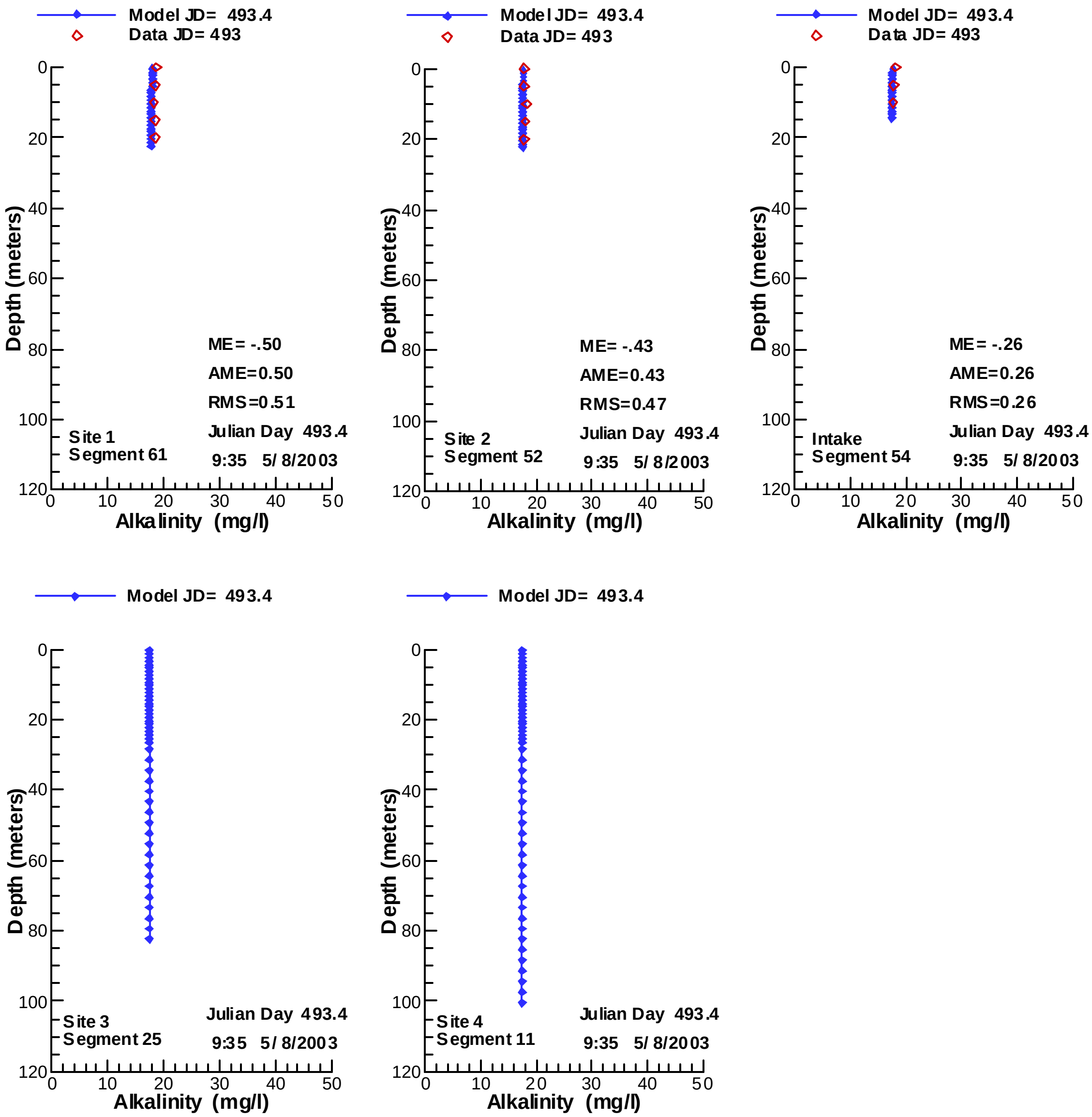

Figure 380. Vertical profiles of Alkalinity compared with data for 5/ 8/2003.

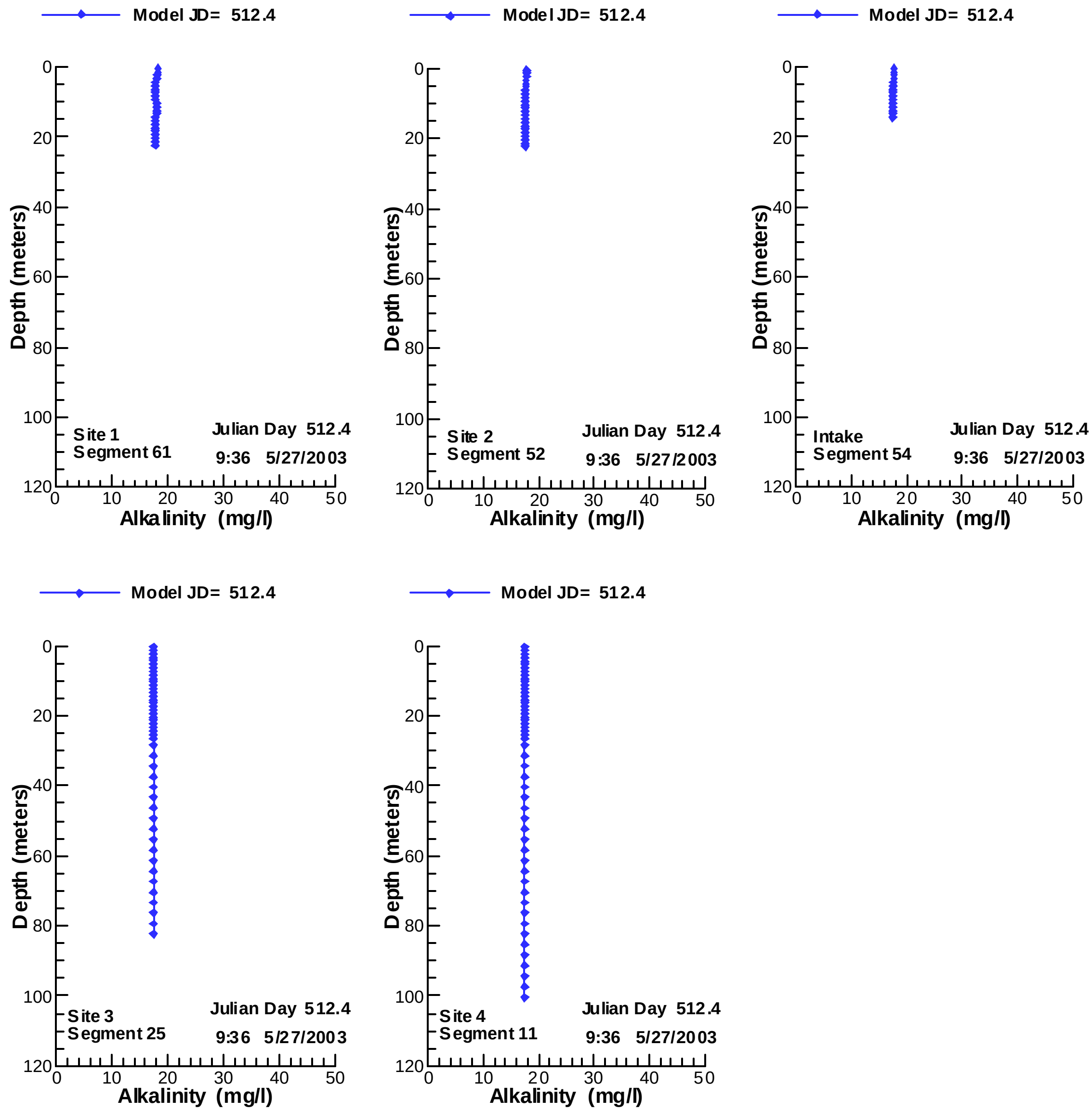

Figure 381. Vertical profiles of Alkalinity compared with data for 5/27/2003.

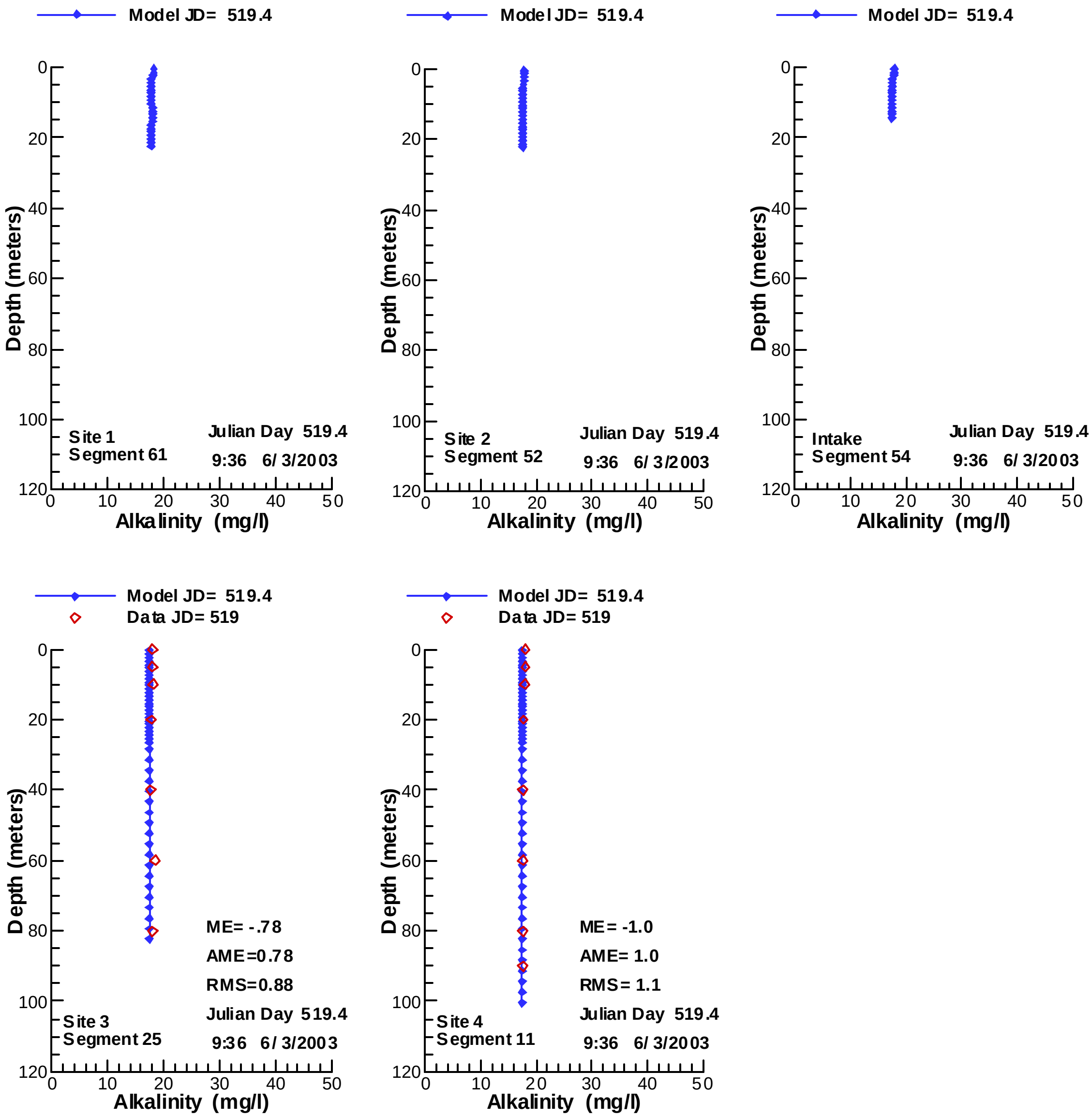

Figure 382. Vertical profiles of Alkalinity compared with data for 6/ 3/2003.

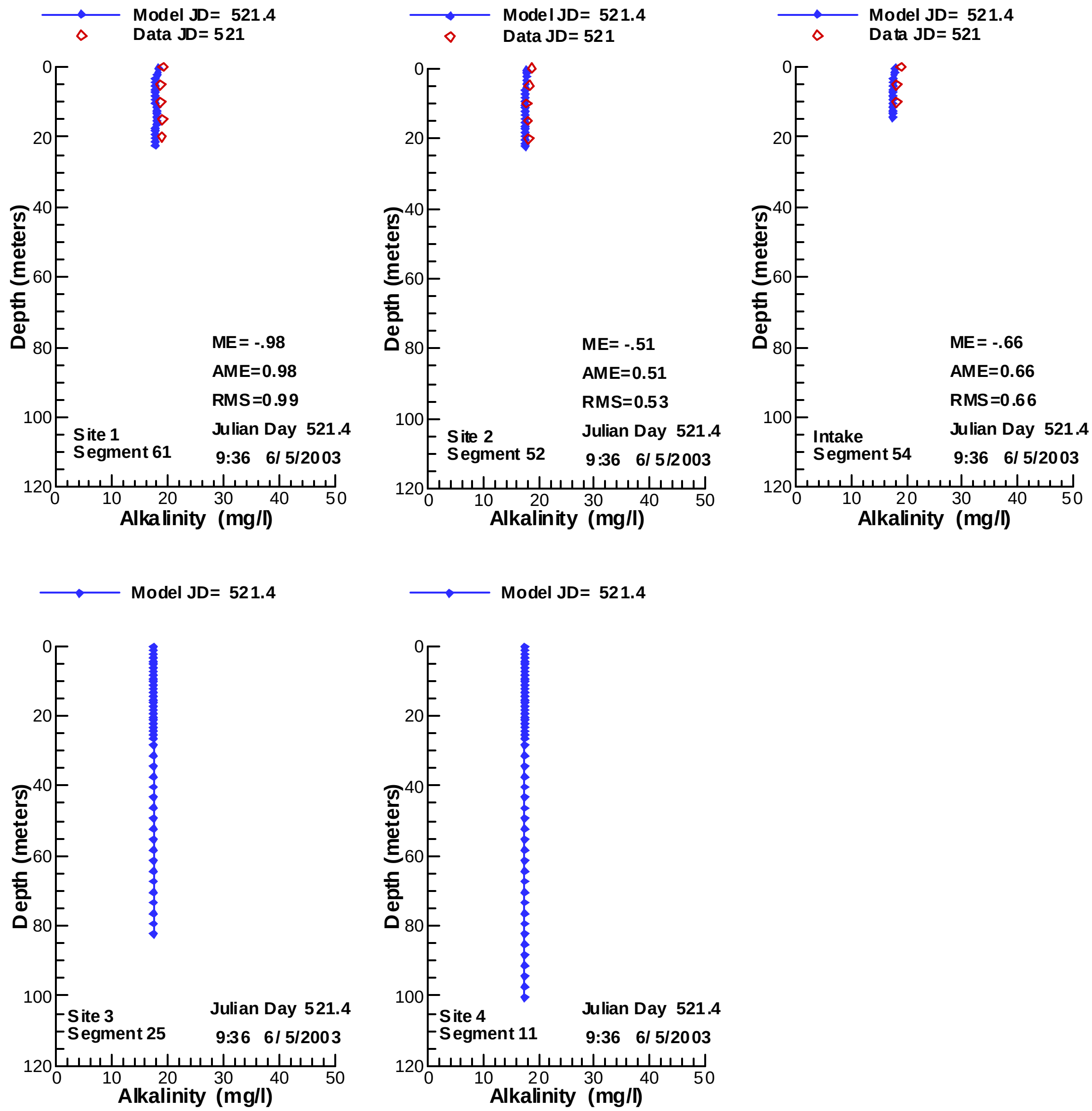

Figure 383. Vertical profiles of Alkalinity compared with data for 6/ 5/2003.

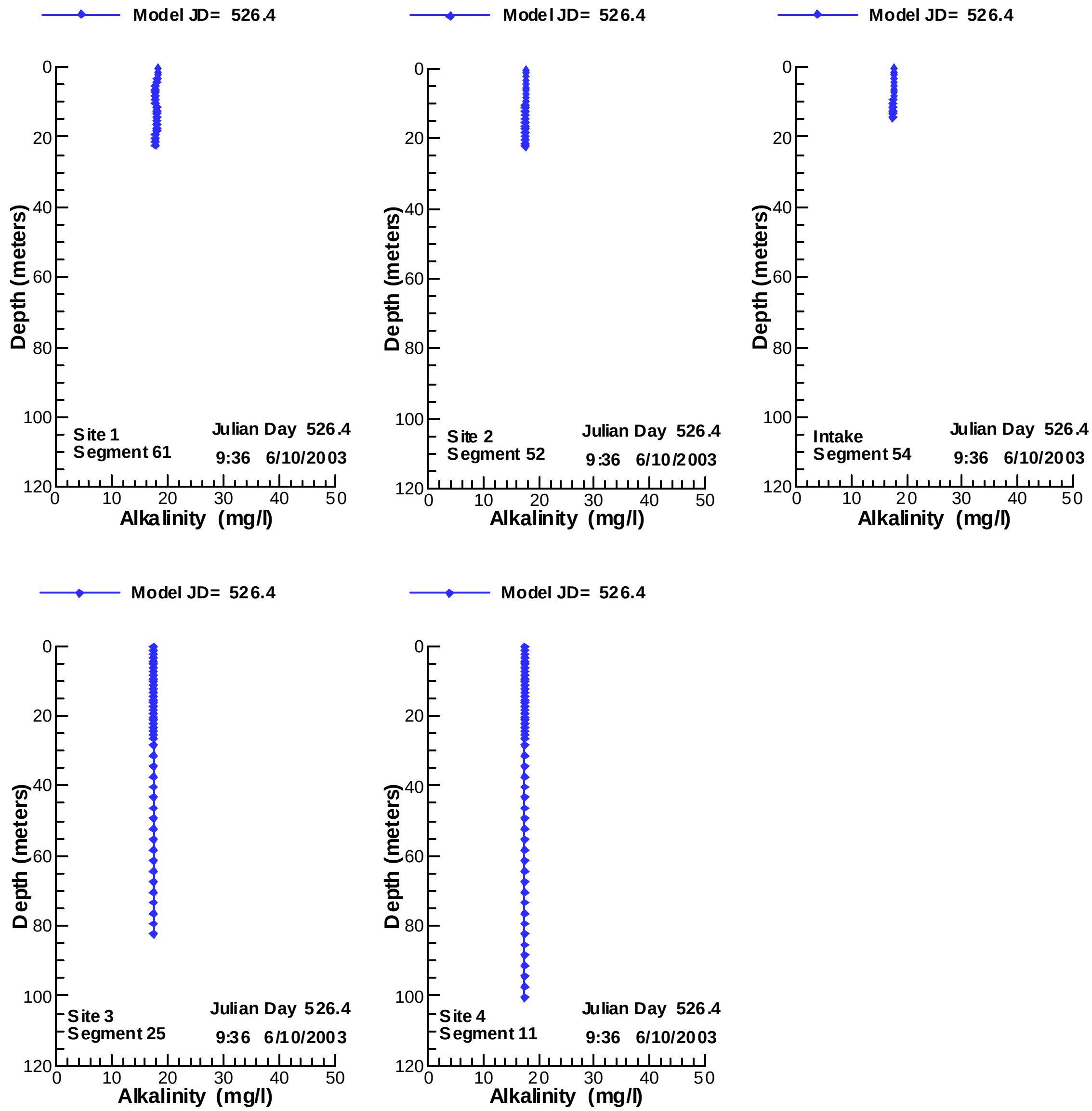

Figure 384. Vertical profiles of Alkalinity compared with data for 6/10/2003.

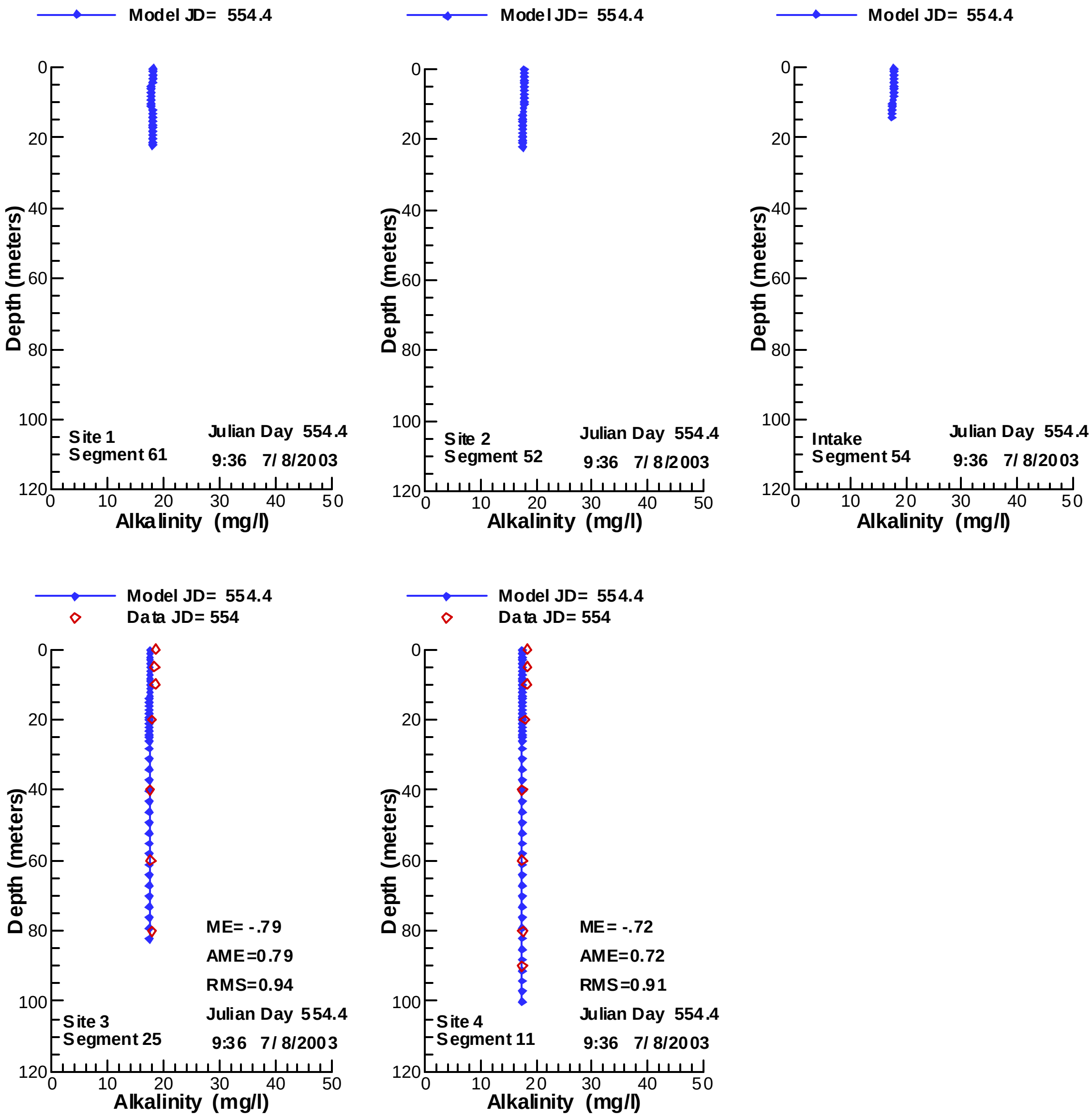

Figure 385. Vertical profiles of Alkalinity compared with data for 7/ 8/2003.

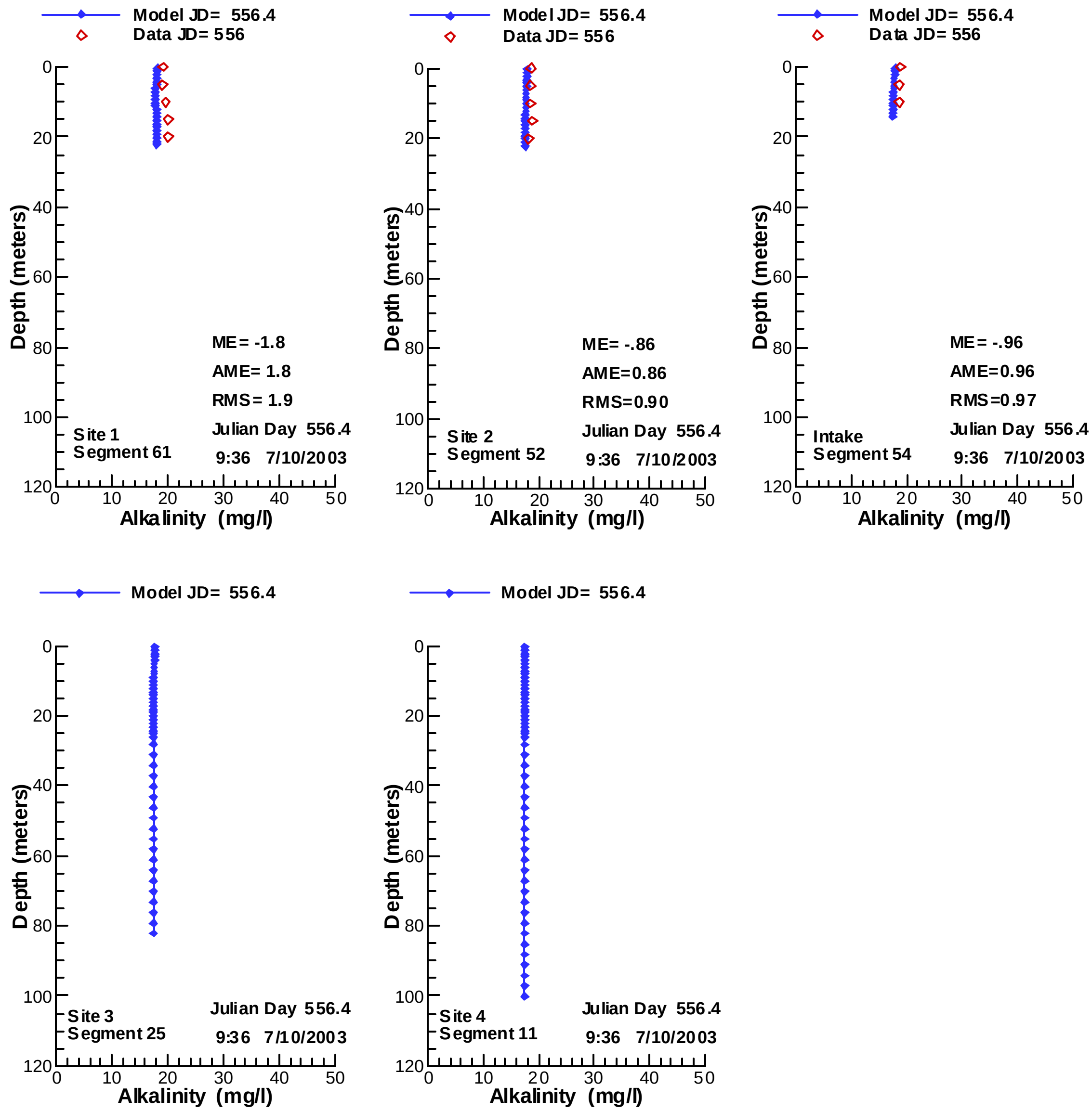

Figure 386. Vertical profiles of Alkalinity compared with data for 7/10/2003.

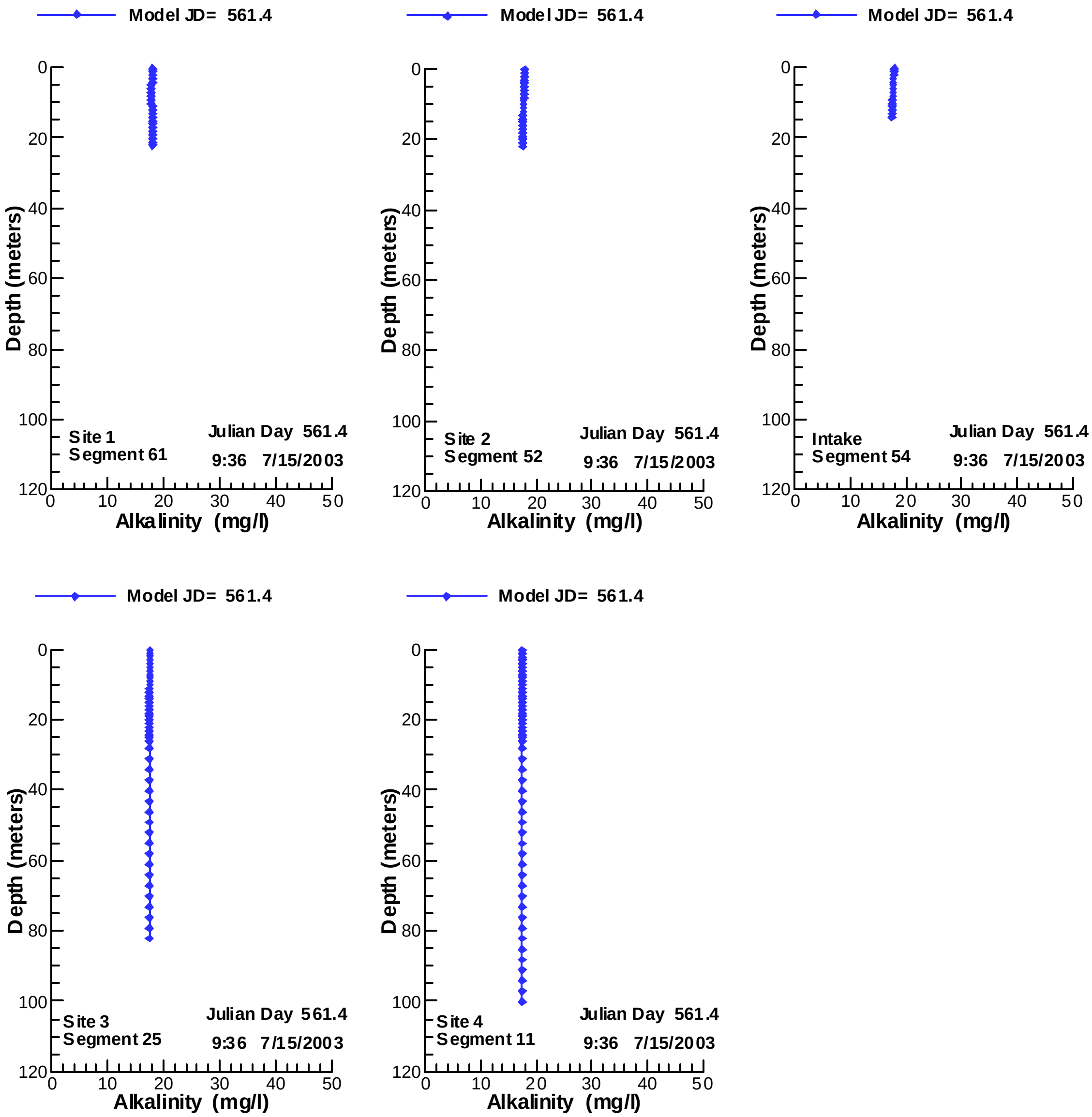

Figure 387. Vertical profiles of Alkalinity compared with data for 7/15/2003.

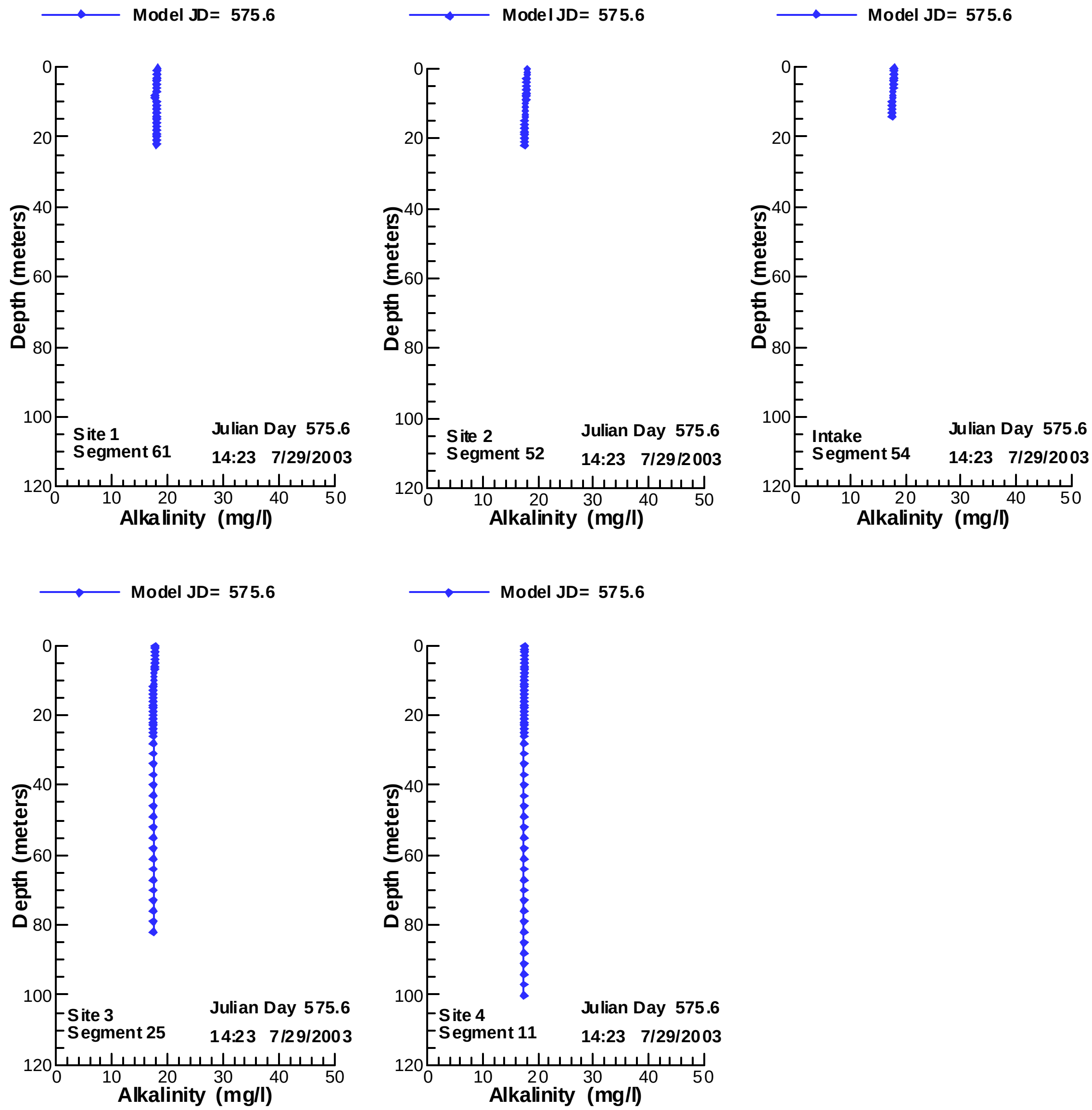

Figure 388. Vertical profiles of Alkalinity compared with data for 7/29/2003.

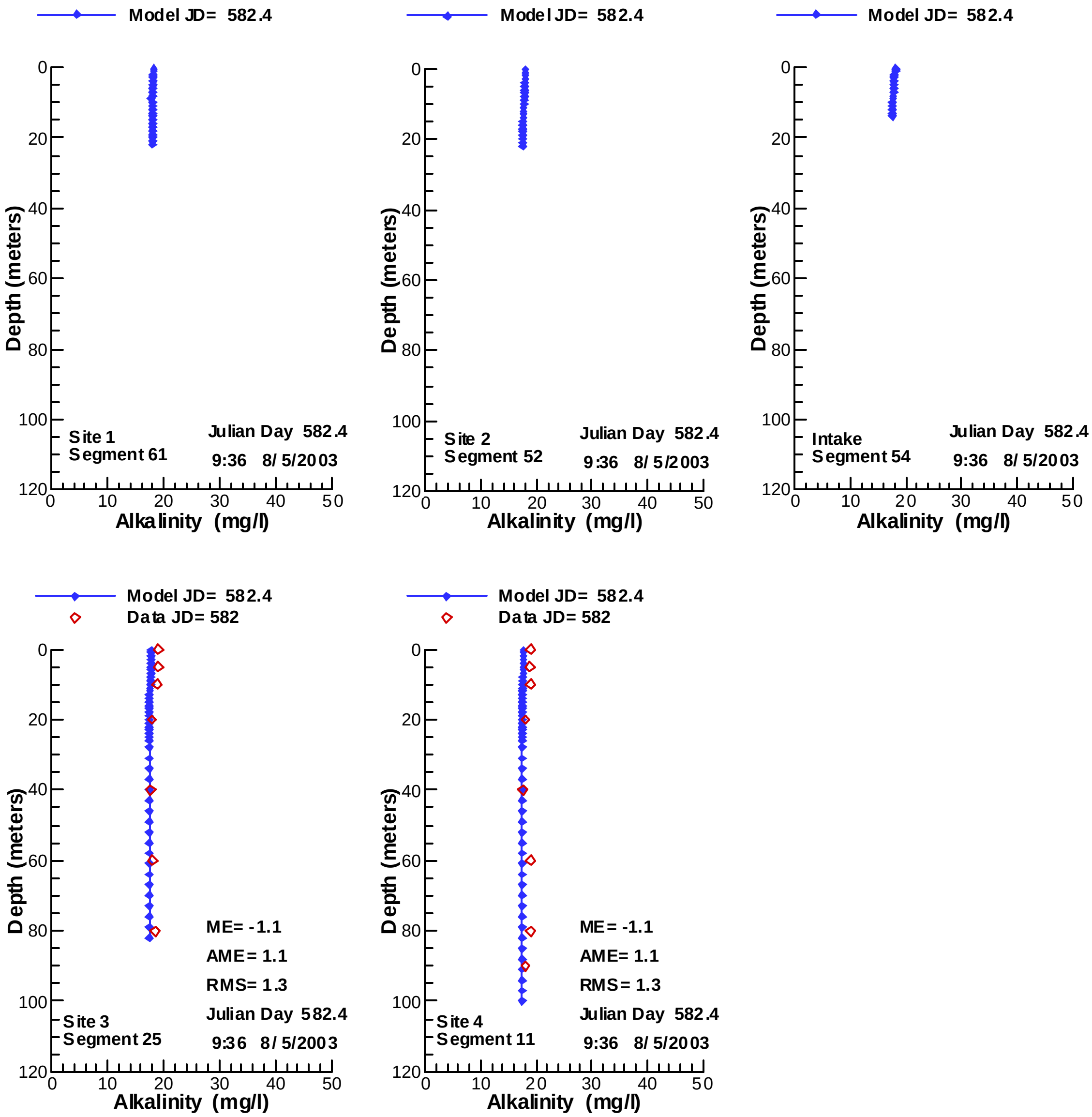

Figure 389. Vertical profiles of Alkalinity compared with data for 8/ 5/2003.

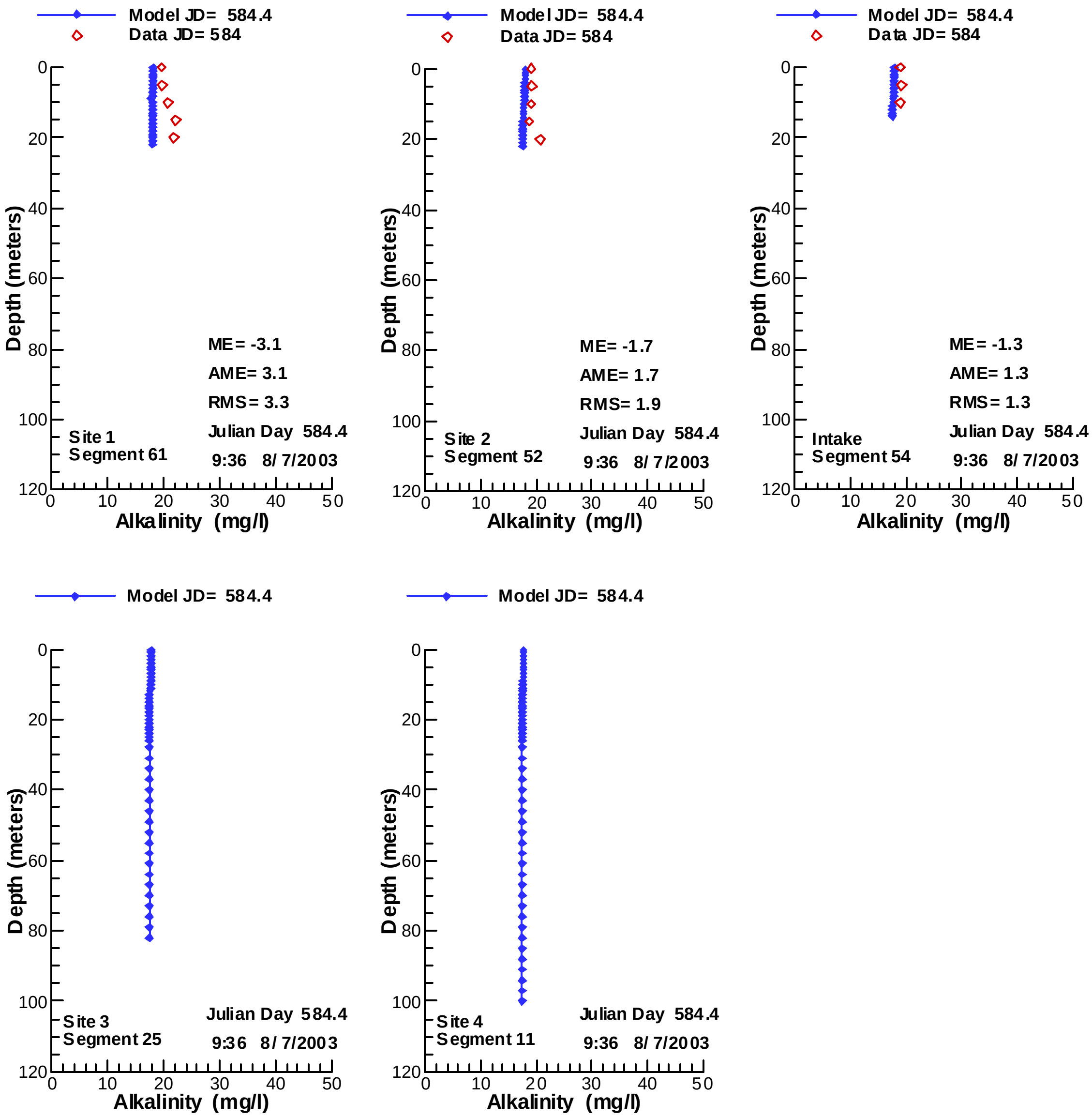

Figure 390. Vertical profiles of Alkalinity compared with data for 8/ 7/2003.

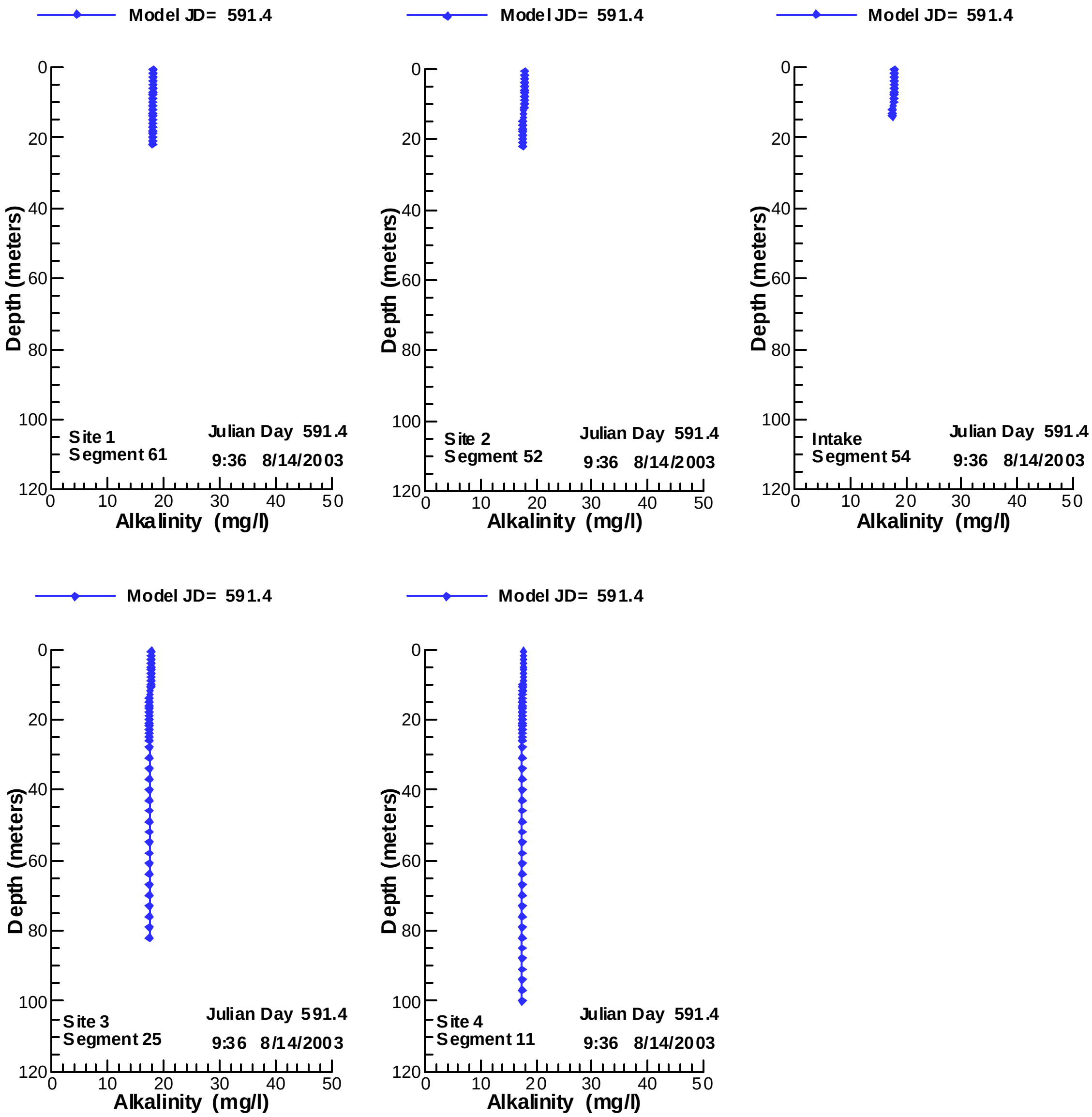

Figure 391. Vertical profiles of Alkalinity compared with data for 8/14/2003.

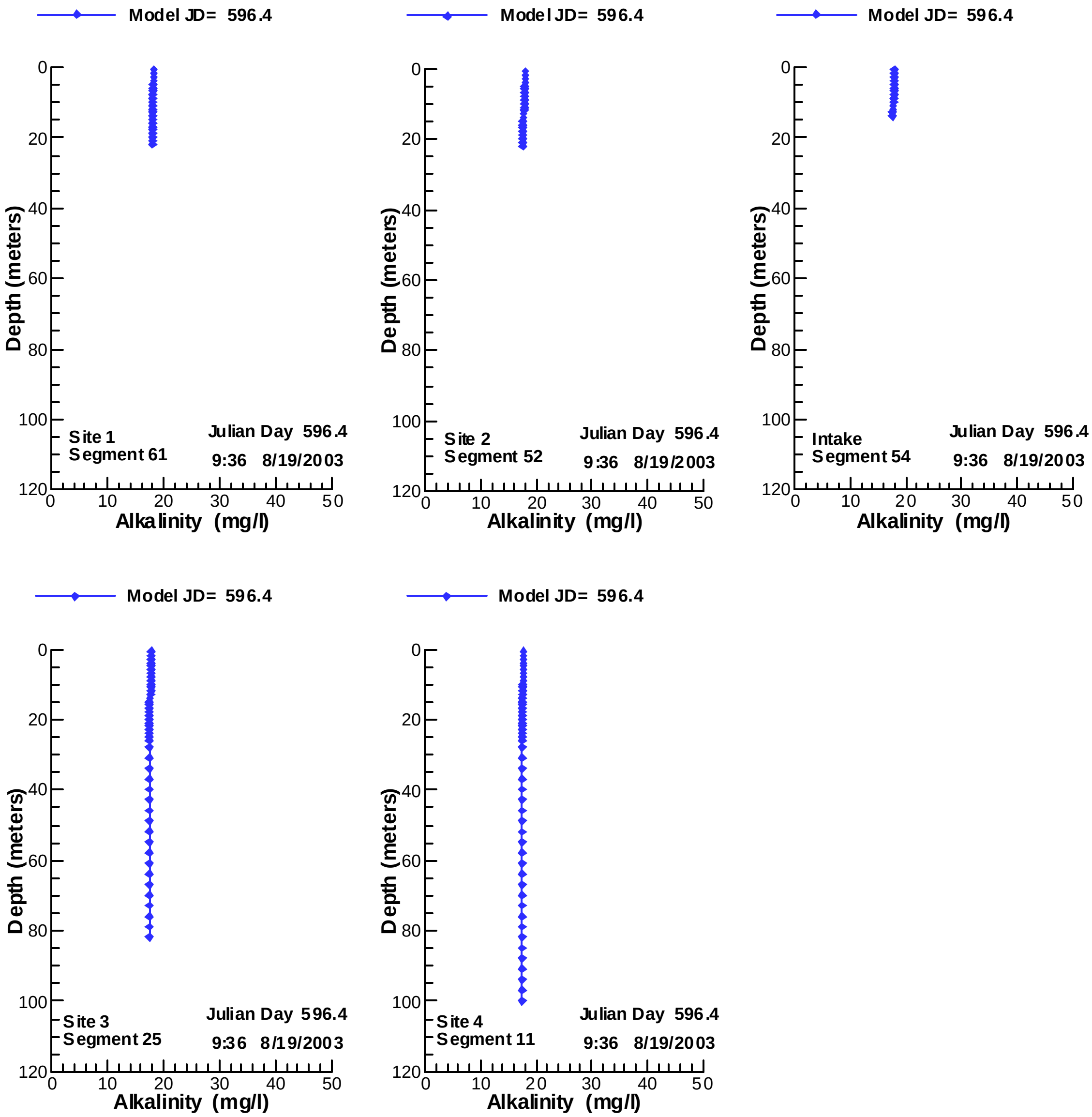

Figure 392. Vertical profiles of Alkalinity compared with data for 8/19/2003.

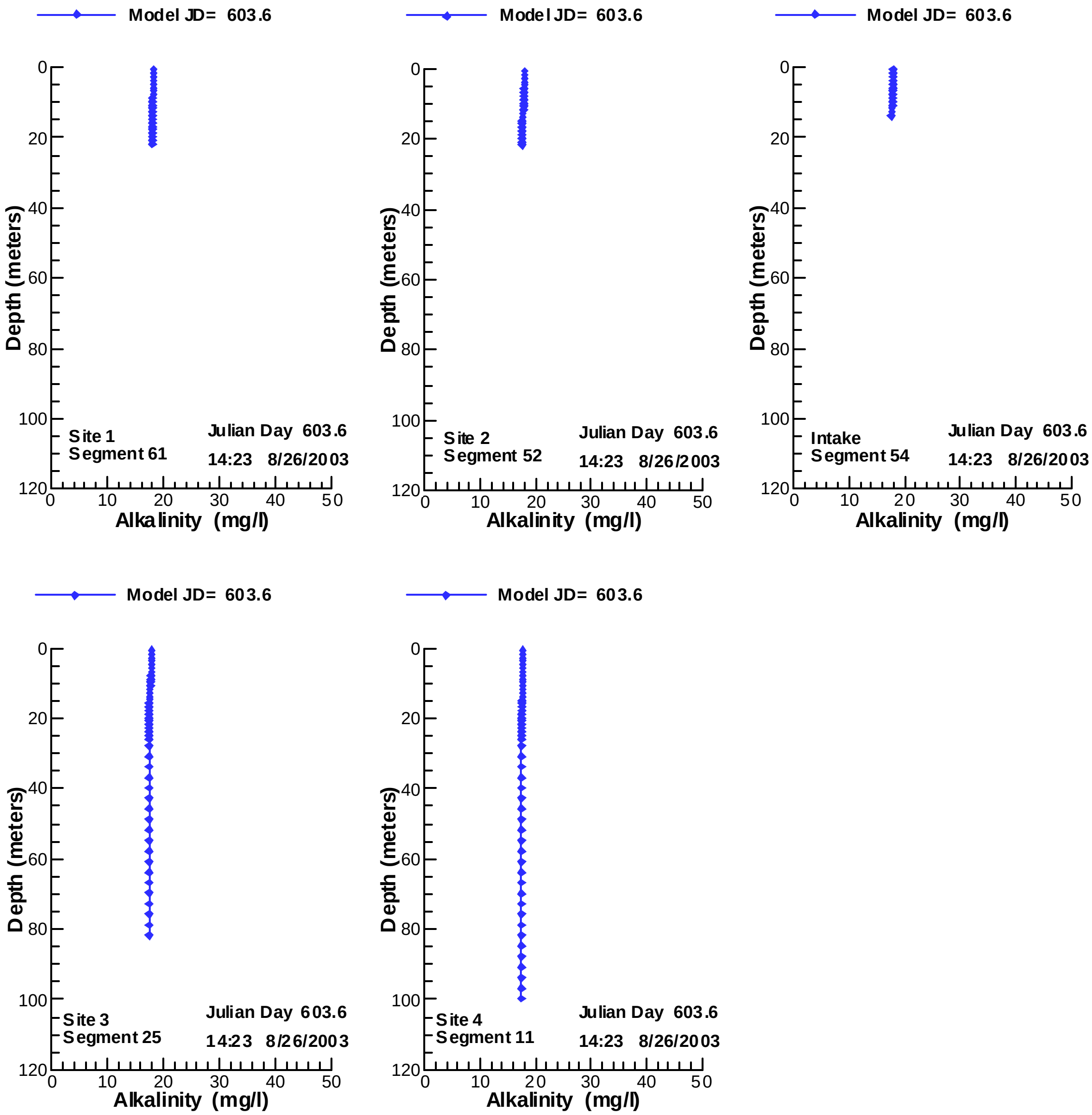

Figure 393. Vertical profiles of Alkalinity compared with data for 8/26/2003.

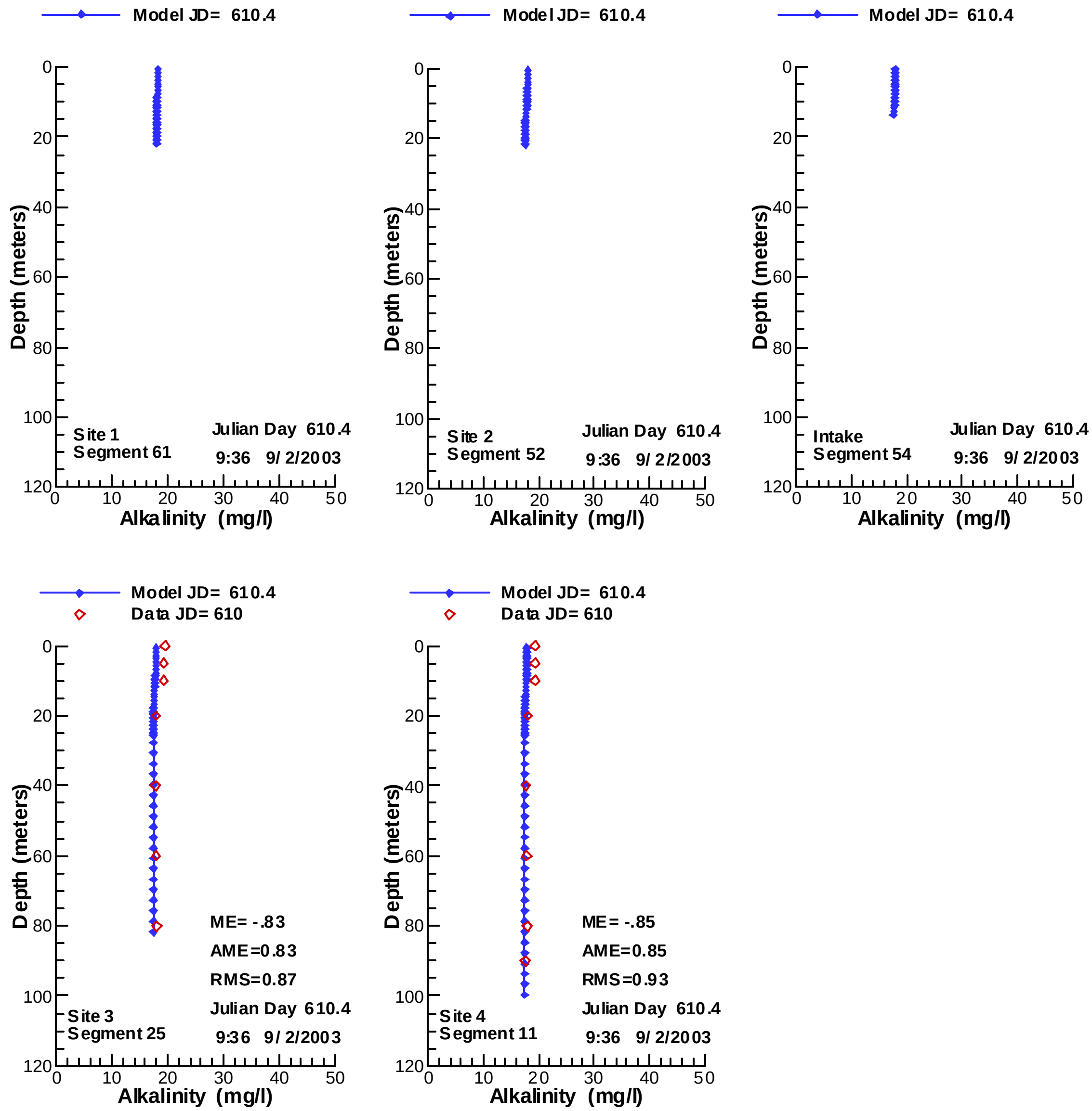

Figure 394. Vertical profiles of Alkalinity compared with data for 9/ 2/2003.

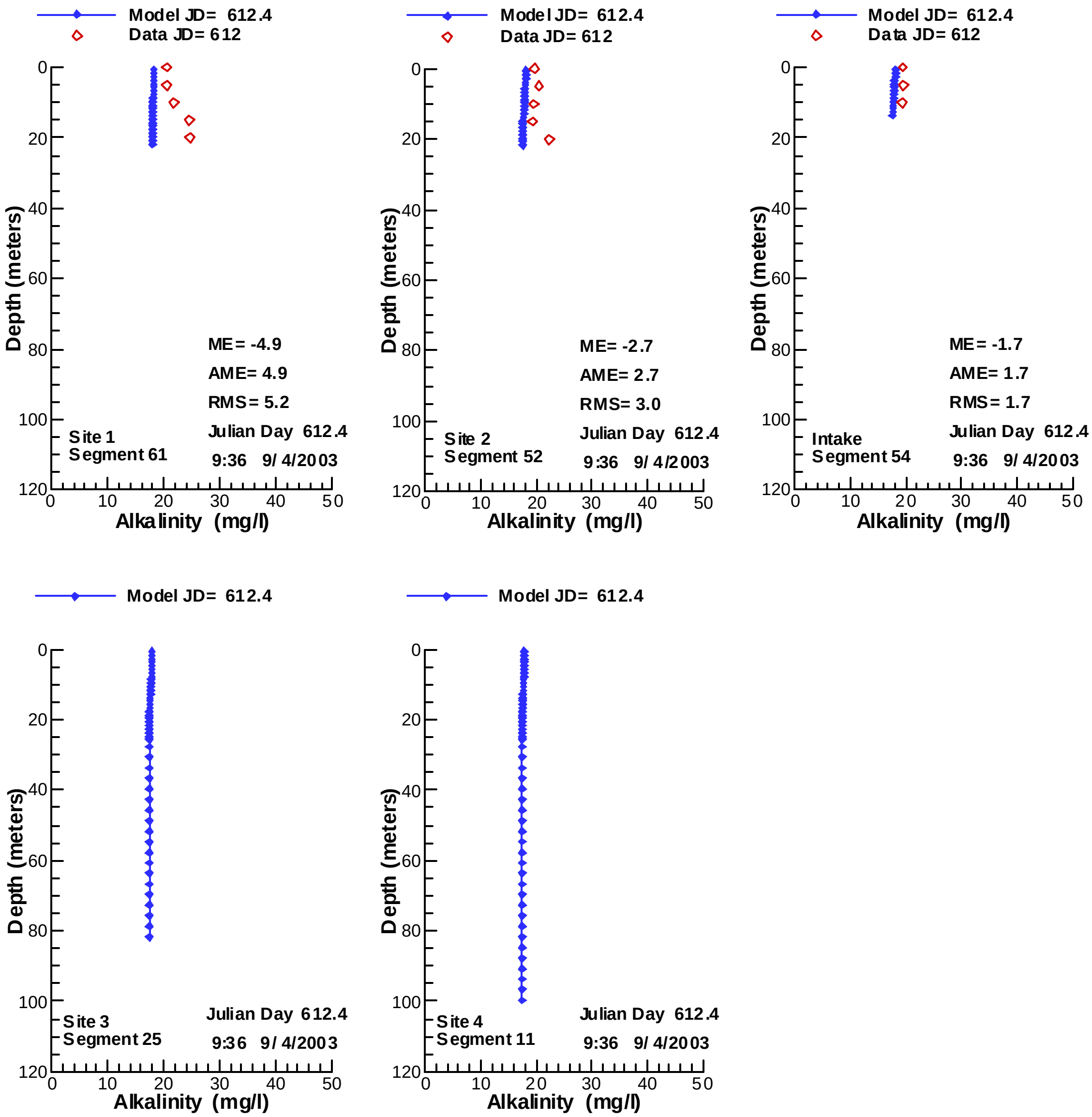

Figure 395. Vertical profiles of Alkalinity compared with data for 9/ 4/2003.

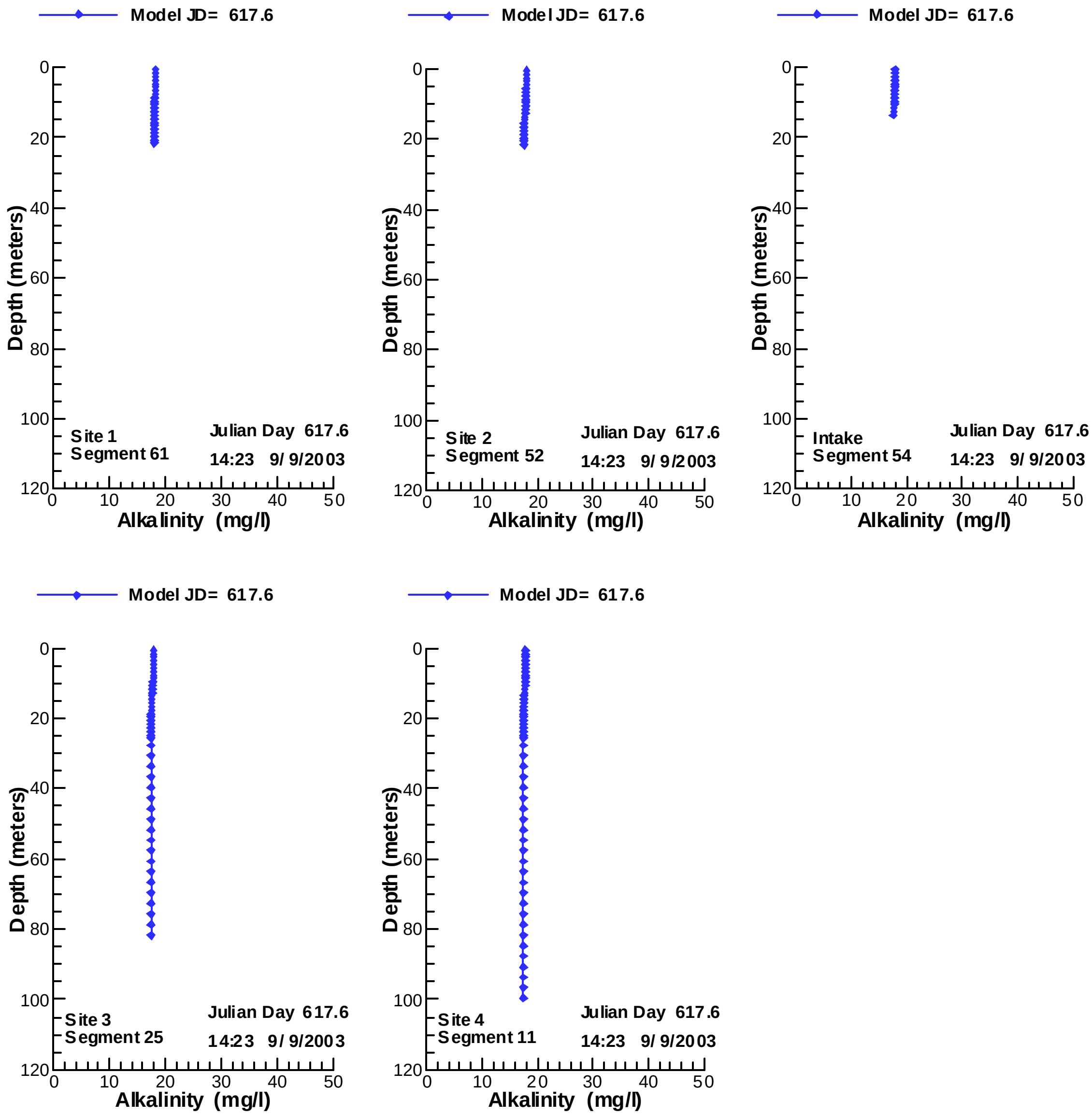

Figure 396. Vertical profiles of Alkalinity compared with data for 9/ 9/2003.

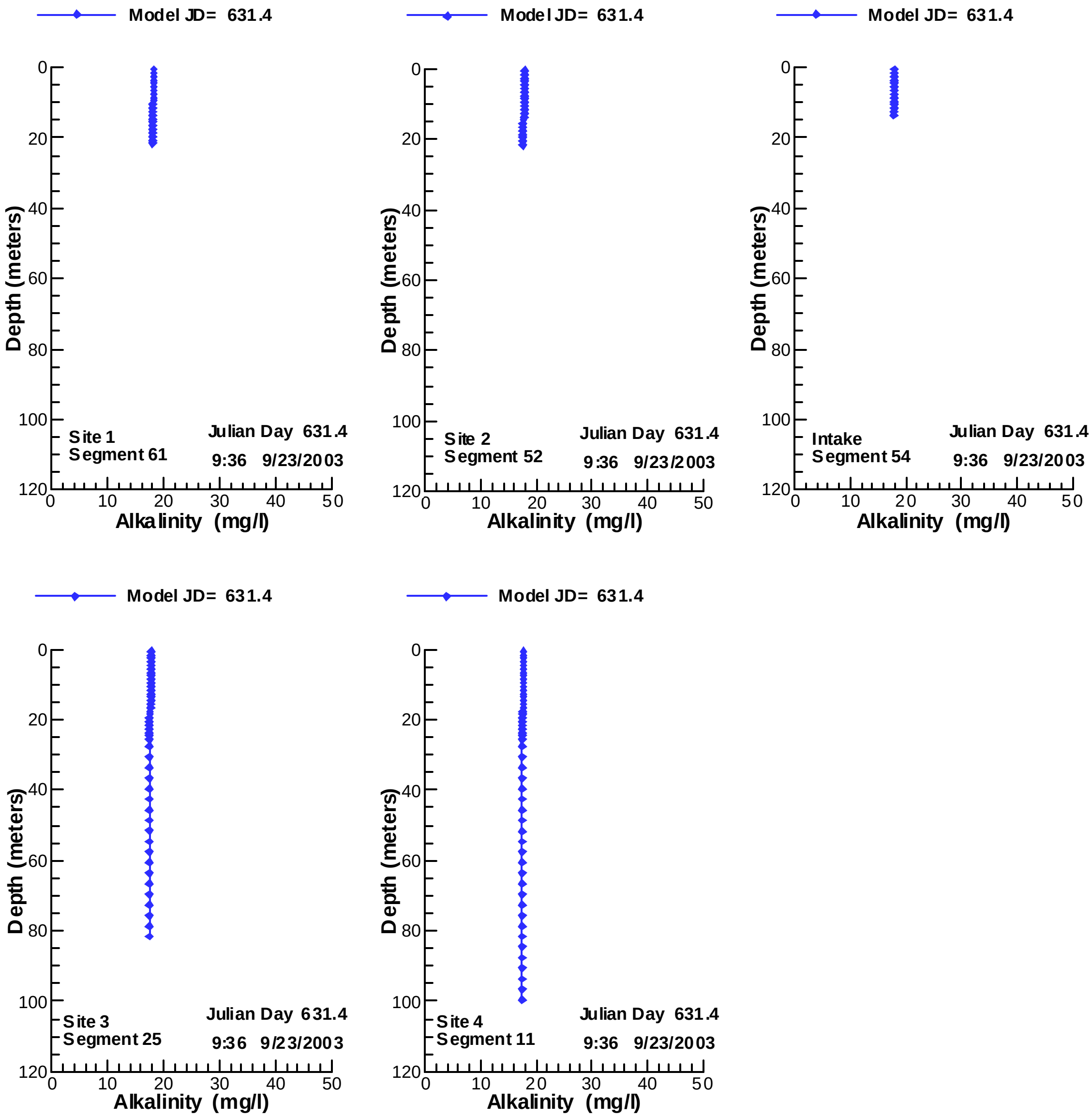

Figure 397. Vertical profiles of Alkalinity compared with data for 9/23/2003.

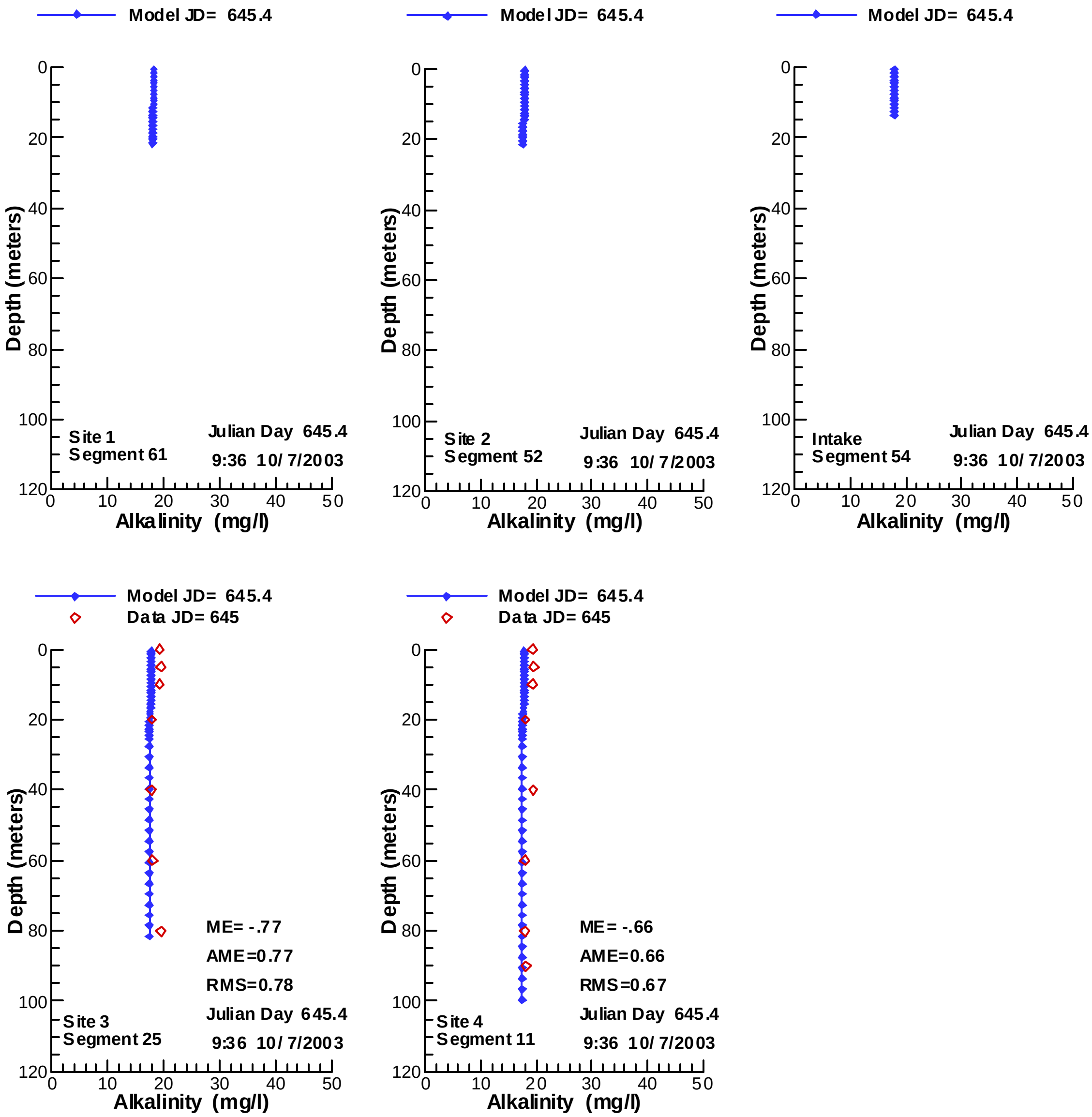

Figure 398. Vertical profiles of Alkalinity compared with data for 10/ 7/2003.

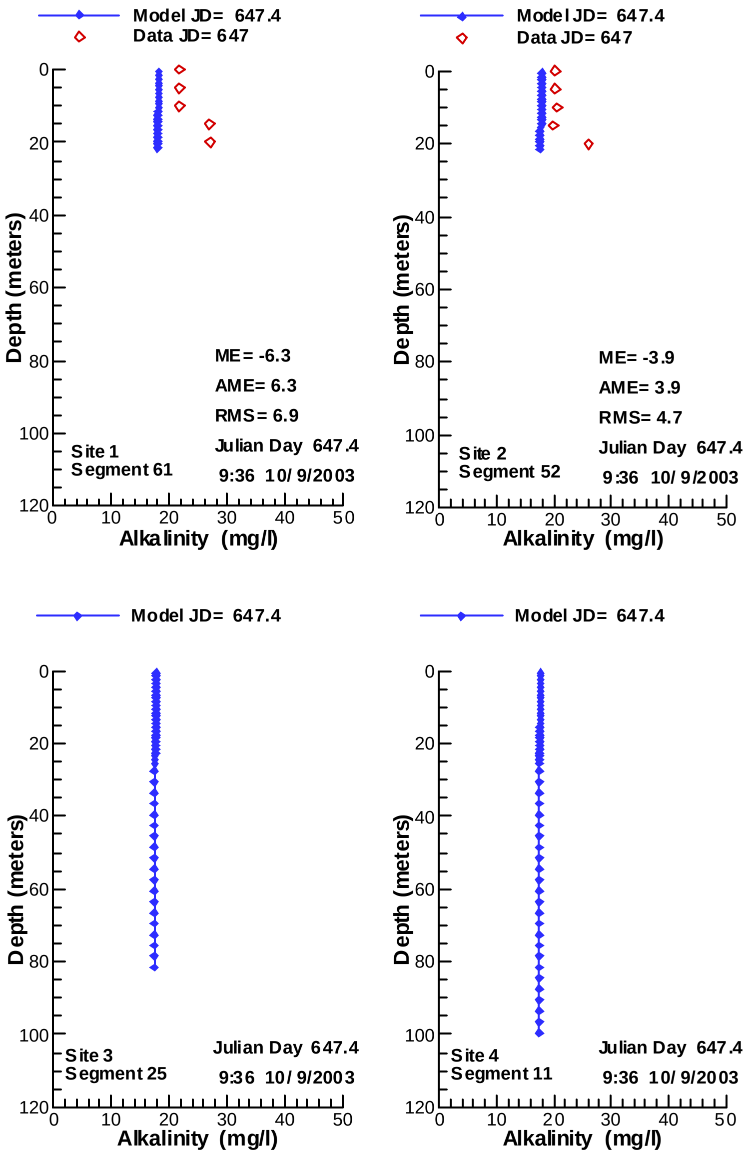

Figure 399. Vertical profiles of Alkalinity compared with data for 10/ 9/2003.

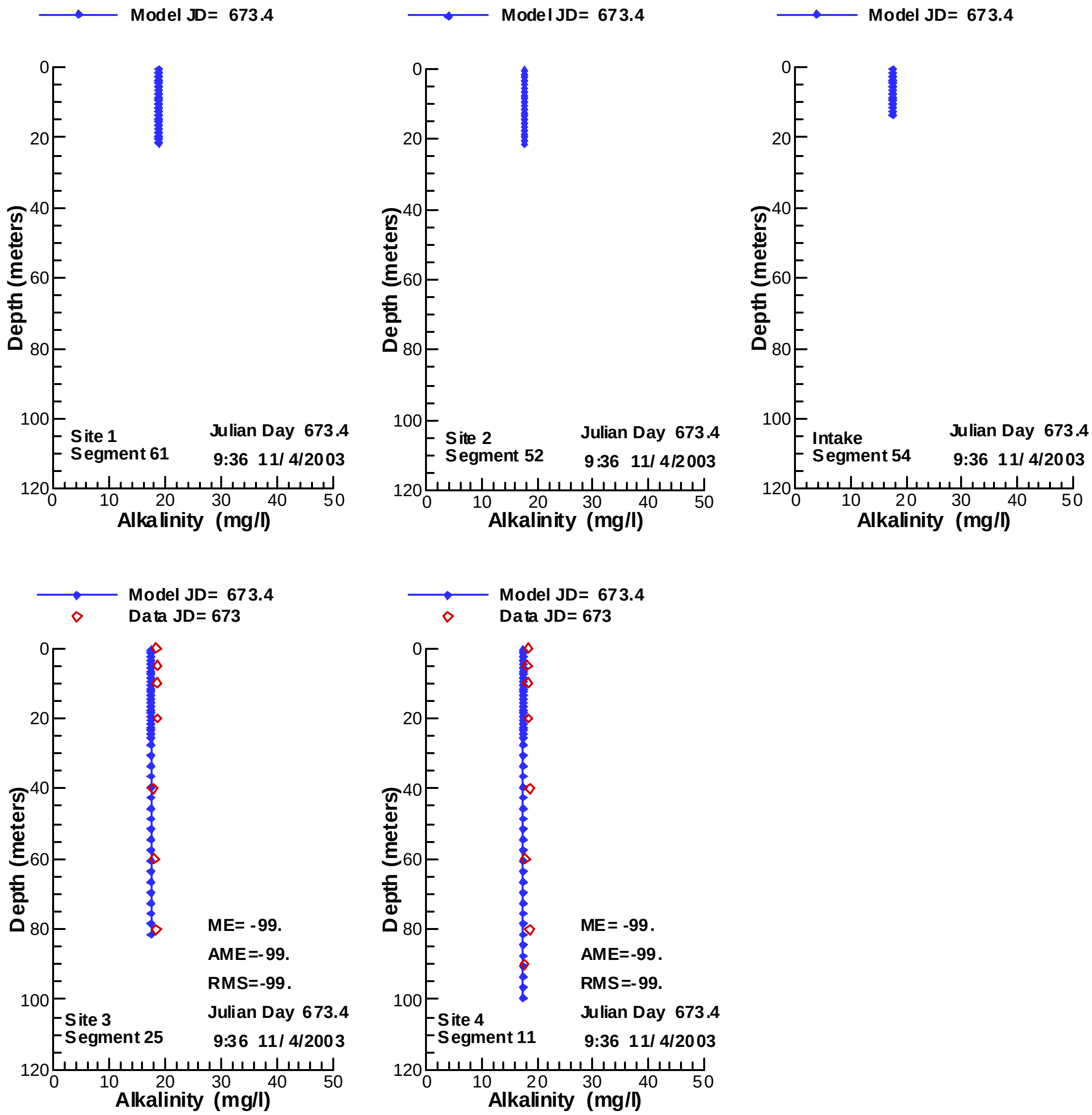

Figure 400. Vertical profiles of Alkalinity compared with data for 11/ 4/2003.

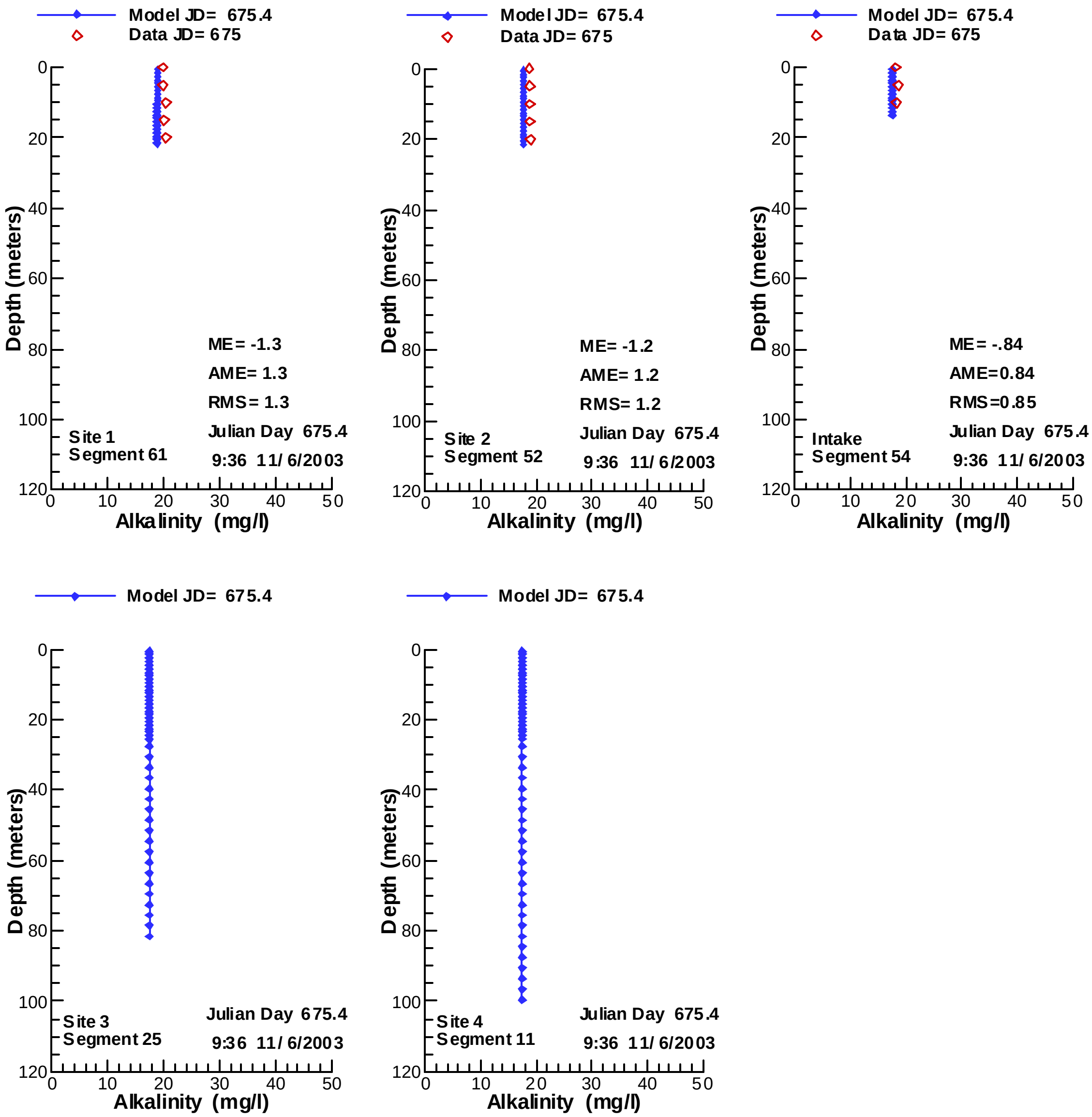

Figure 401. Vertical profiles of Alkalinity compared with data for 11/ 6/2003.

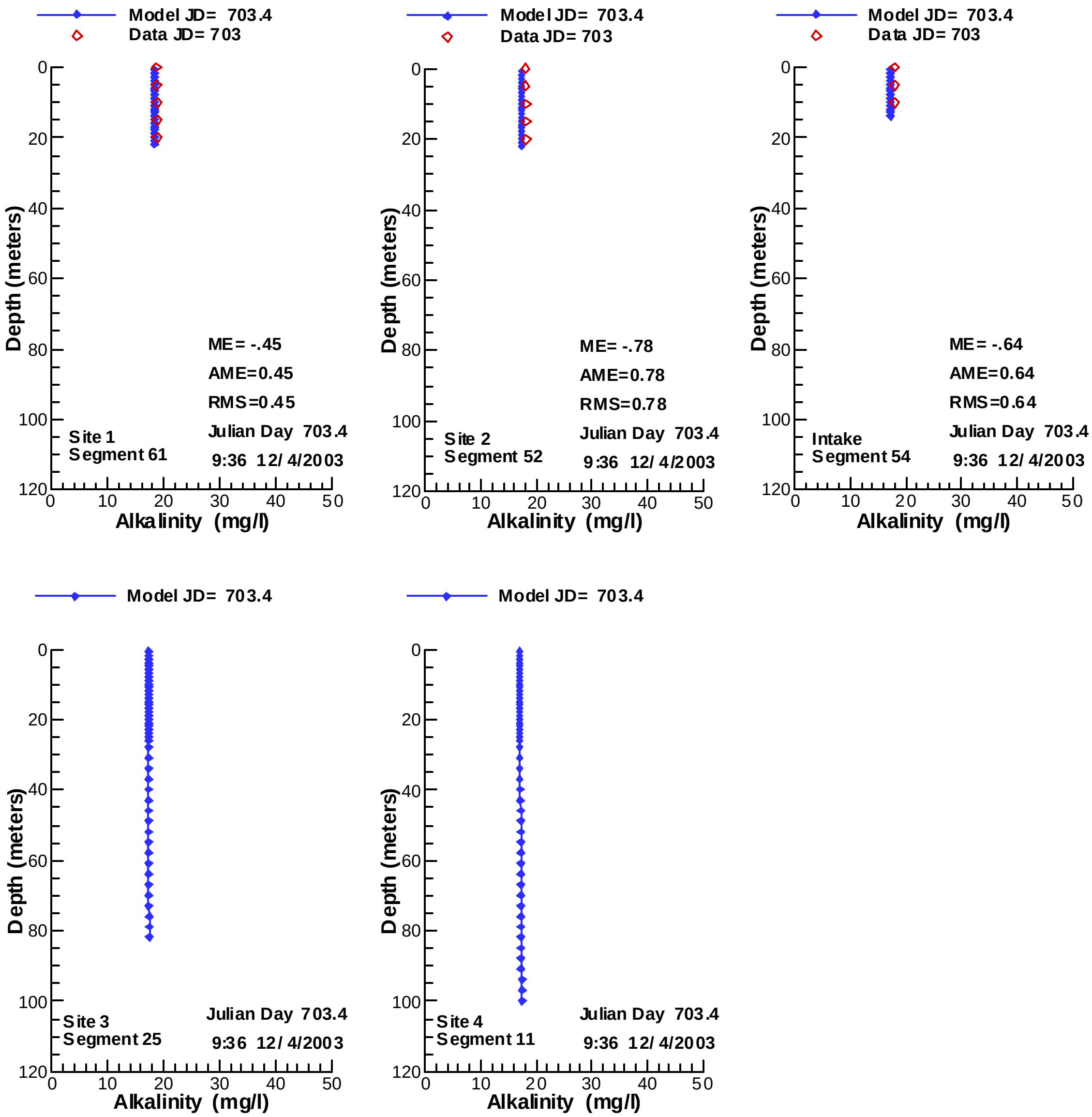

Figure 402. Vertical profiles of Alkalinity compared with data for 12/ 4/2003.

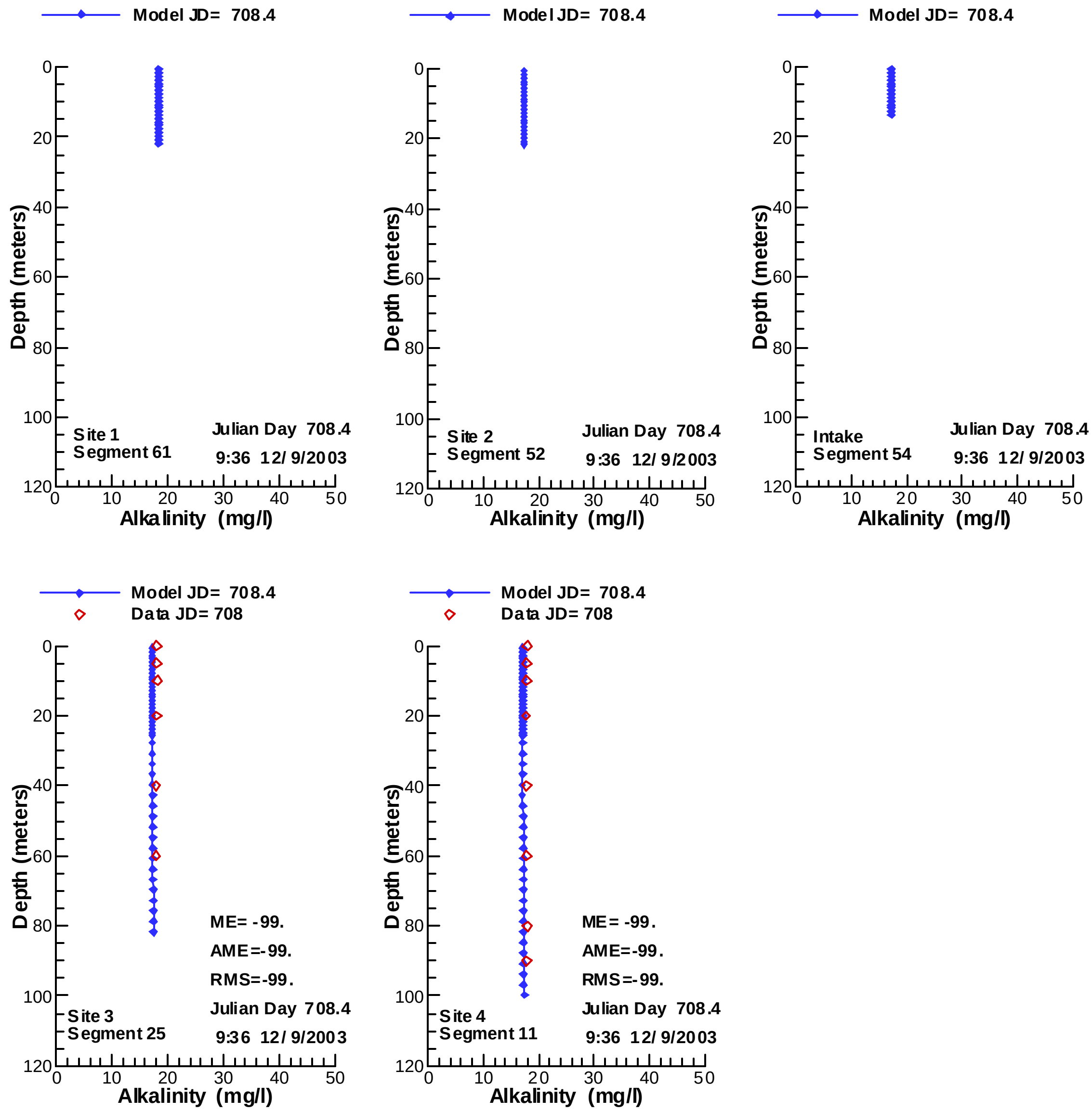

Figure 403. Vertical profiles of Alkalinity compared with data for 12/ 9/2003.

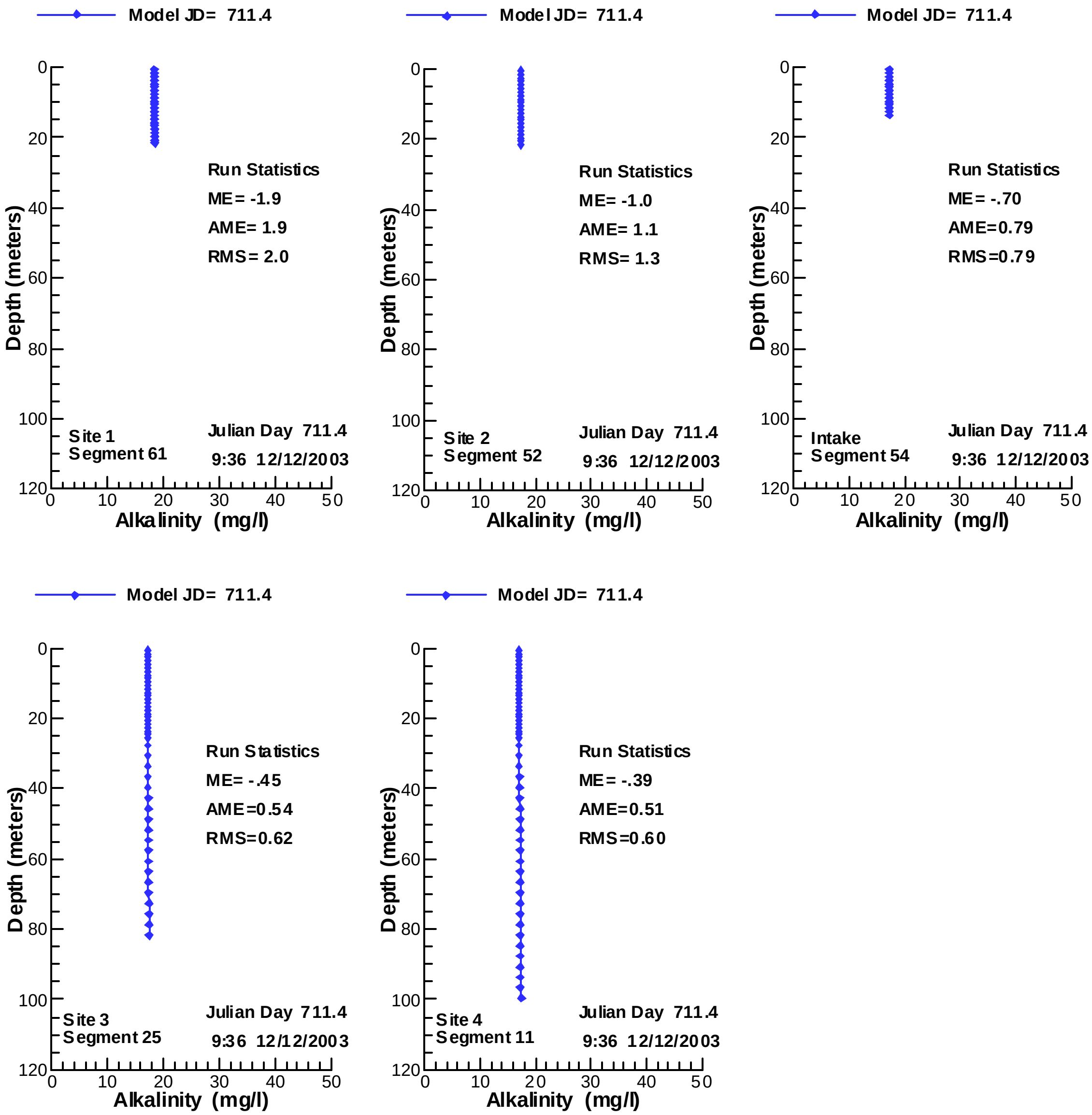

Figure 404. Vertical profiles of Alkalinity compared with data for 12/12/2003.

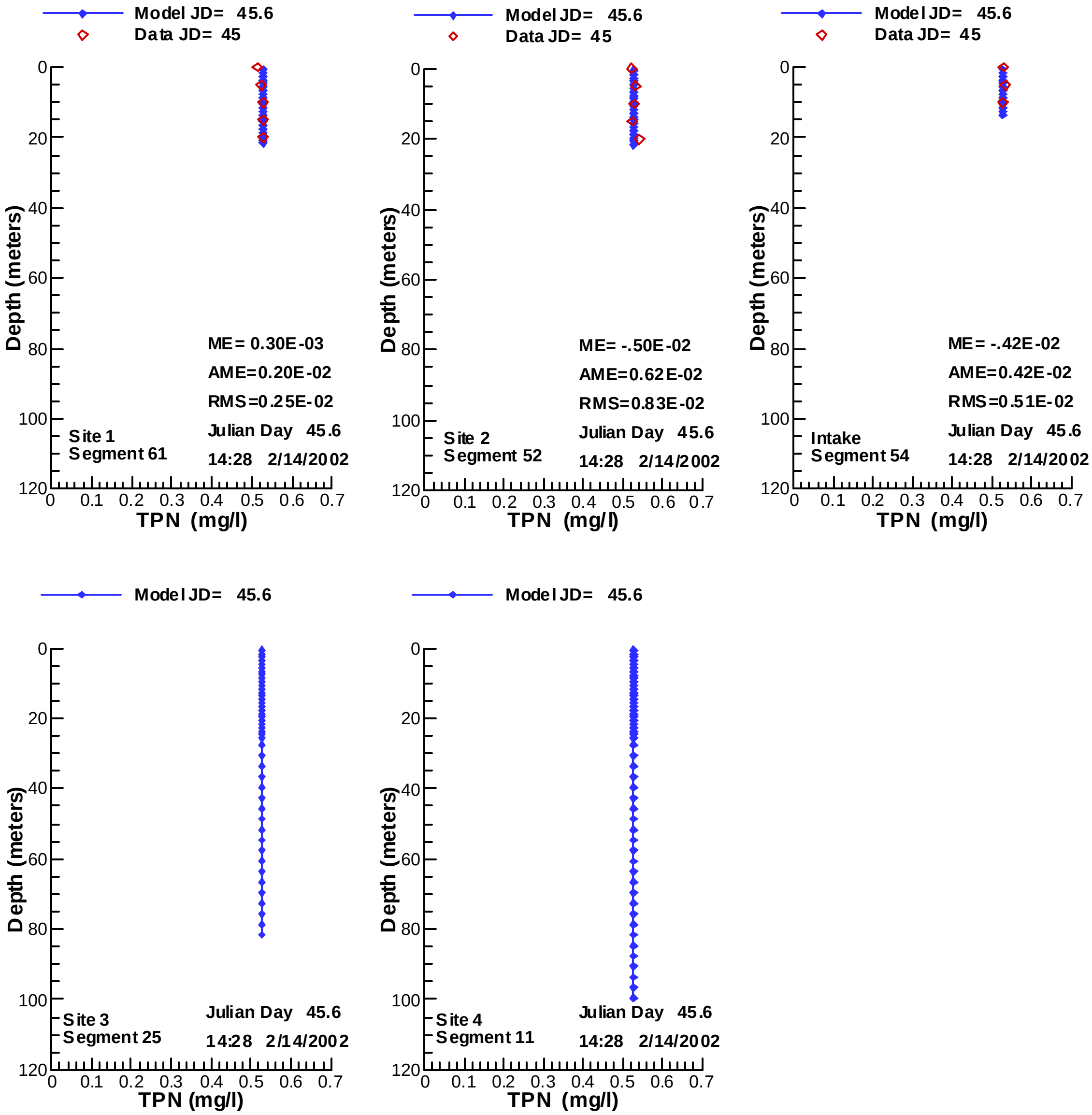

Figure 405. Vertical profiles of TPN compared with data for 2/14/2002.

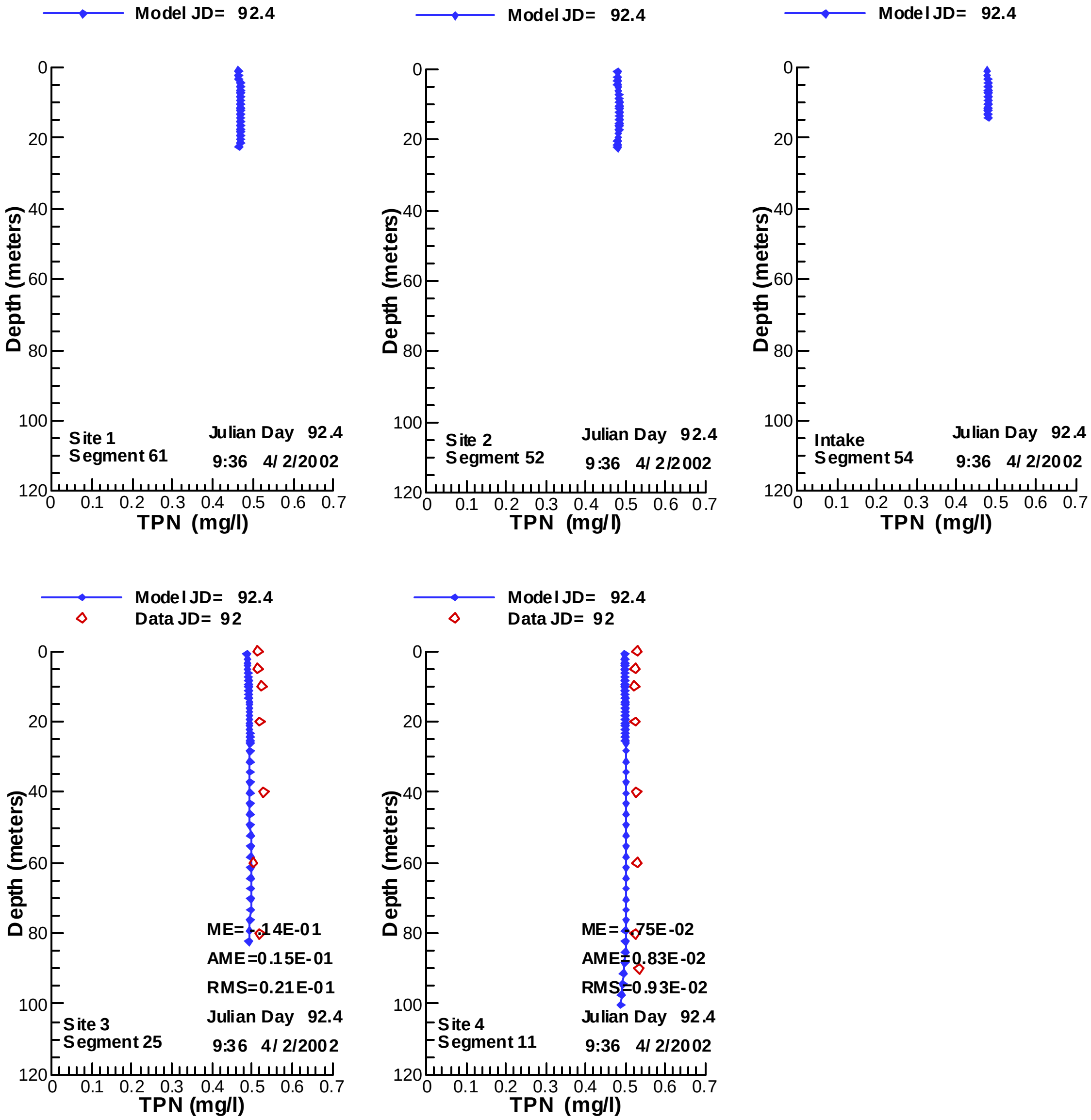

Figure 406. Vertical profiles of TPN compared with data for 4/ 2/2002.

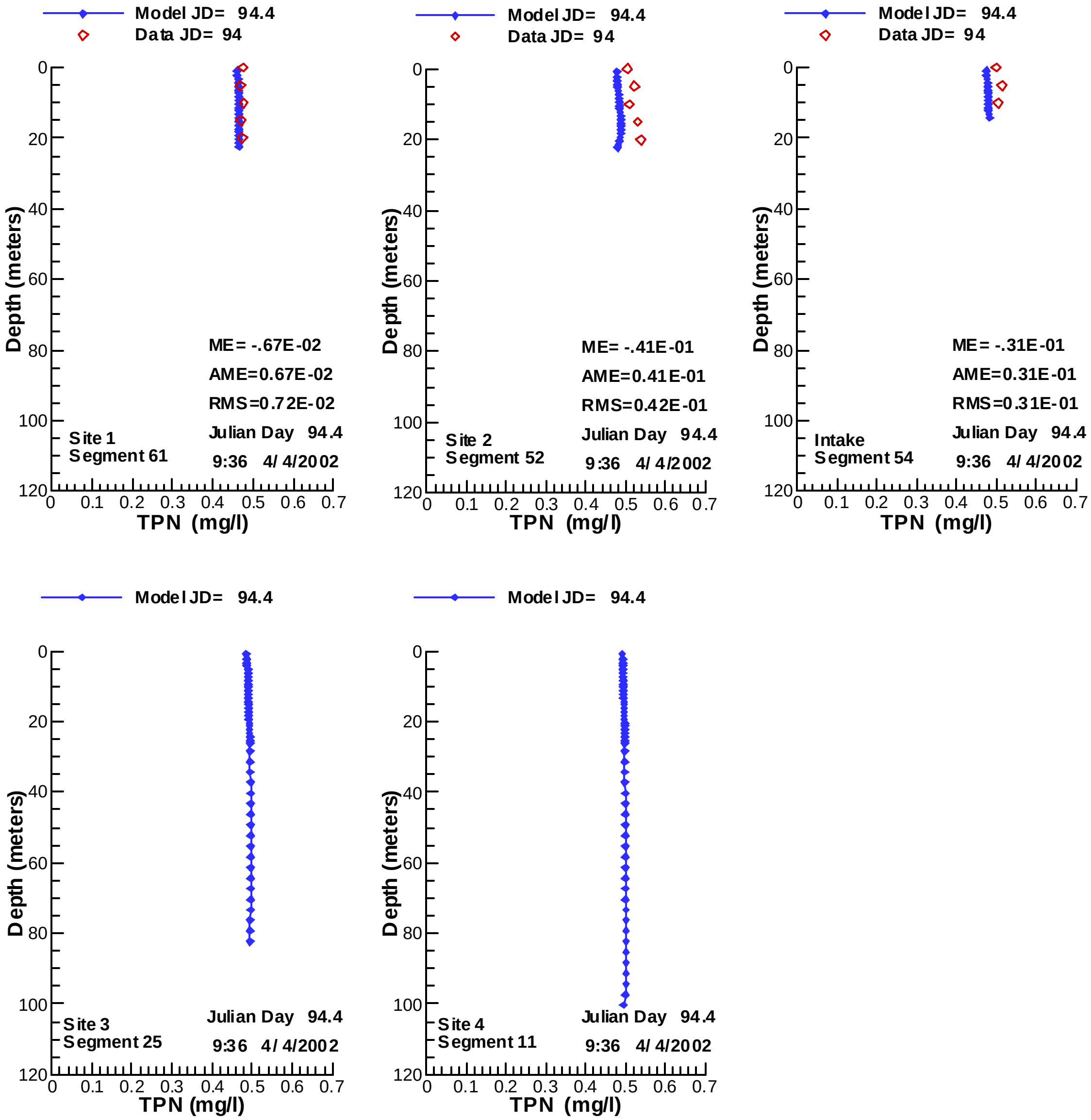

Figure 407. Vertical profiles of TPN compared with data for 4/ 4/2002.

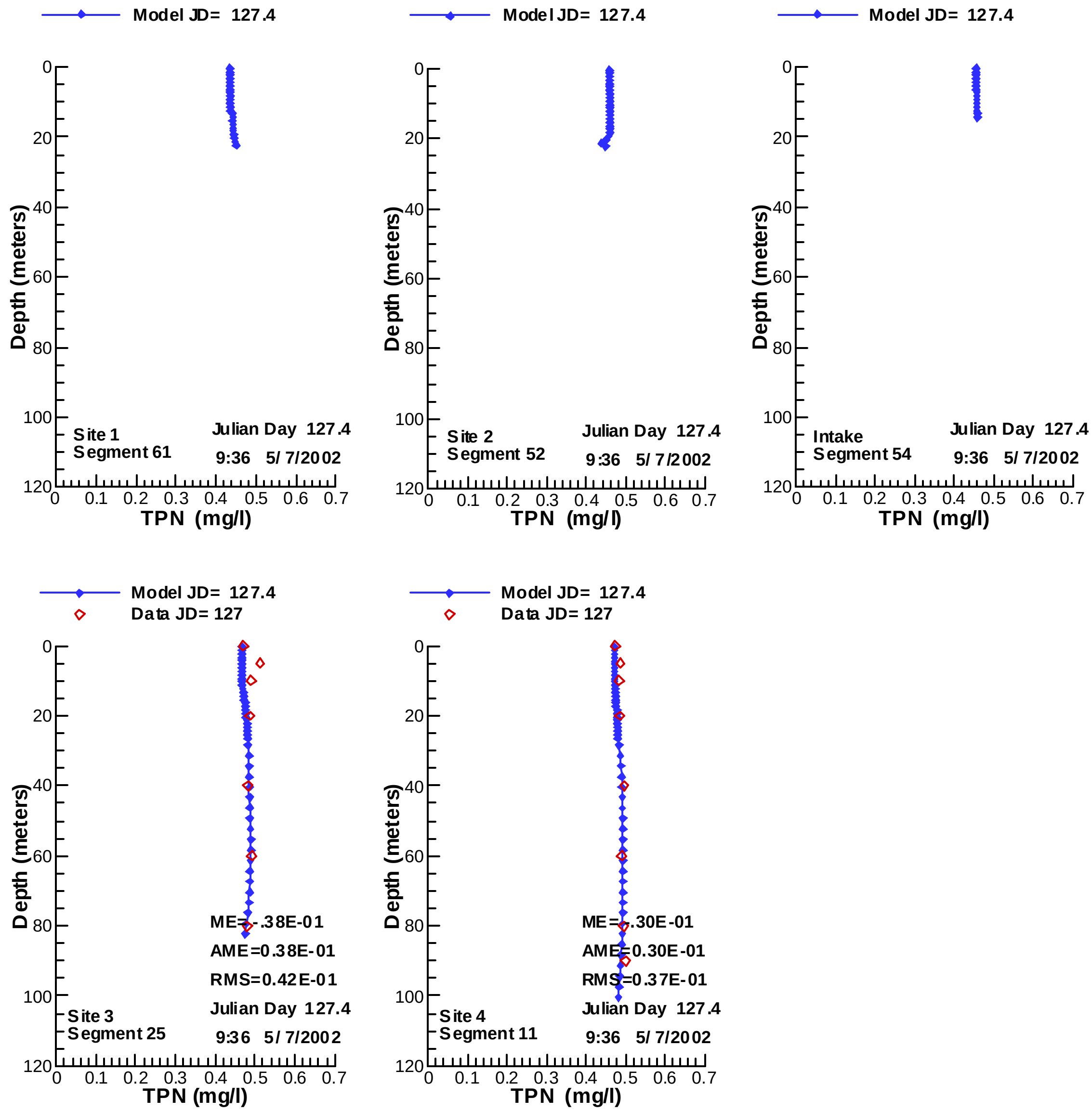

Figure 408. Vertical profiles of TPN compared with data for 5/ 7/2002.

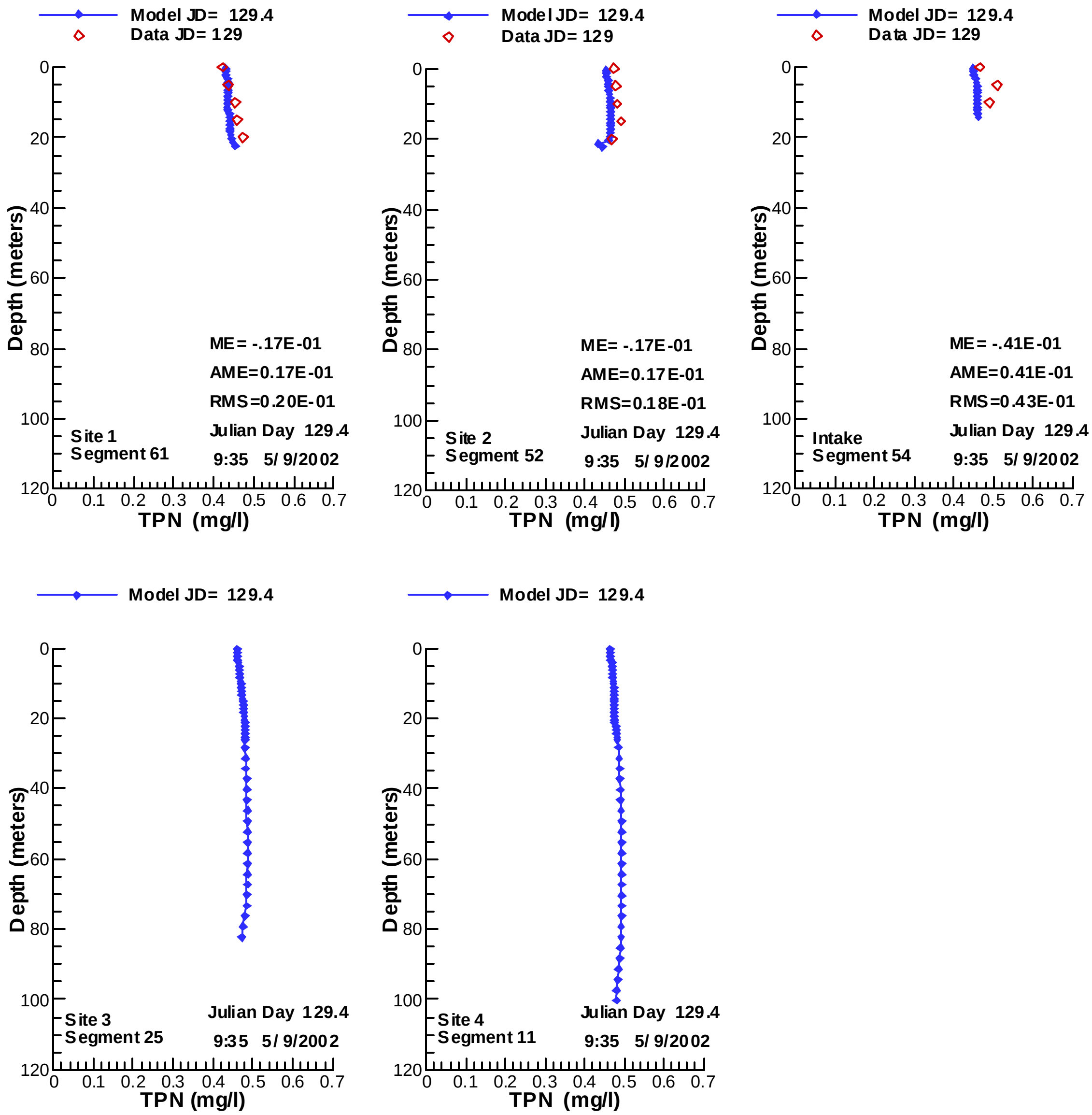

Figure 409. Vertical profiles of TPN compared with data for 5/ 9/2002.

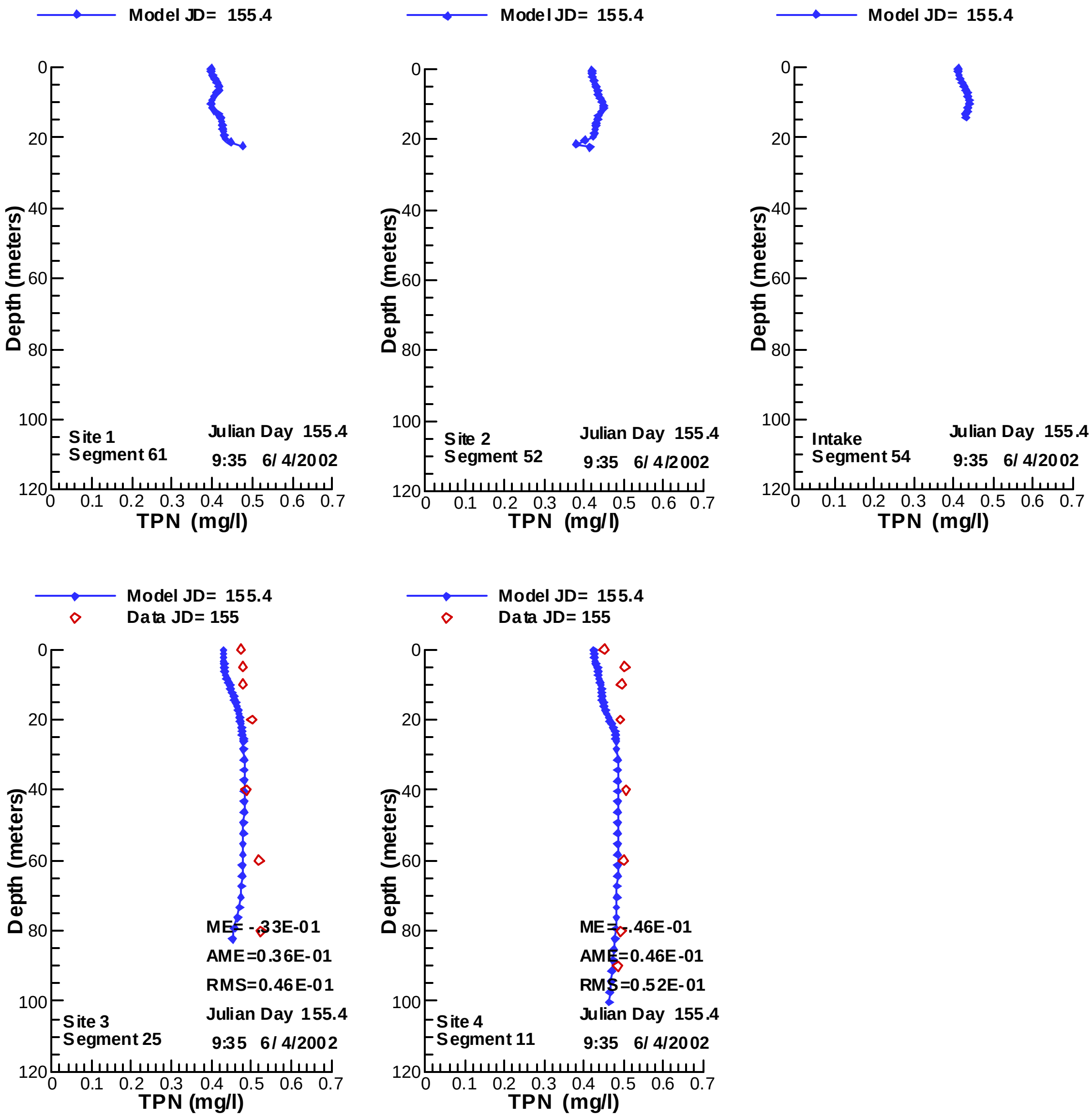

Figure 410. Vertical profiles of TPN compared with data for 6/ 4/2002.

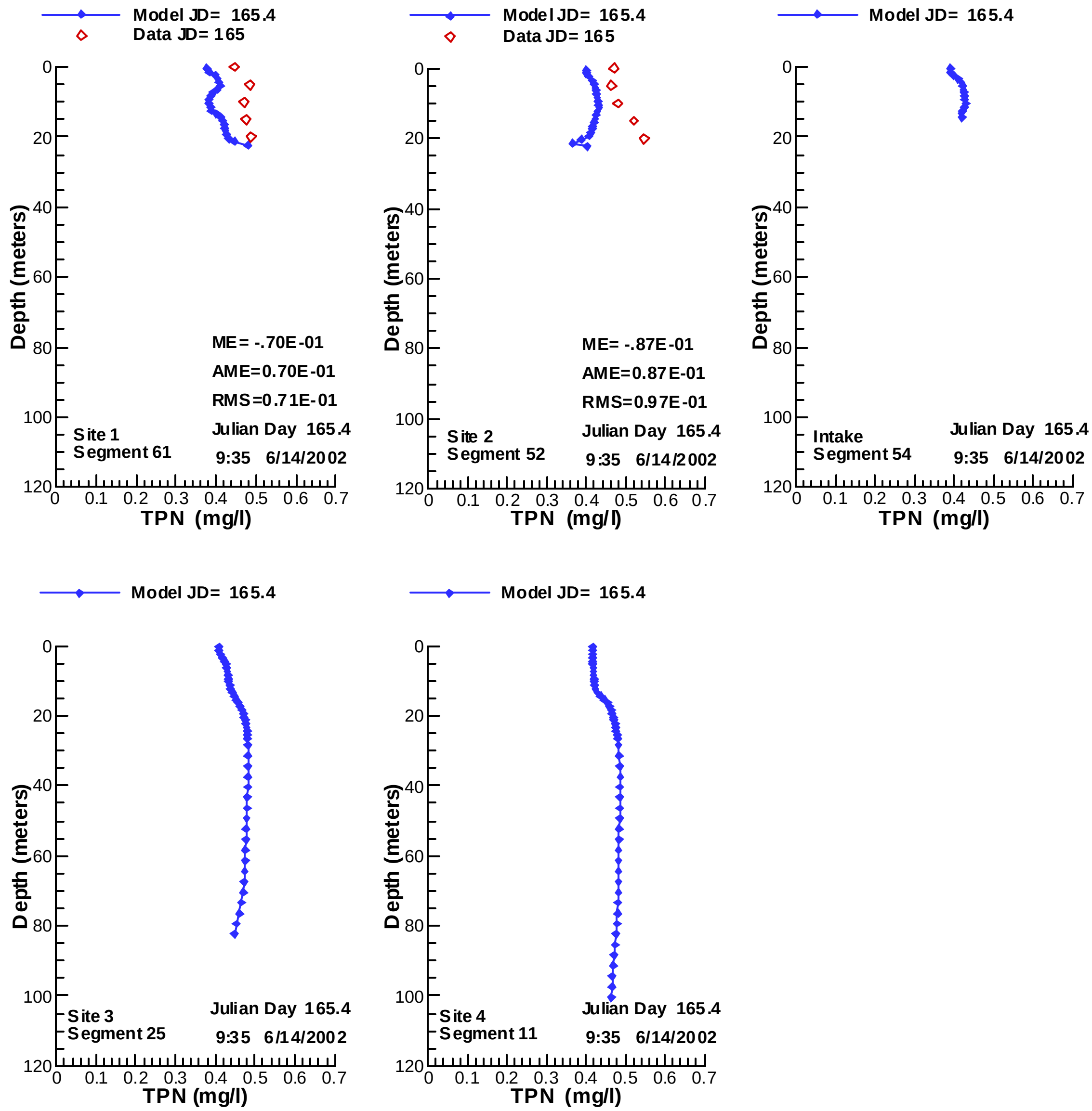

Figure 411. Vertical profiles of TPN compared with data for 6/14/2002.

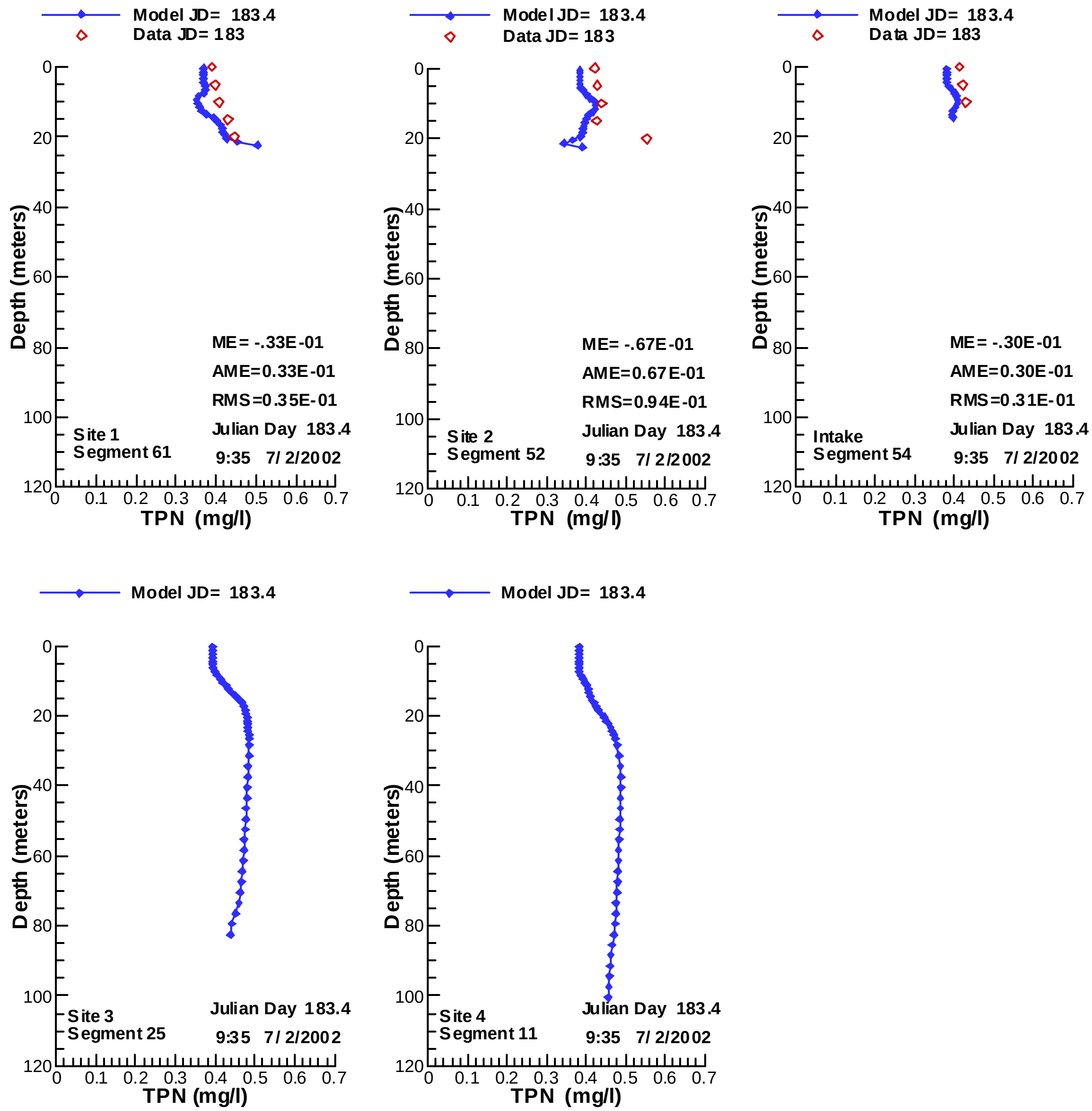

Figure 412. Vertical profiles of TPN compared with data for 7/ 2/2002.

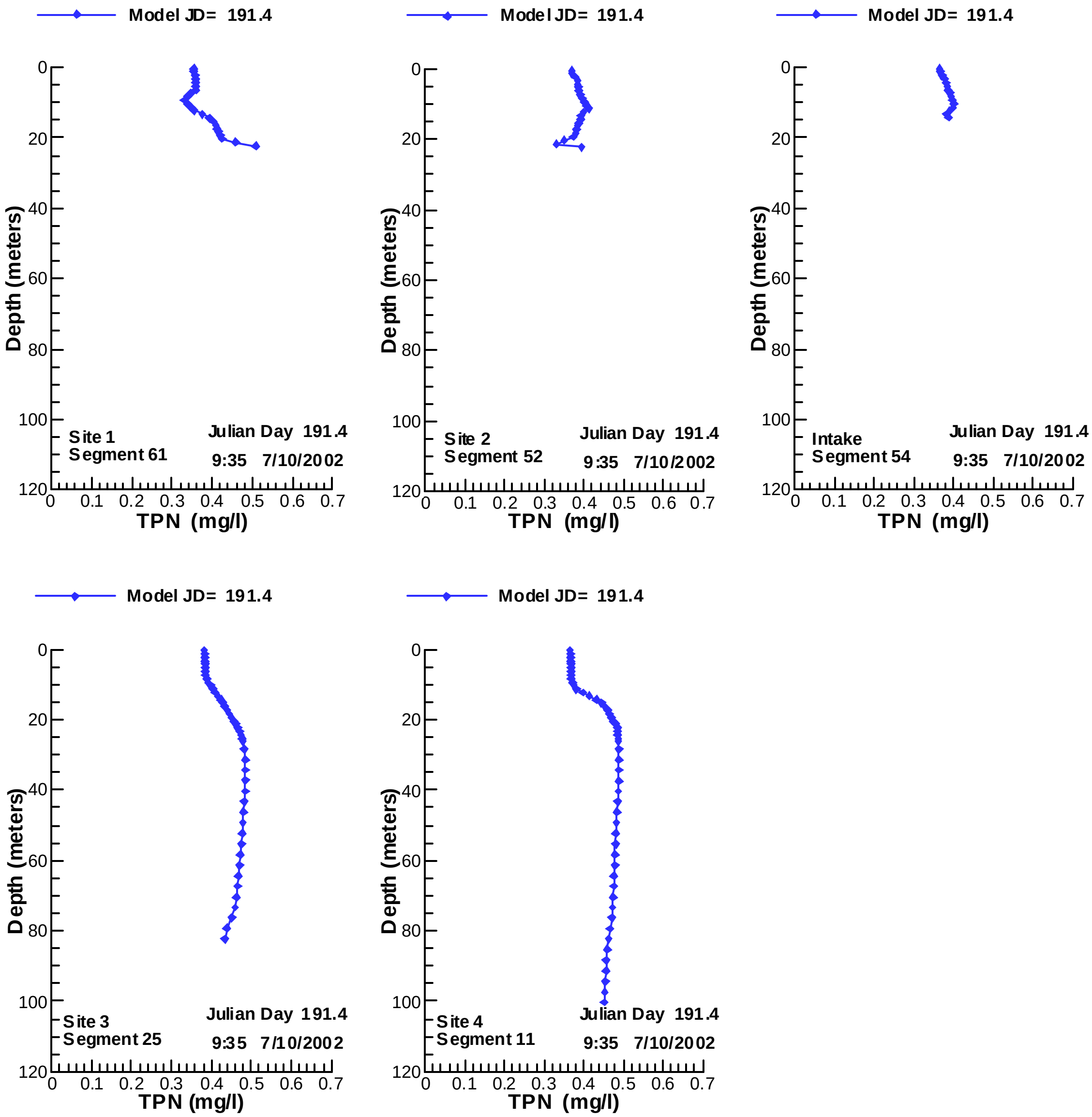

Figure 413. Vertical profiles of TPN compared with data for 7/10/2002.

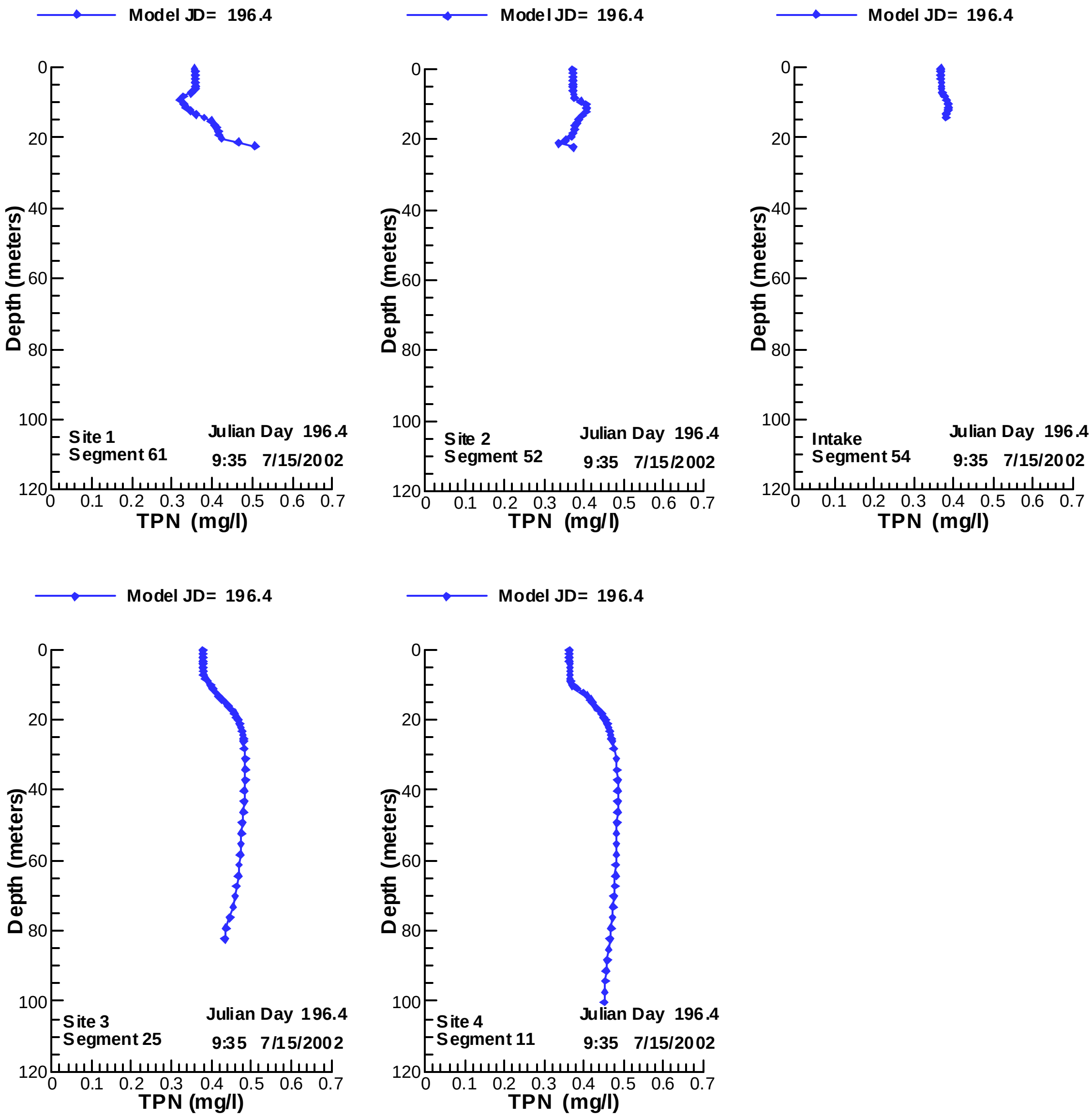

Figure 414. Vertical profiles of TPN compared with data for 7/15/2002.

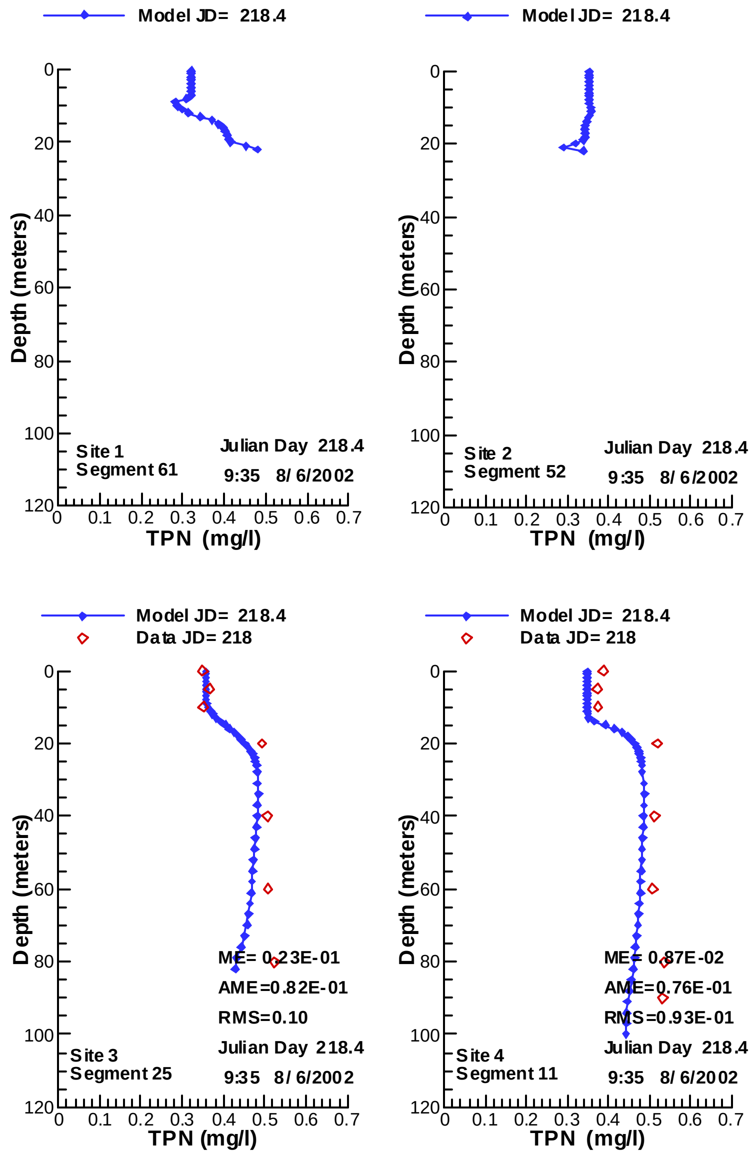

Figure 415. Vertical profiles of TPN compared with data for 8/ 6/2002.

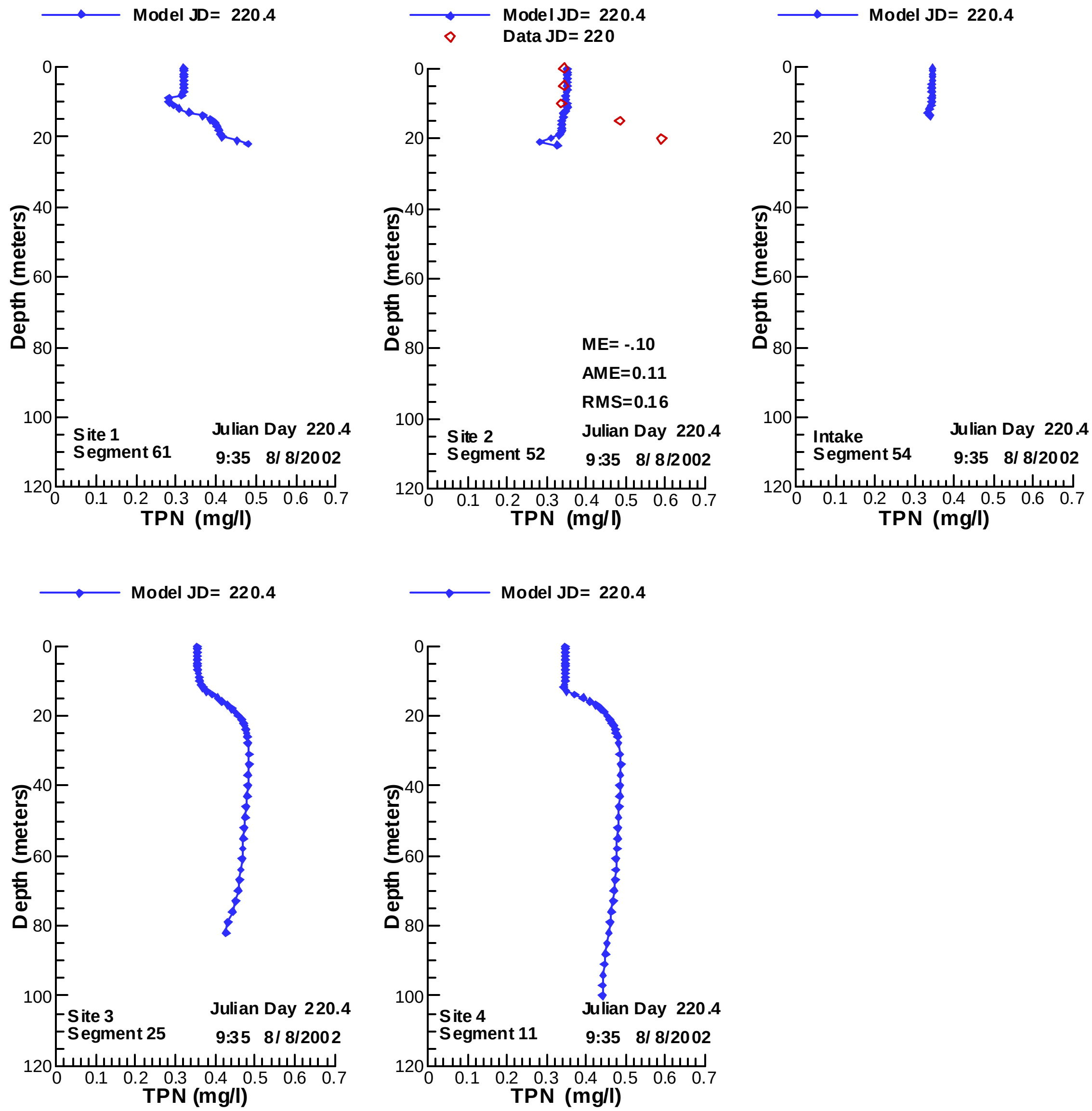

Figure 416. Vertical profiles of TPN compared with data for 8/ 8/2002.

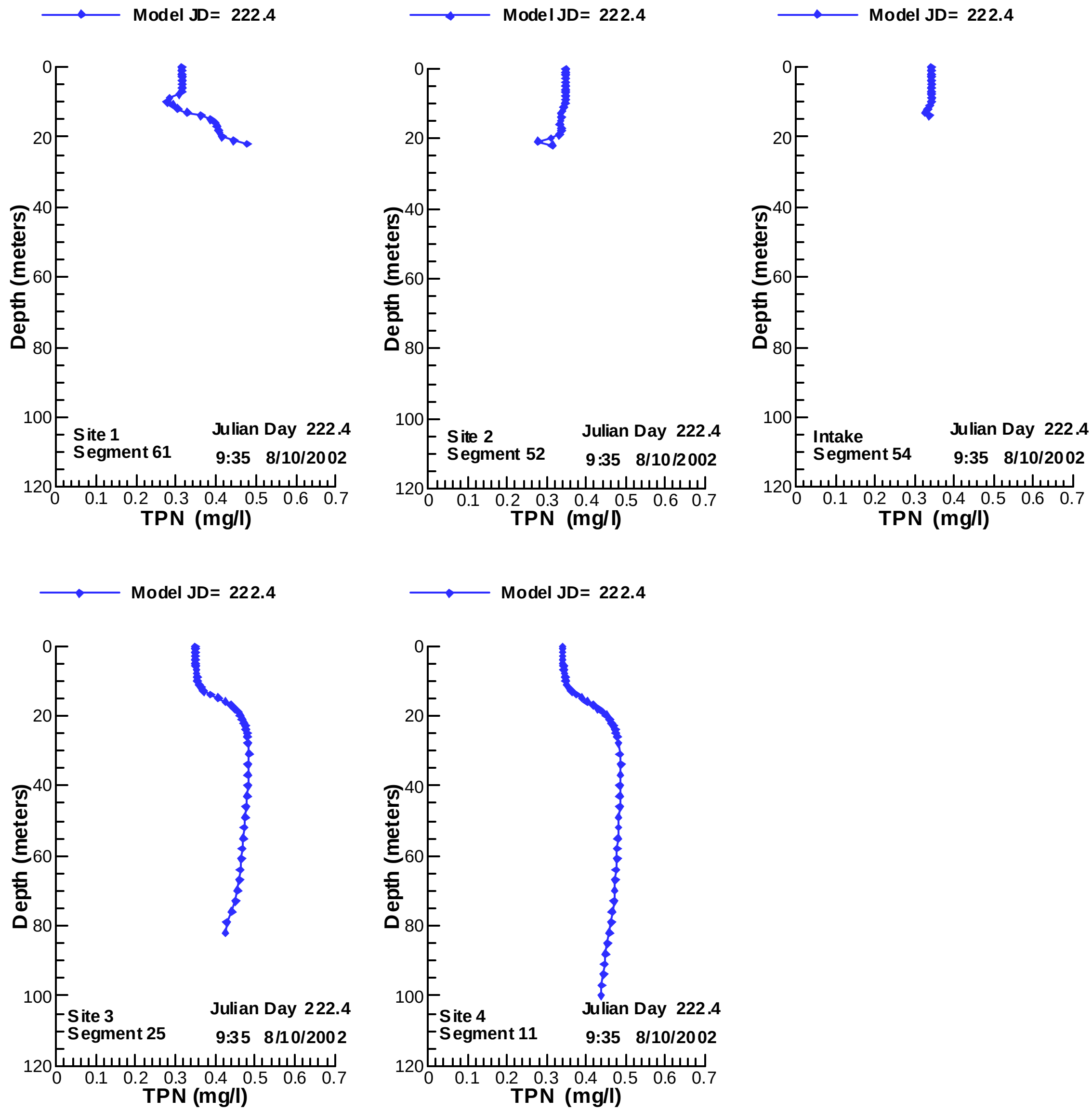

Figure 417. Vertical profiles of TPN compared with data for 8/10/2002.

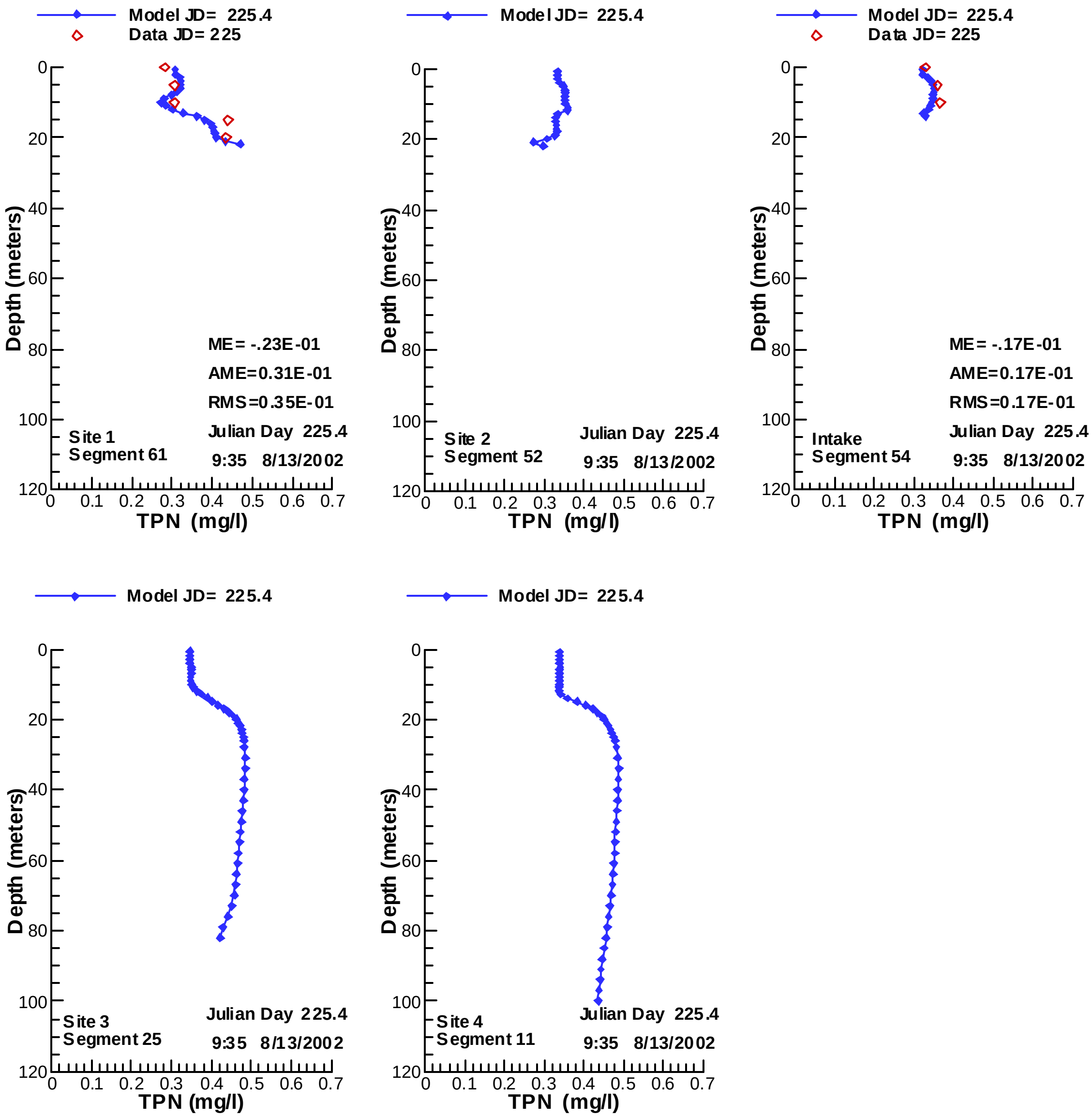

Figure 418. Vertical profiles of TPN compared with data for 8/13/2002.

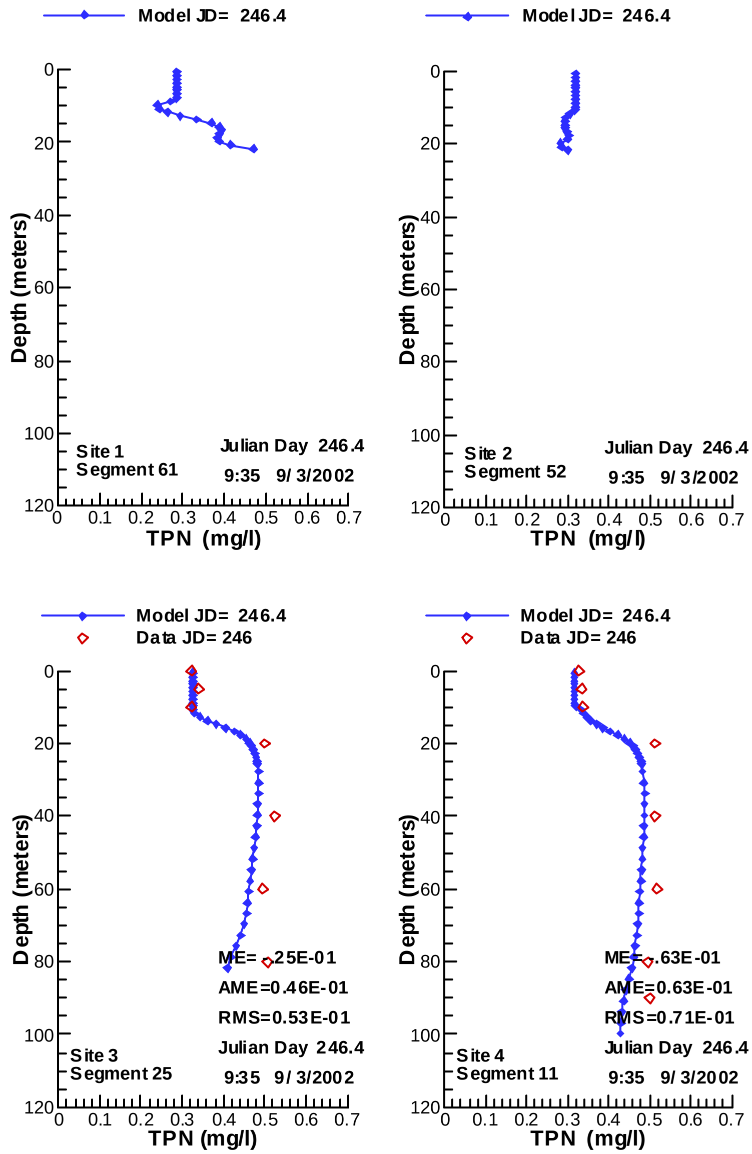

Figure 419. Vertical profiles of TPN compared with data for 9/ 3/2002.

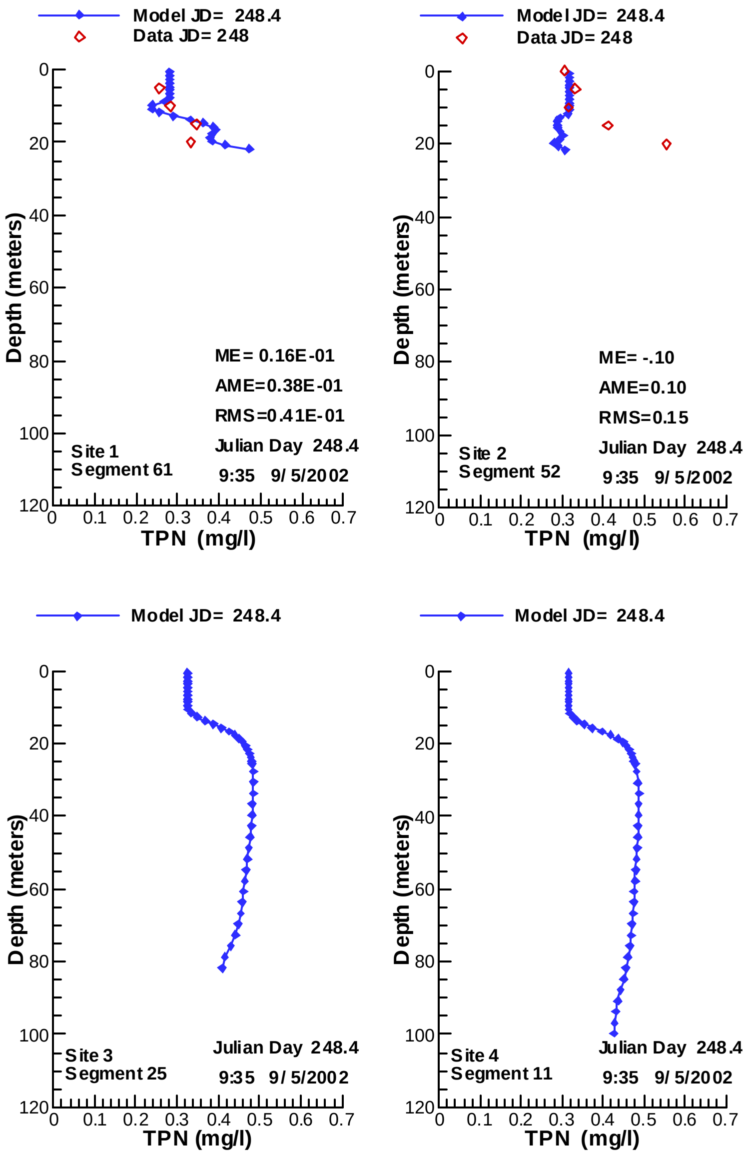

Figure 420. Vertical profiles of TPN compared with data for 9/ 5/2002.

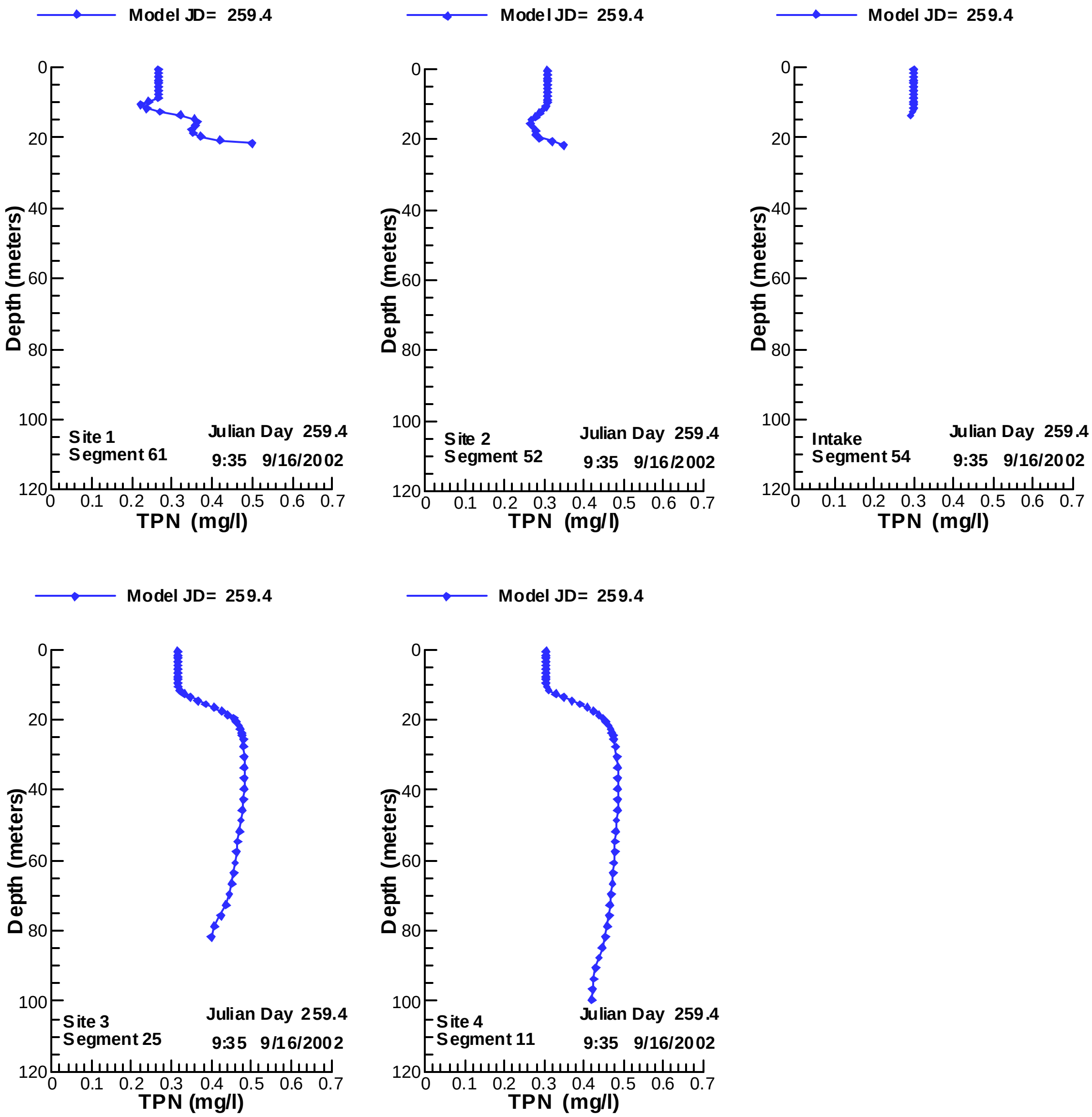

Figure 421. Vertical profiles of TPN compared with data for 9/16/2002.

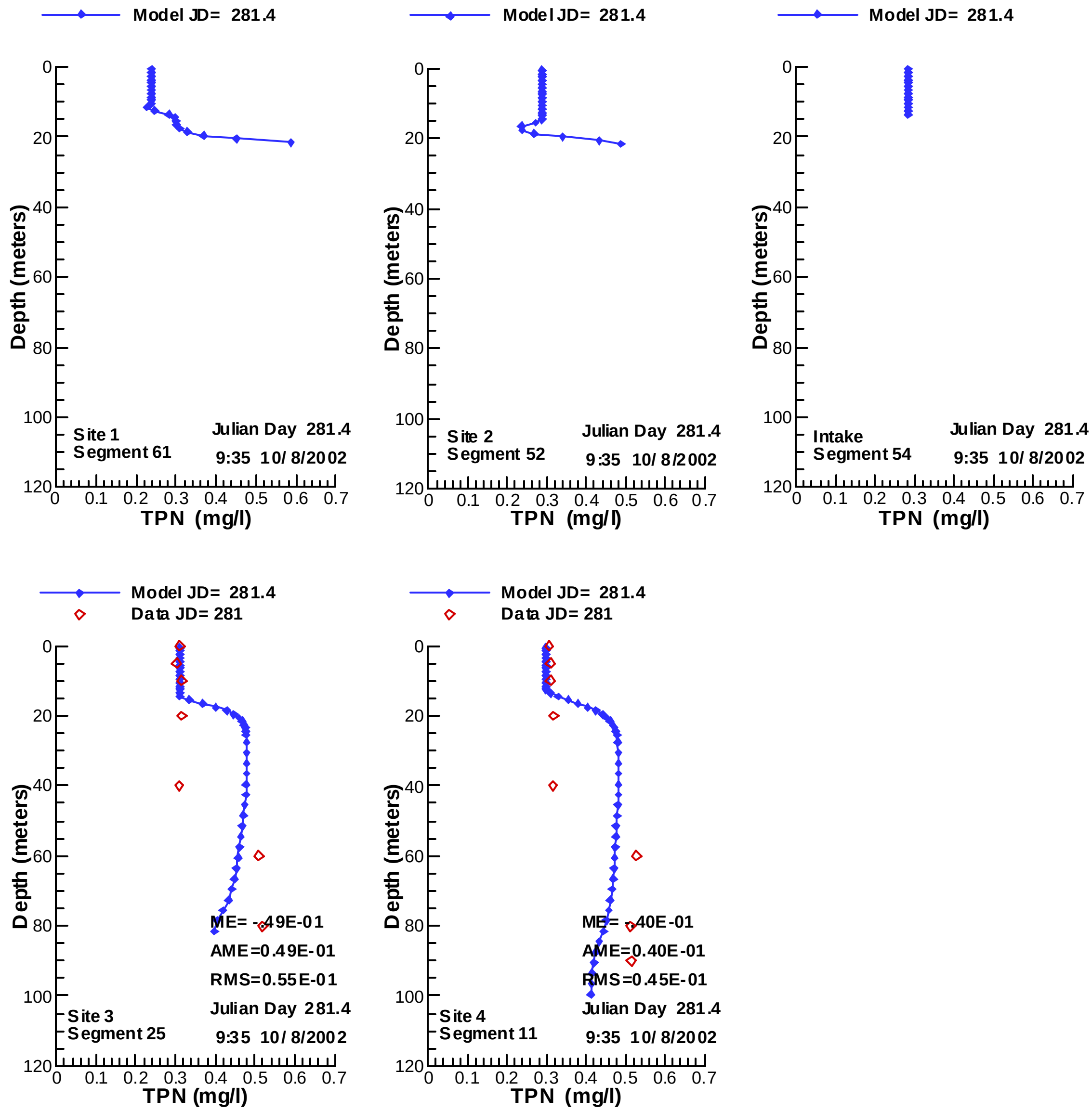

Figure 422. Vertical profiles of TPN compared with data for 10/ 8/2002.

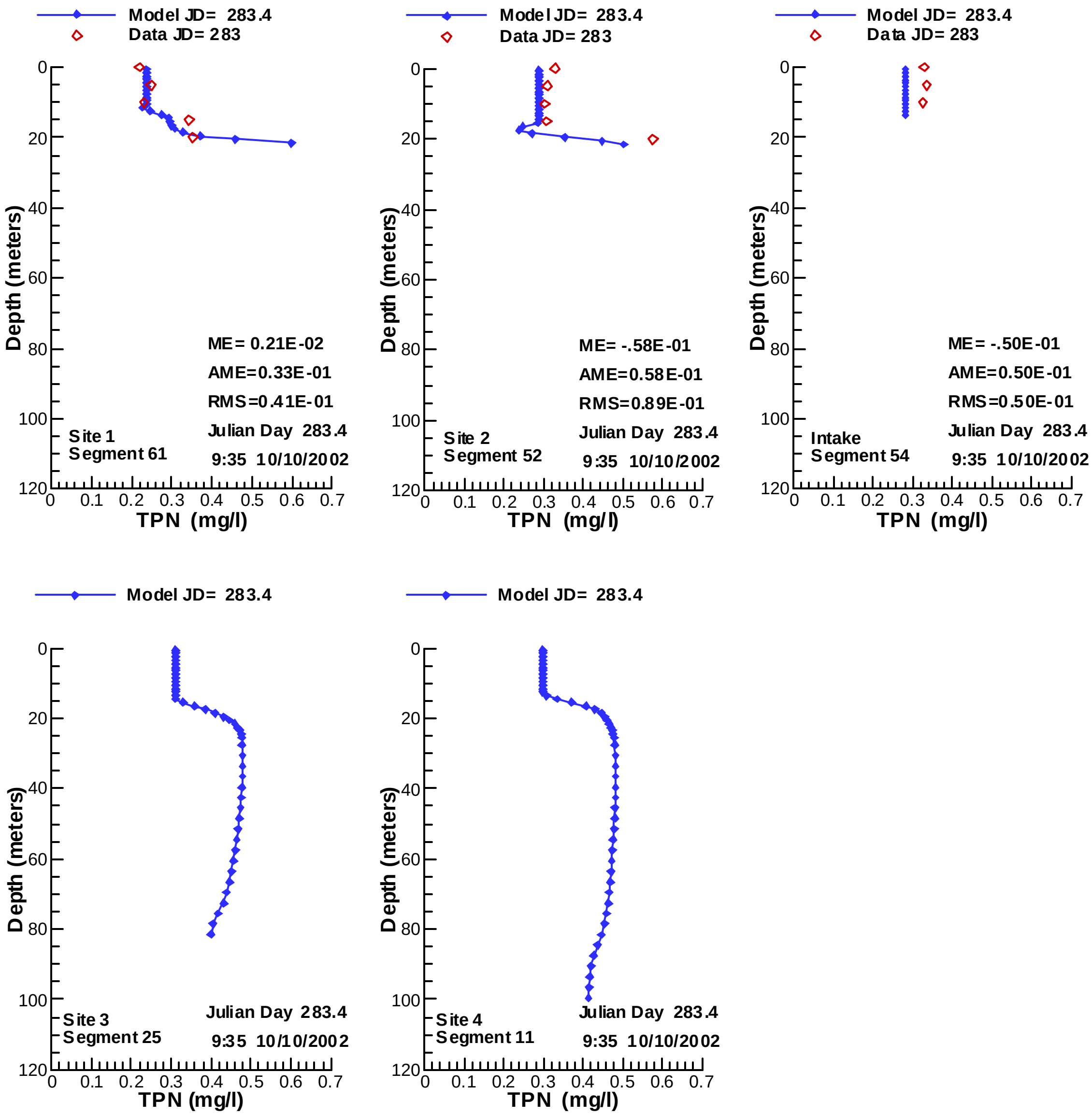

Figure 423. Vertical profiles of TPN compared with data for 10/10/2002.

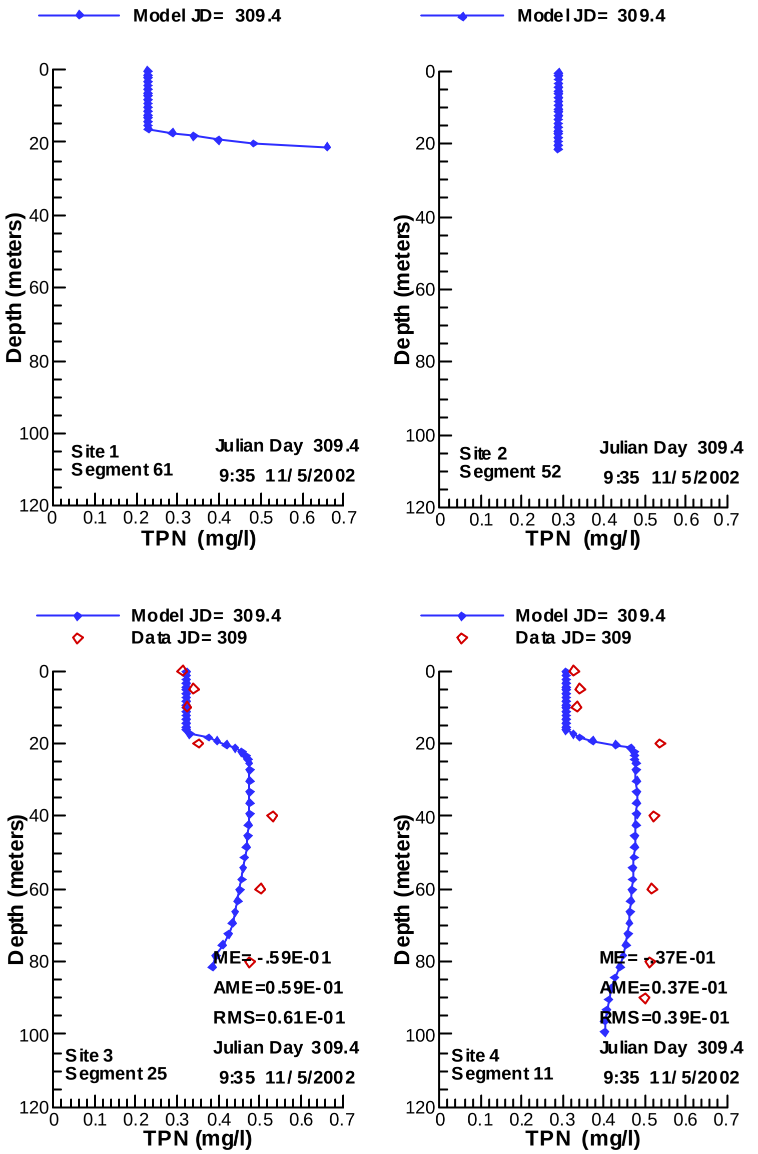

Figure 424. Vertical profiles of TPN compared with data for 11/ 5/2002.

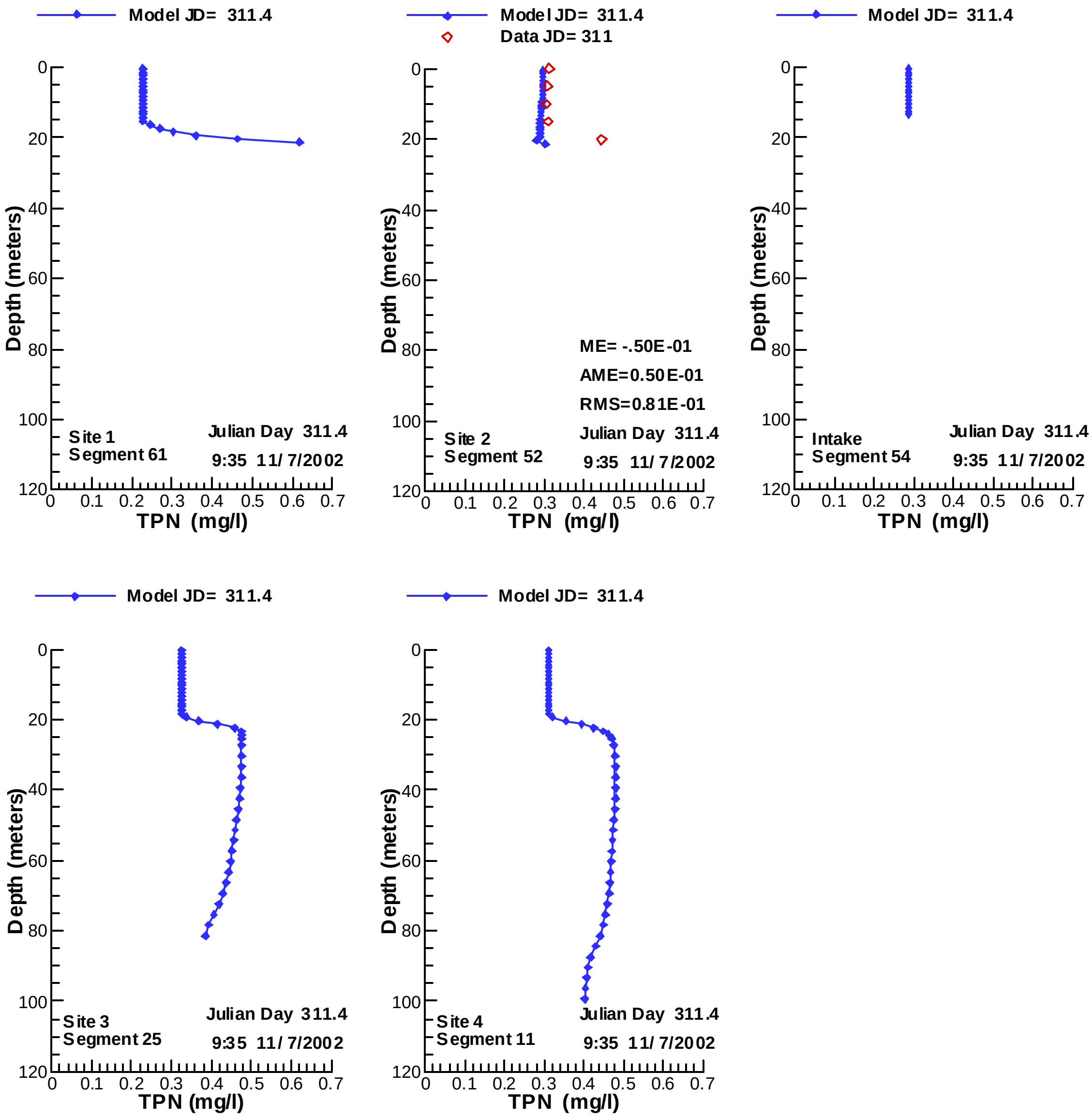

Figure 425. Vertical profiles of TPN compared with data for 11/ 7/2002.

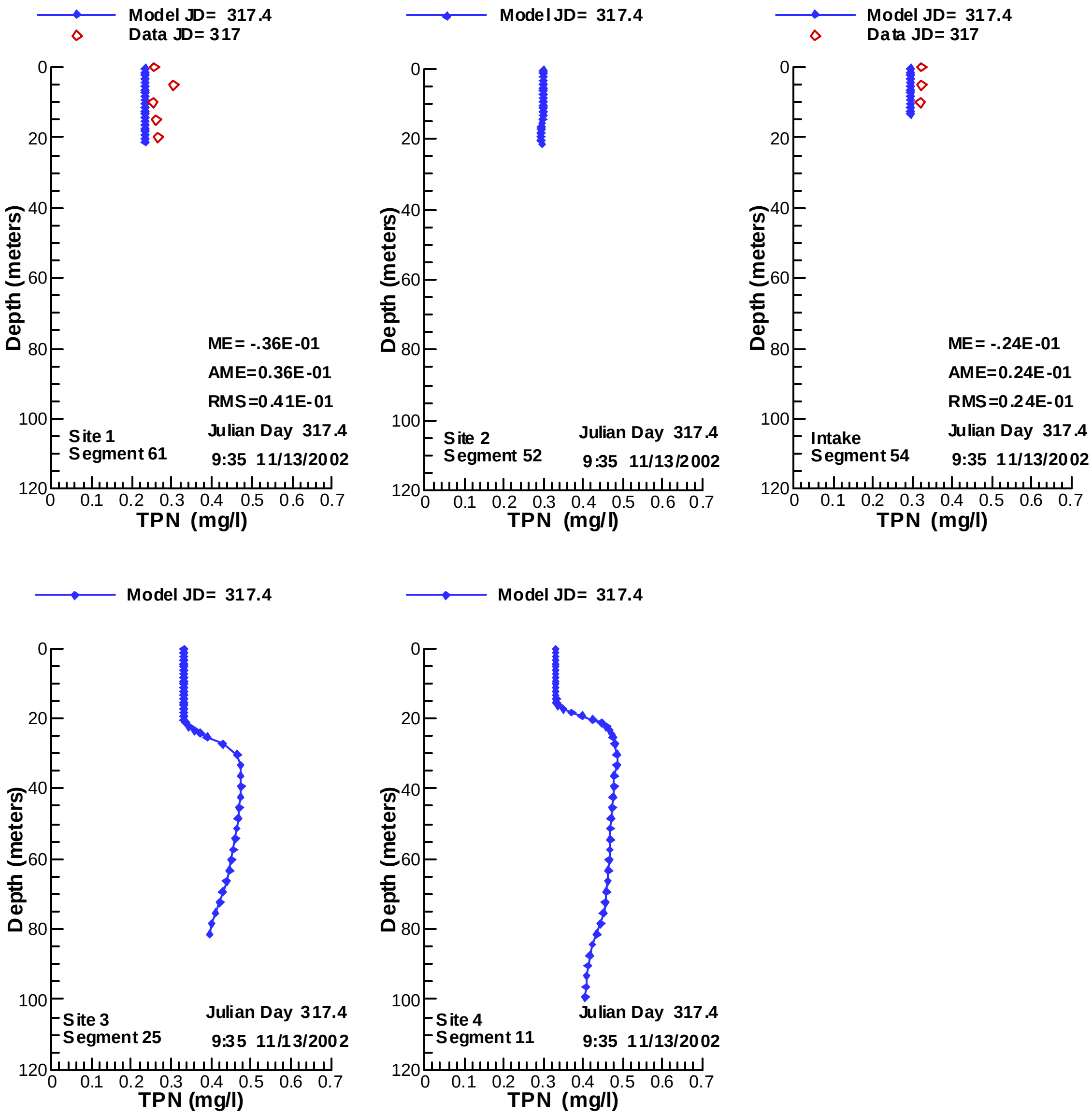

Figure 426. Vertical profiles of TPN compared with data for 11/13/2002.

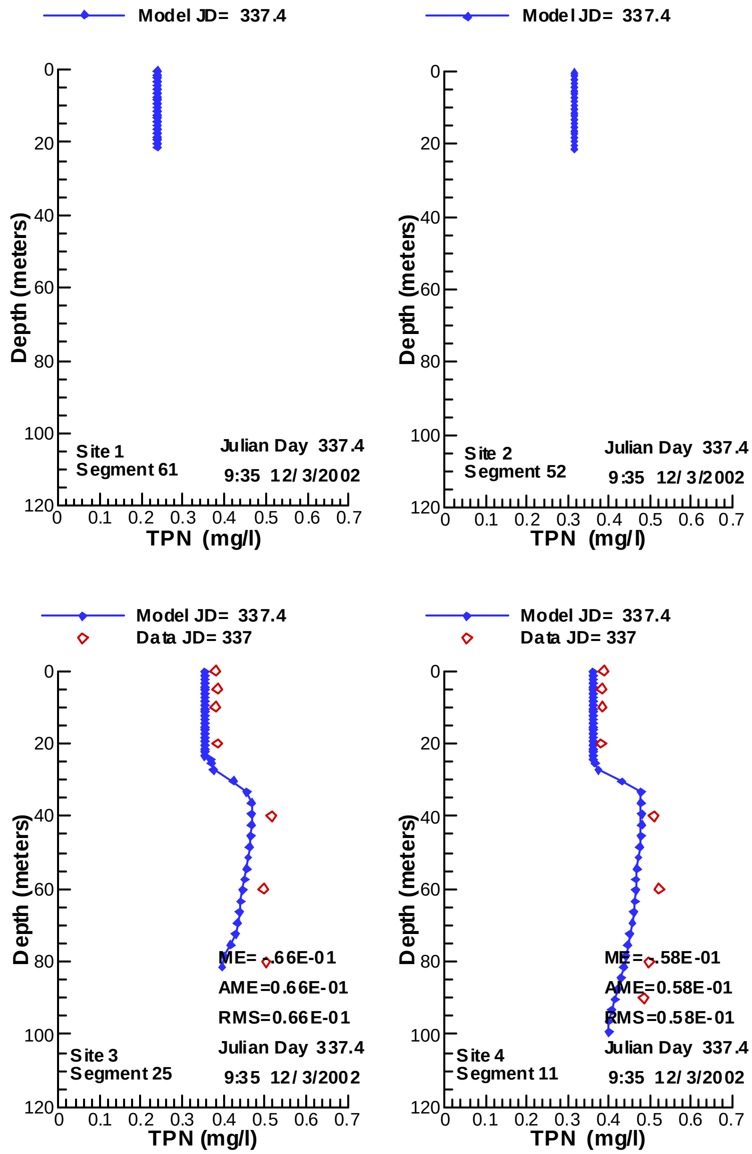

Figure 427. Vertical profiles of TPN compared with data for 12/ 3/2002.

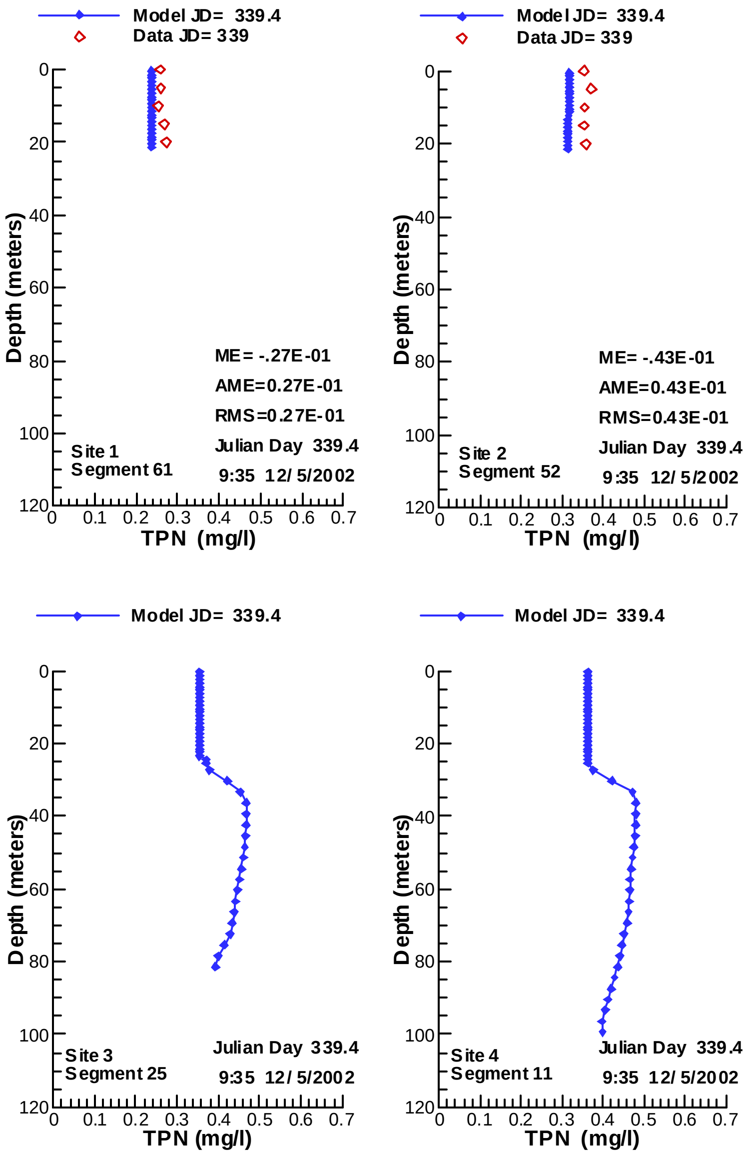

Figure 428. Vertical profiles of TPN compared with data for 12/ 5/2002.

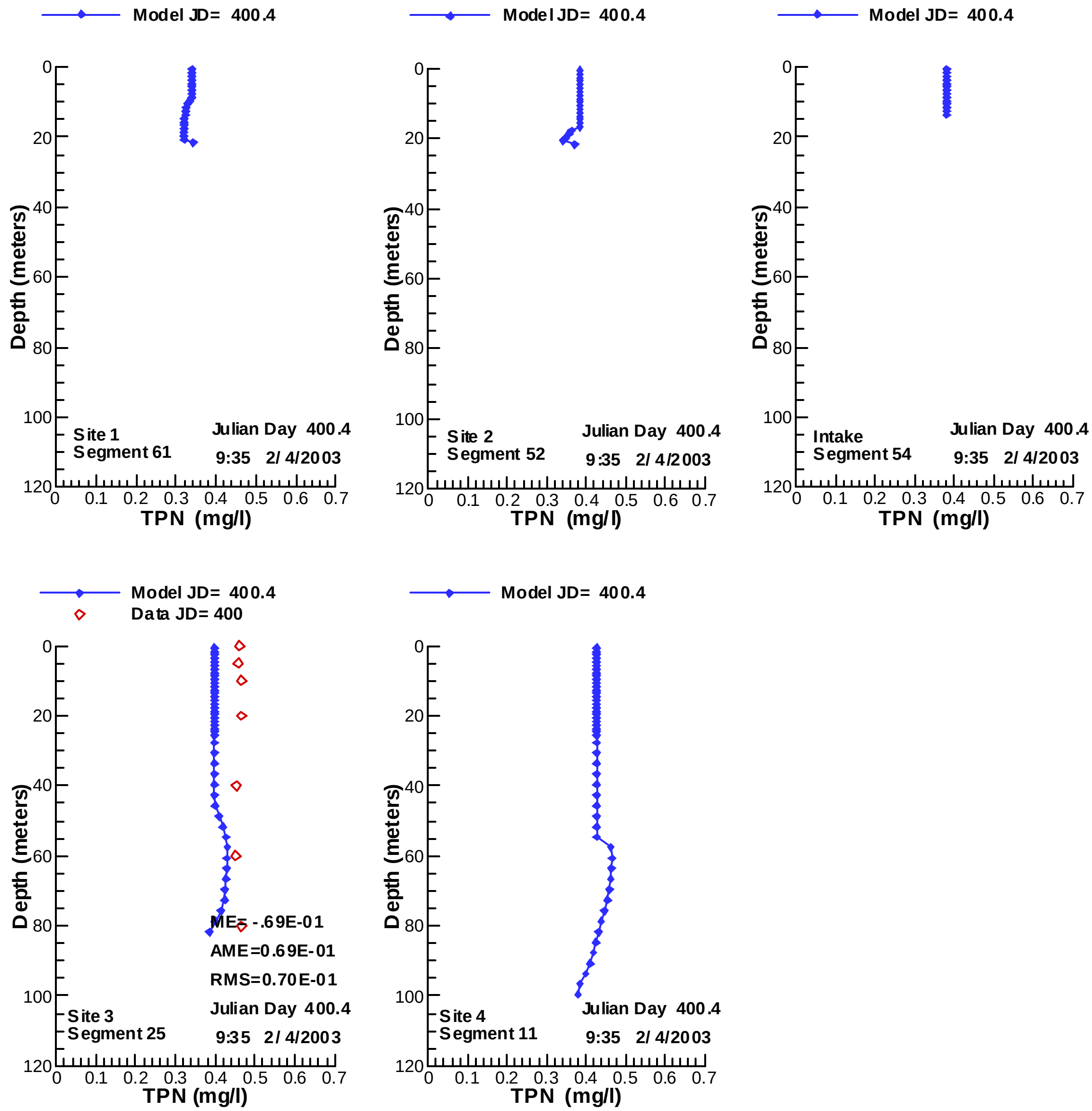

Figure 429. Vertical profiles of TPN compared with data for 2/ 4/2003.

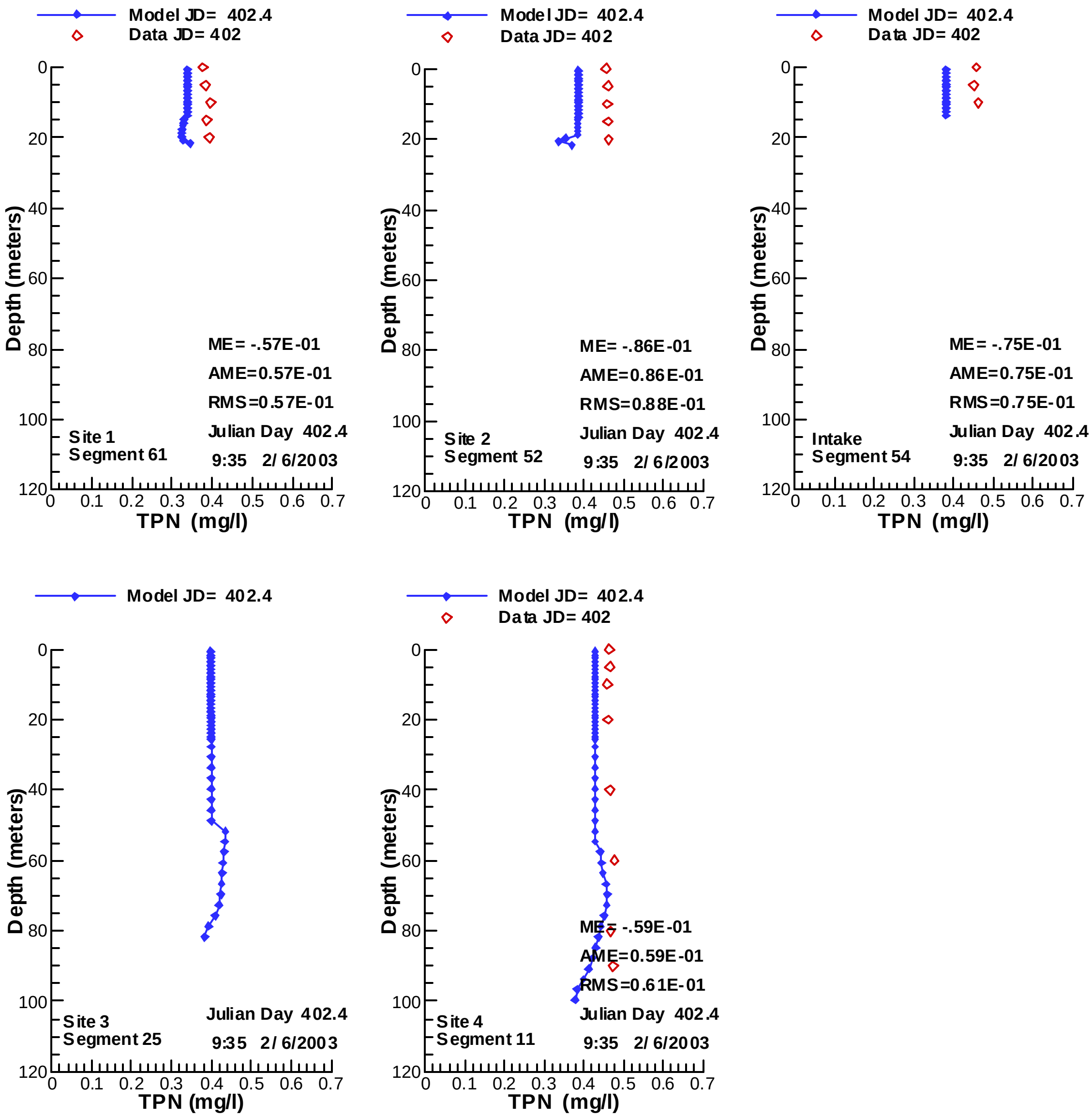

Figure 430. Vertical profiles of TPN compared with data for 2/ 6/2003.

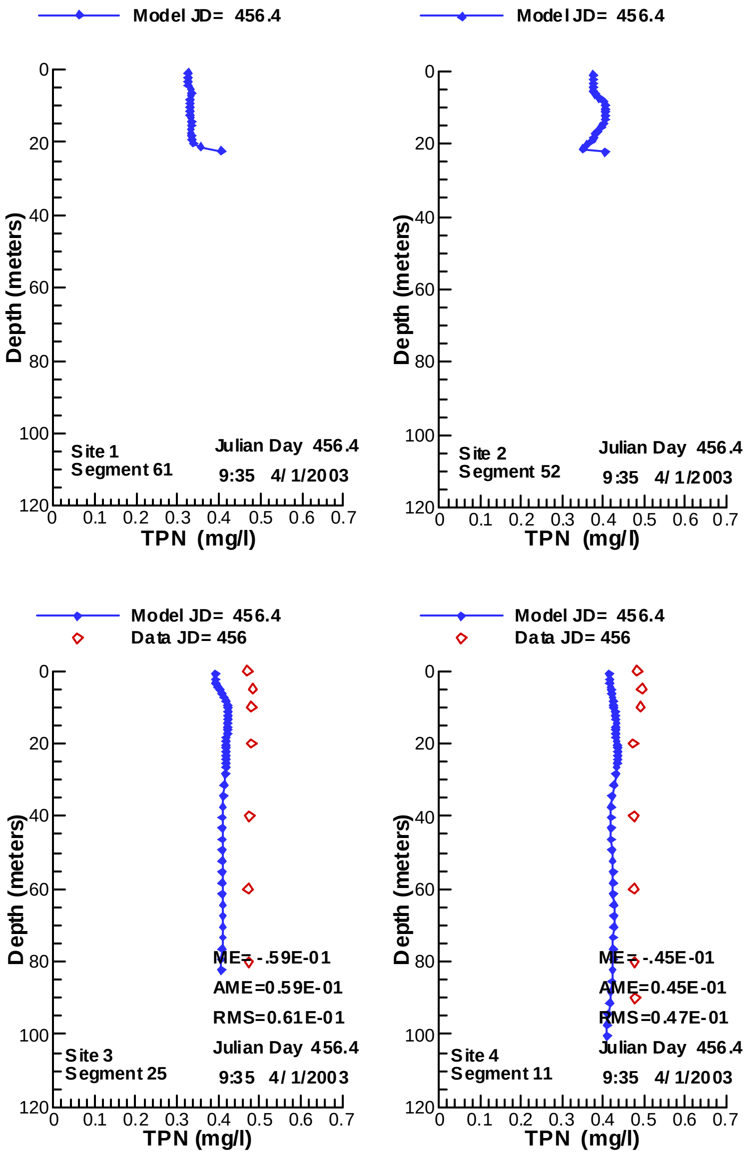

Figure 431. Vertical profiles of TPN compared with data for 4/ 1/2003.

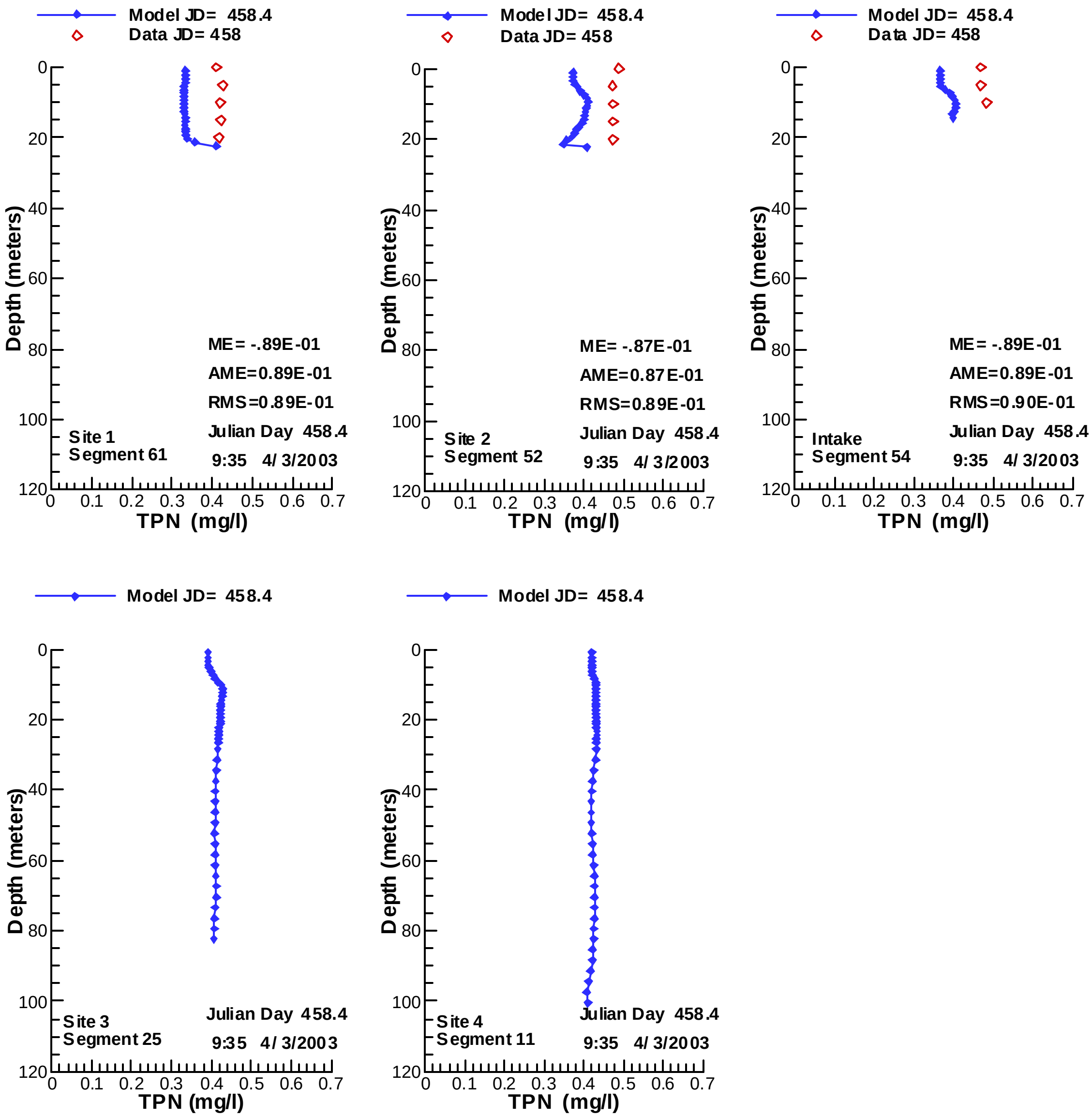

Figure 432. Vertical profiles of TPN compared with data for 4/ 3/2003.

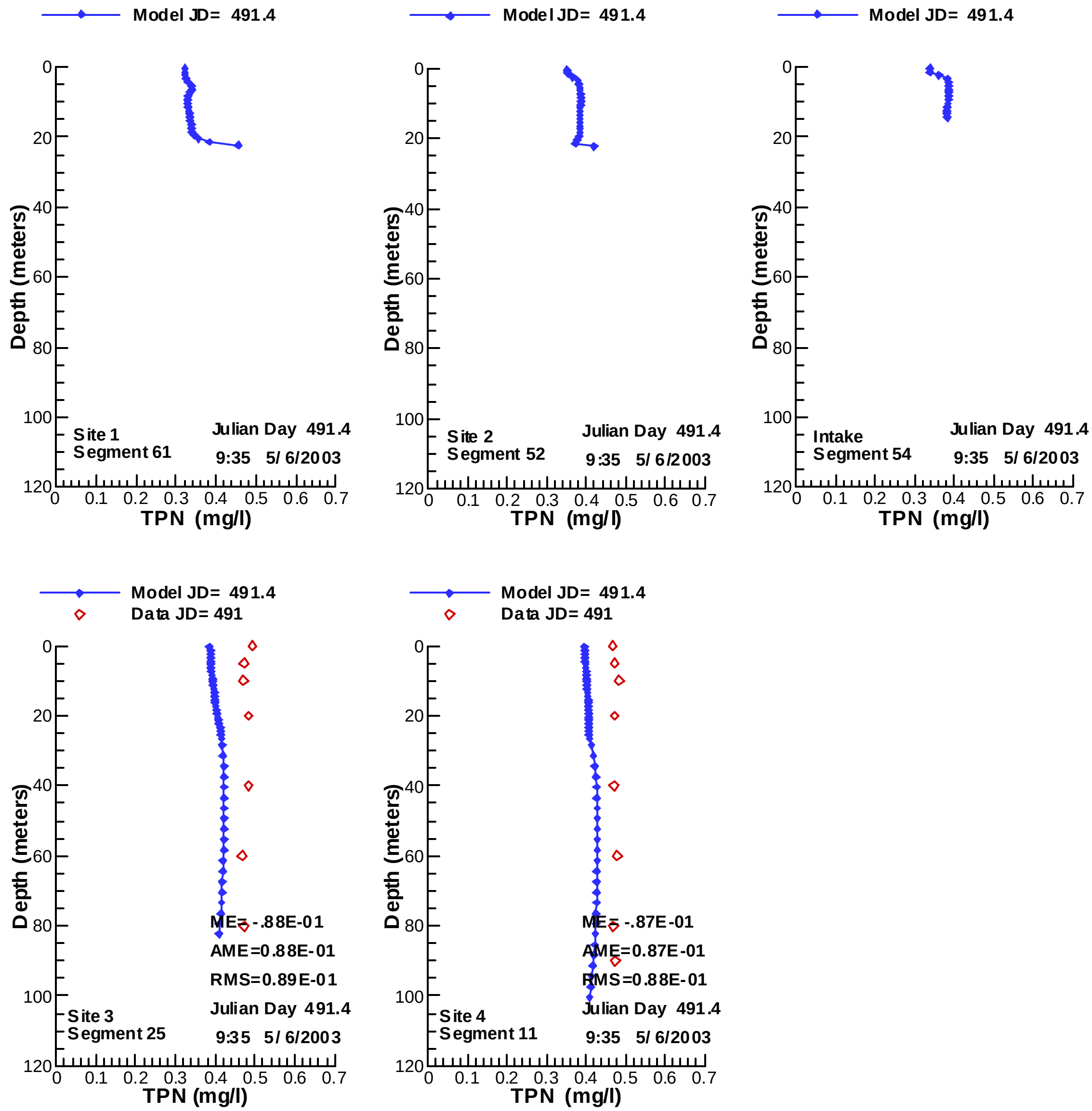

Figure 433. Vertical profiles of TPN compared with data for 5/ 6/2003.

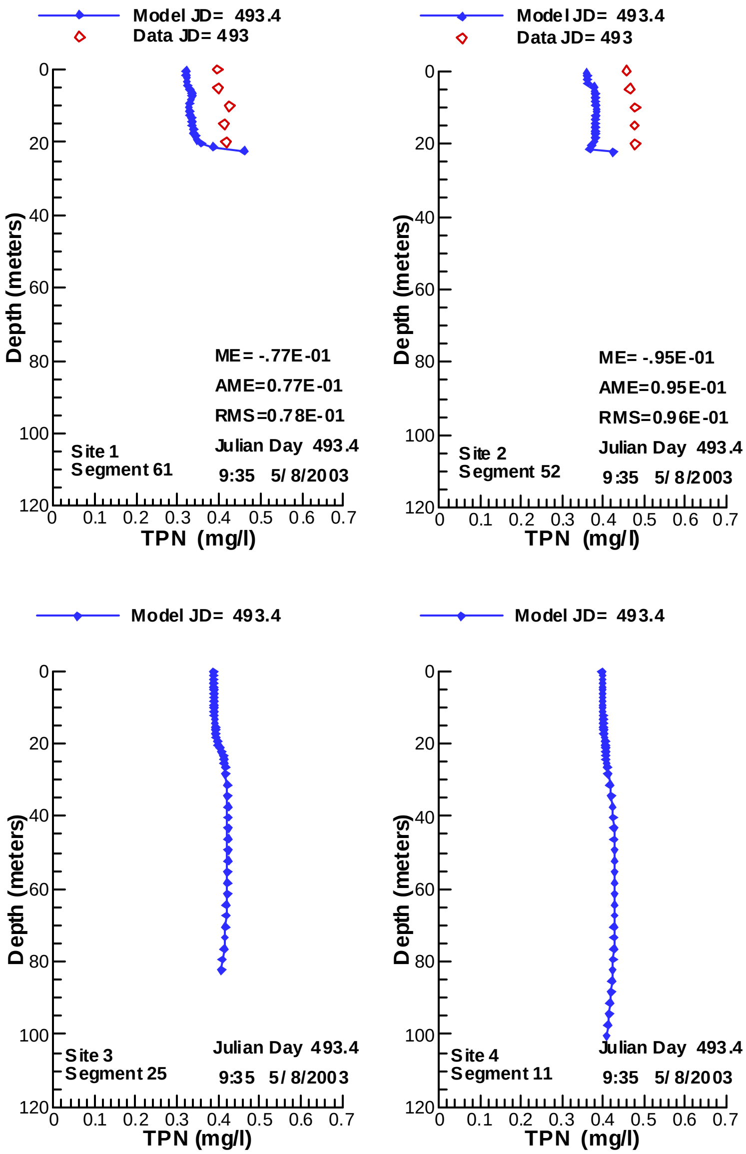

Figure 434. Vertical profiles of TPN compared with data for 5/ 8/2003.

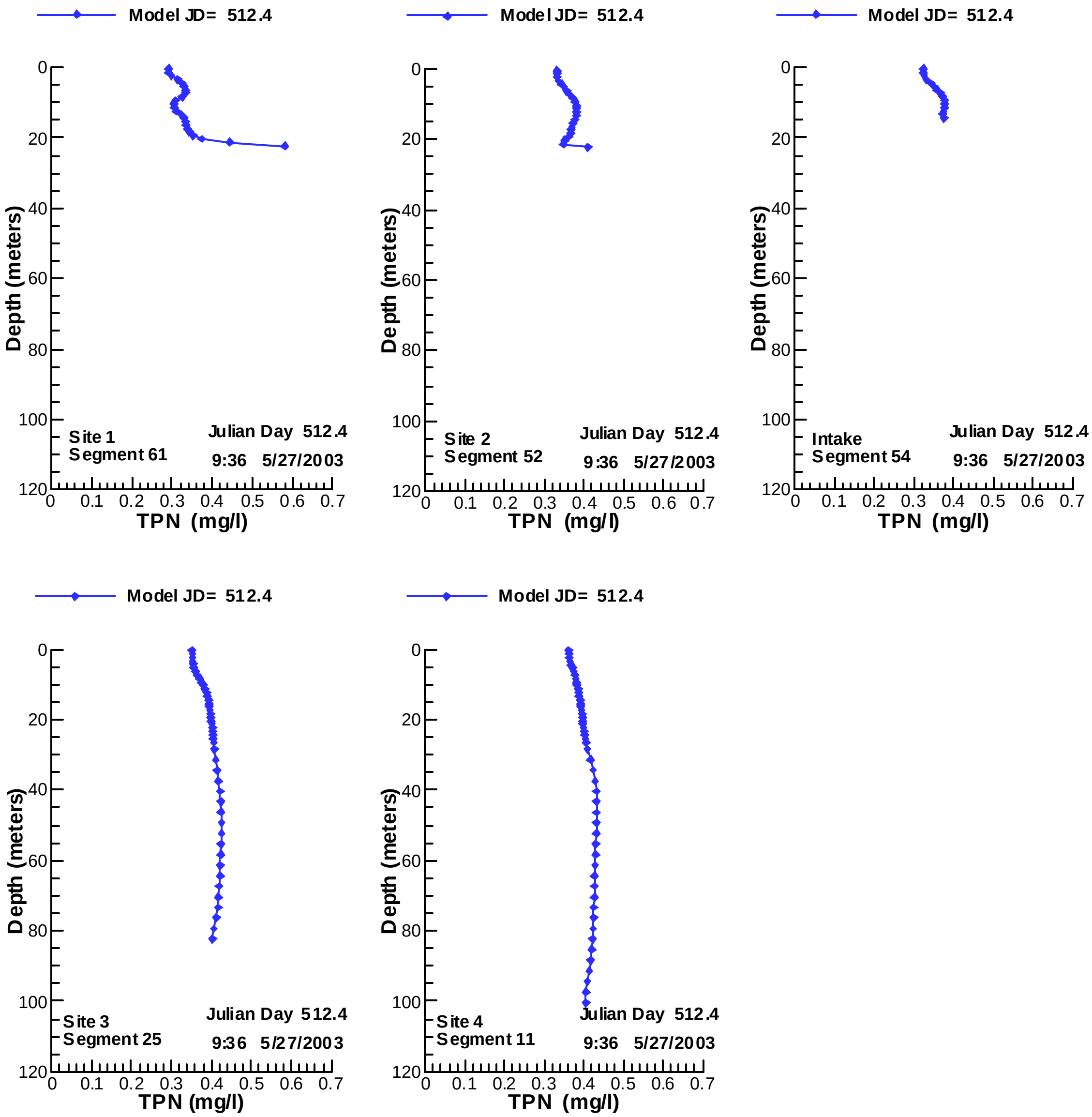

Figure 435. Vertical profiles of TPN compared with data for 5/27/2003.

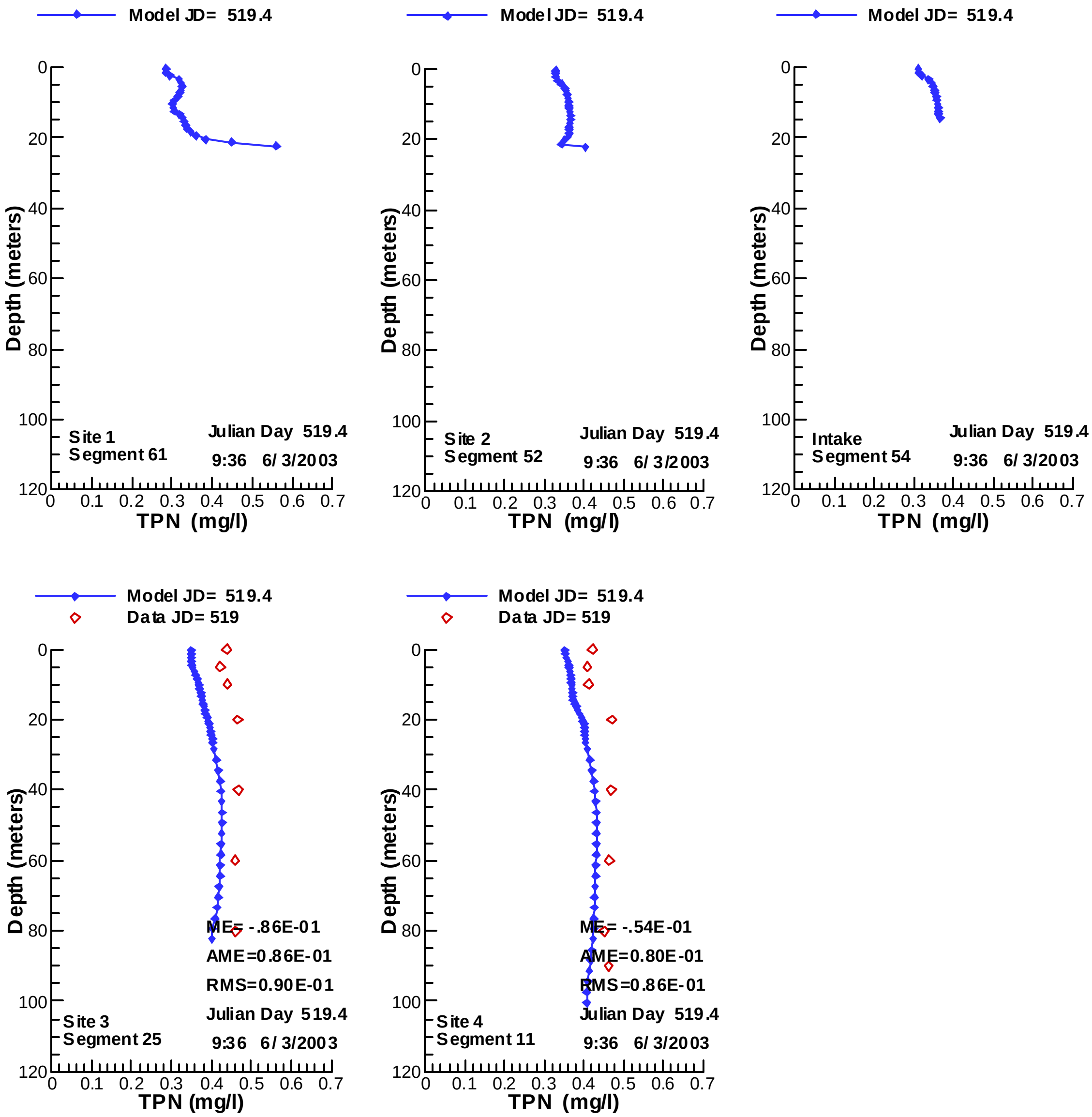

Figure 436. Vertical profiles of TPN compared with data for 6/ 3/2003.

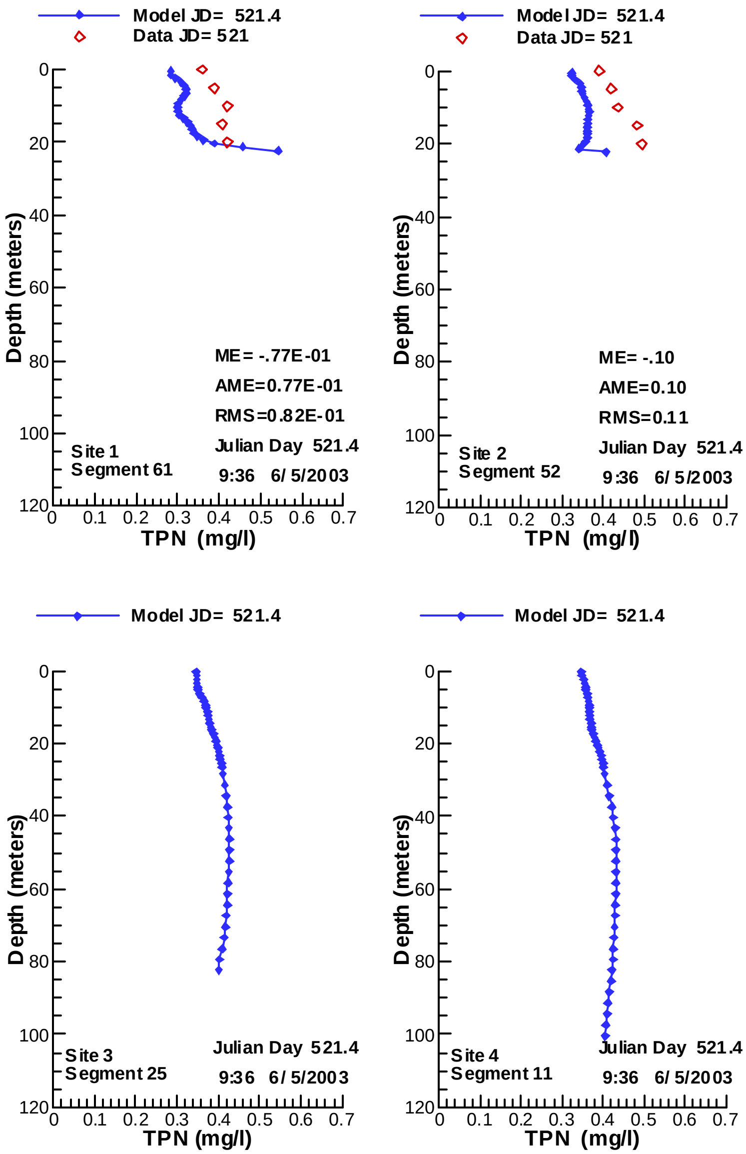

Figure 437. Vertical profiles of TPN compared with data for 6/ 5/2003.

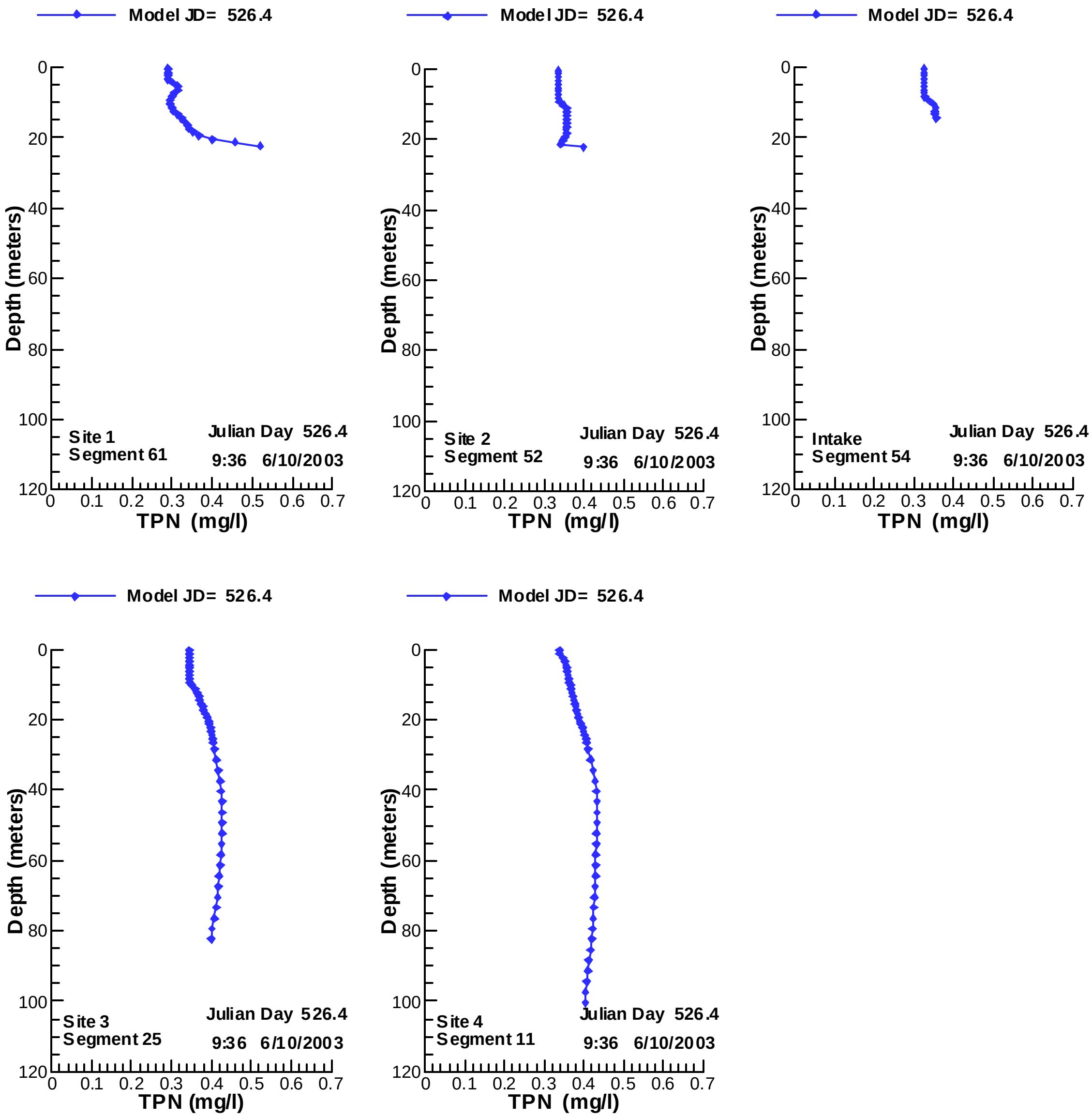

Figure 438. Vertical profiles of TPN compared with data for 6/10/2003.

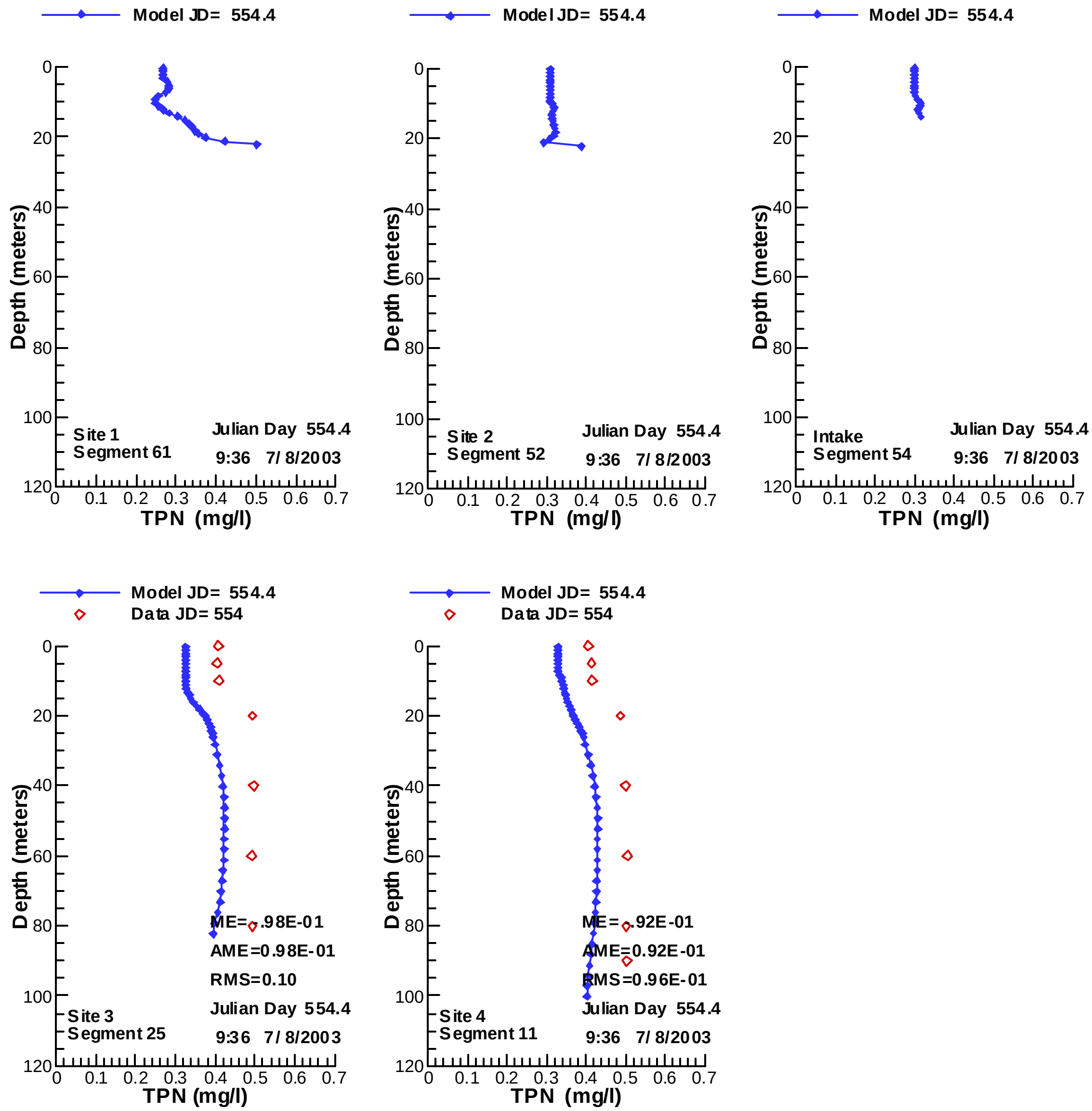

Figure 439. Vertical profiles of TPN compared with data for 7/ 8/2003.

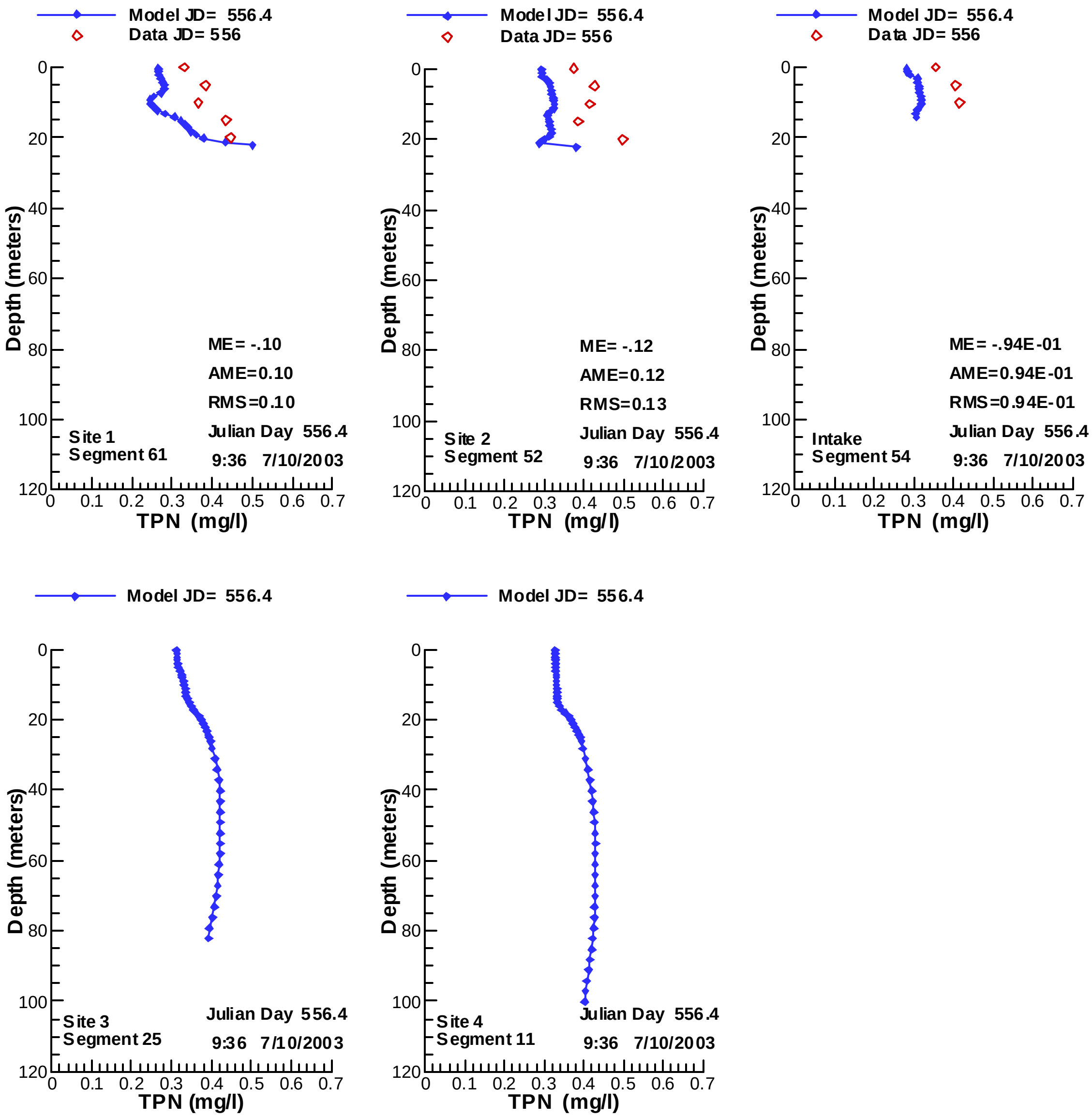

Figure 440. Vertical profiles of TPN compared with data for 7/10/2003.

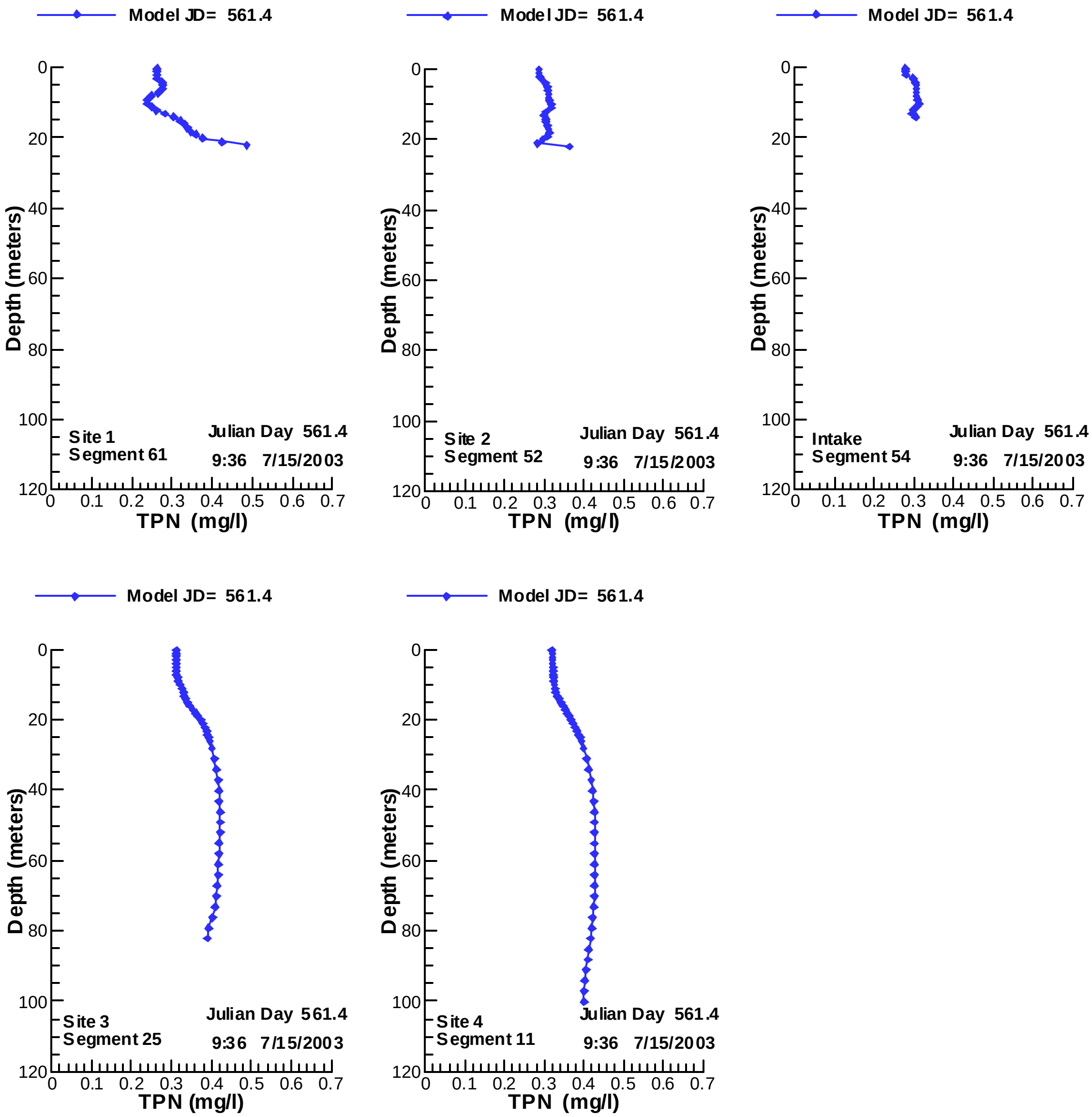

Figure 441. Vertical profiles of TPN compared with data for 7/15/2003.

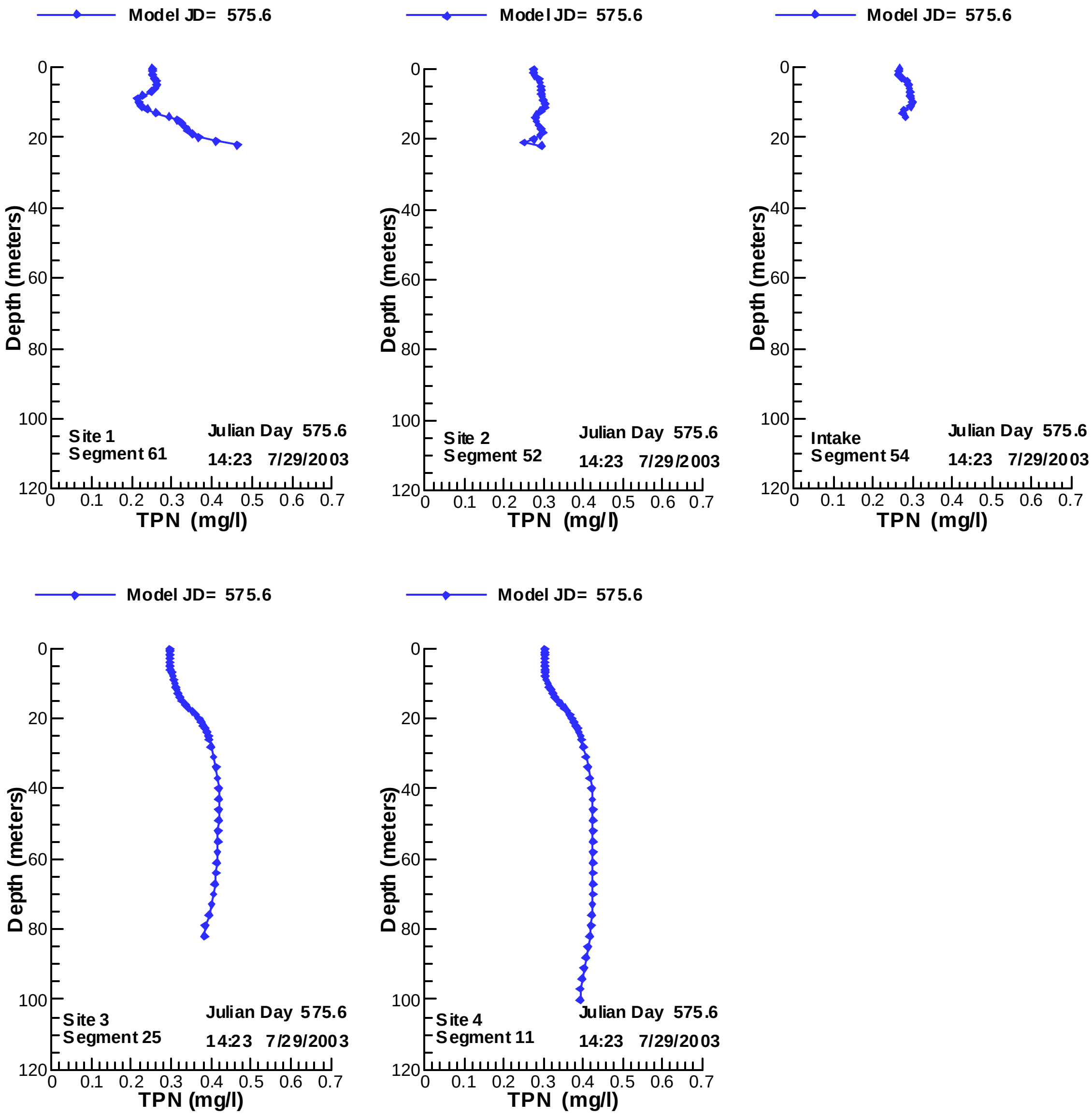

Figure 442. Vertical profiles of TPN compared with data for 7/29/2003.

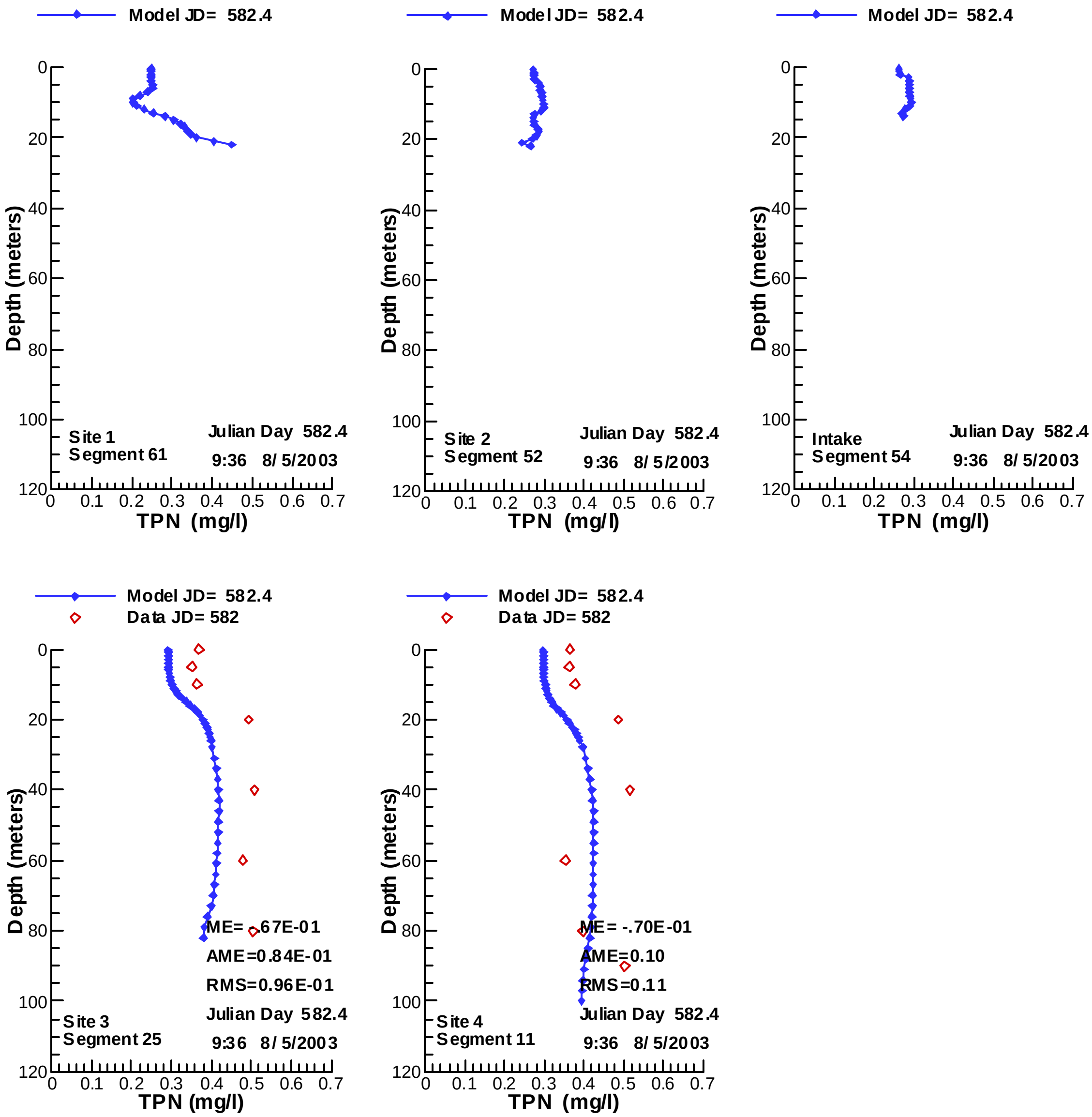

Figure 443. Vertical profiles of TPN compared with data for 8/ 5/2003.

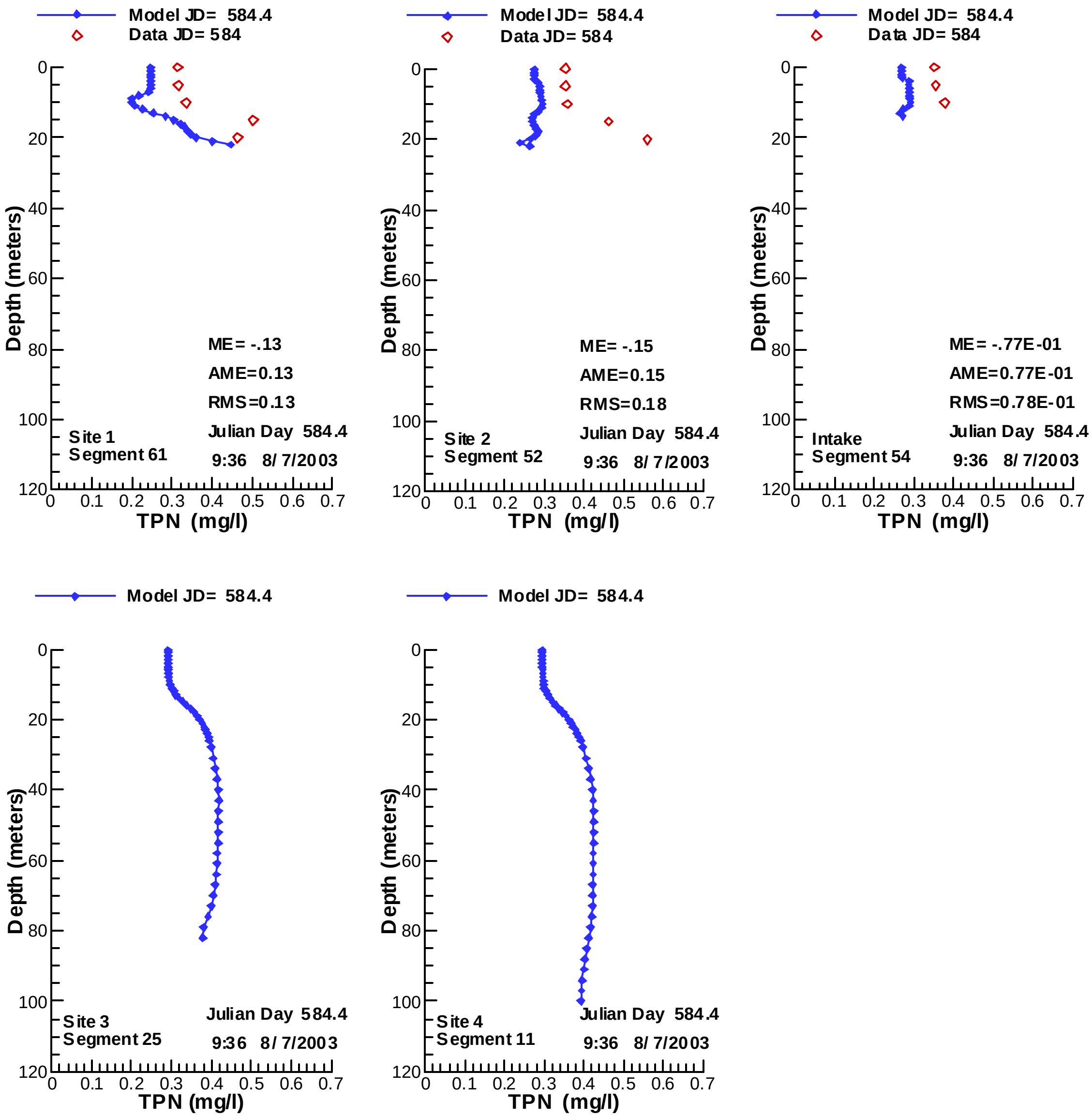

Figure 444. Vertical profiles of TPN compared with data for 8/ 7/2003.

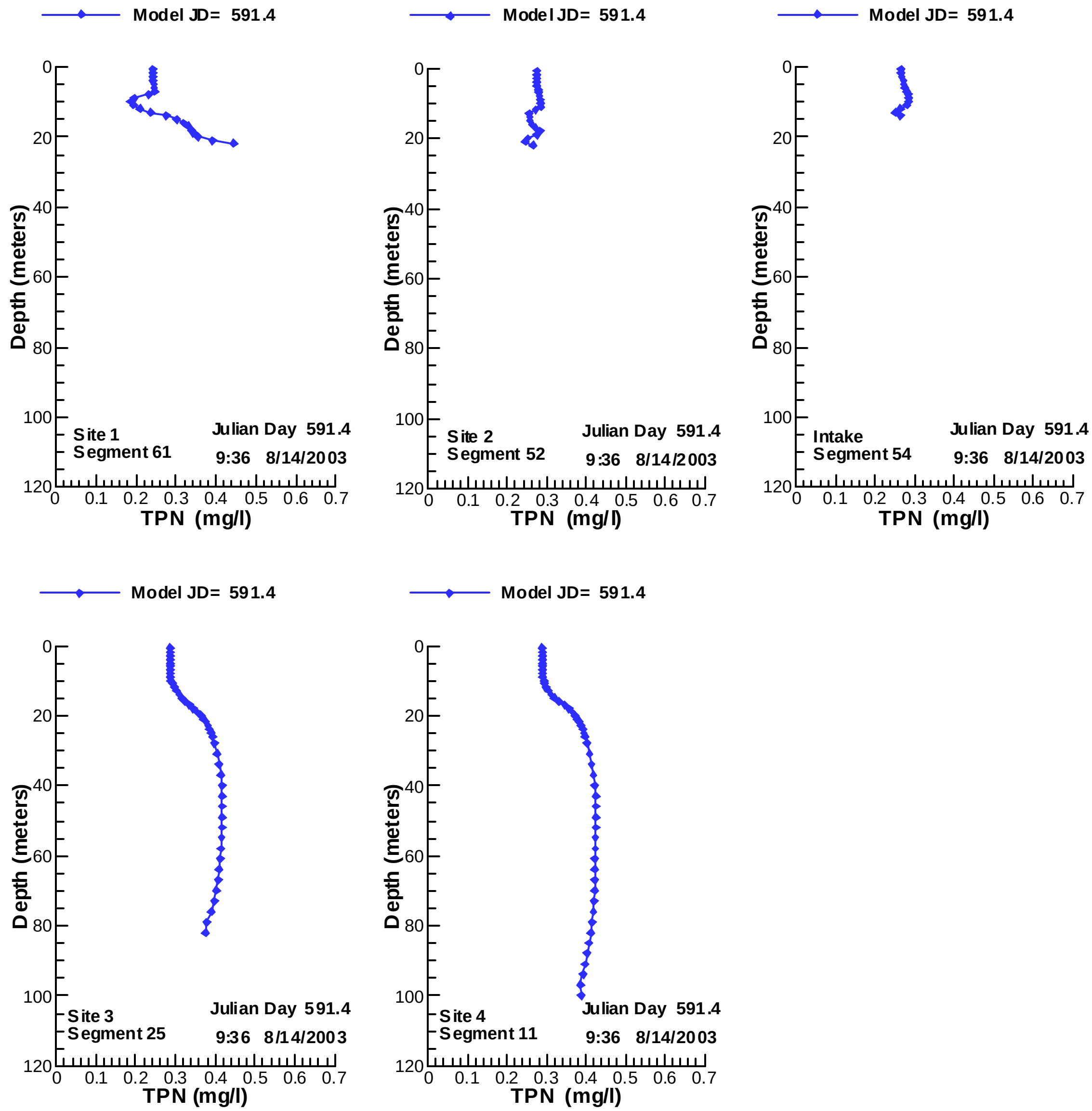

Figure 445. Vertical profiles of TPN compared with data for 8/14/2003.

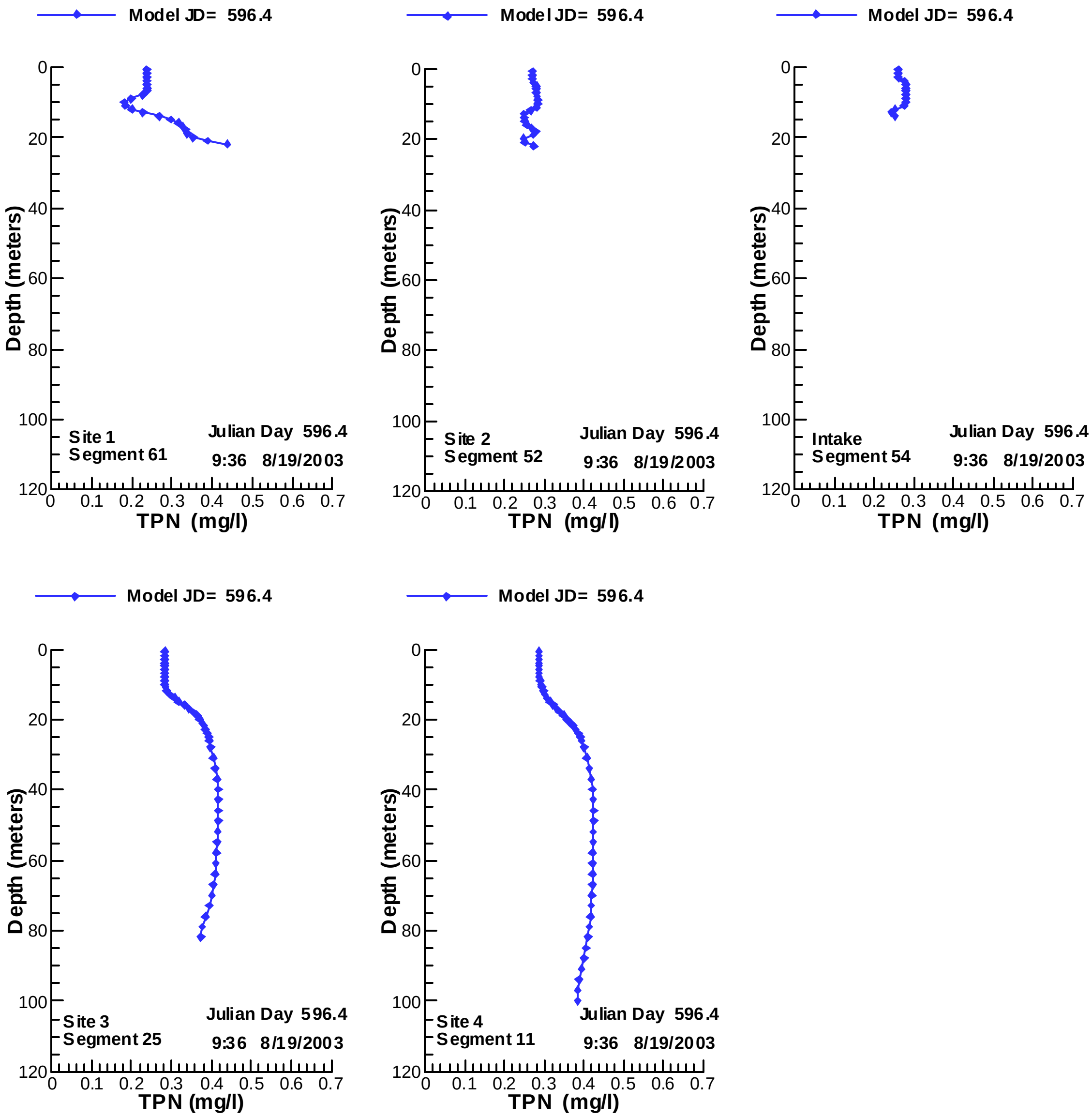

Figure 446. Vertical profiles of TPN compared with data for 8/19/2003.

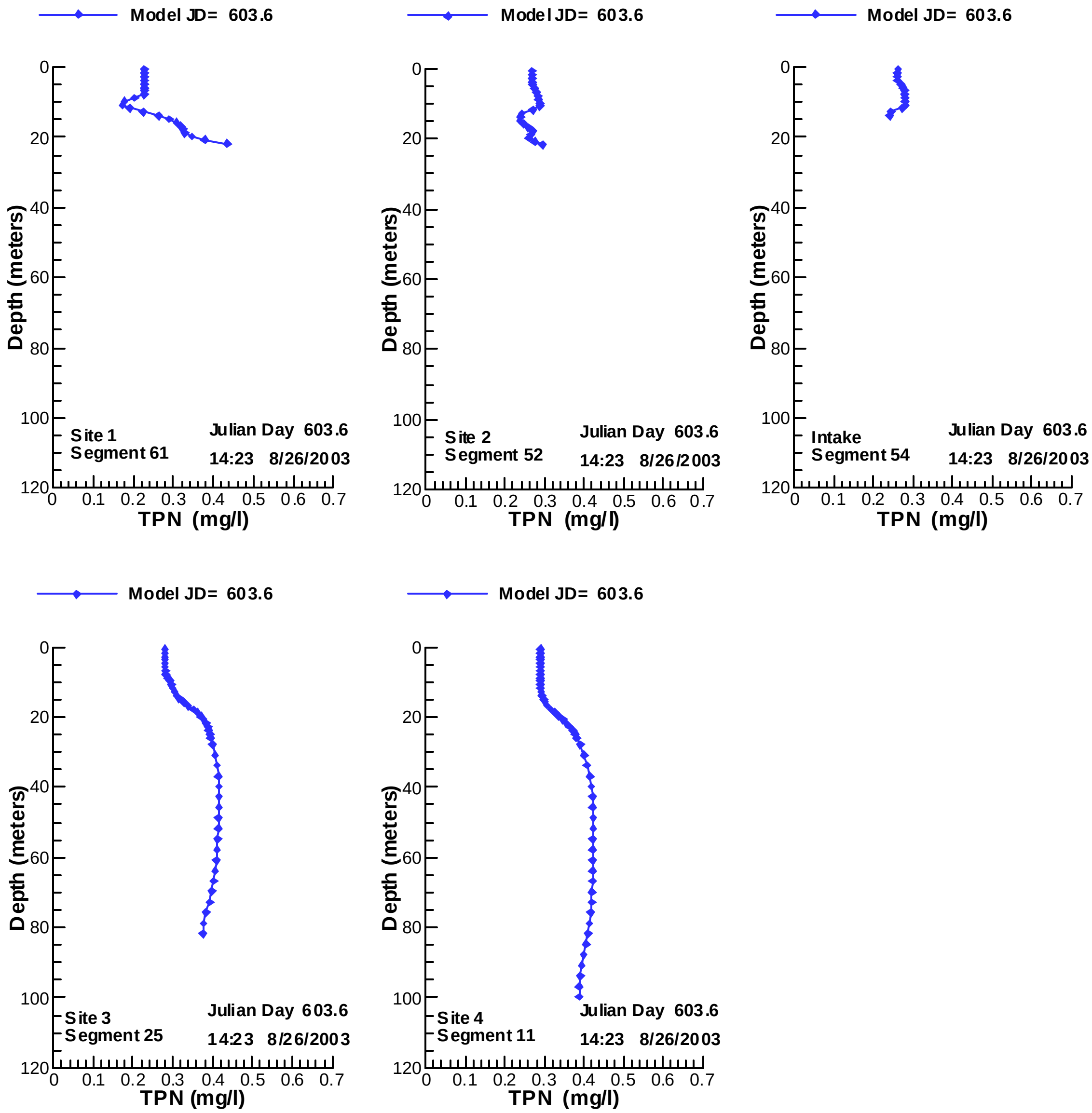

Figure 447. Vertical profiles of TPN compared with data for 8/26/2003.

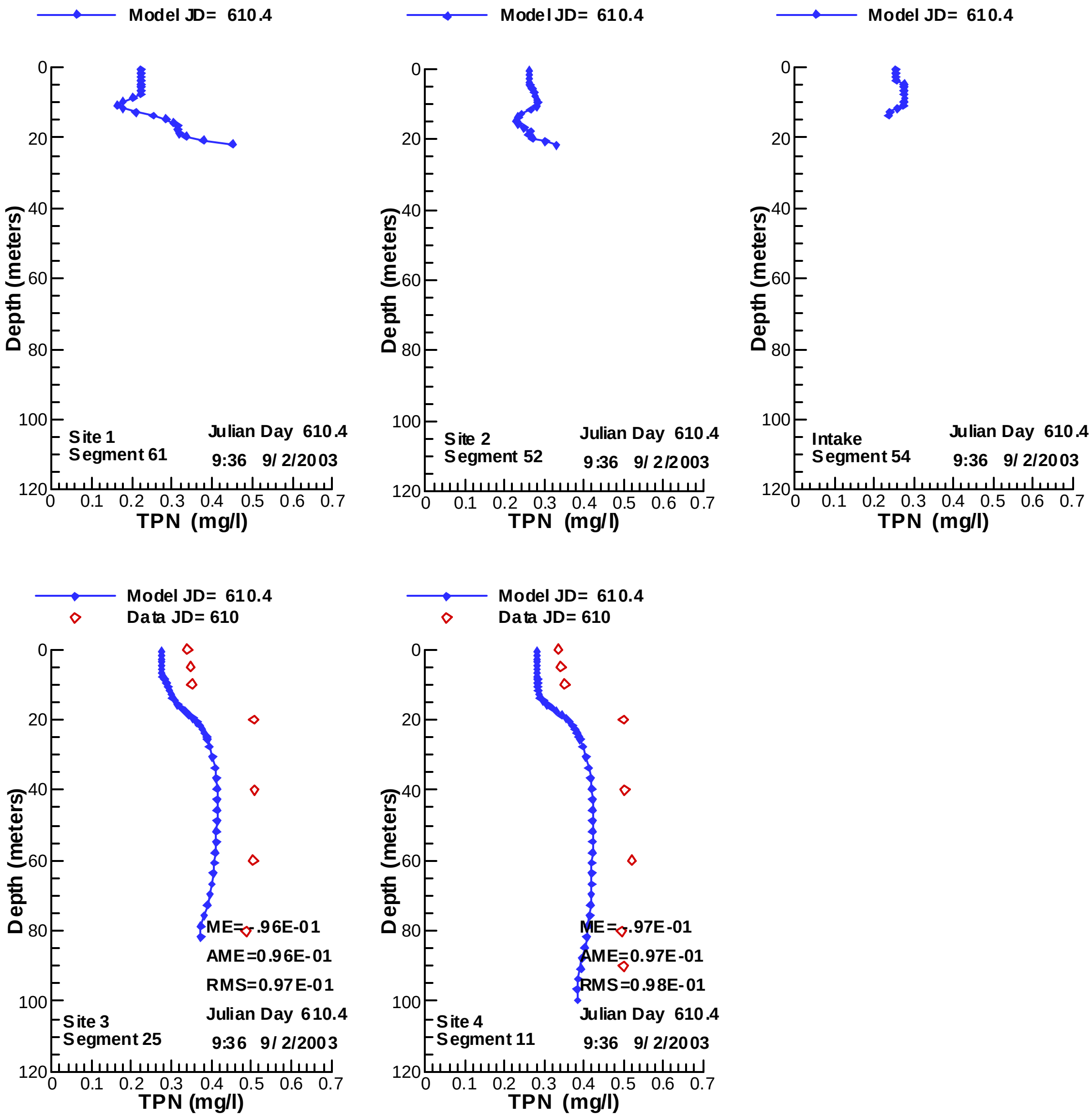

Figure 448. Vertical profiles of TPN compared with data for 9/ 2/2003.

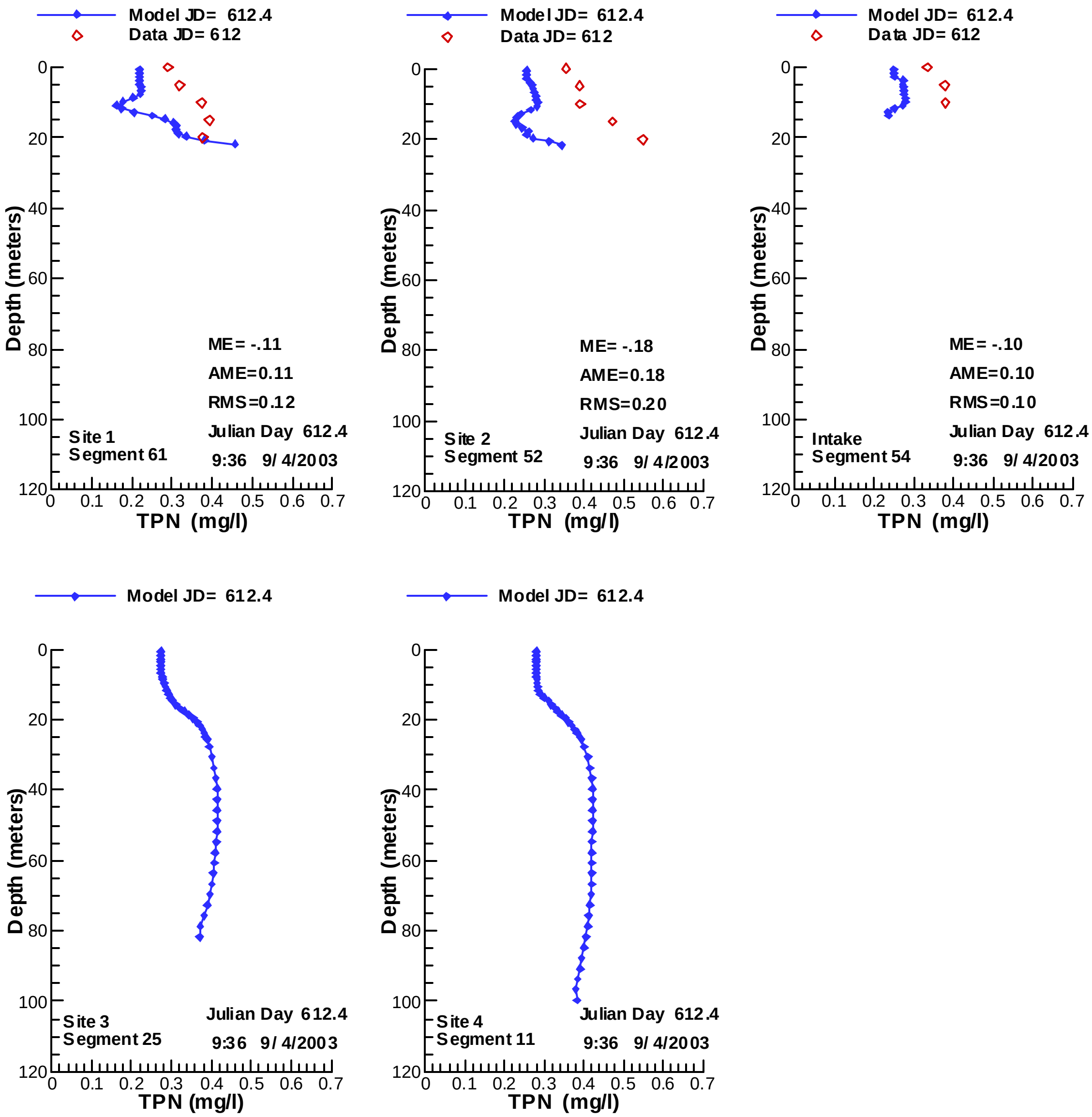

Figure 449. Vertical profiles of TPN compared with data for 9/ 4/2003.

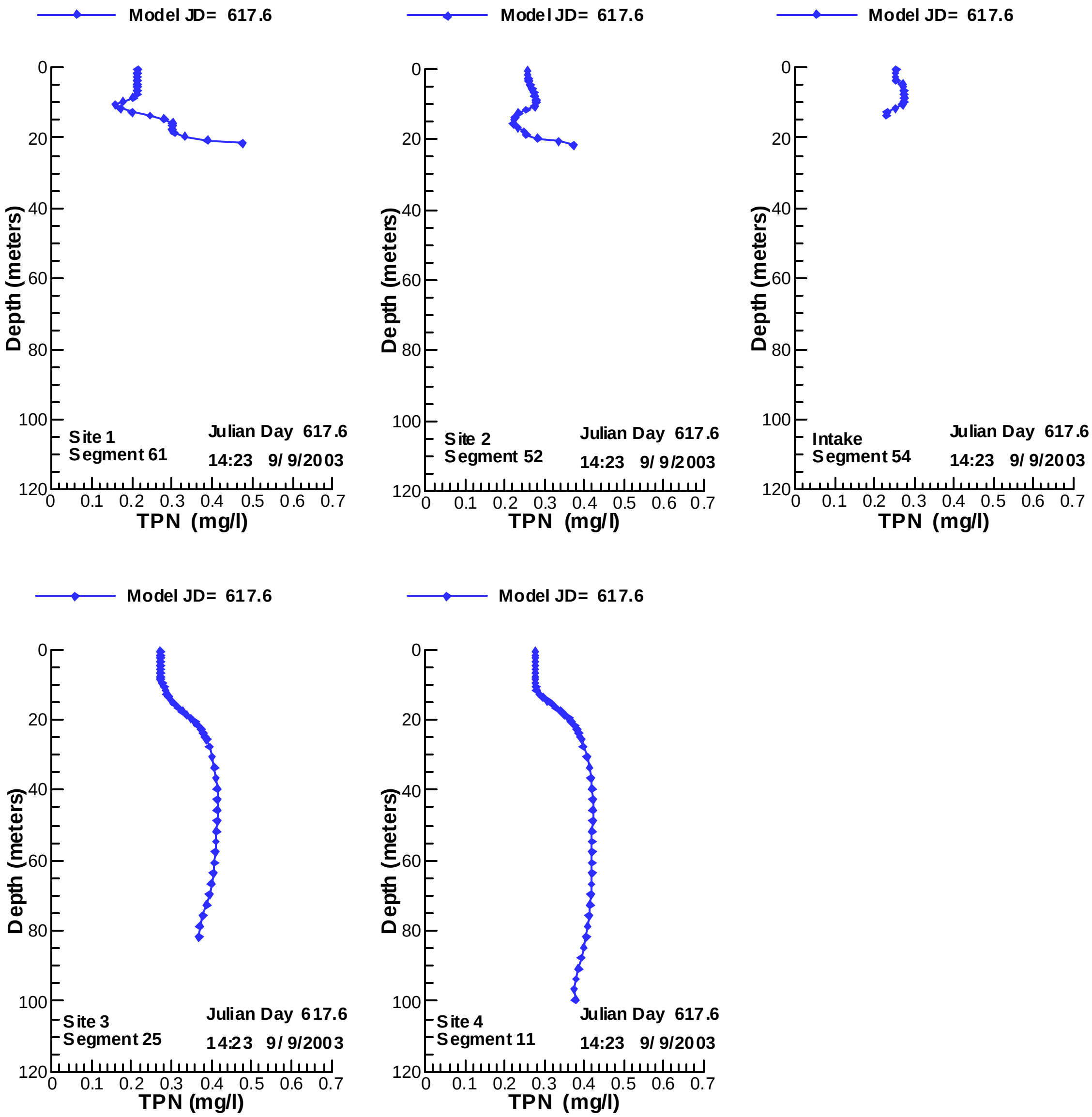

Figure 450. Vertical profiles of TPN compared with data for 9/ 9/2003.

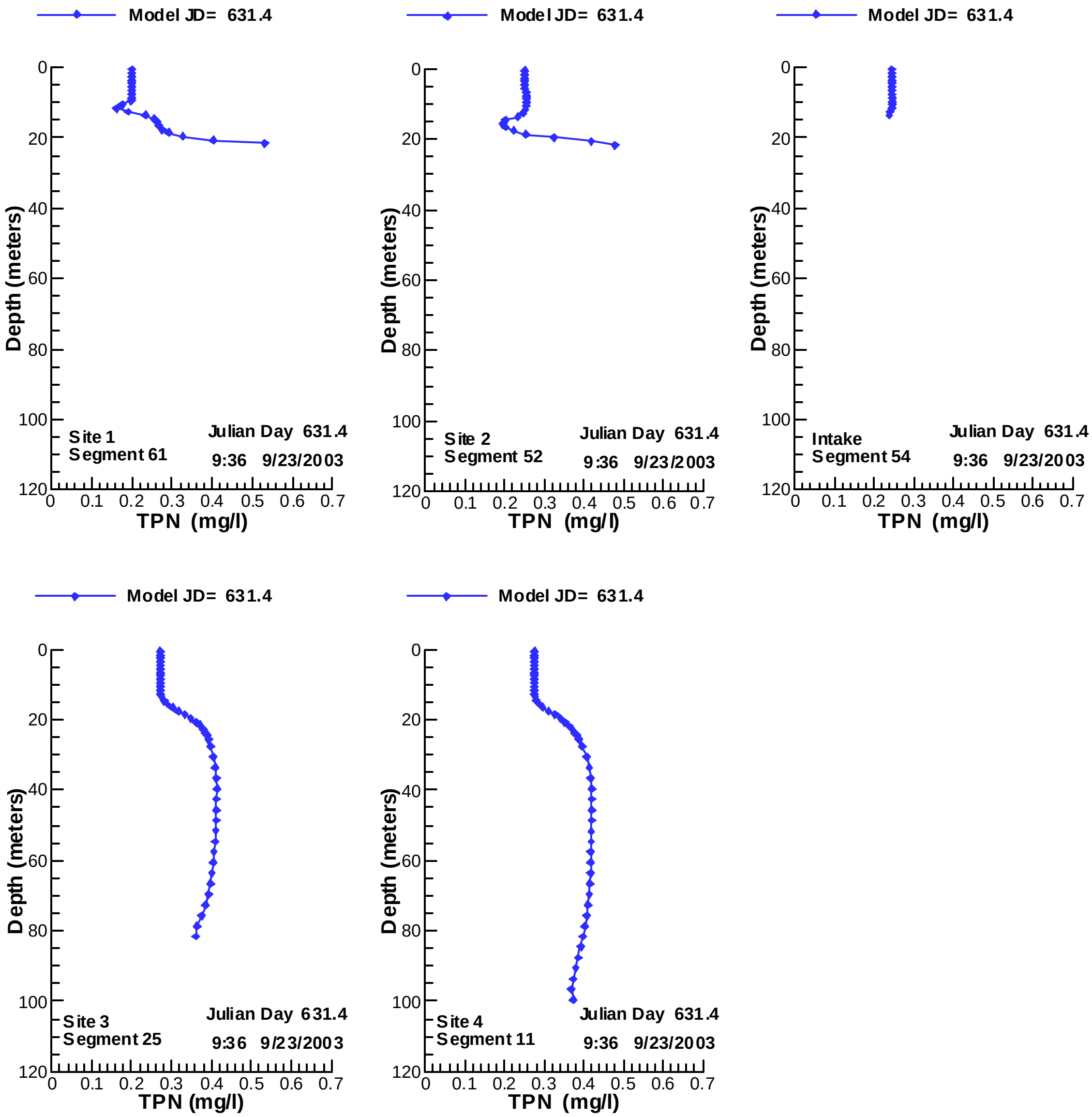

Figure 451. Vertical profiles of TPN compared with data for 9/23/2003.

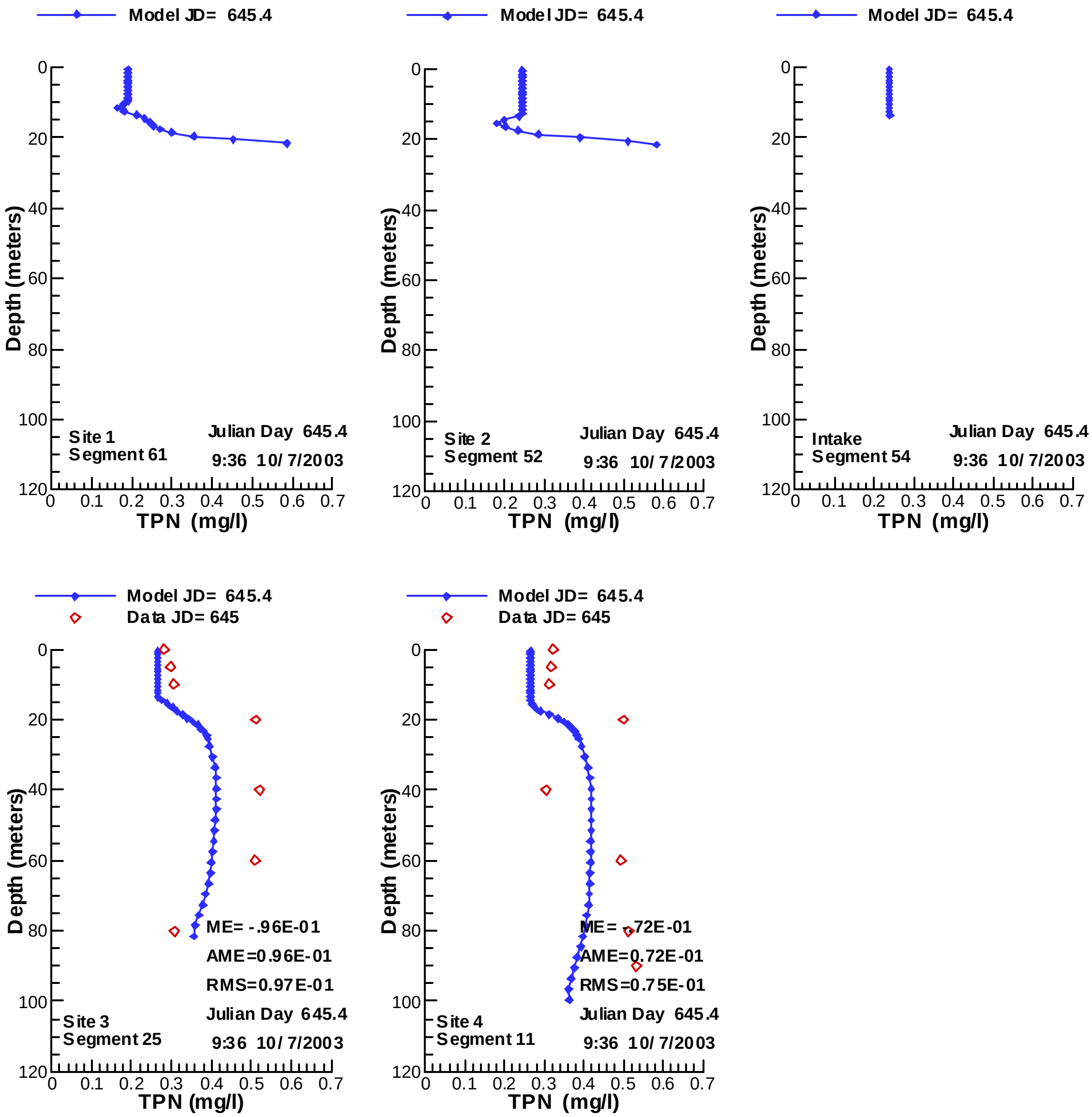

Figure 452. Vertical profiles of TPN compared with data for 10/ 7/2003.

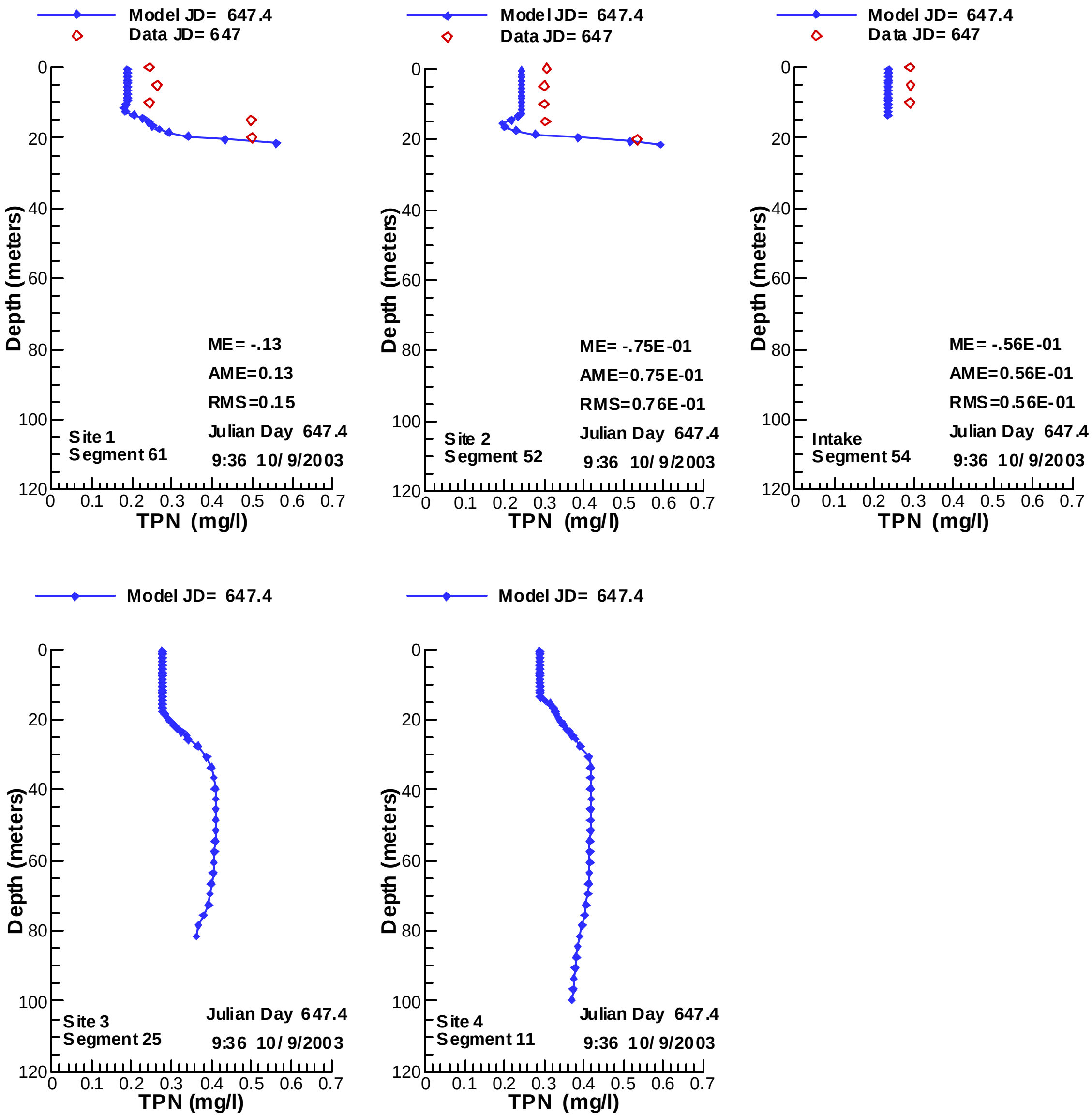

Figure 453. Vertical profiles of TPN compared with data for 10/ 9/2003.

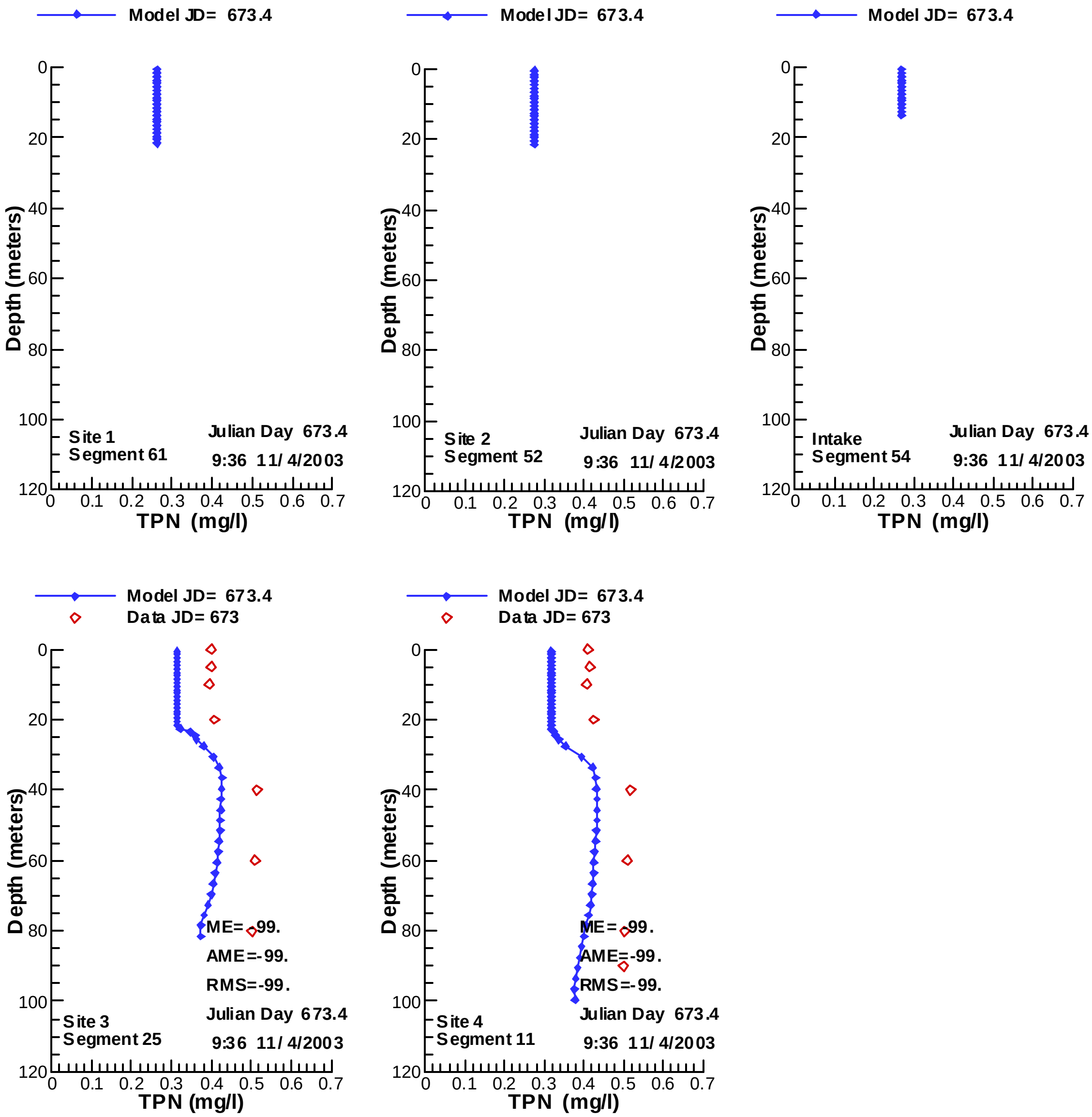

Figure 454. Vertical profiles of TPN compared with data for 11/ 4/2003.

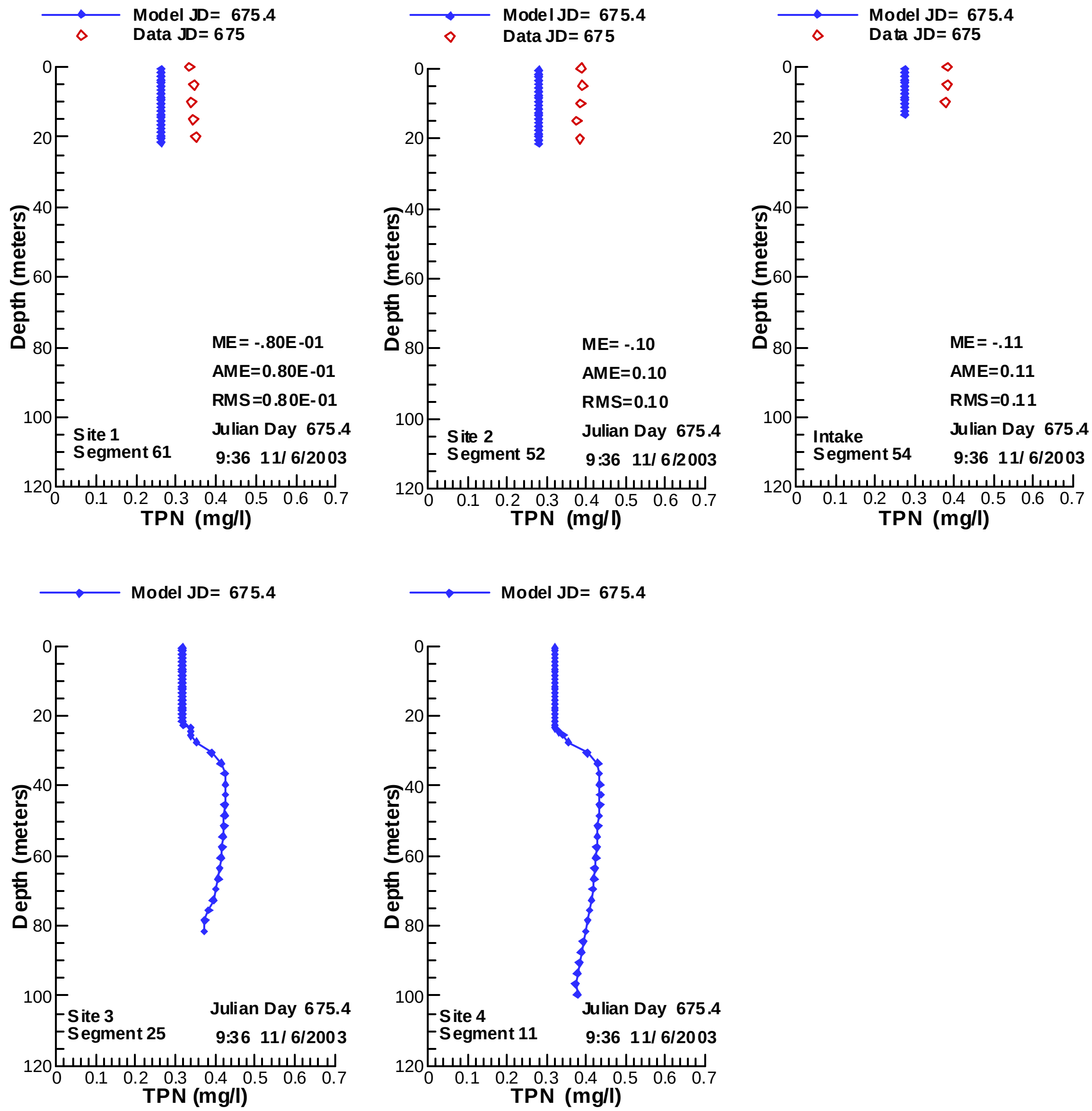

Figure 455. Vertical profiles of TPN compared with data for 11/ 6/2003.

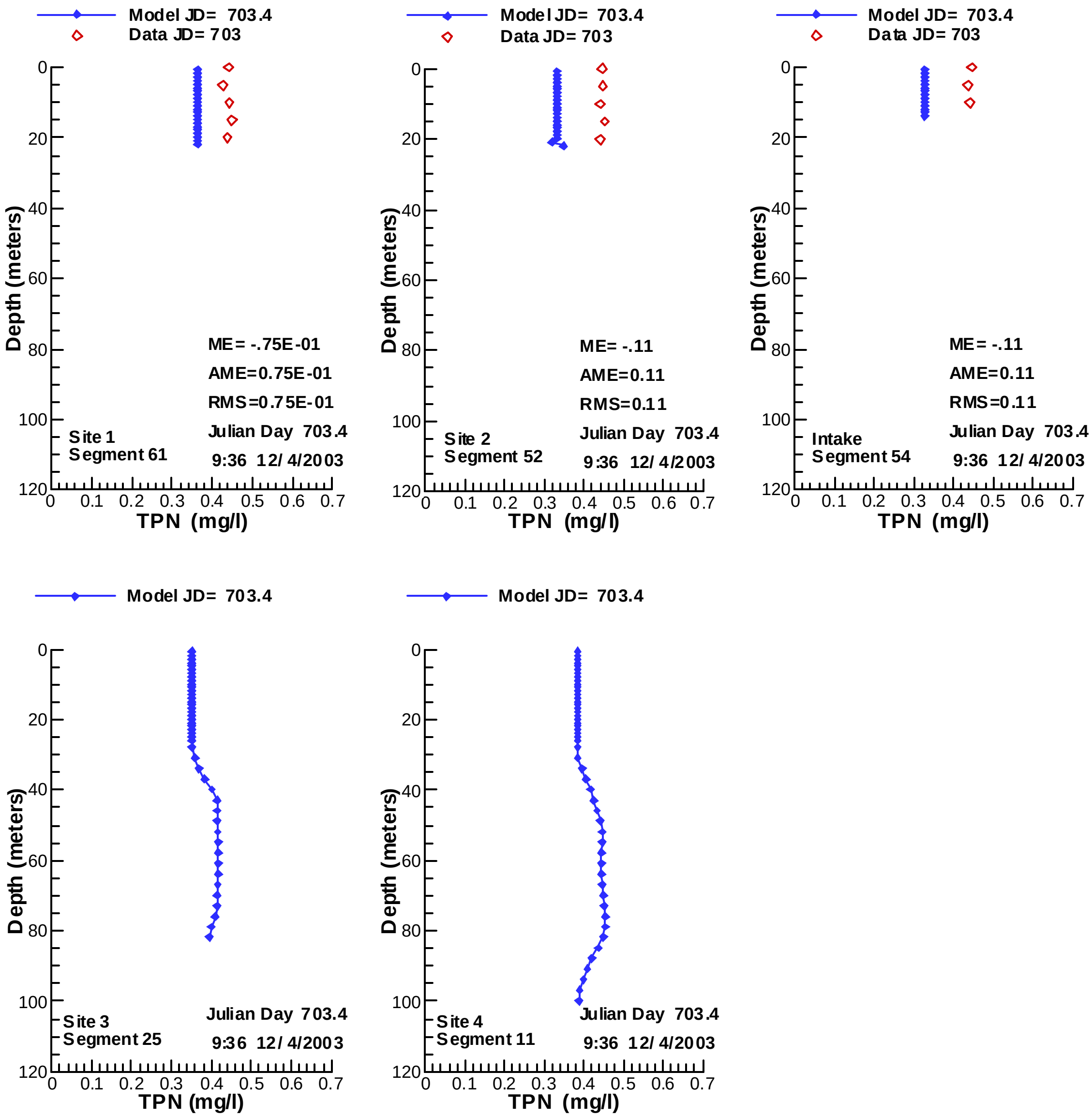

Figure 456. Vertical profiles of TPN compared with data for 12/ 4/2003.

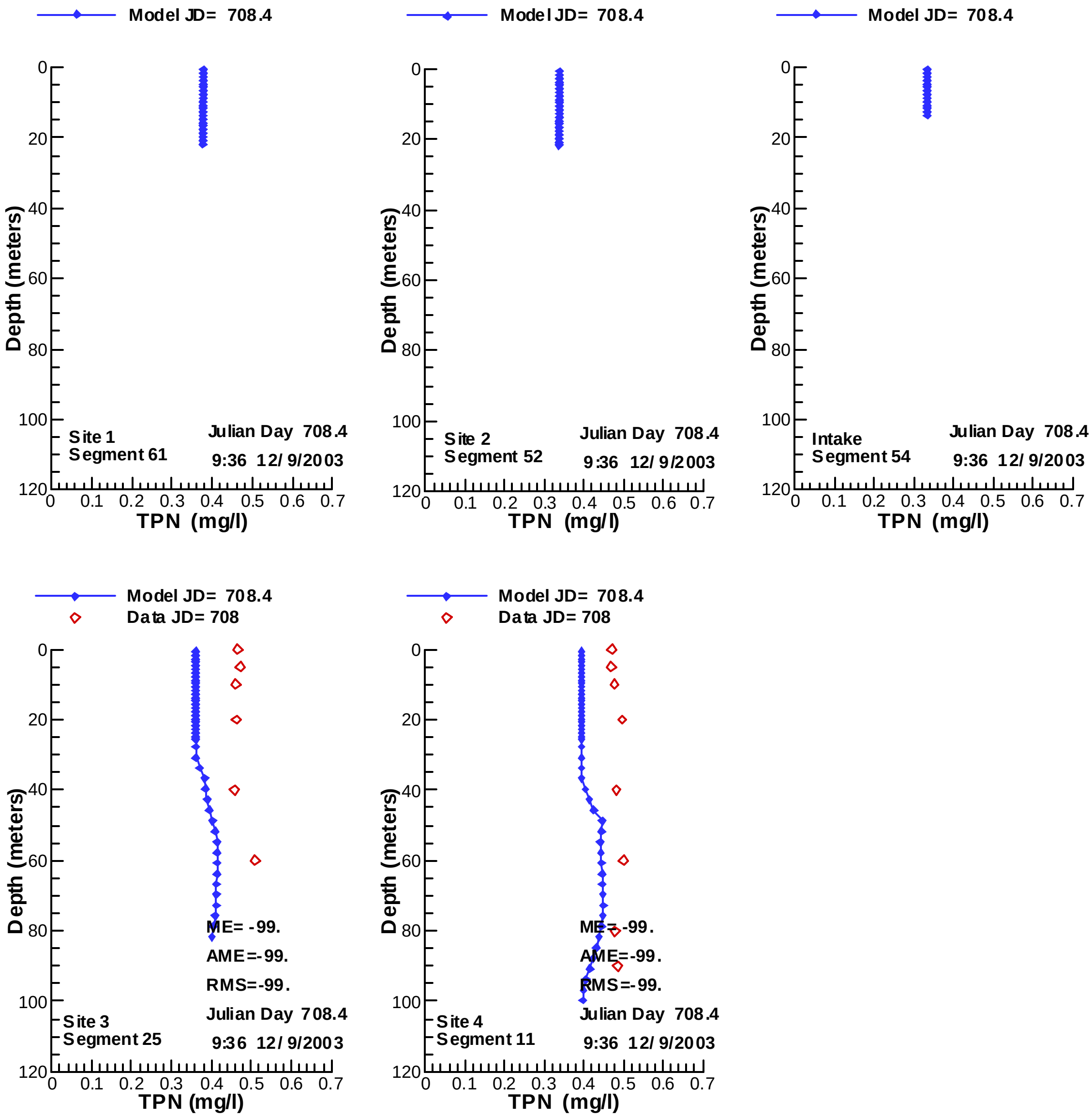

Figure 457. Vertical profiles of TPN compared with data for 12/ 9/2003.

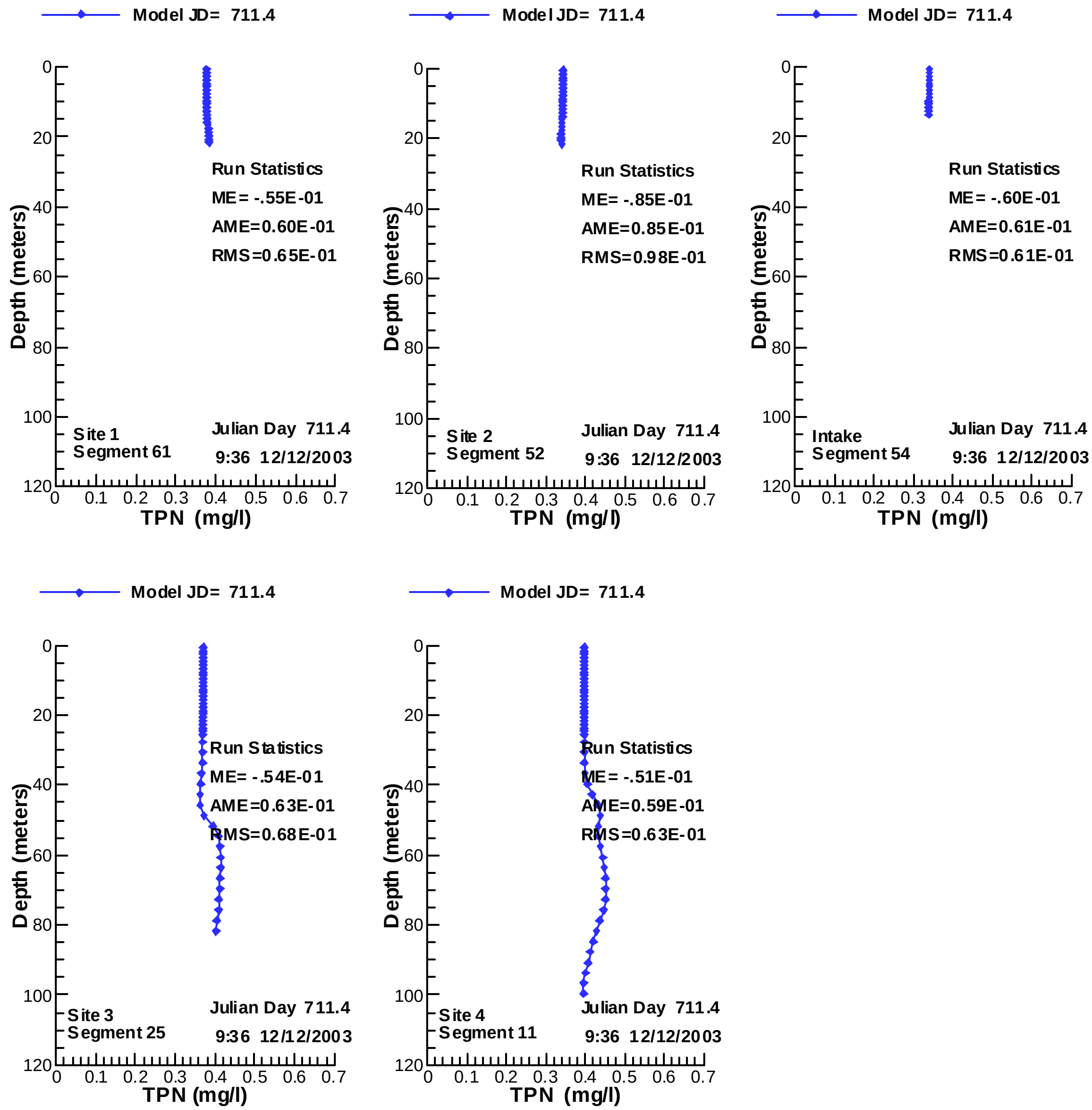

Figure 458. Vertical profiles of TPN compared with data for 12/12/2003.

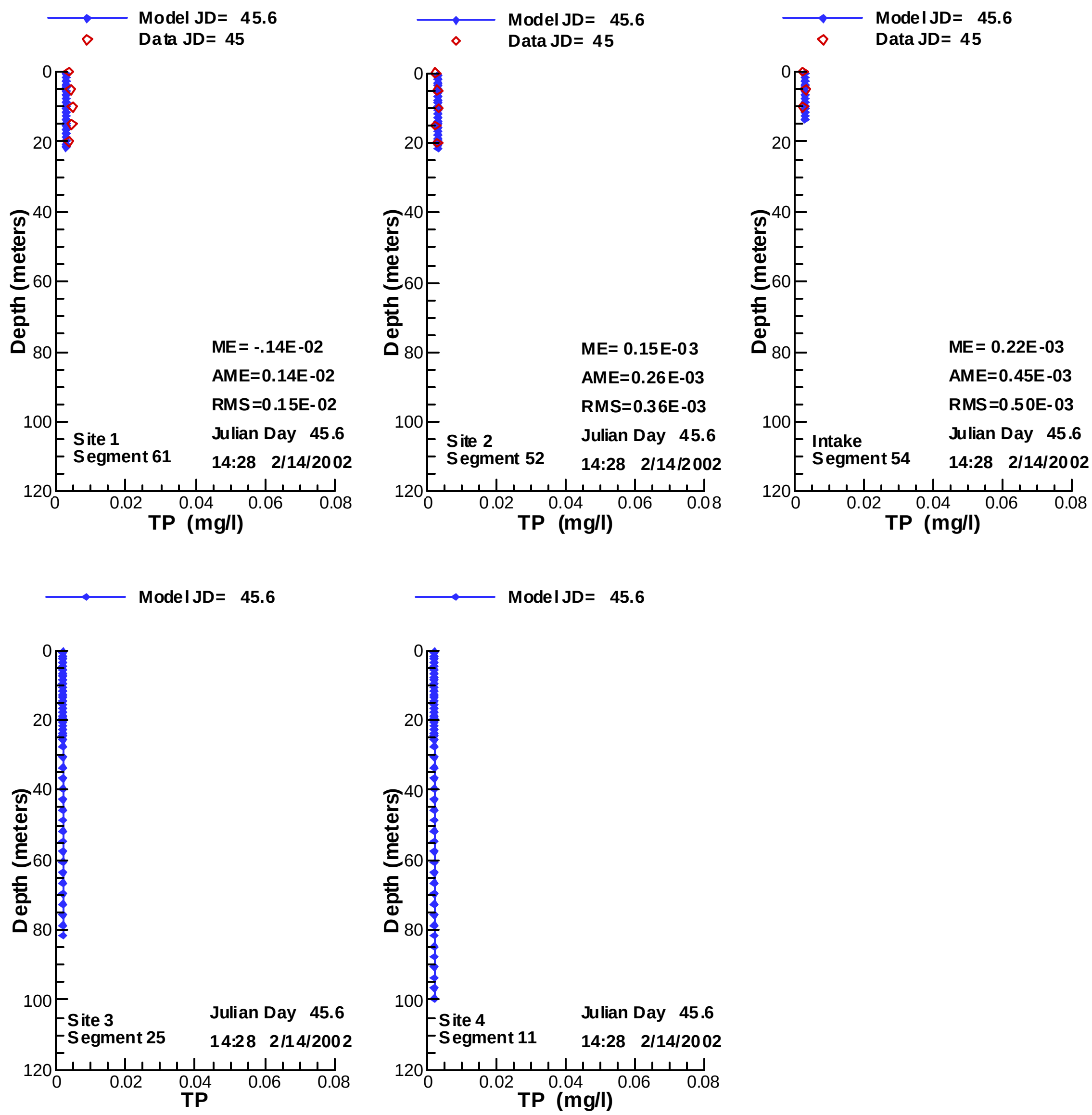

Figure 459. Vertical profiles of TP compared with data for 2/14/2002.

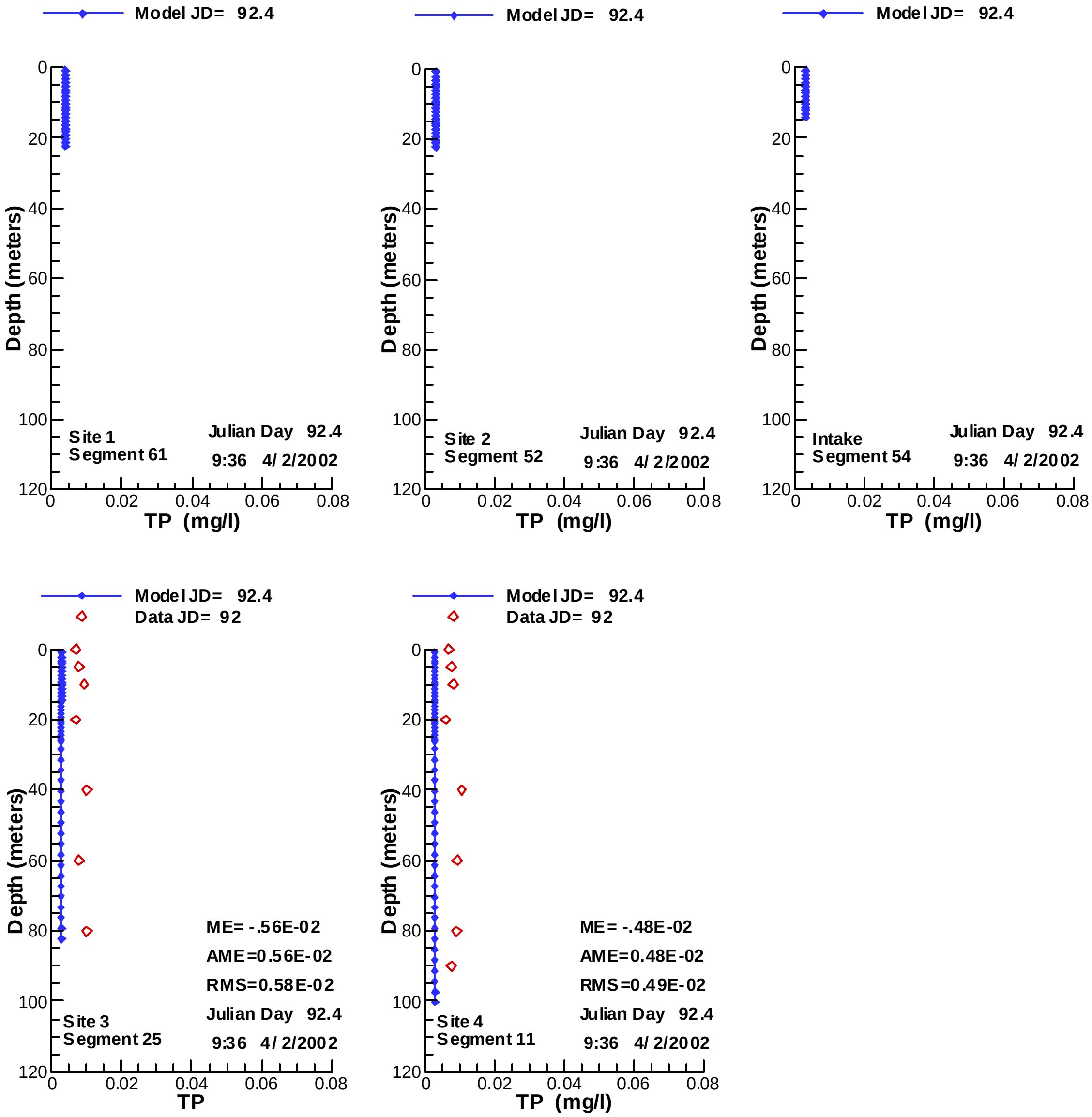

Figure 460. Vertical profiles of TP compared with data for 4/ 2/2002.

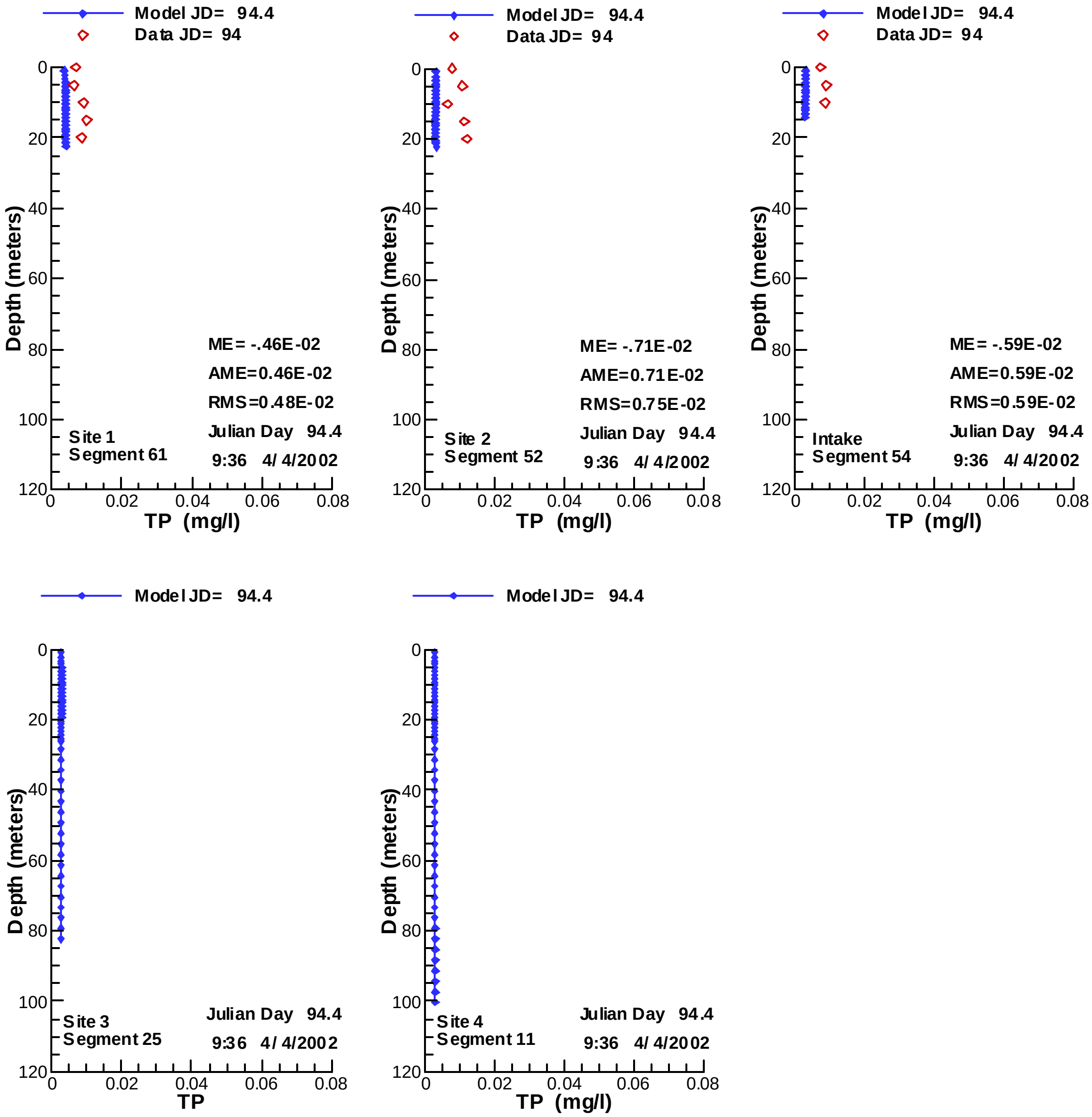

Figure 461. Vertical profiles of TP compared with data for 4/ 4/2002.

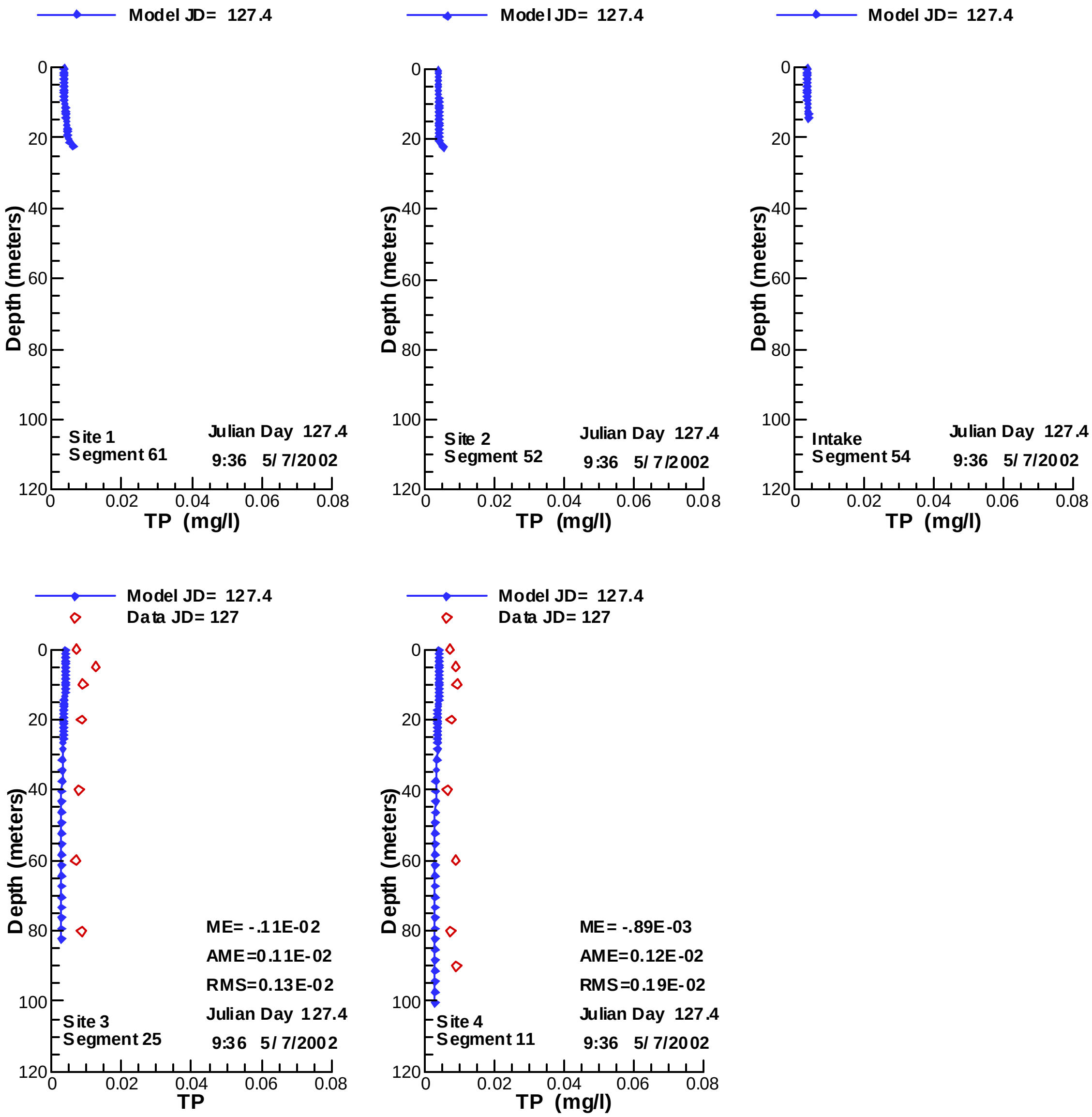

Figure 462. Vertical profiles of TP compared with data for 5/ 7/2002.

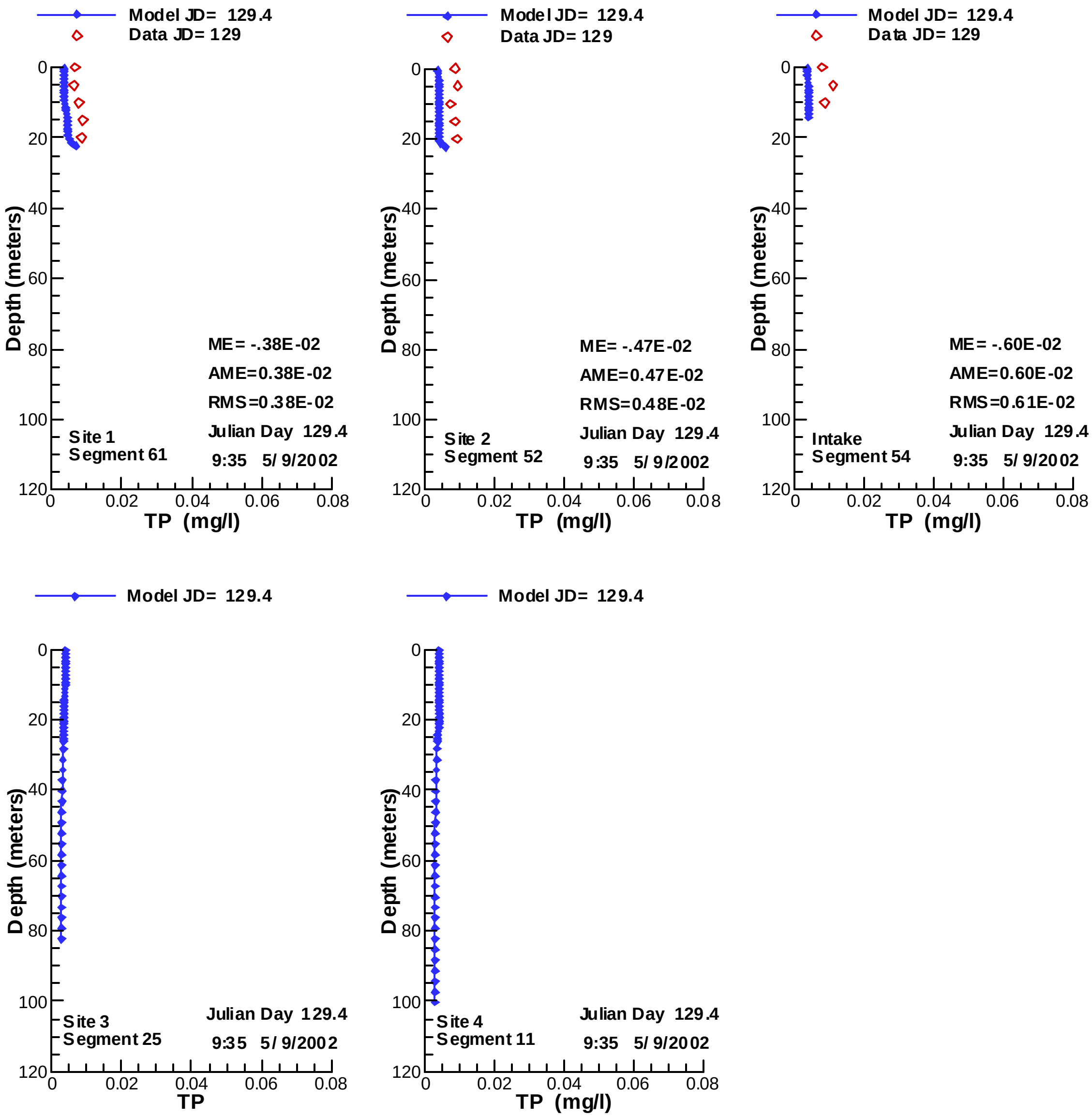

Figure 463. Vertical profiles of TP compared with data for 5/ 9/2002.

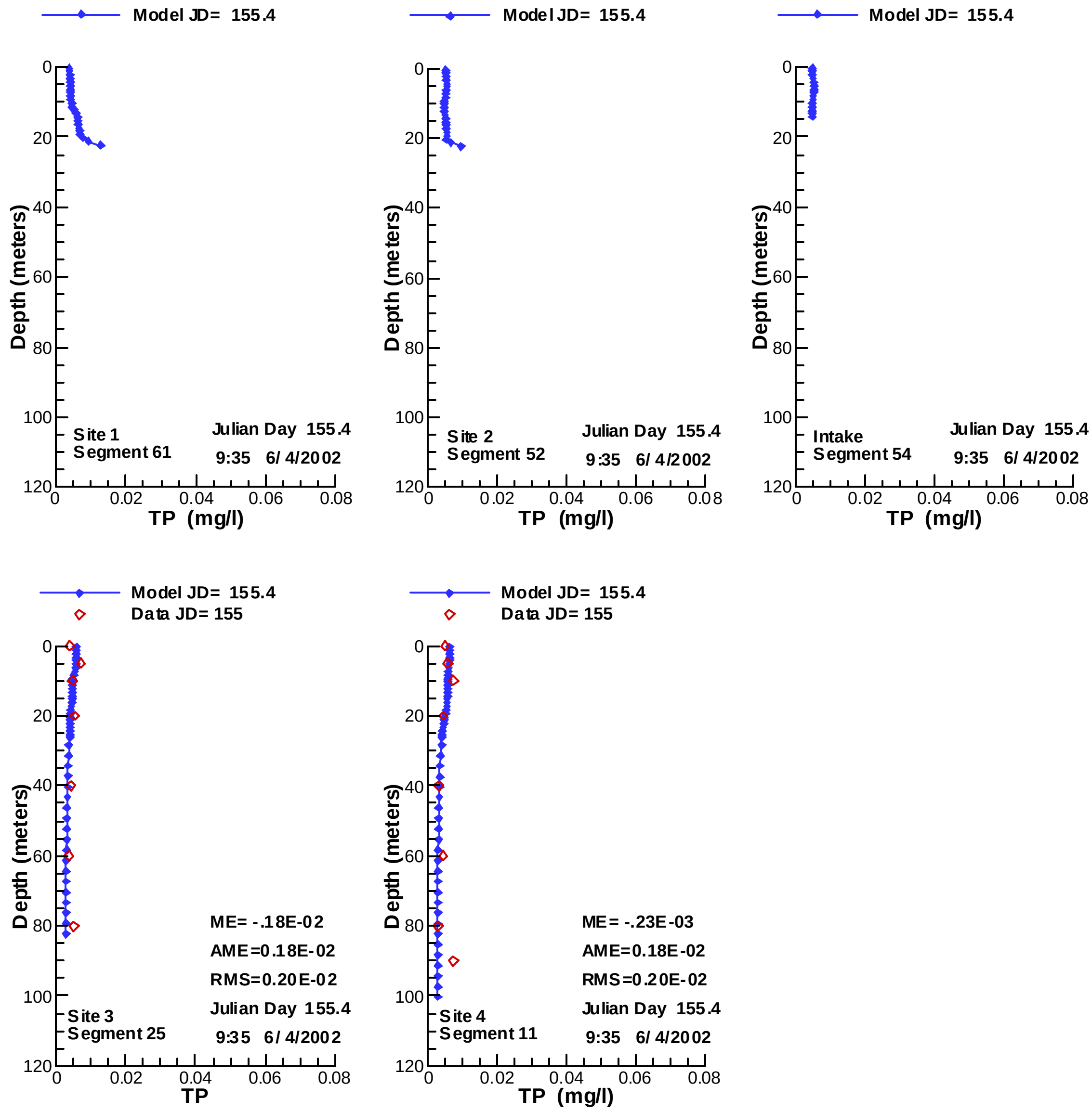

Figure 464. Vertical profiles of TP compared with data for 6/ 4/2002.

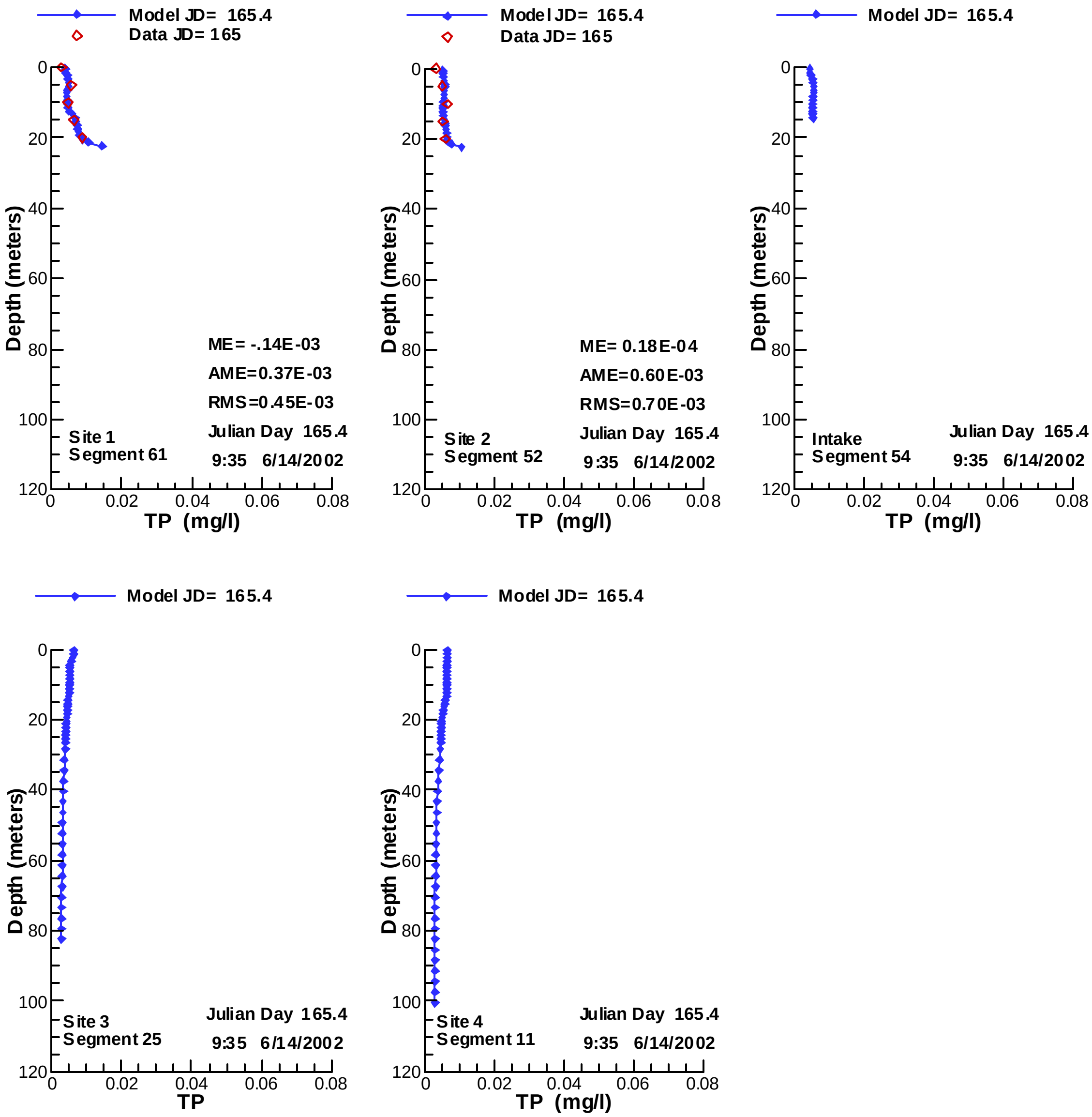

Figure 465. Vertical profiles of TP compared with data for 6/14/2002.

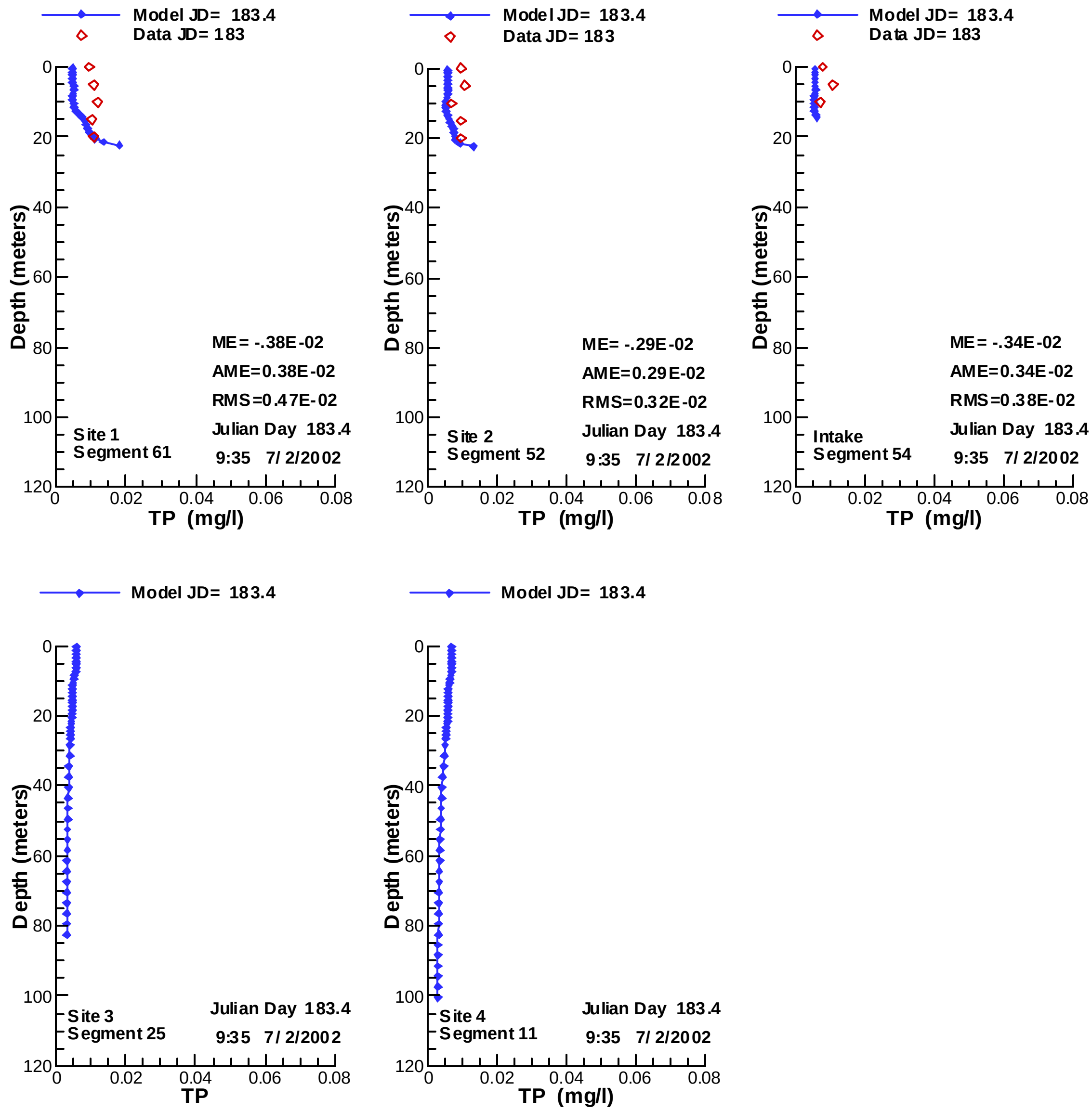

Figure 466. Vertical profiles of TP compared with data for 7/ 2/2002.

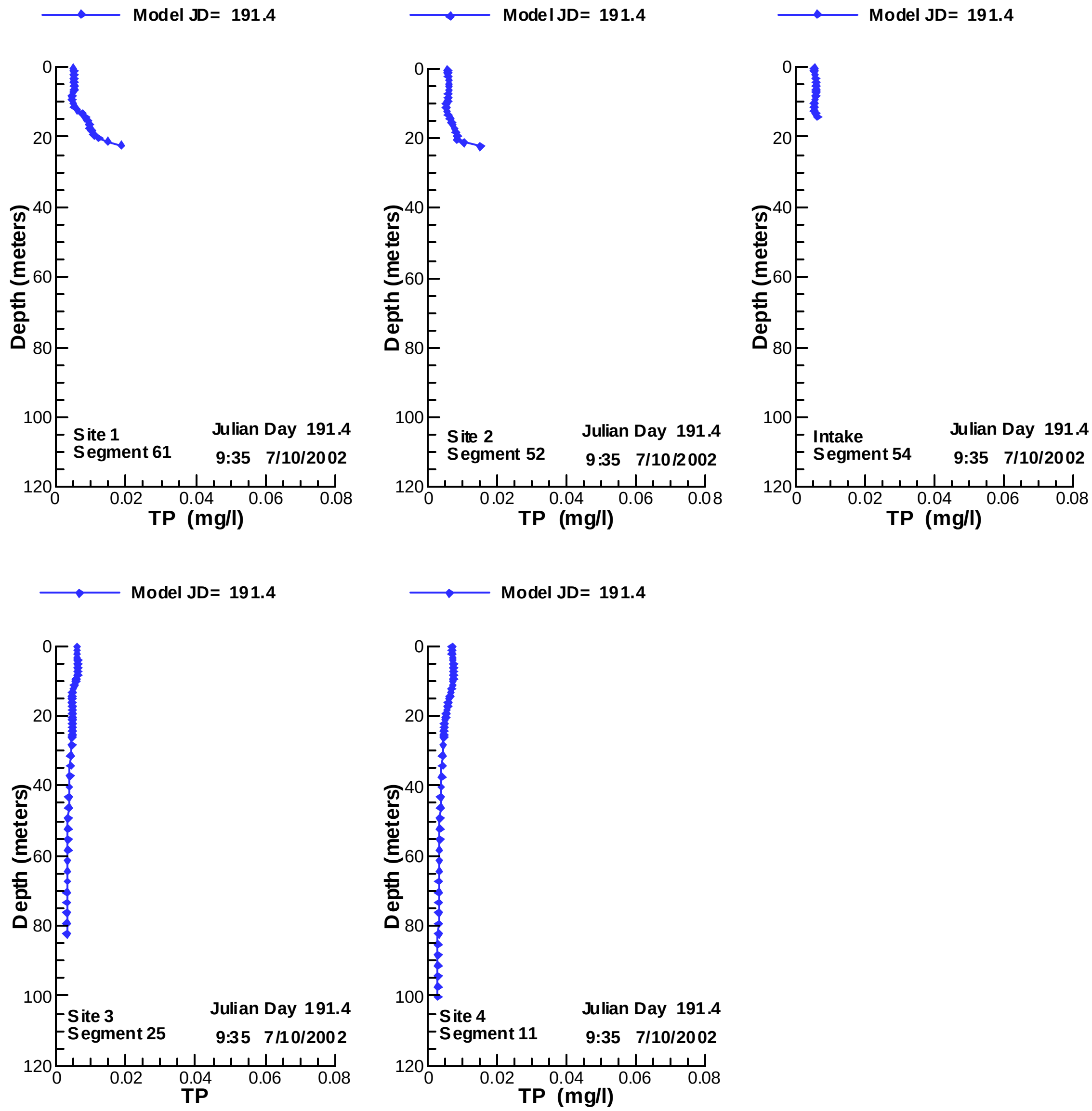

Figure 467. Vertical profiles of TP compared with data for 7/10/2002.

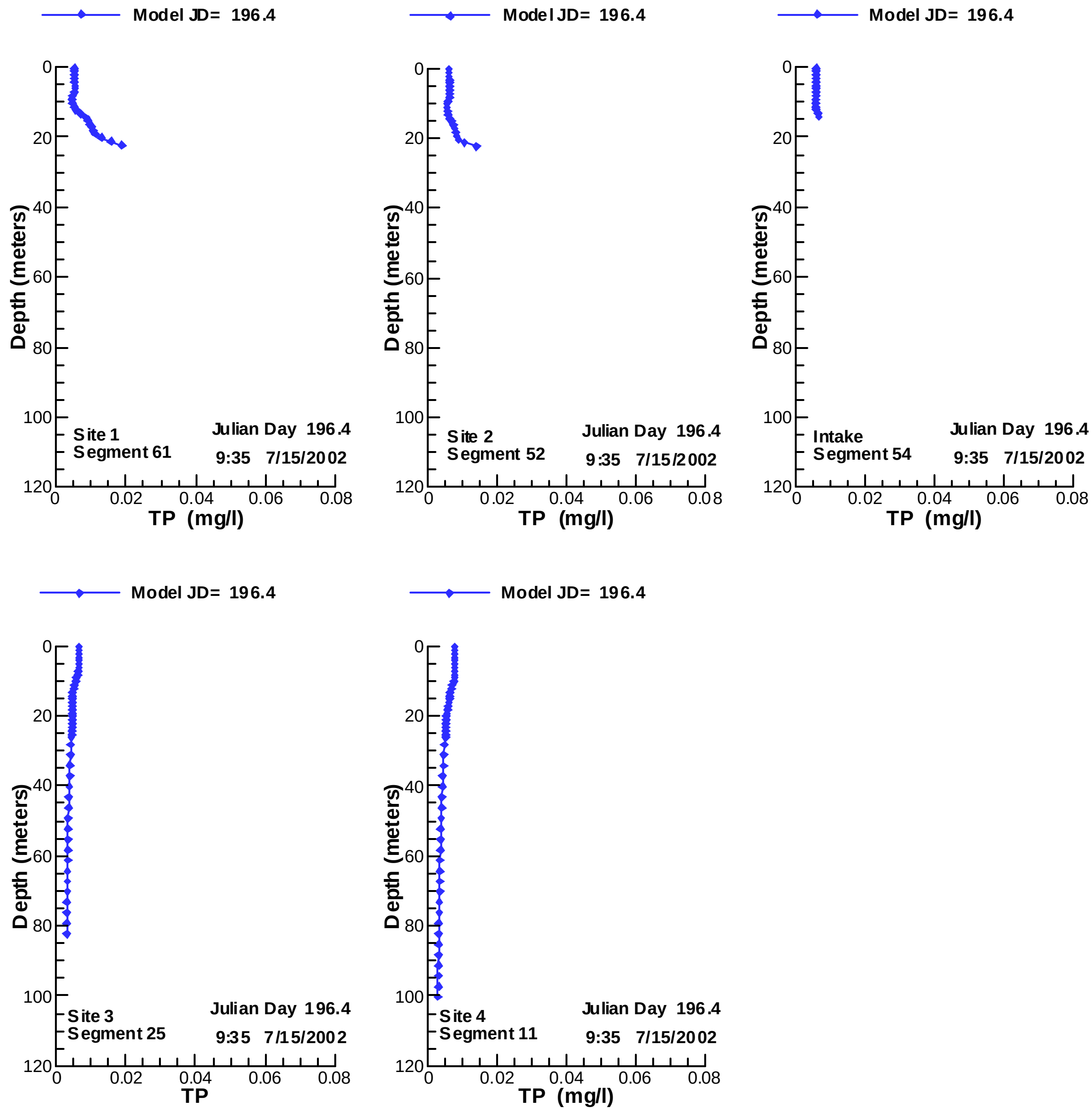

Figure 468. Vertical profiles of TP compared with data for 7/15/2002.

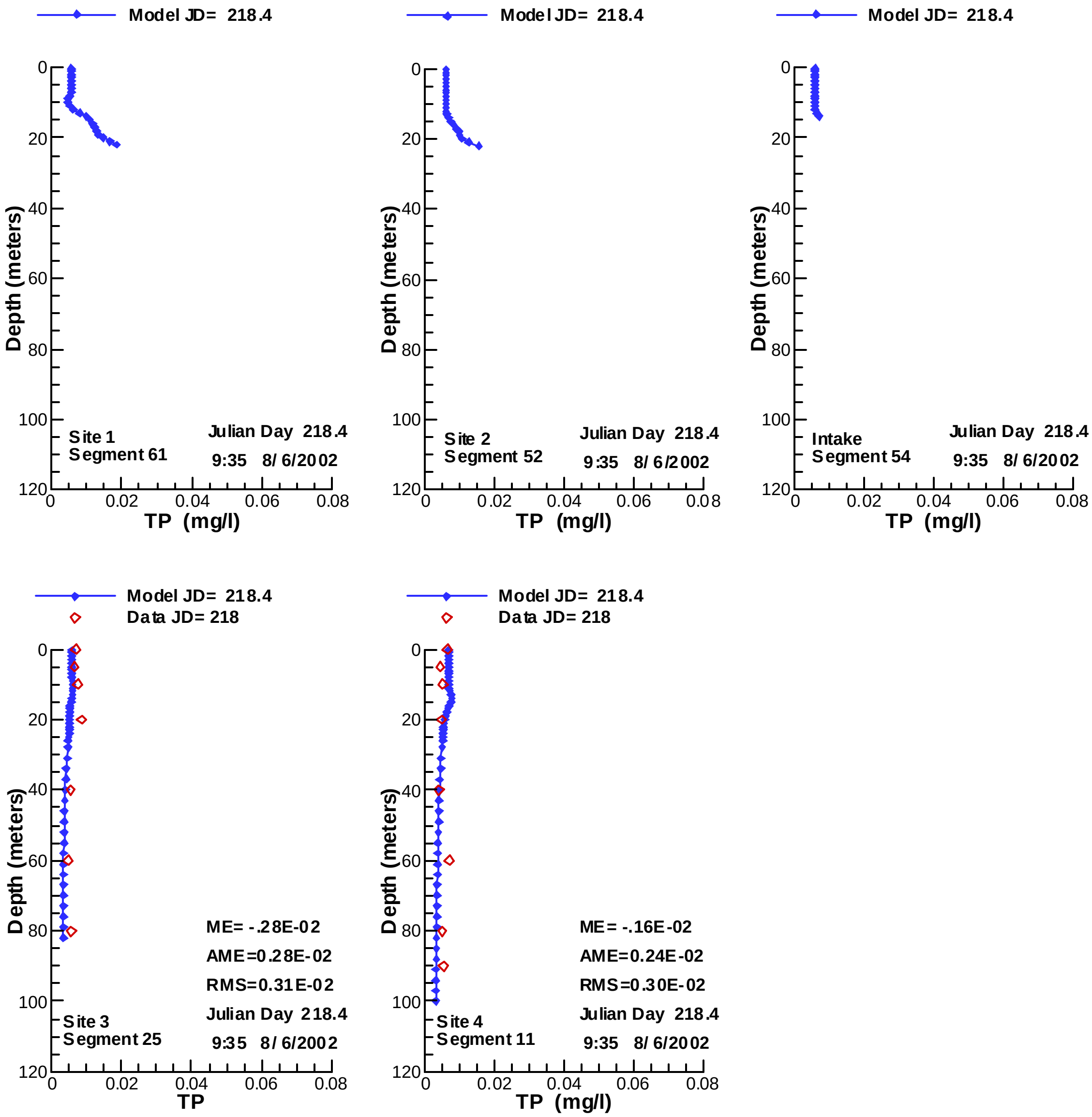

Figure 469. Vertical profiles of TP compared with data for 8/ 6/2002.

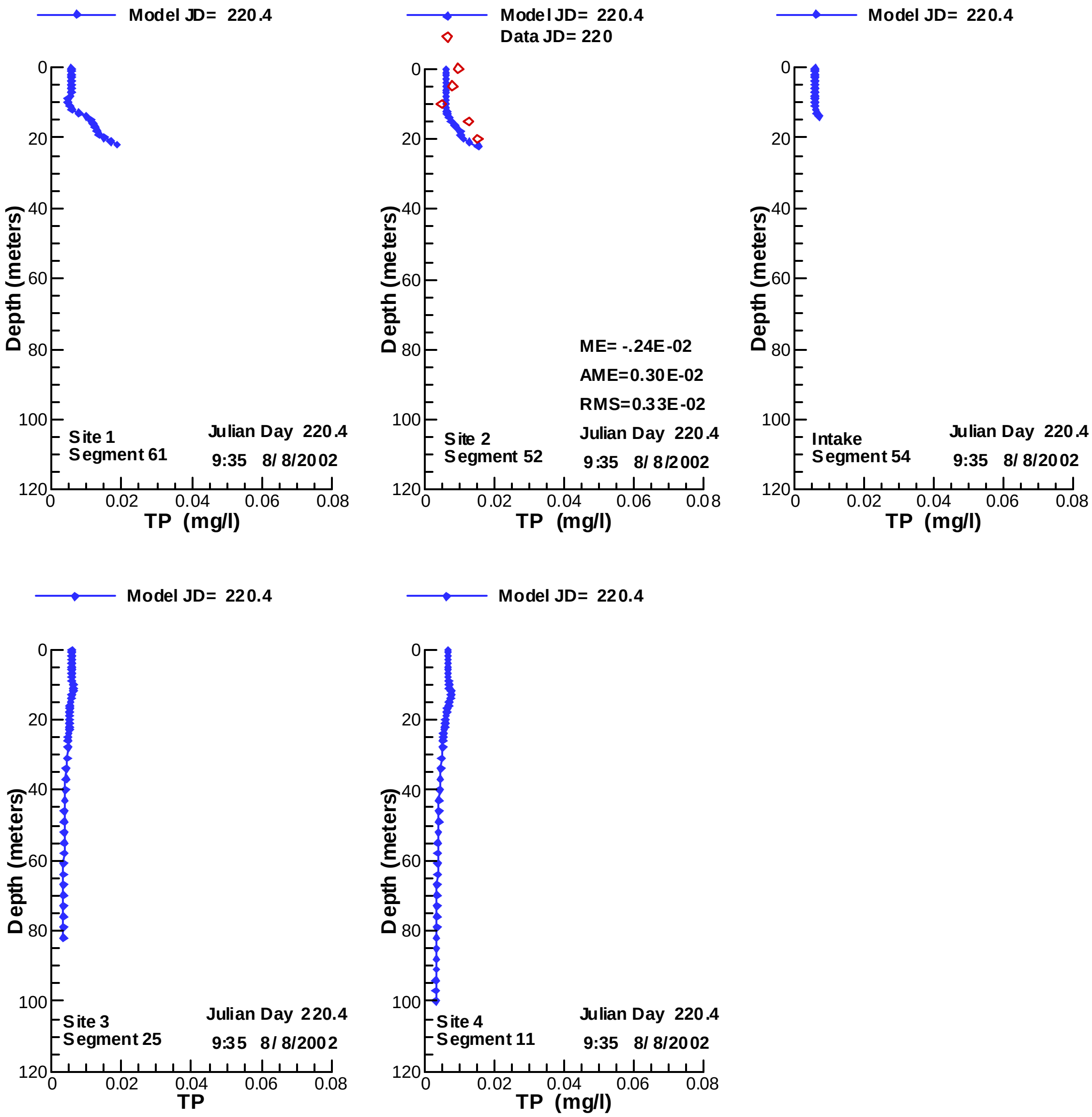

Figure 470. Vertical profiles of TP compared with data for 8/ 8/2002.

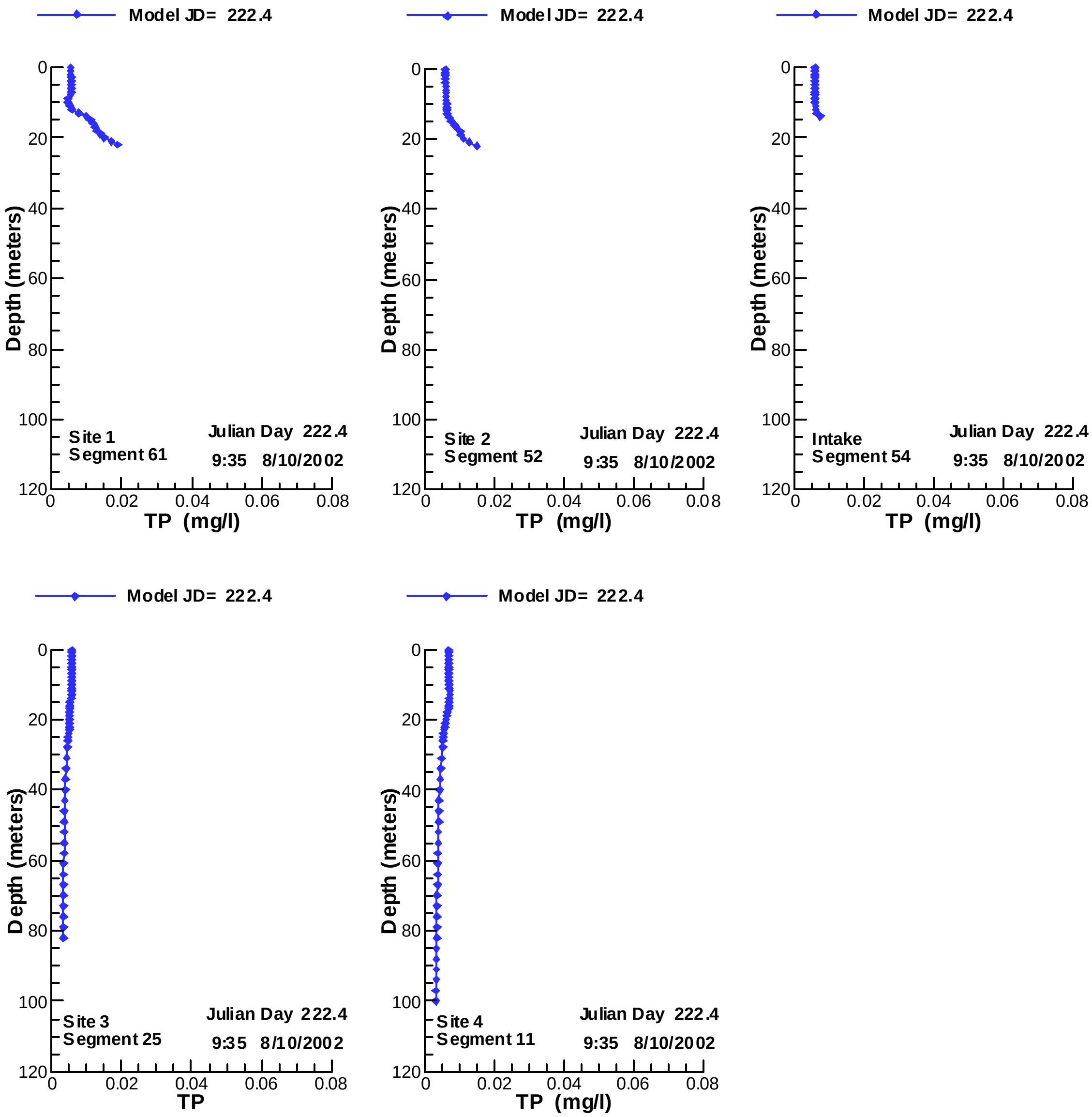

Figure 471. Vertical profiles of TP compared with data for 8/10/2002.

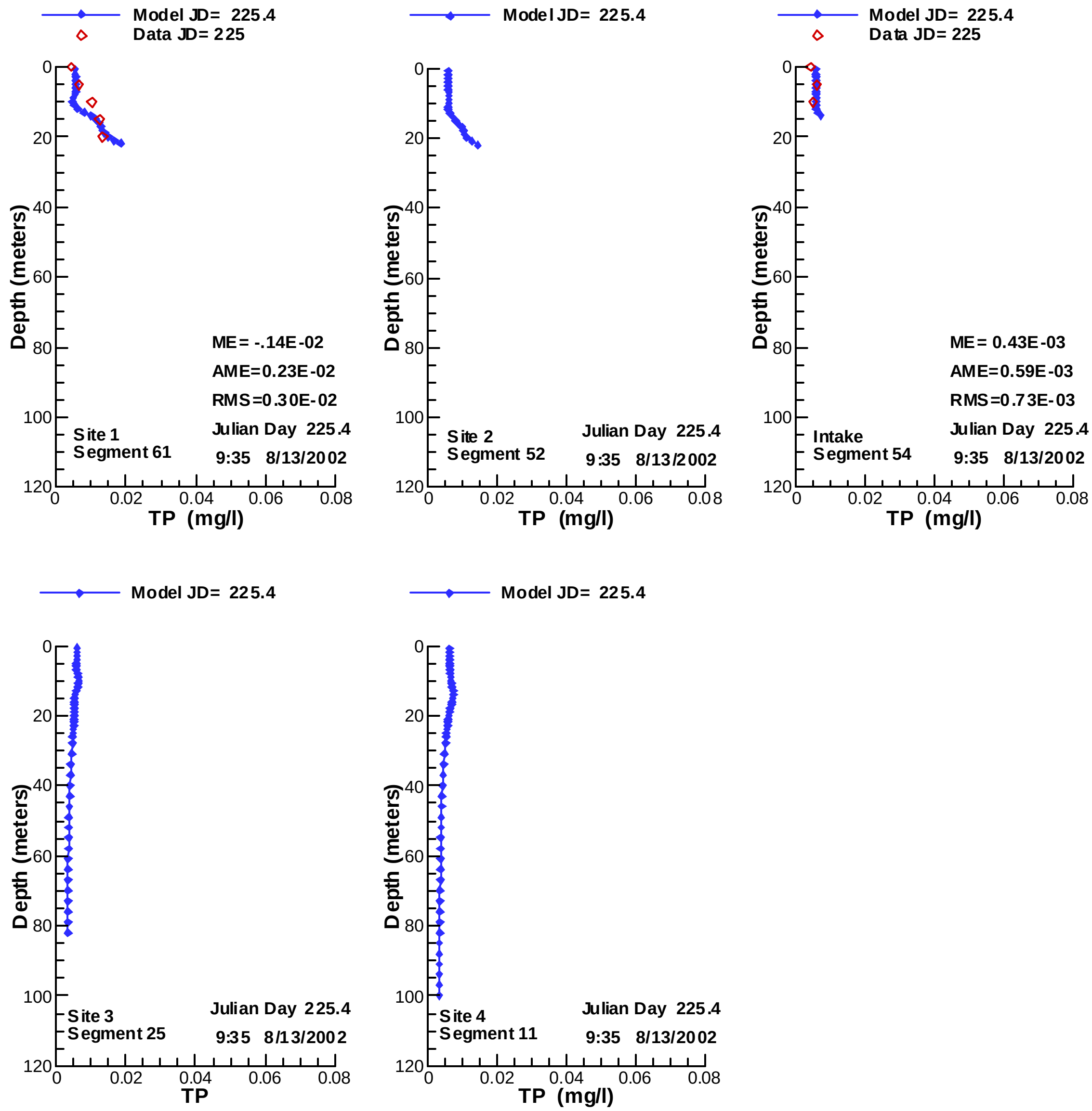

Figure 472. Vertical profiles of TP compared with data for 8/13/2002.

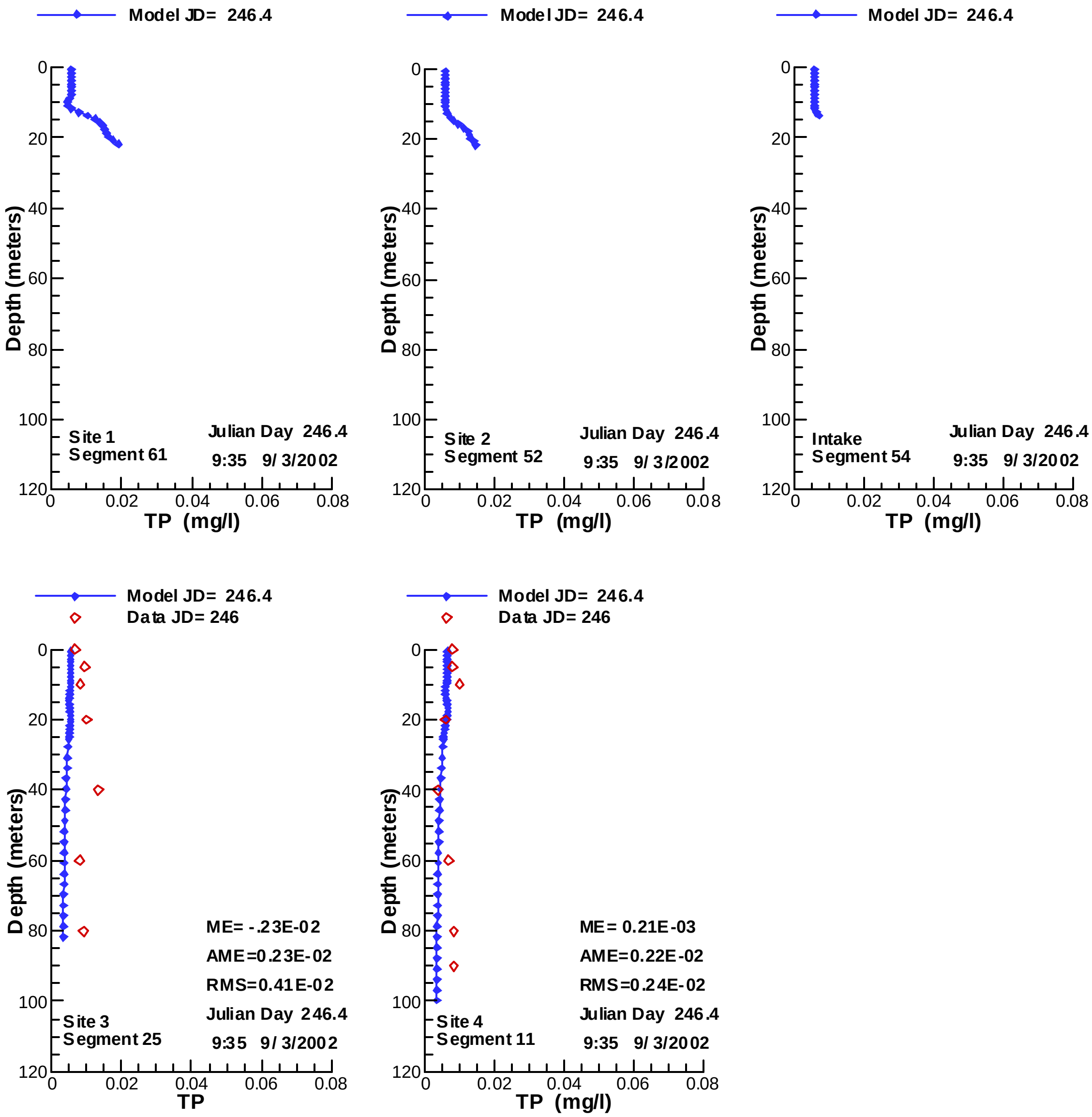

Figure 473. Vertical profiles of TP compared with data for 9/ 3/2002.

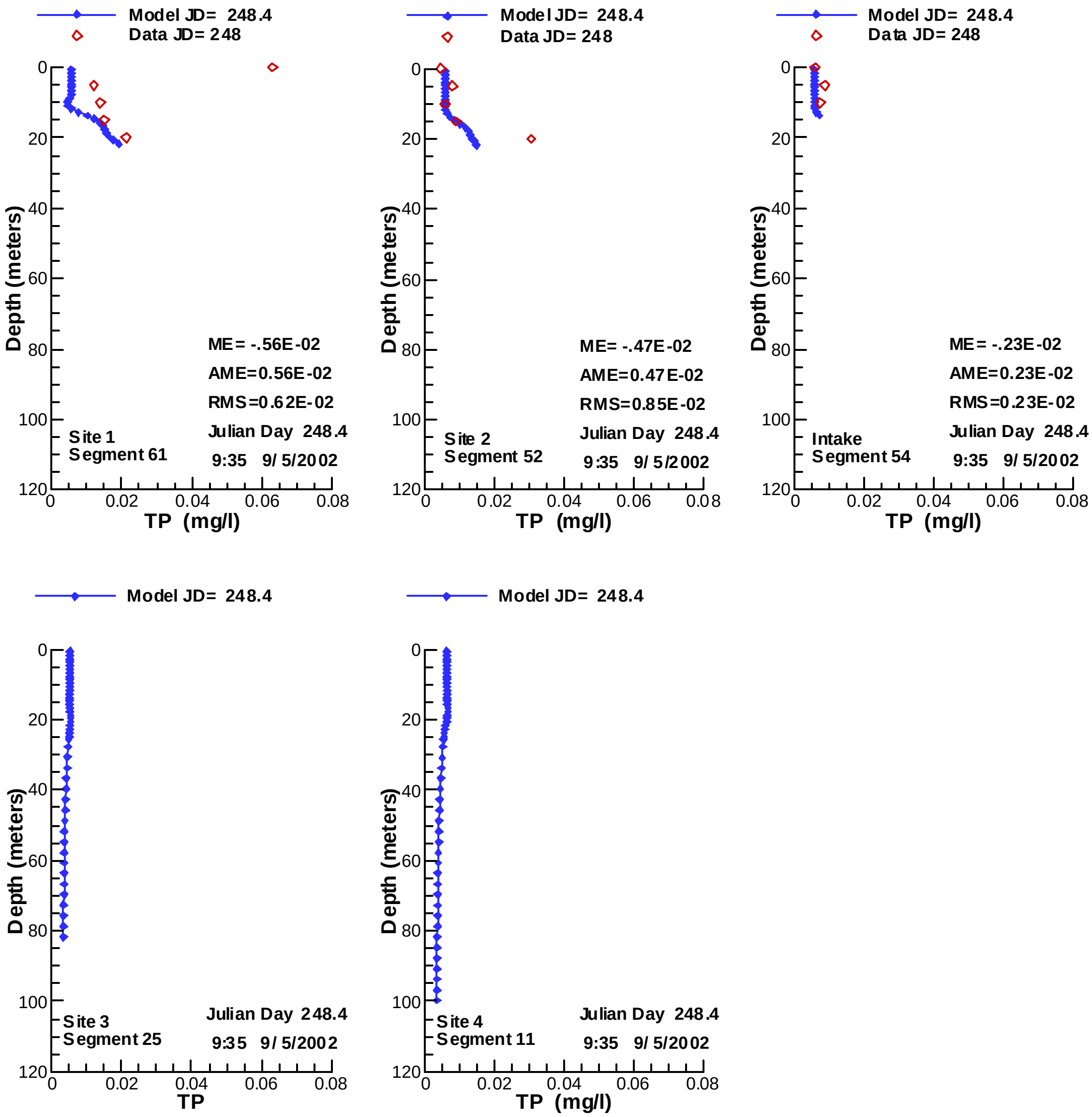

Figure 474. Vertical profiles of TP compared with data for 9/ 5/2002.

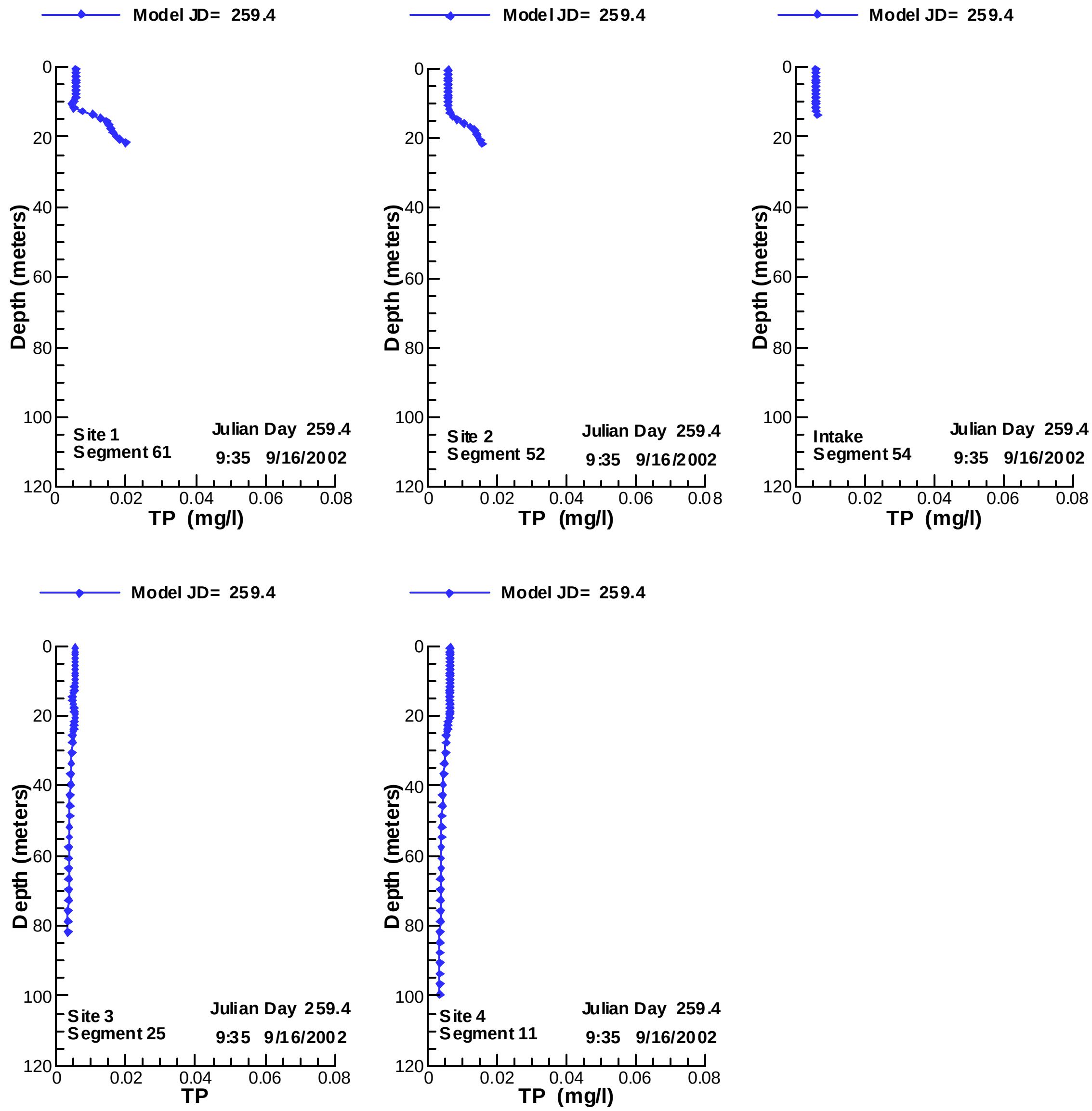

Figure 475. Vertical profiles of TP compared with data for 9/16/2002.

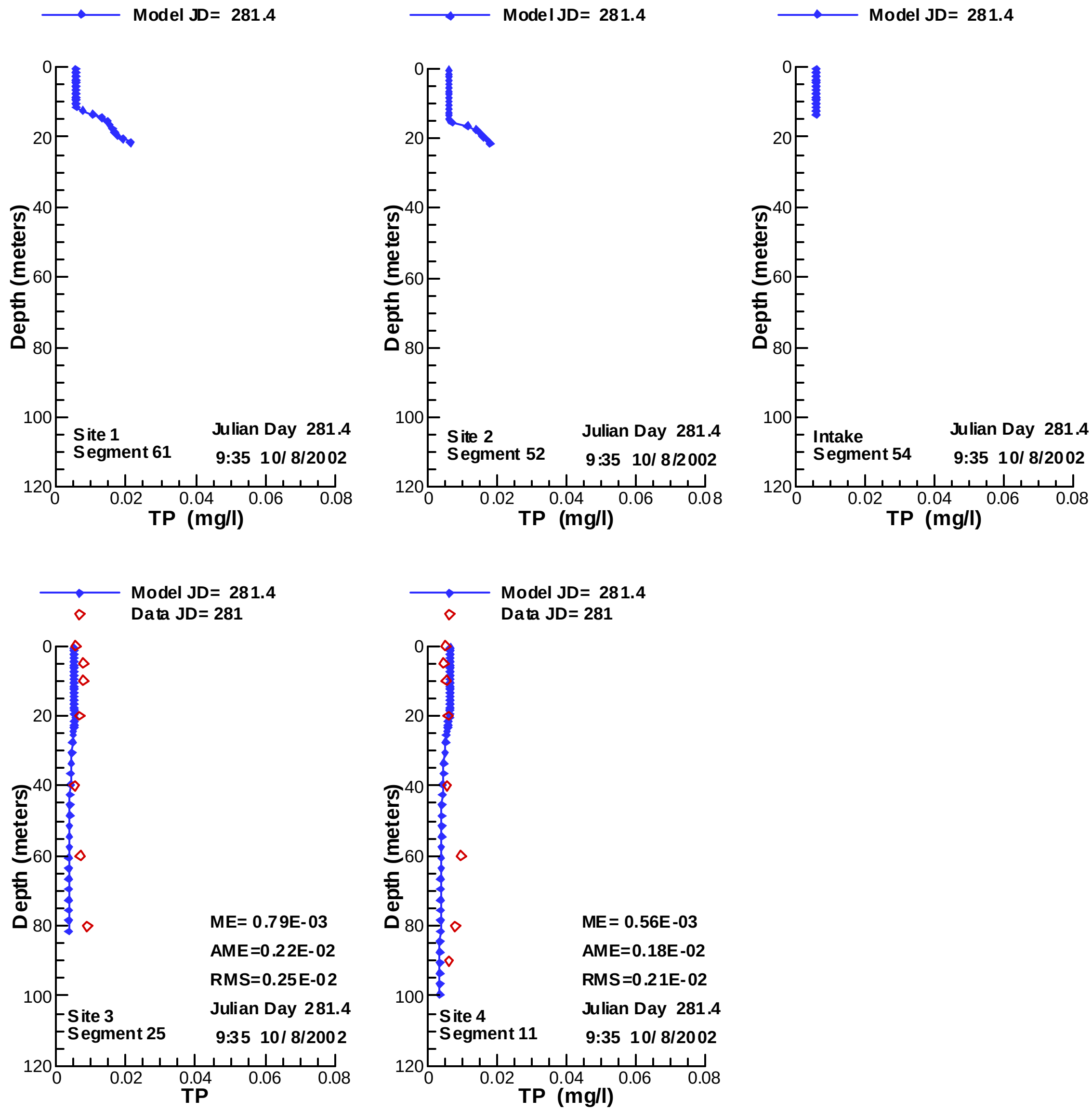

Figure 476. Vertical profiles of TP compared with data for 10/ 8/2002.

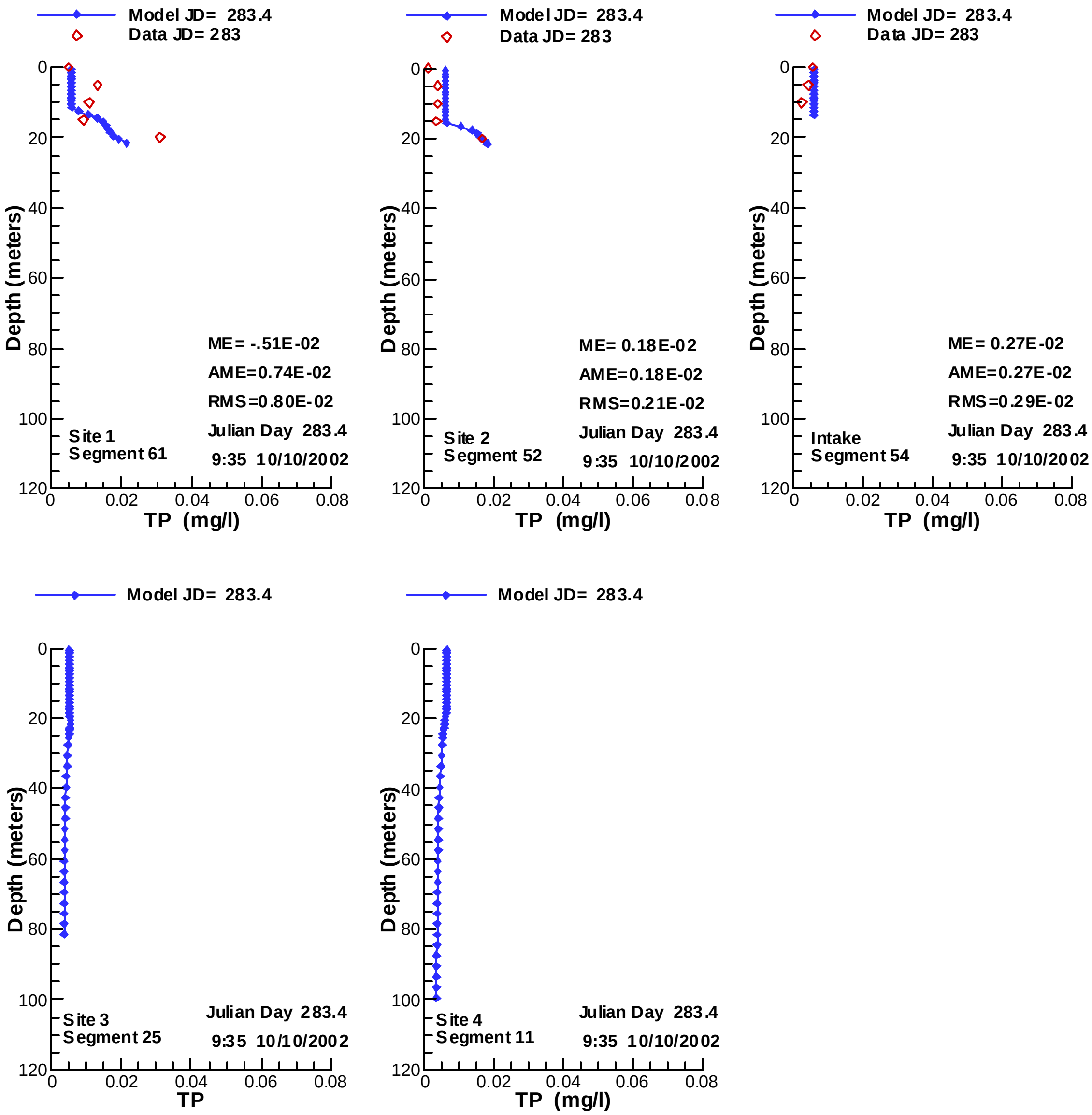

Figure 477. Vertical profiles of TP compared with data for 10/10/2002.

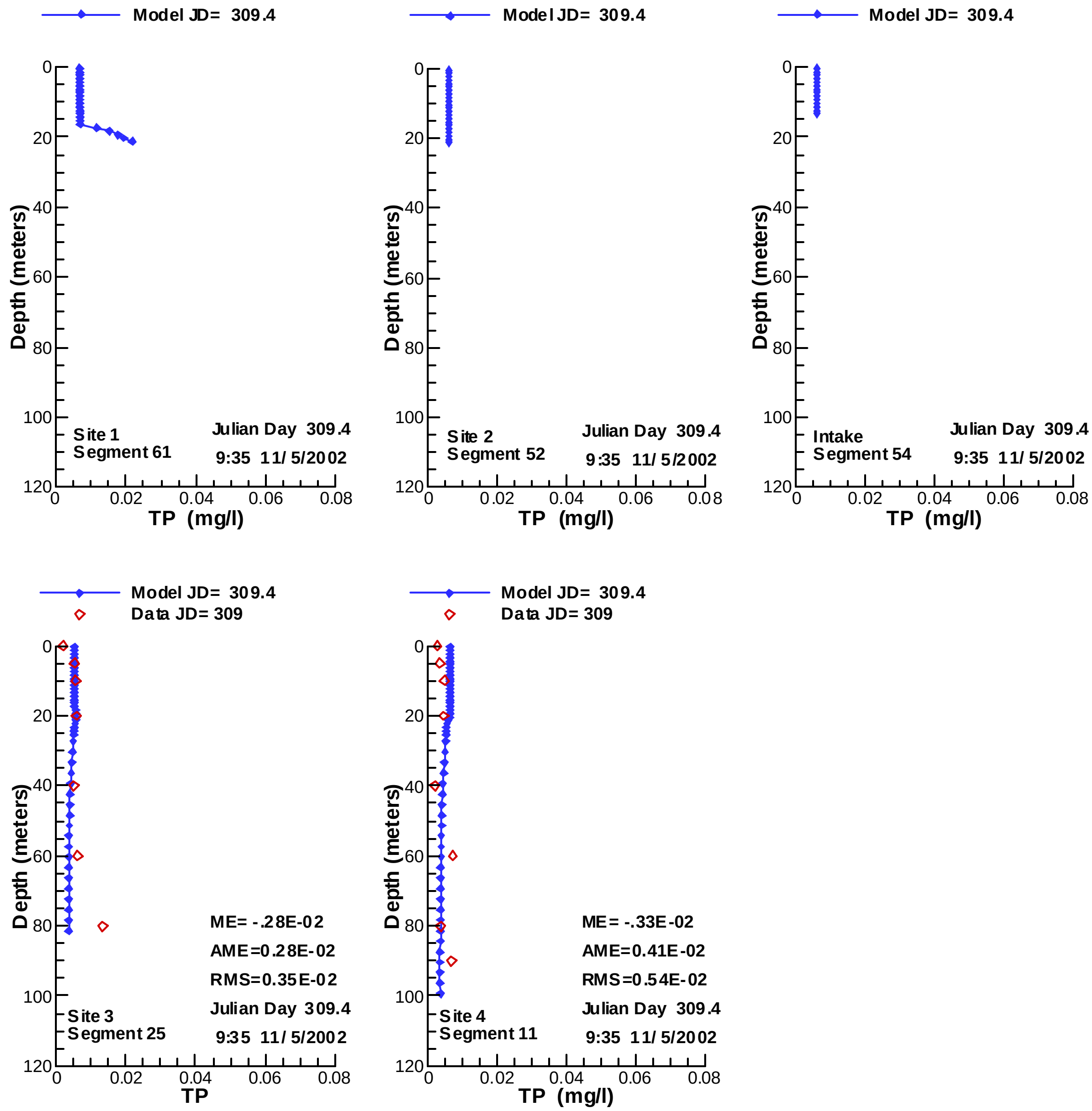

Figure 478. Vertical profiles of TP compared with data for 11/ 5/2002.

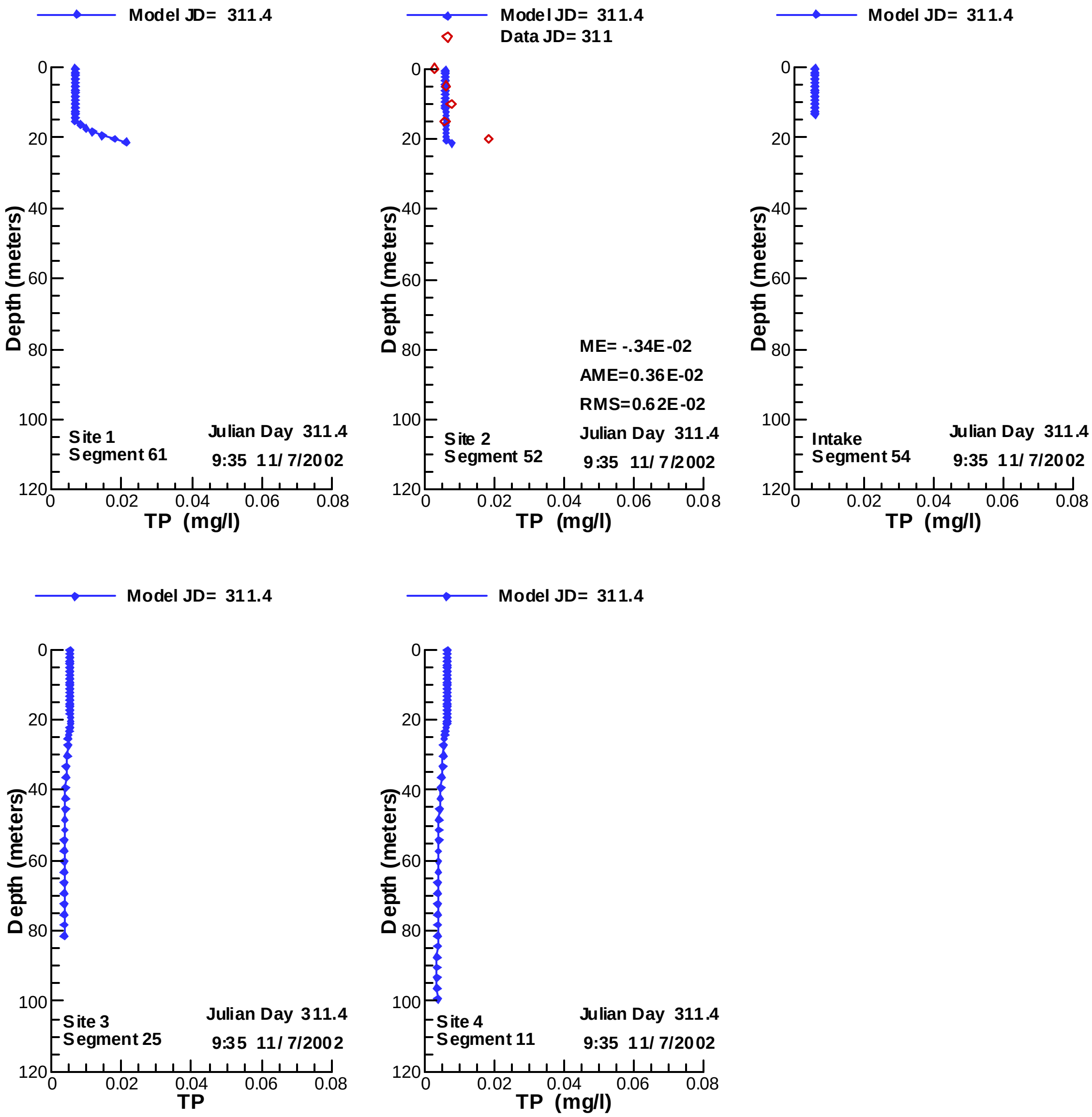

Figure 479. Vertical profiles of TP compared with data for 11/ 7/2002.

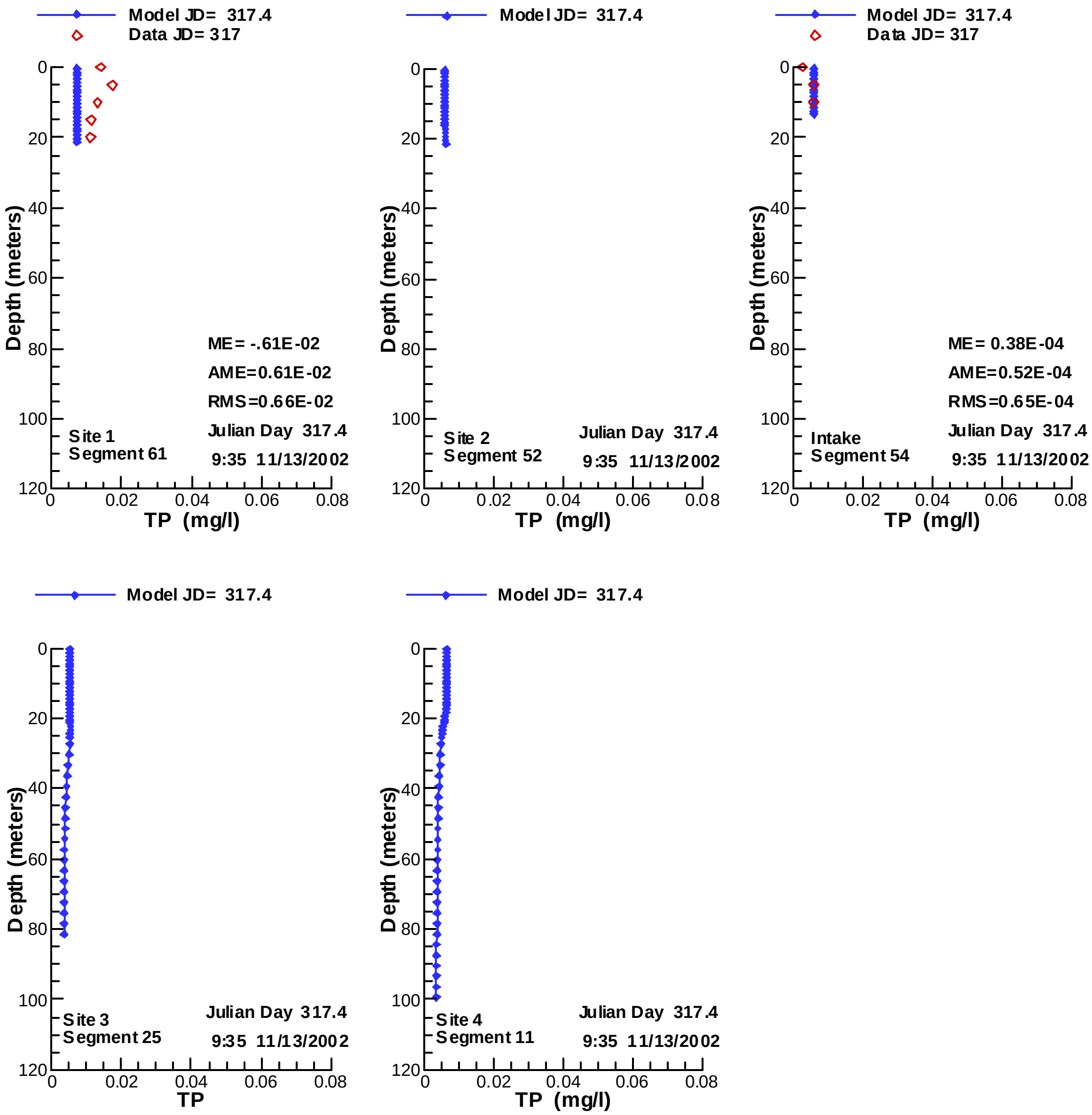

Figure 480. Vertical profiles of TP compared with data for 11/13/2002.

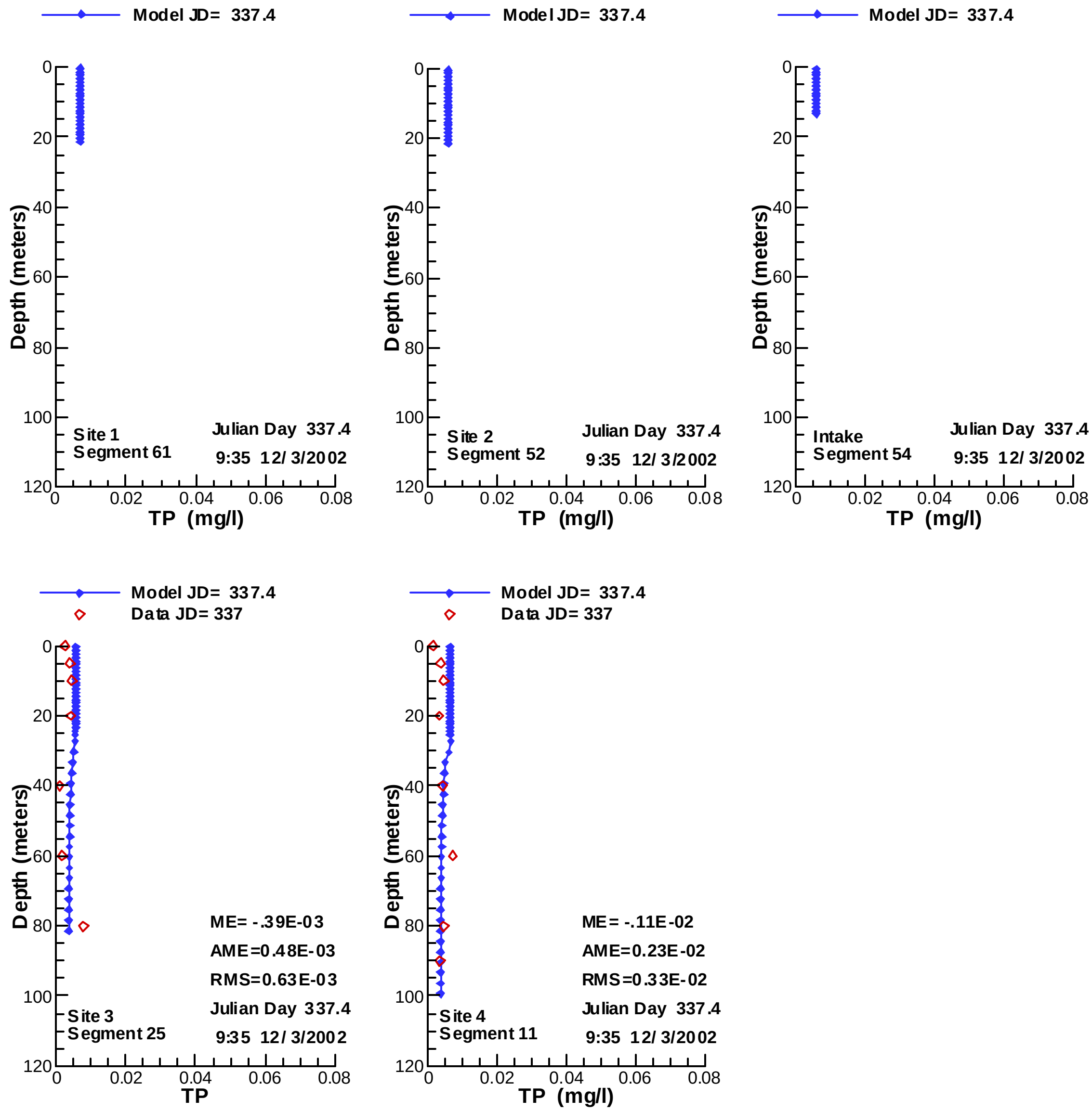

Figure 481. Vertical profiles of TP compared with data for 12/ 3/2002.

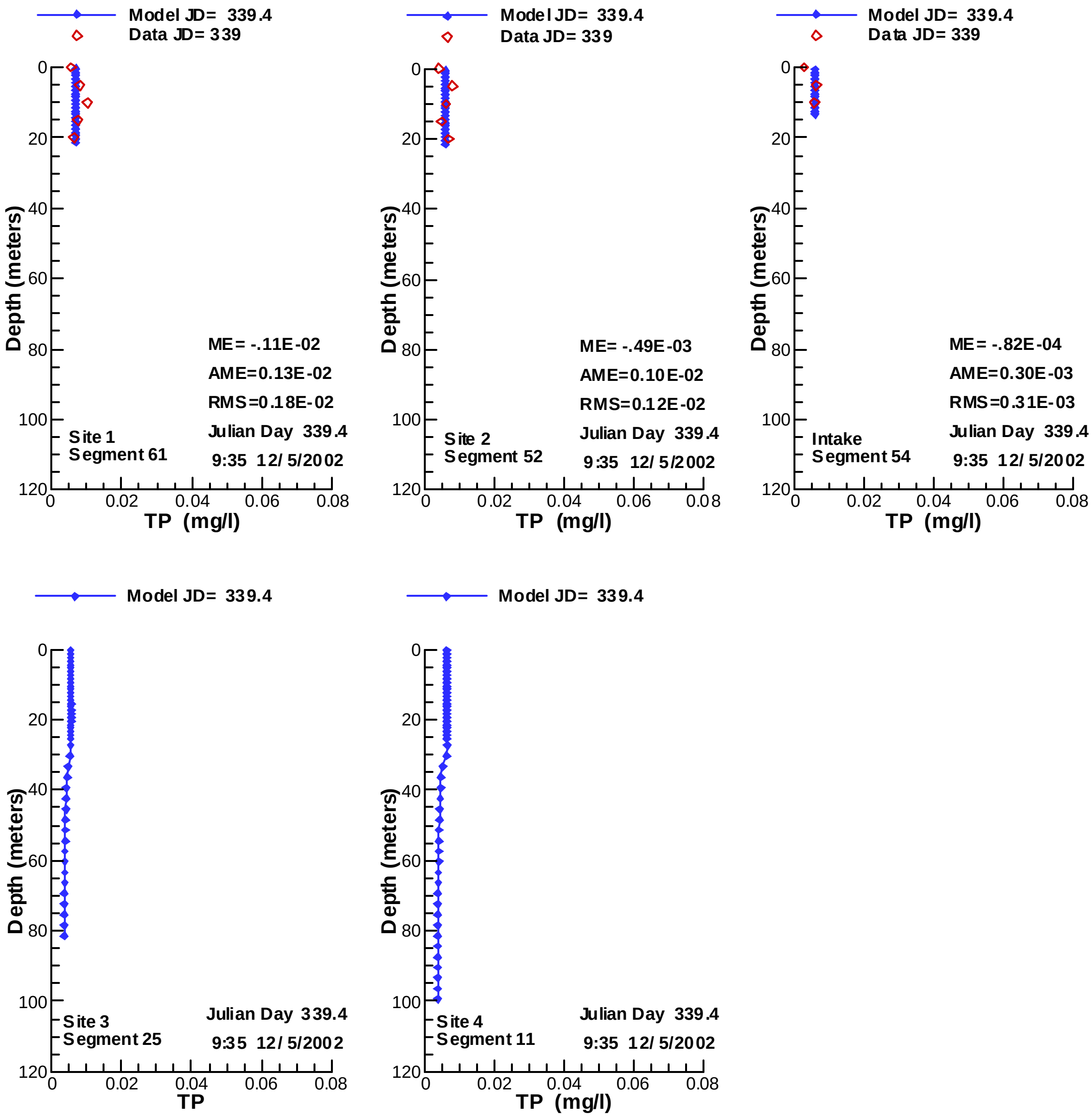

Figure 482. Vertical profiles of TP compared with data for 12/ 5/2002.

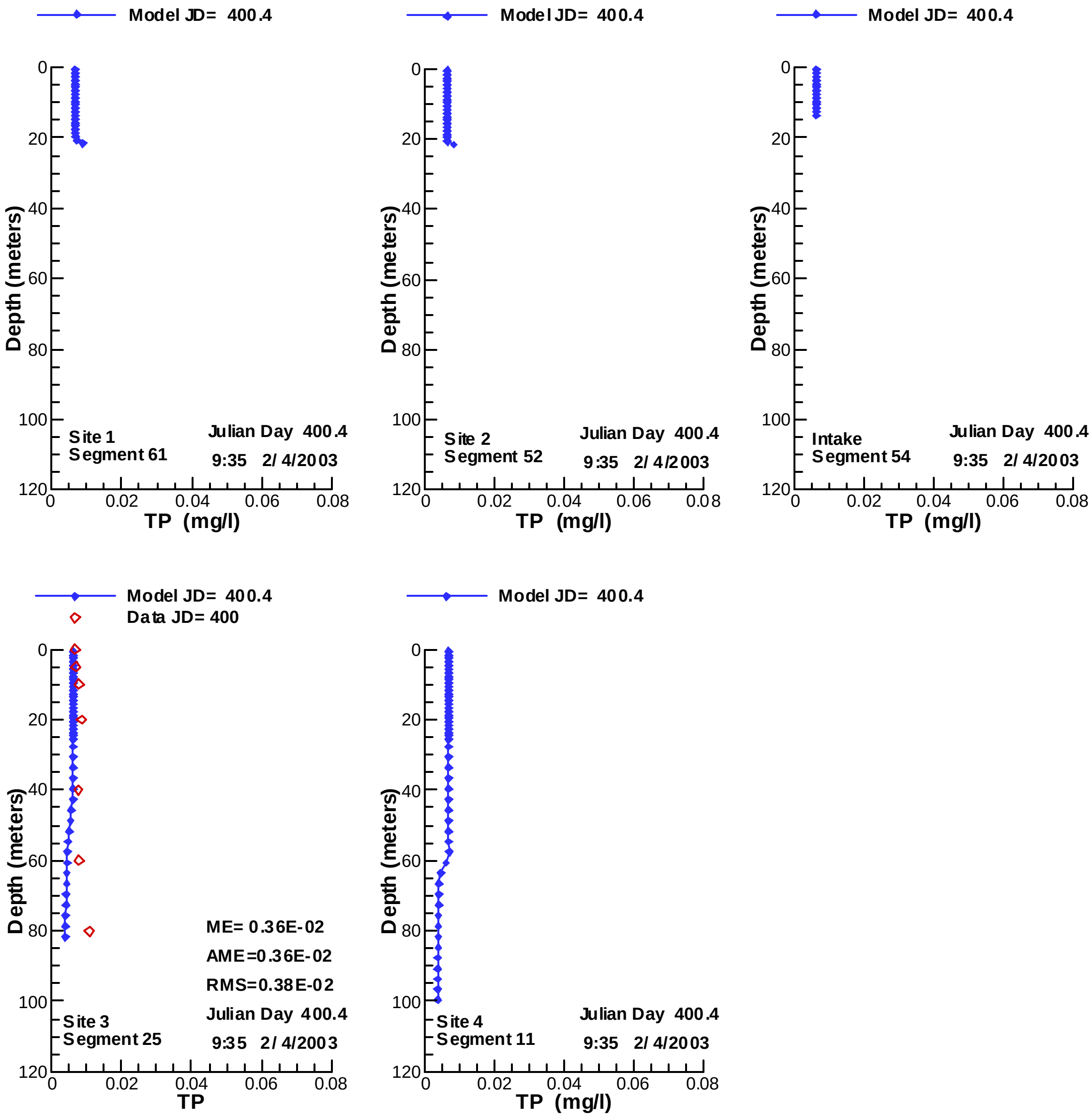

Figure 483. Vertical profiles of TP compared with data for 2/ 4/2003.

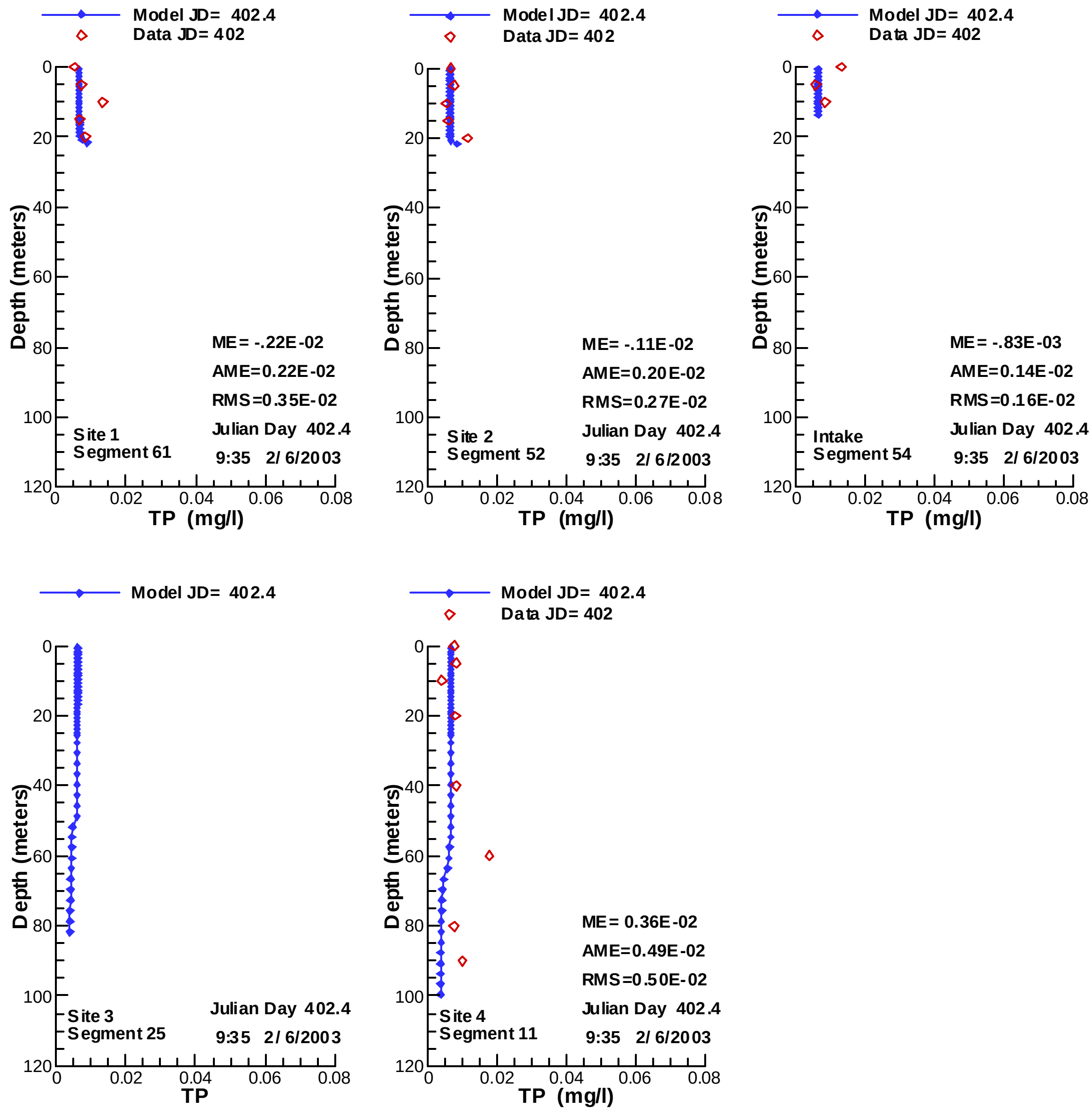

Figure 484. Vertical profiles of TP compared with data for 2/ 6/2003.

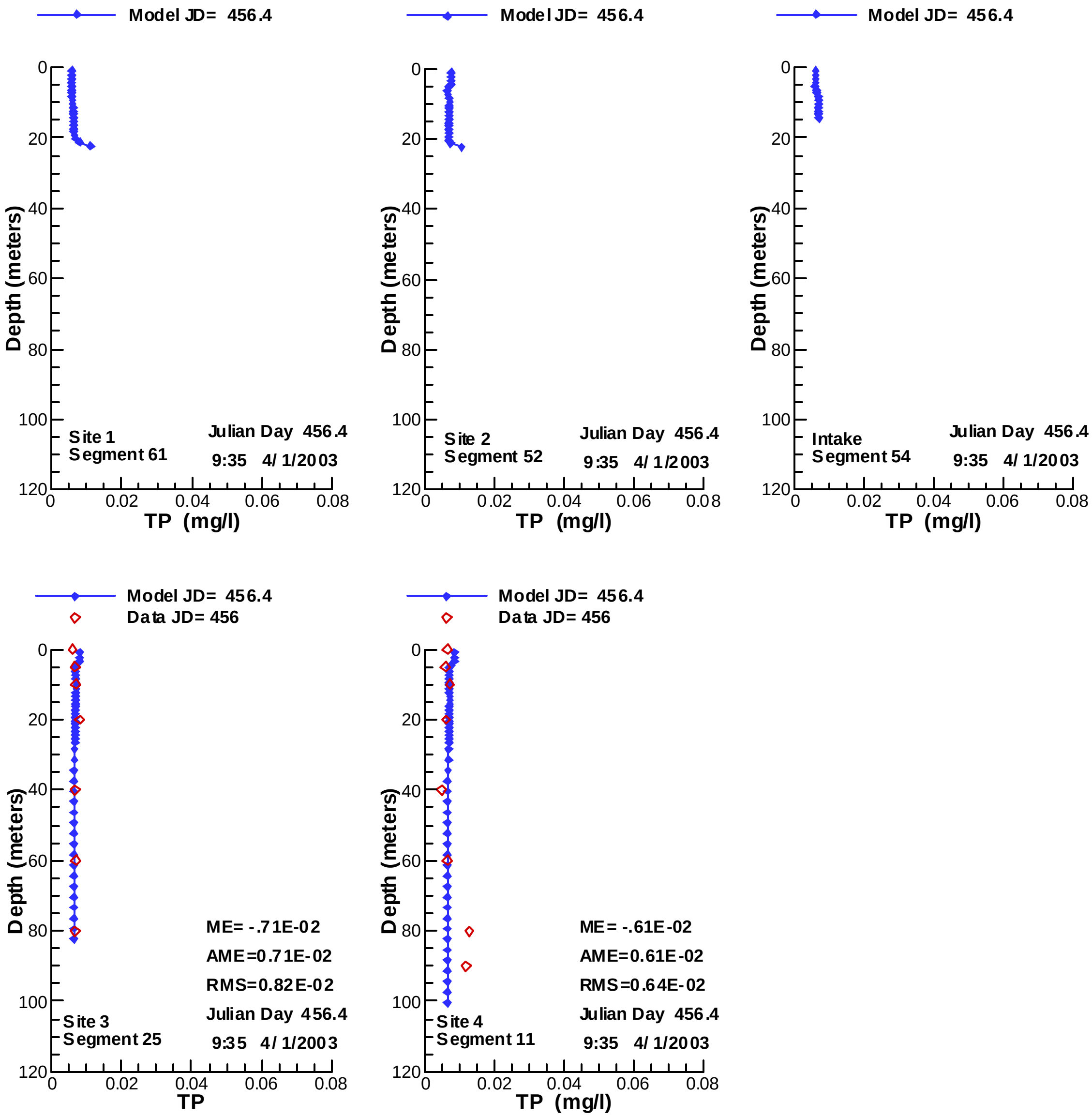

Figure 485. Vertical profiles of TP compared with data for 4/ 1/2003.

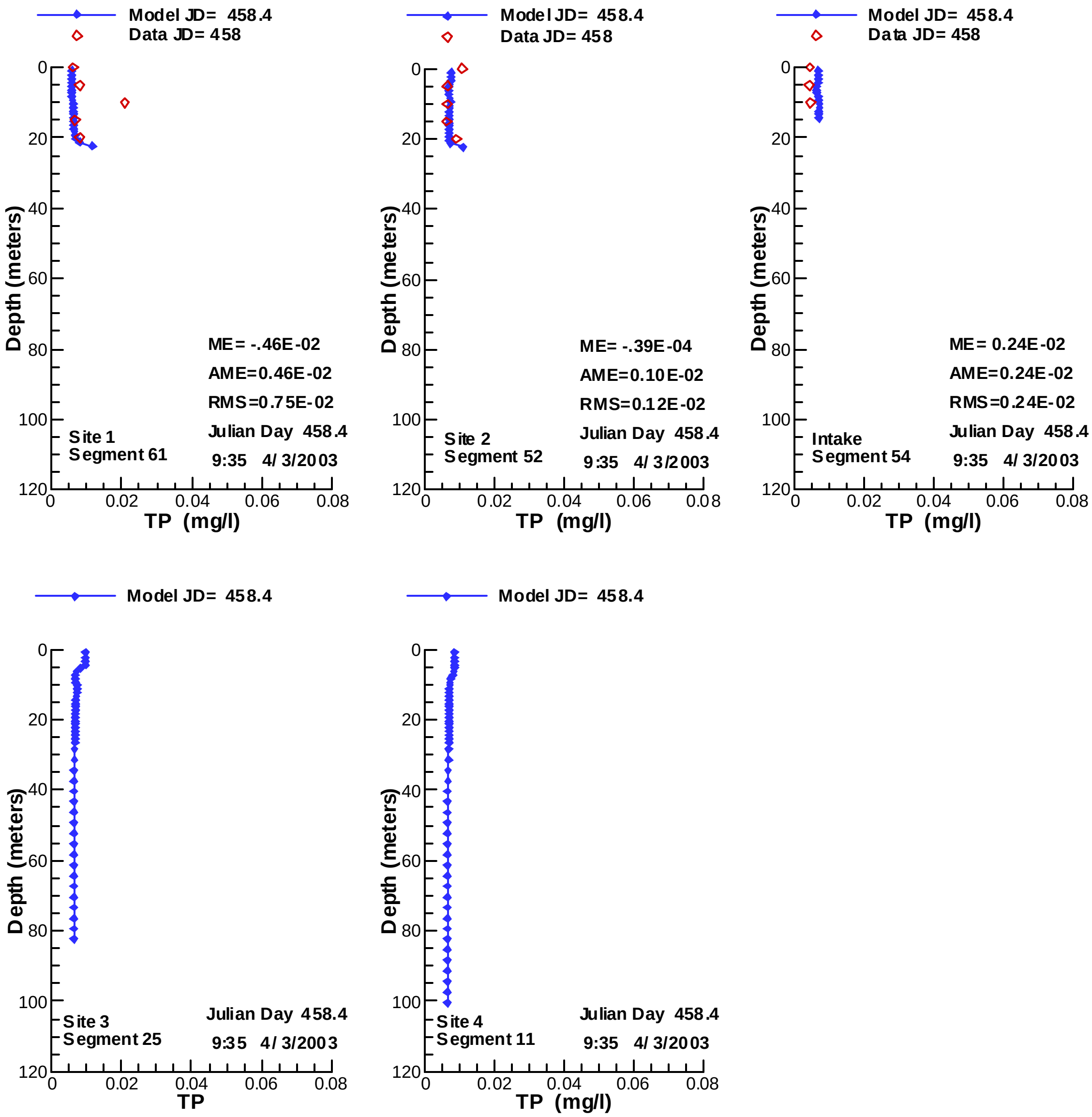

Figure 486. Vertical profiles of TP compared with data for 4/ 3/2003.

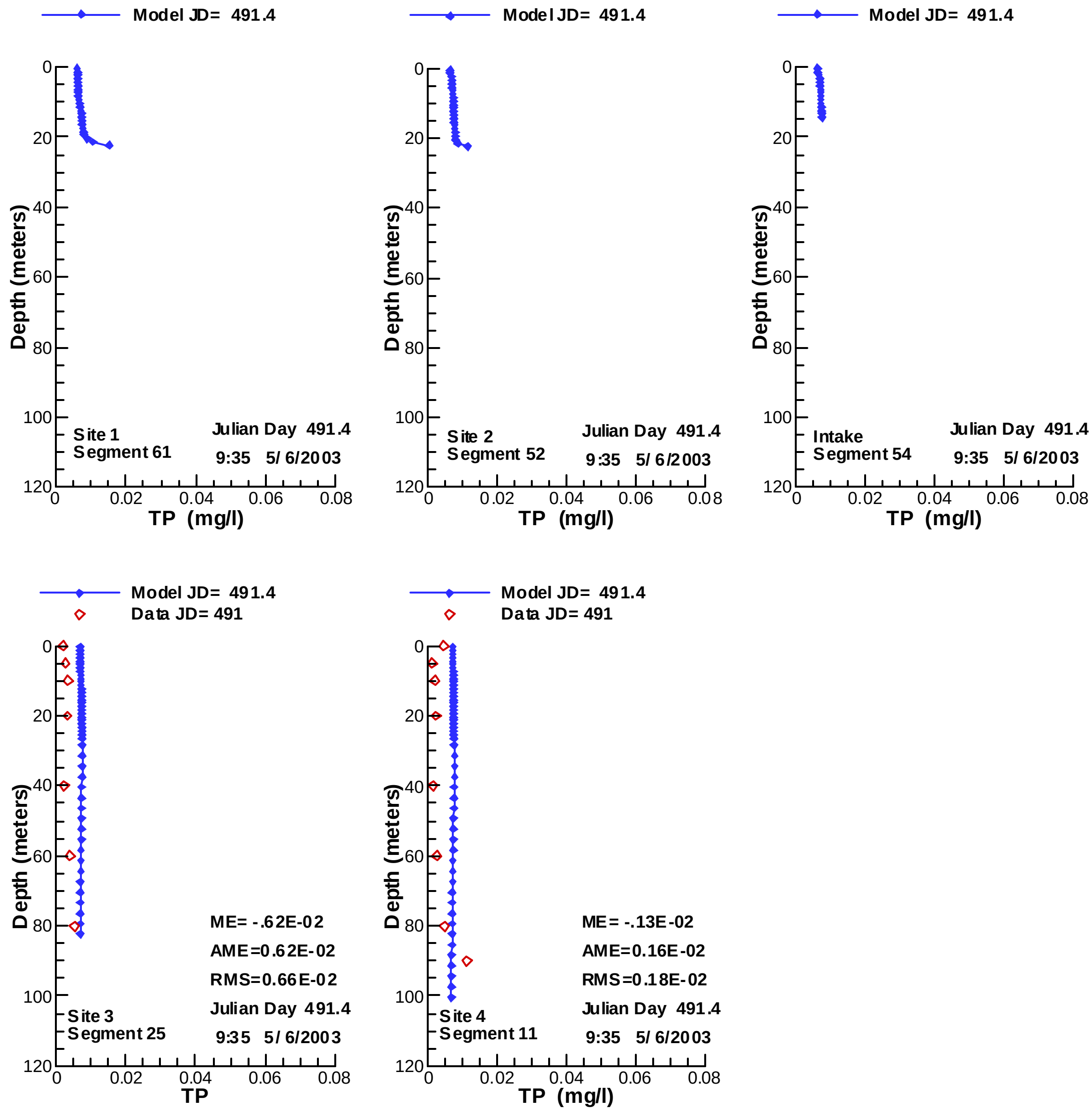

Figure 487. Vertical profiles of TP compared with data for 5/ 6/2003.

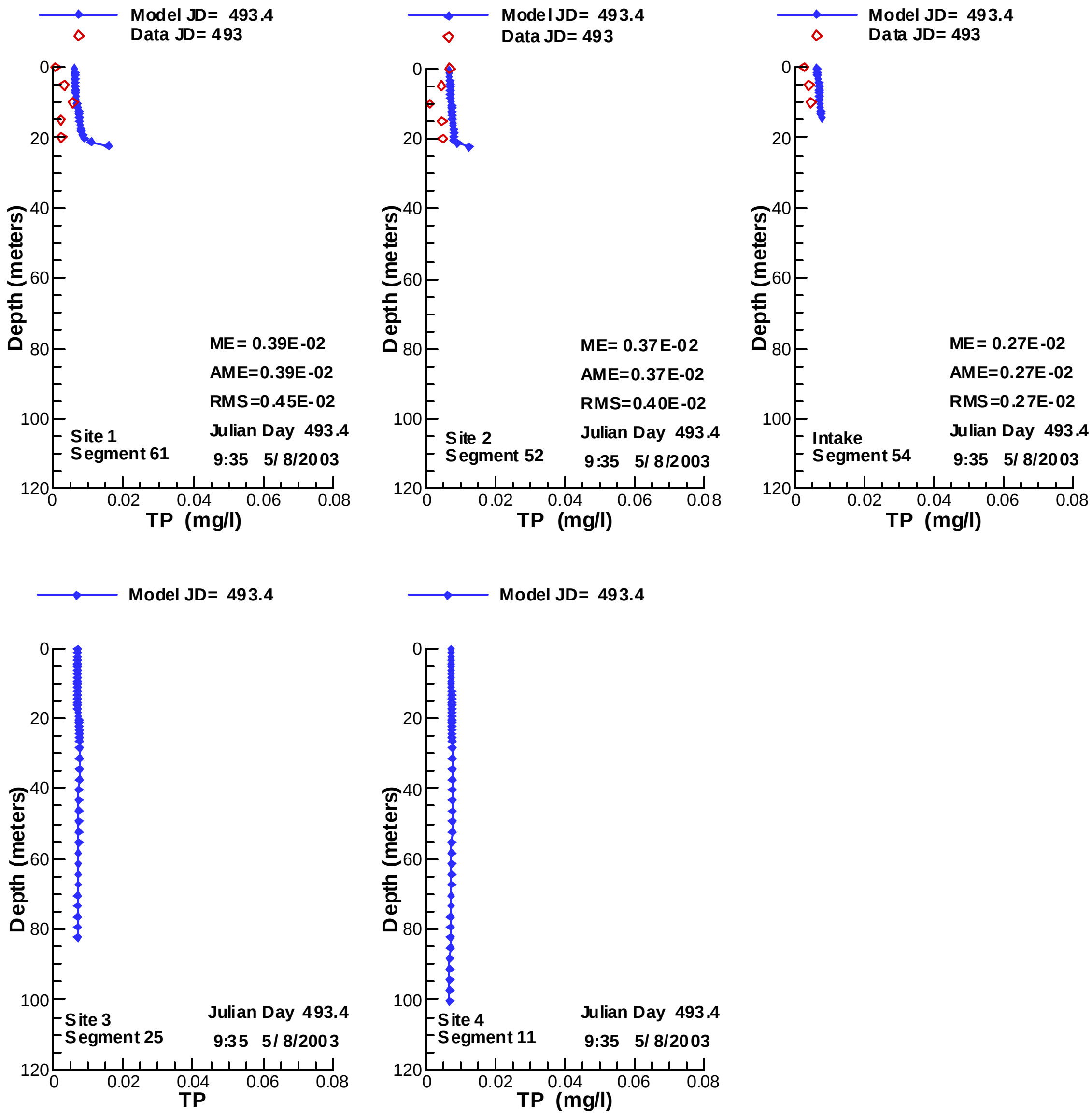

Figure 488. Vertical profiles of TP compared with data for 5/ 8/2003.

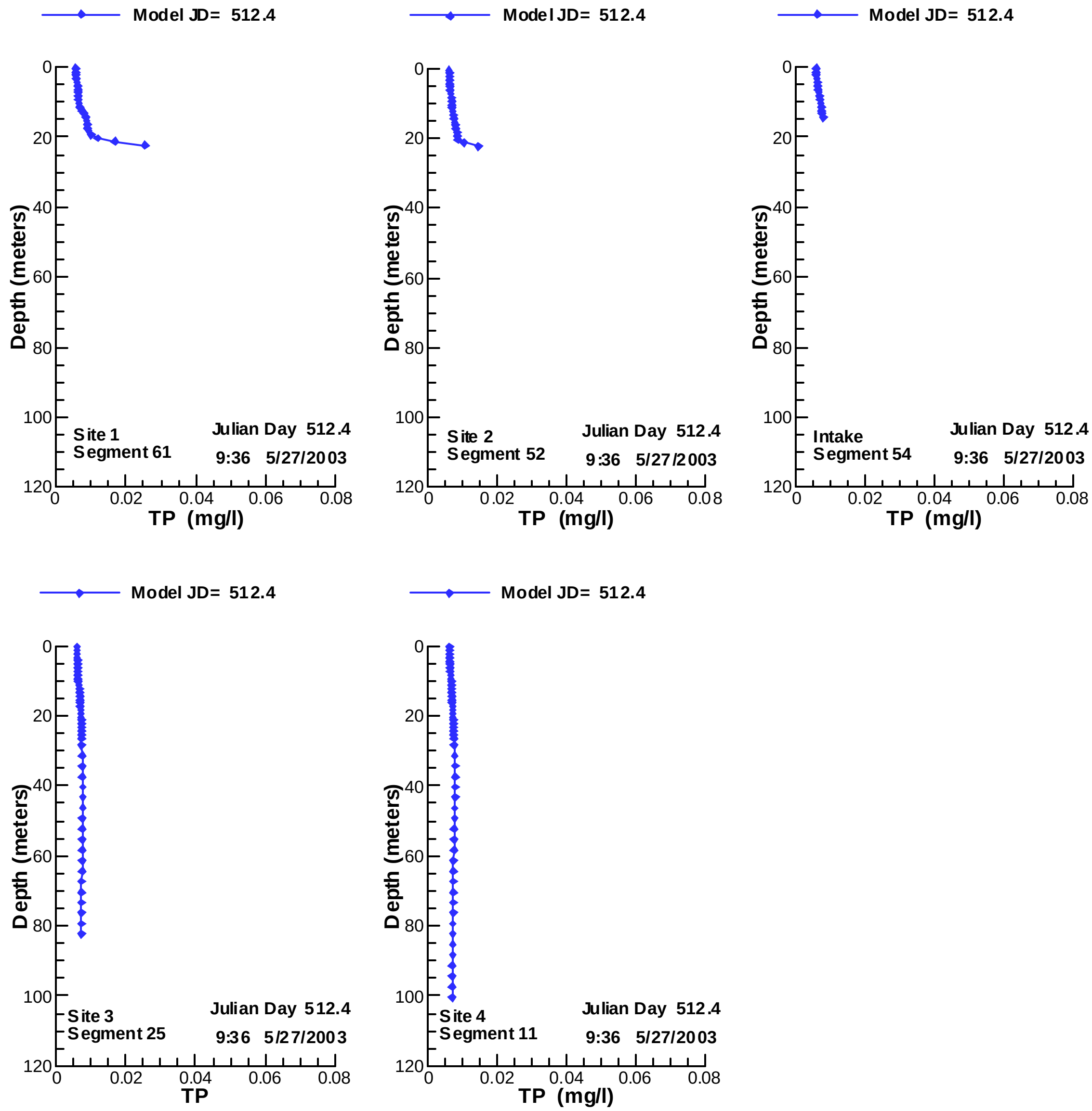

Figure 489. Vertical profiles of TP compared with data for 5/27/2003.

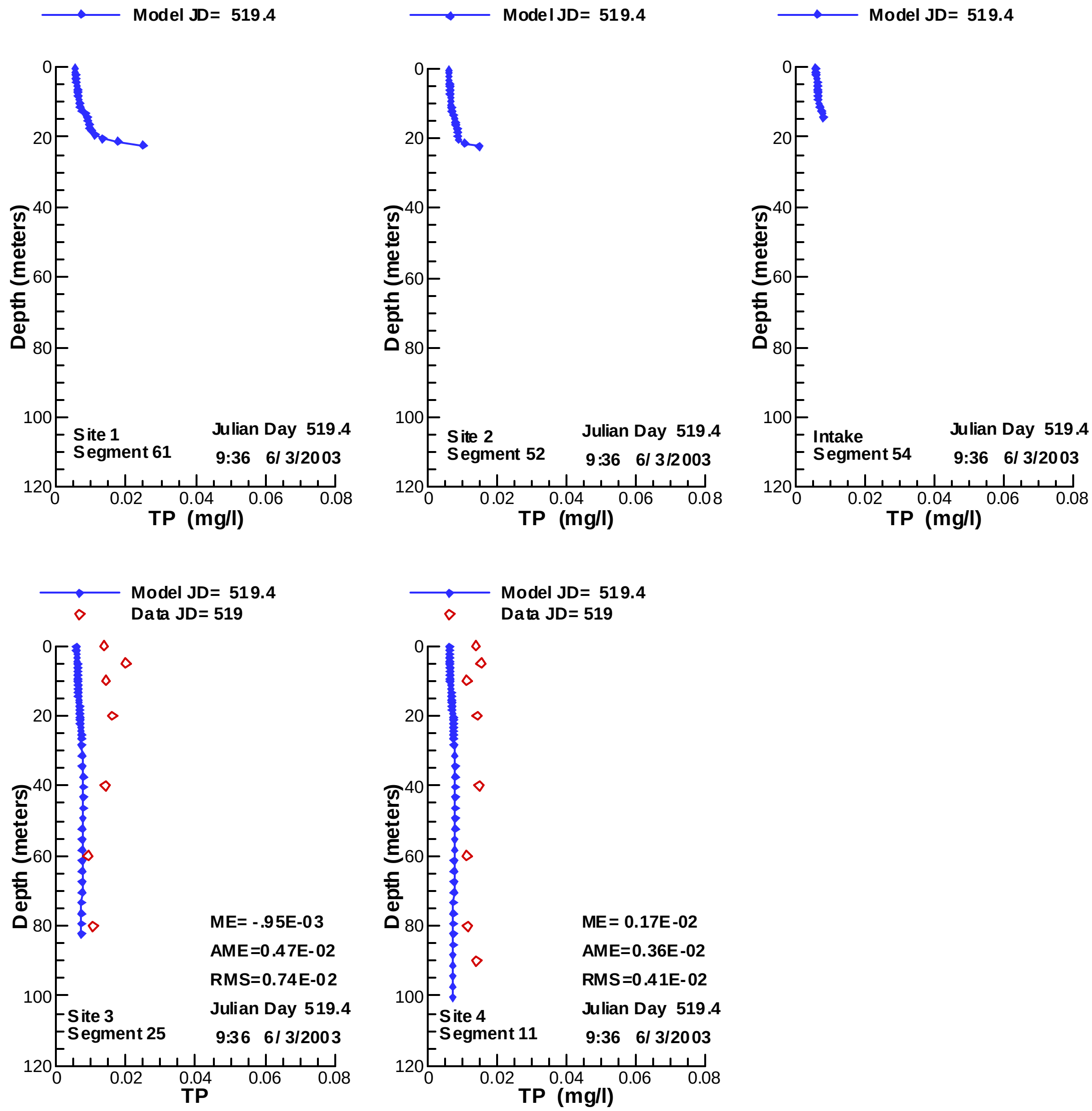

Figure 490. Vertical profiles of TP compared with data for 6/ 3/2003.

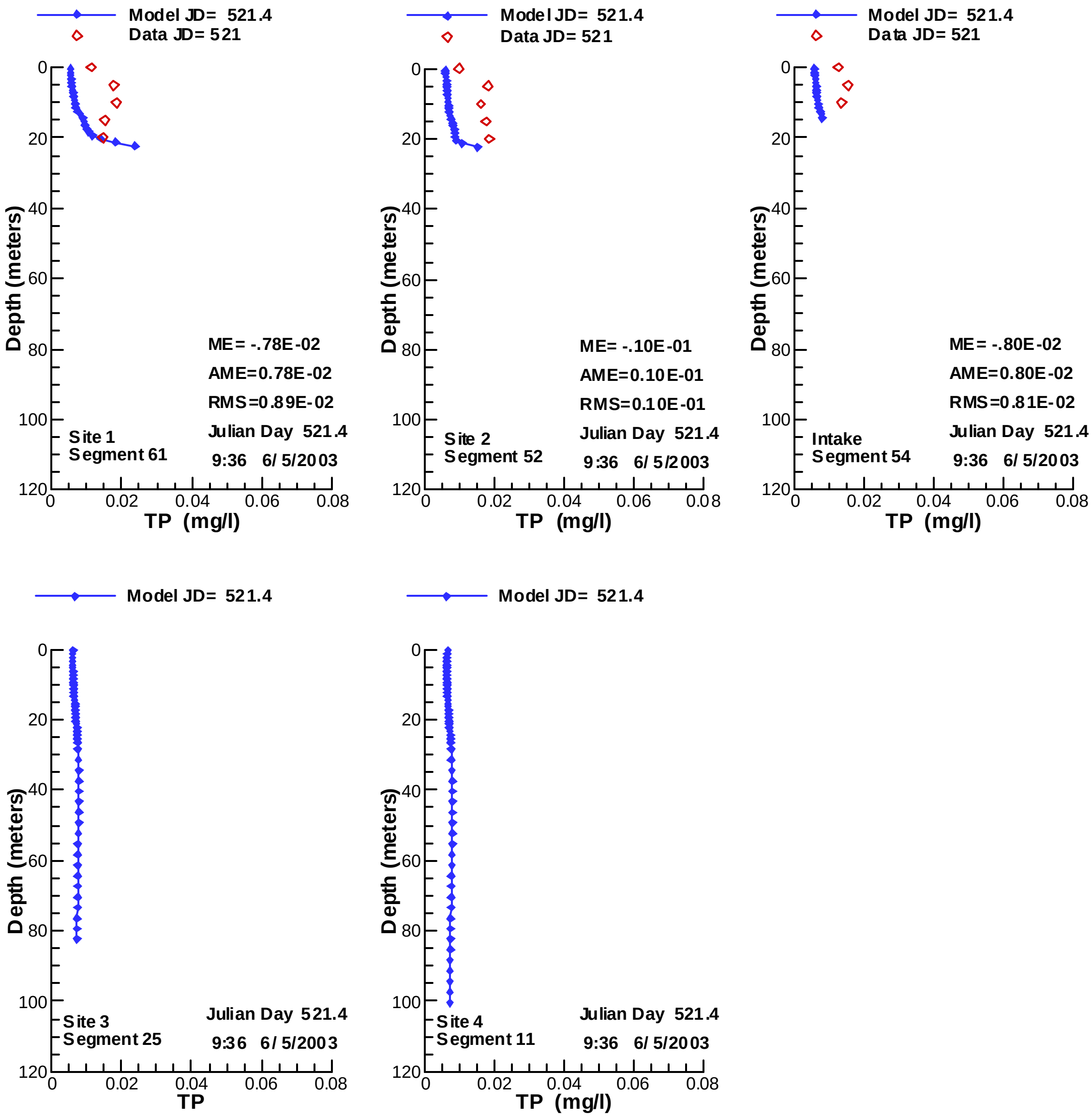

Figure 491. Vertical profiles of TP compared with data for 6/ 5/2003.

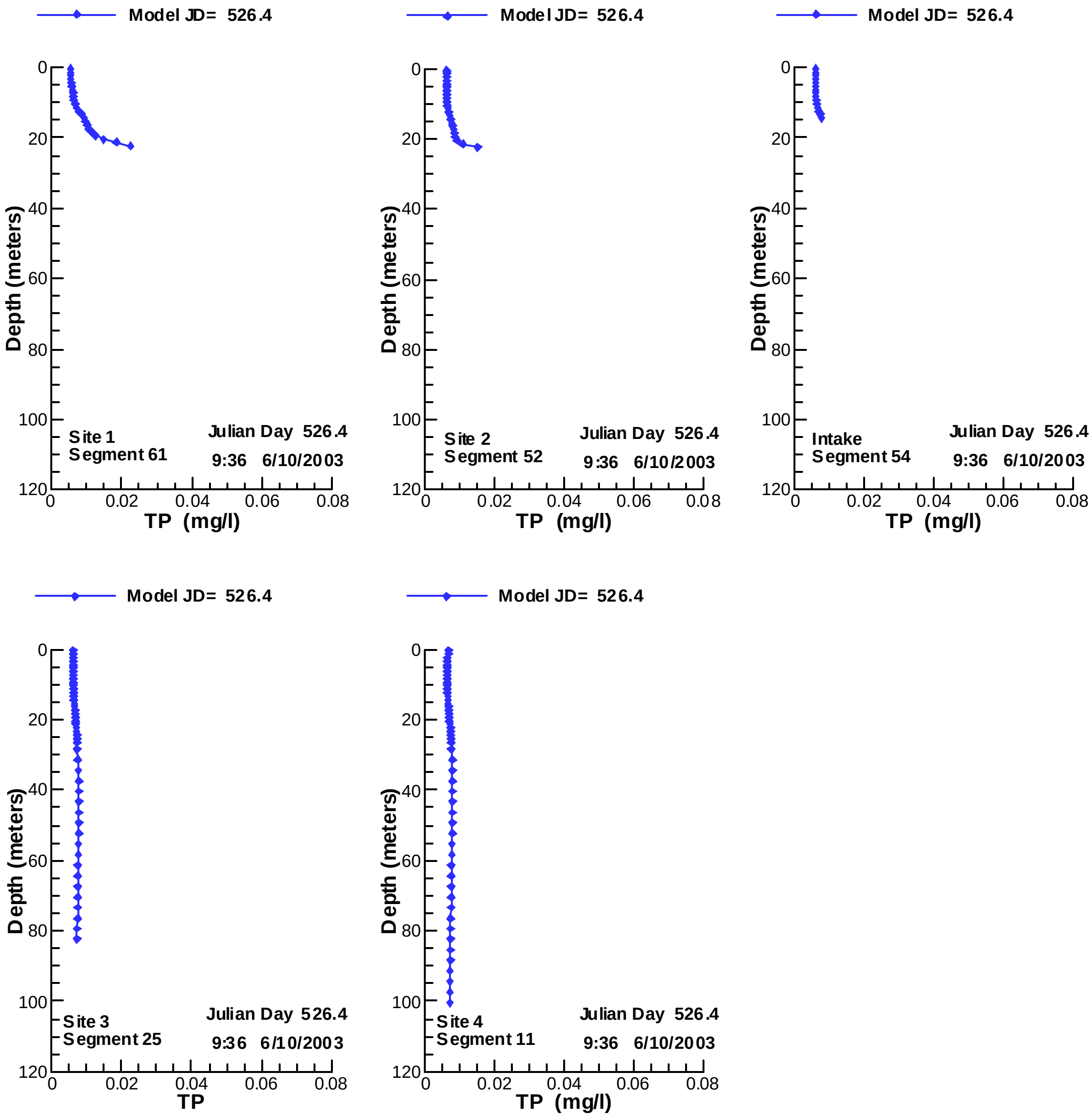

Figure 492. Vertical profiles of TP compared with data for 6/10/2003.

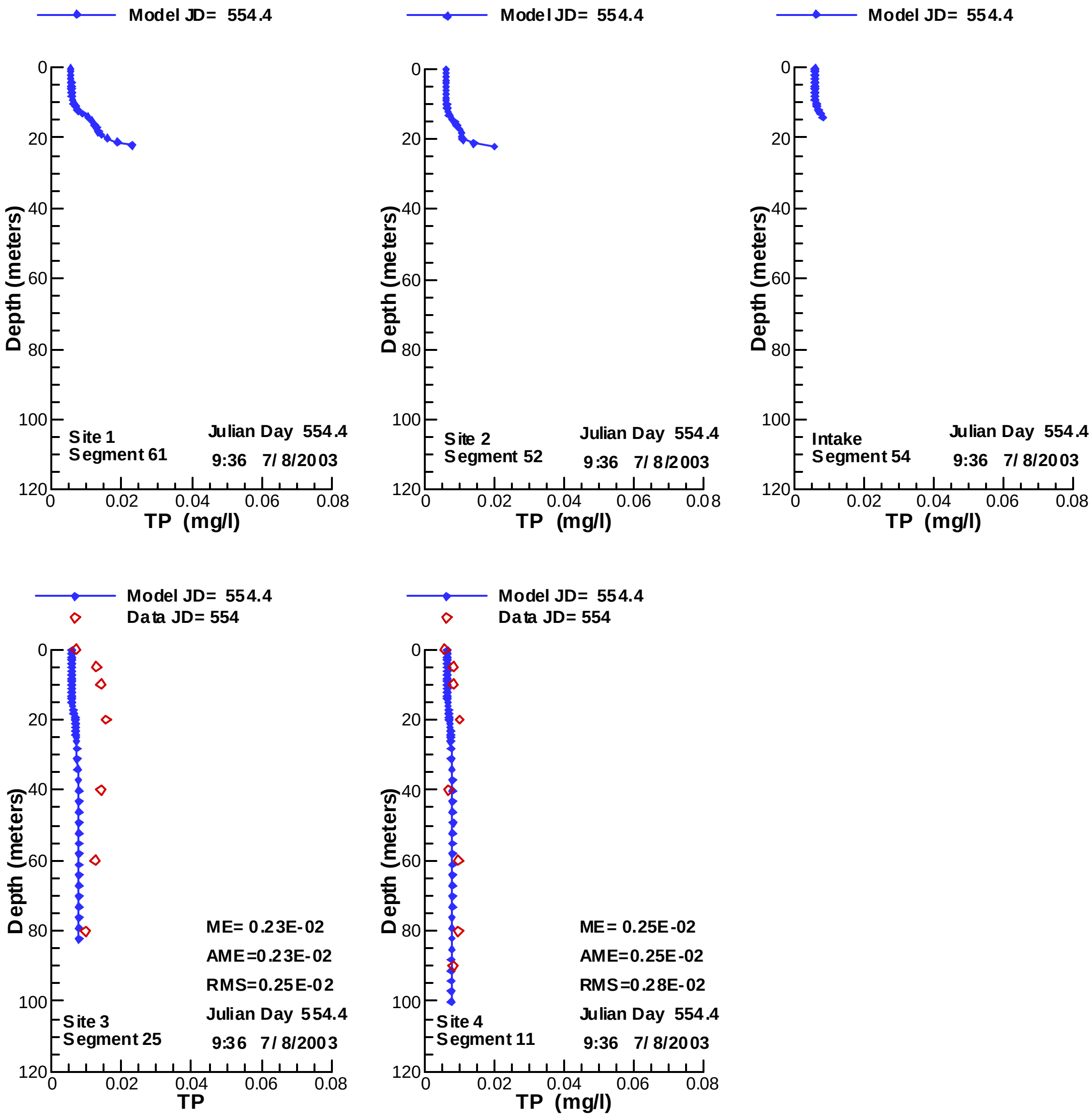

Figure 493. Vertical profiles of TP compared with data for 7/ 8/2003.

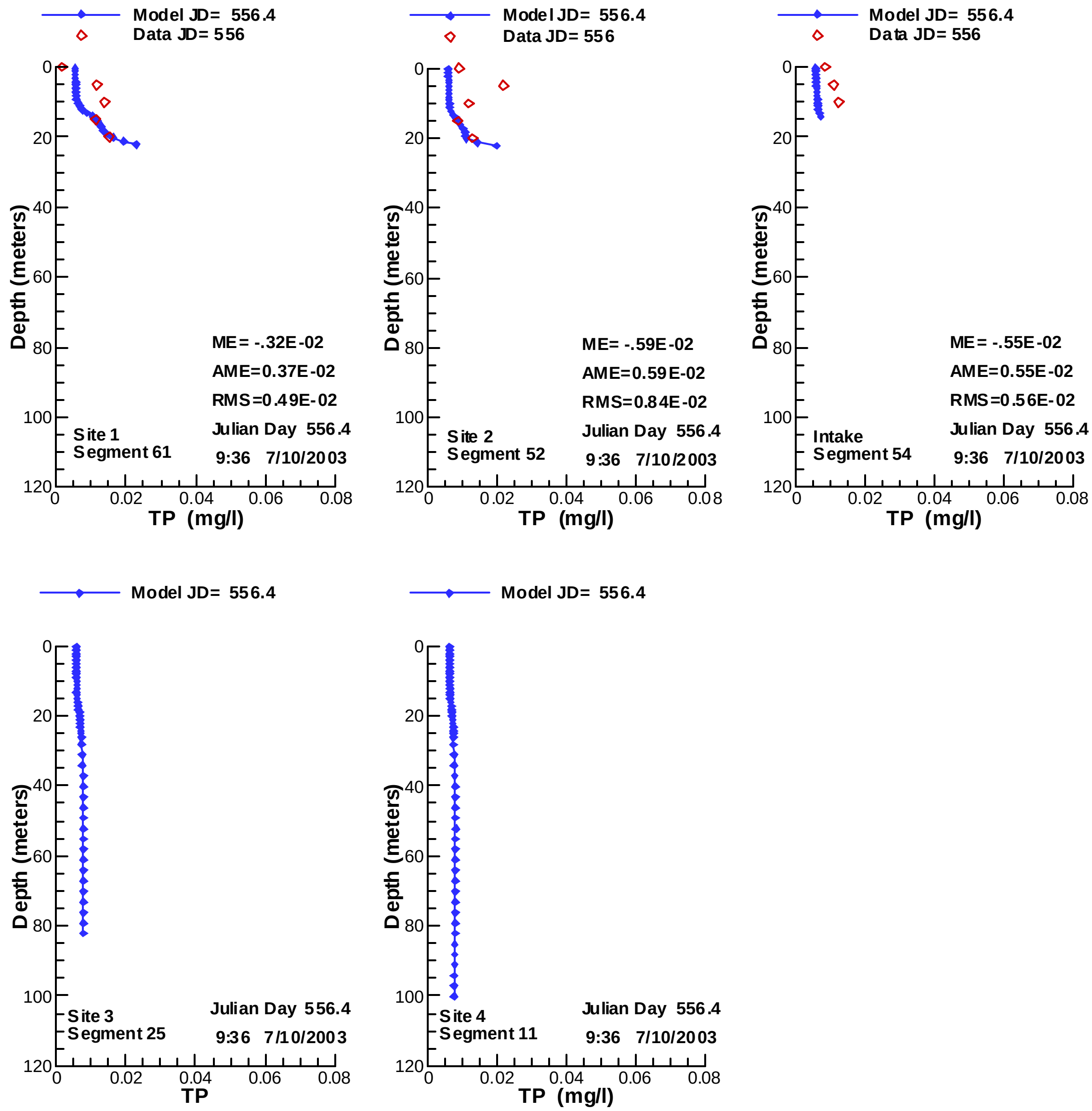

Figure 494. Vertical profiles of TP compared with data for 7/10/2003.

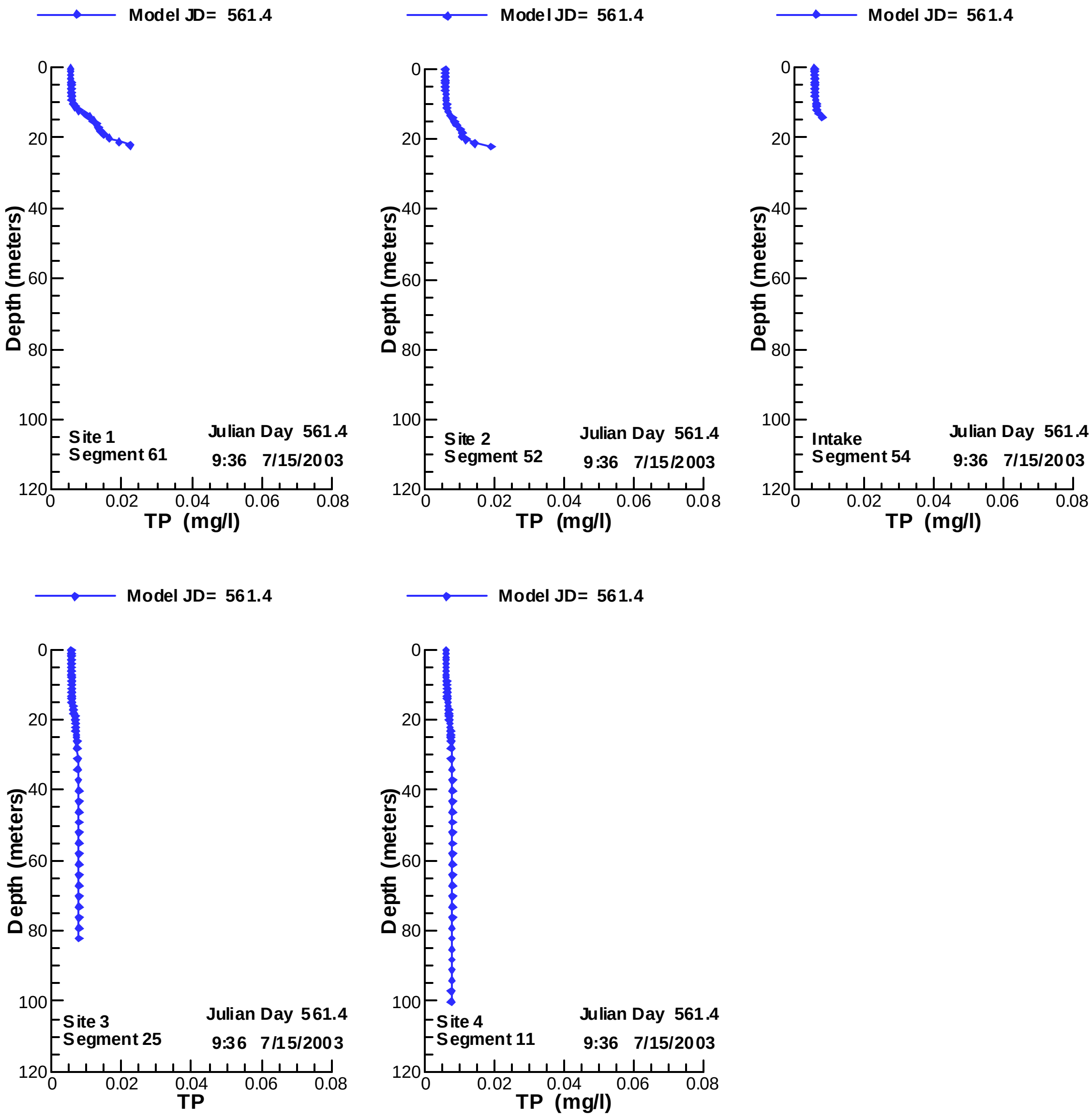

Figure 495. Vertical profiles of TP compared with data for 7/15/2003.

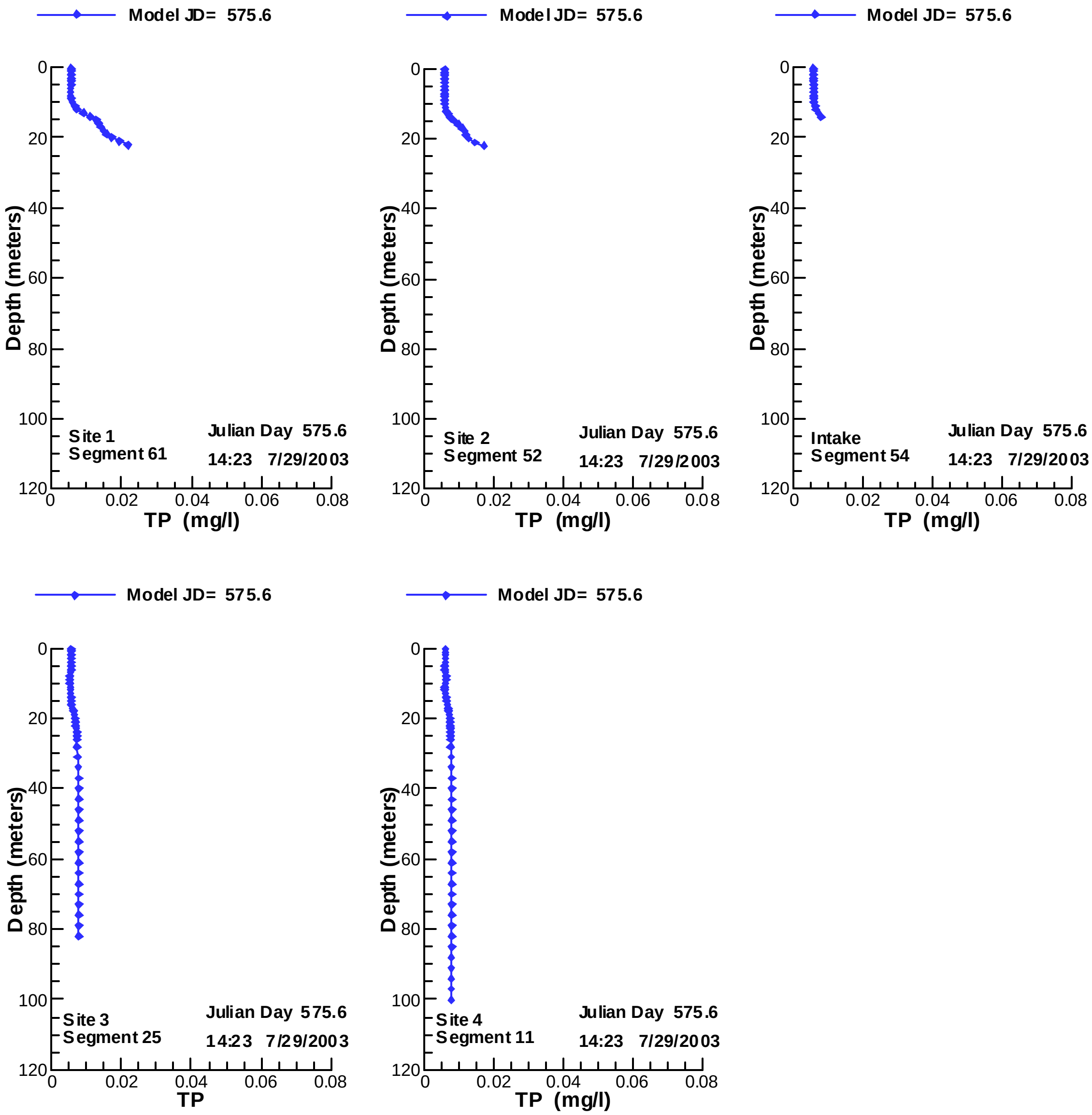

Figure 496. Vertical profiles of TP compared with data for 7/29/2003.

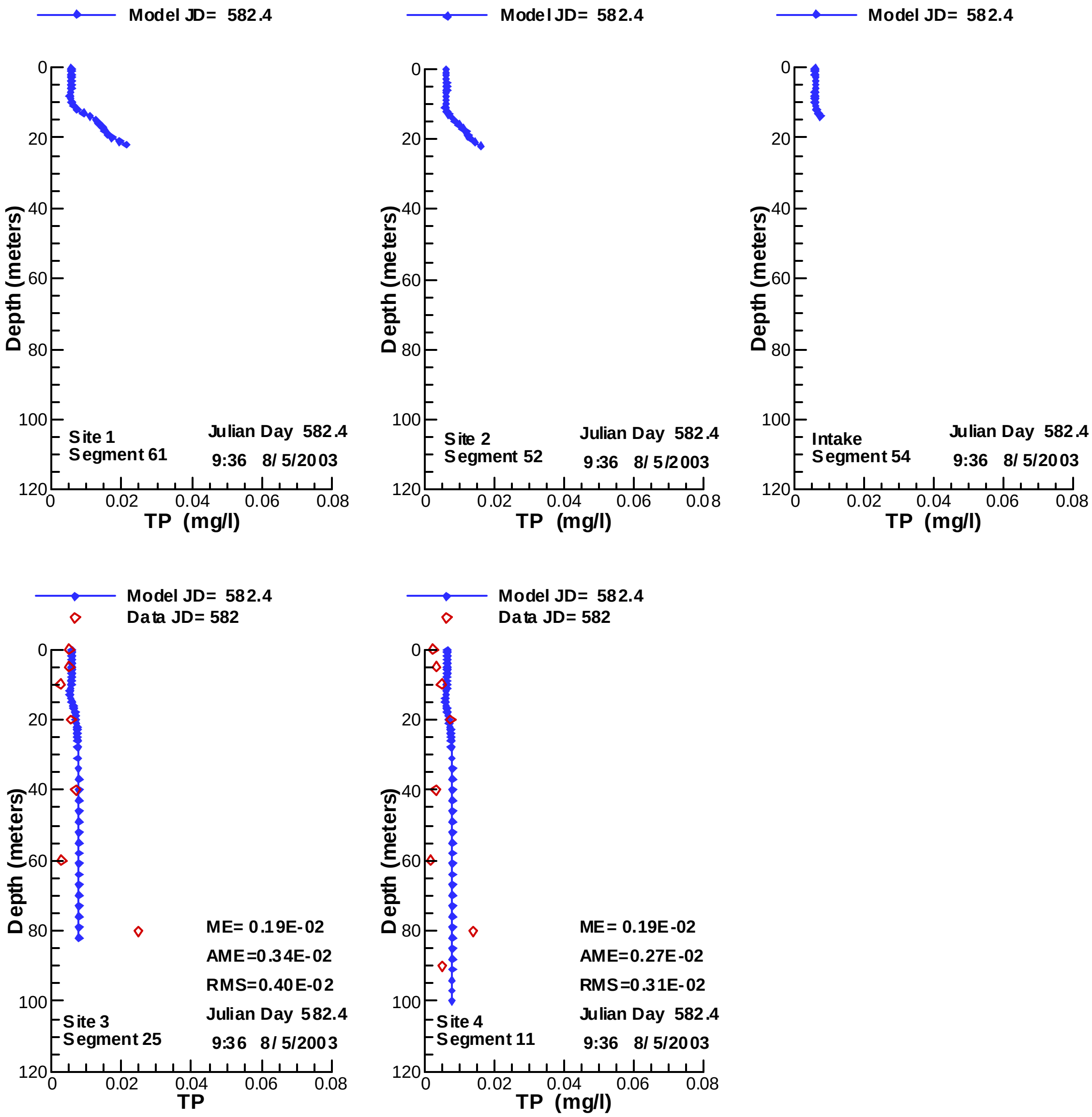

Figure 497. Vertical profiles of TP compared with data for 8/ 5/2003.

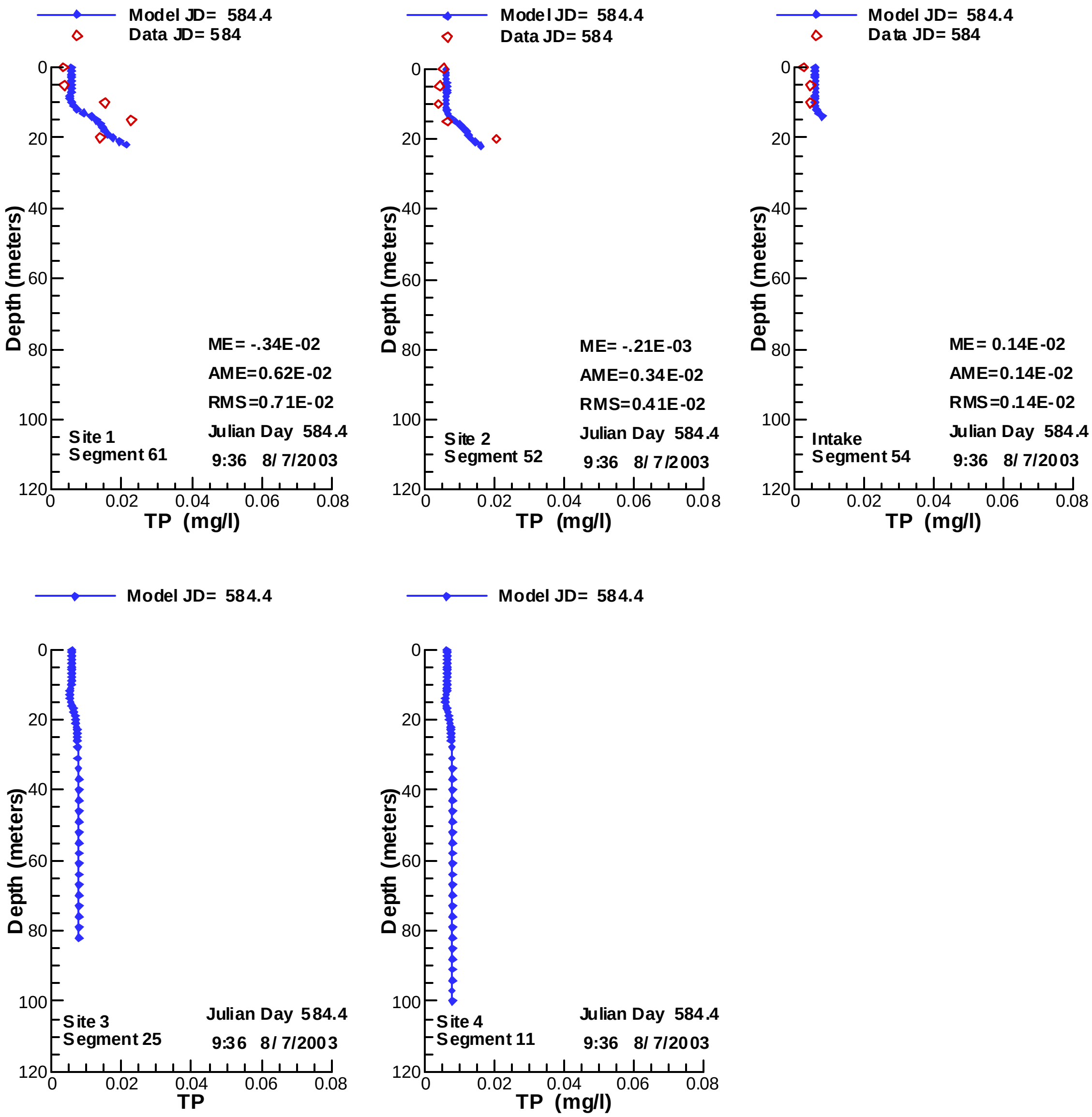

Figure 498. Vertical profiles of TP compared with data for 8/ 7/2003.

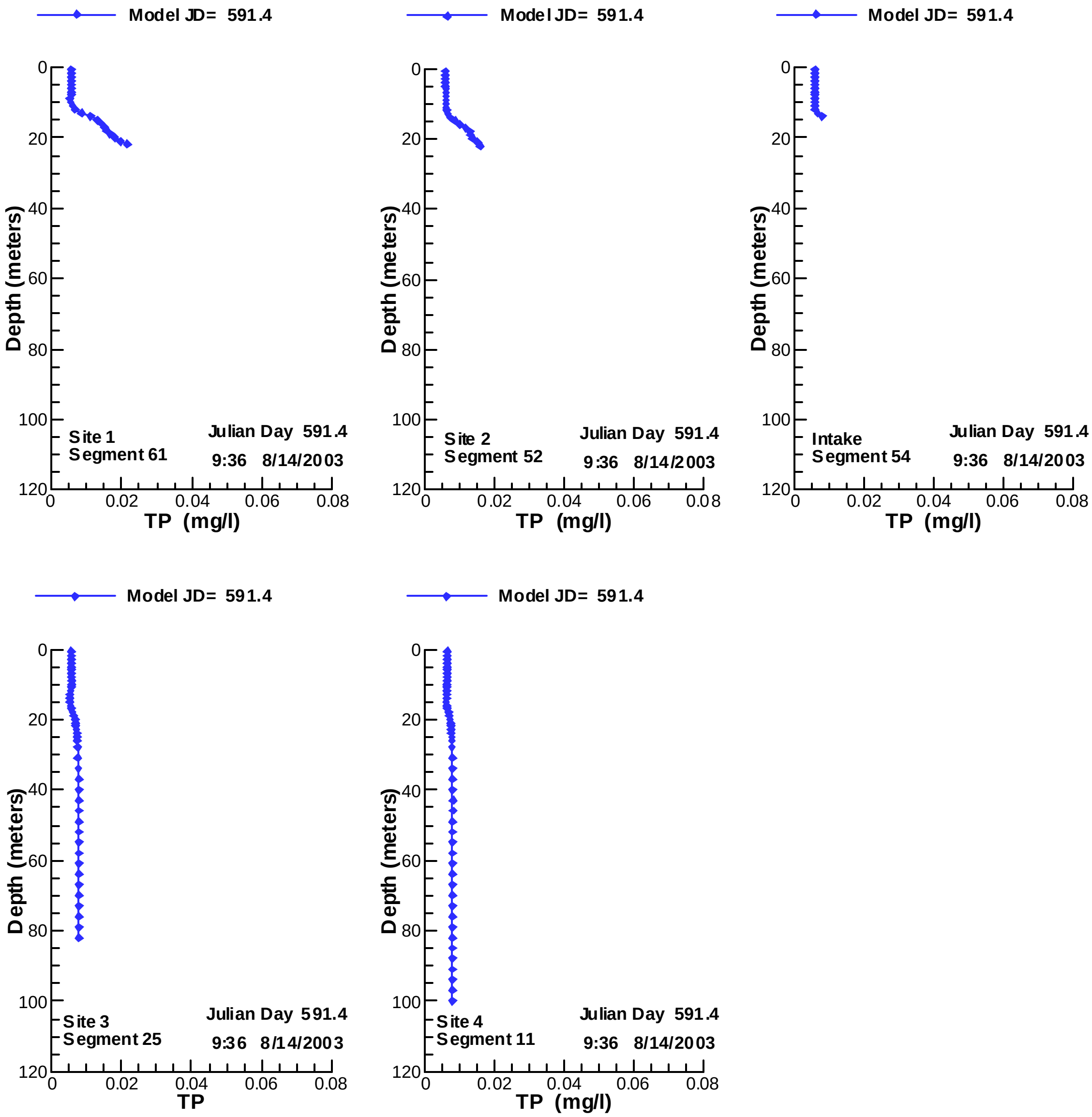

Figure 499. Vertical profiles of TP compared with data for 8/14/2003.

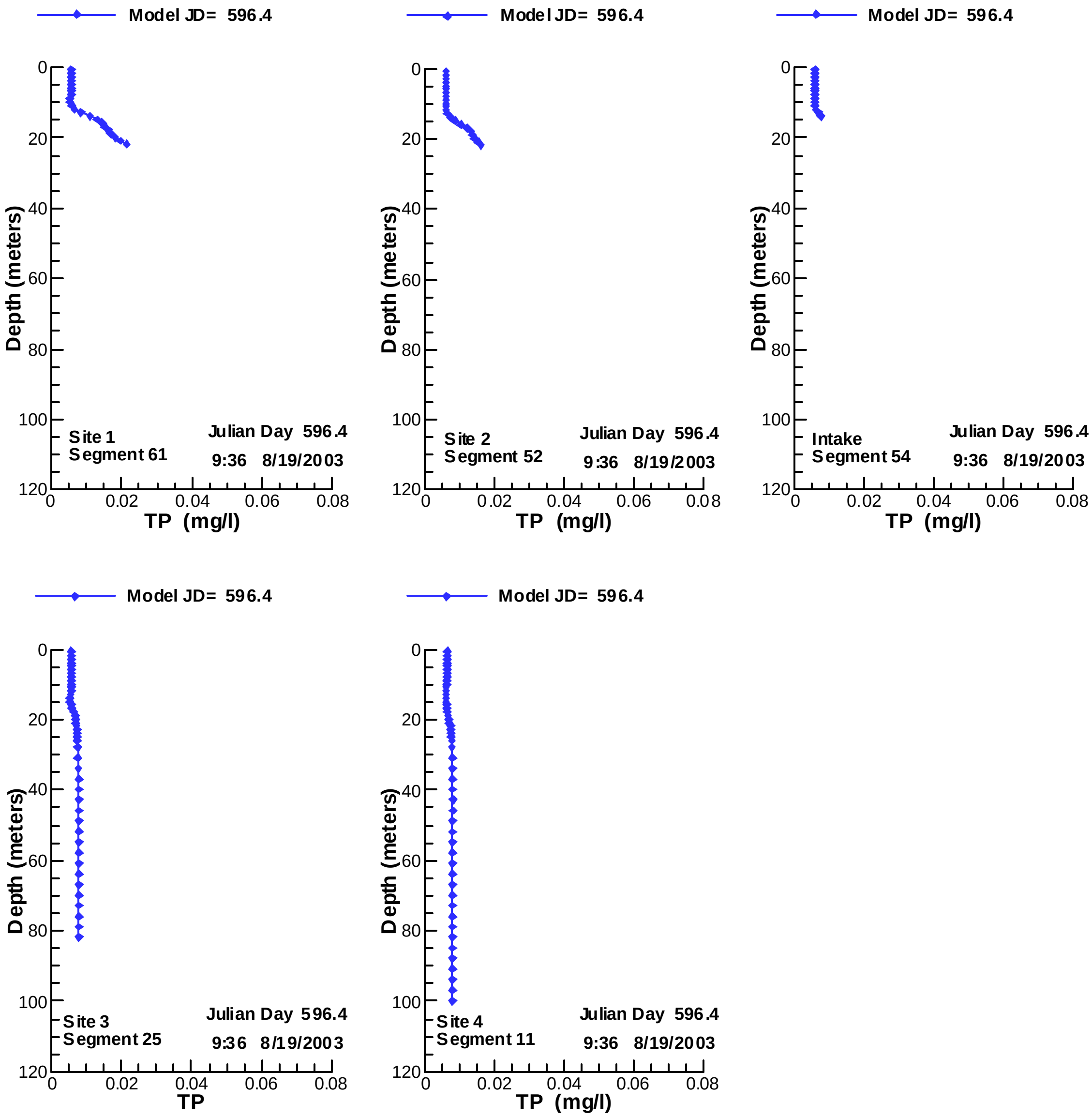

Figure 500. Vertical profiles of TP compared with data for 8/19/2003.

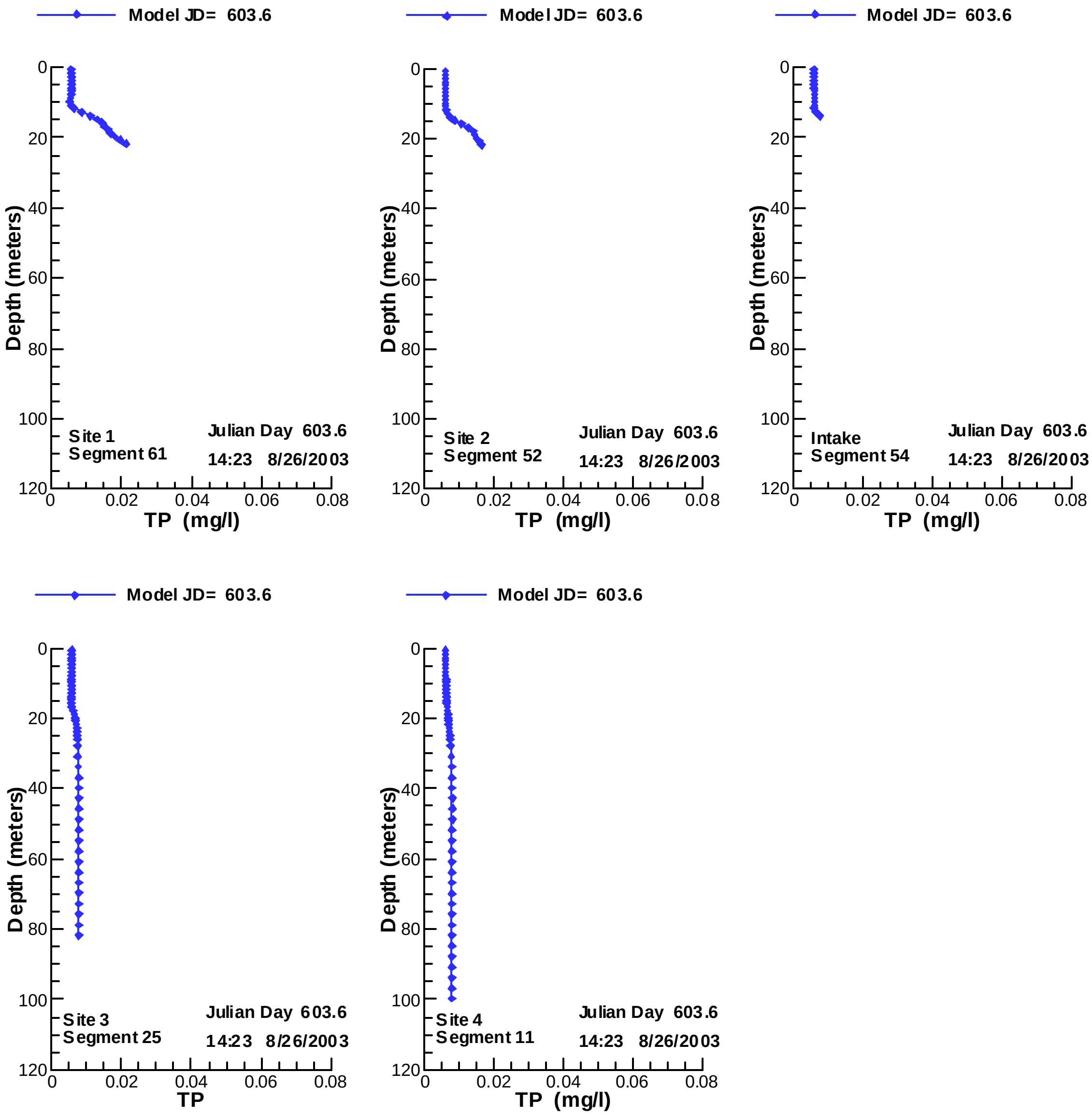

Figure 501. Vertical profiles of TP compared with data for 8/26/2003.

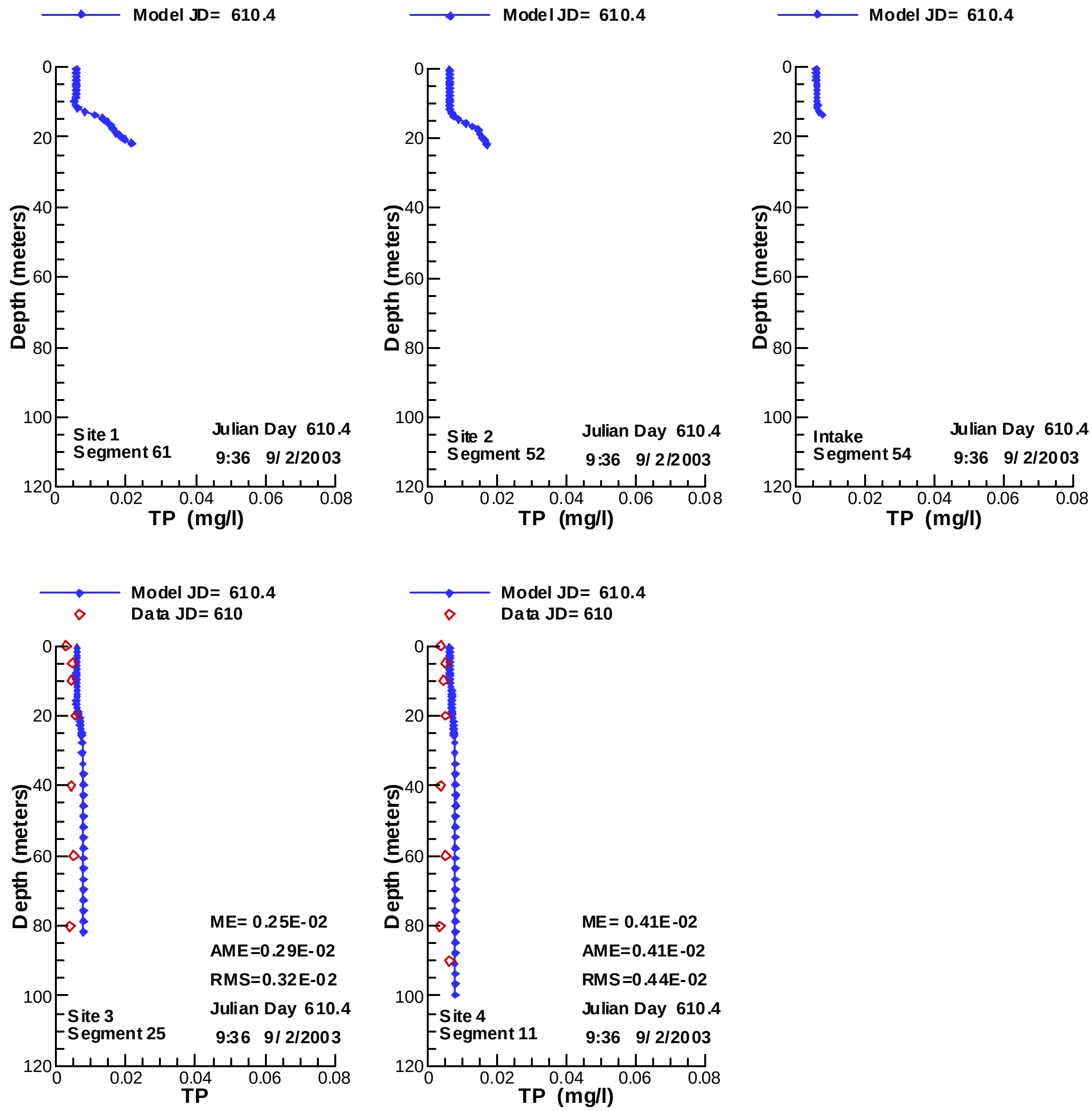

Figure 502. Vertical profiles of TP compared with data for 9/ 2/2003.

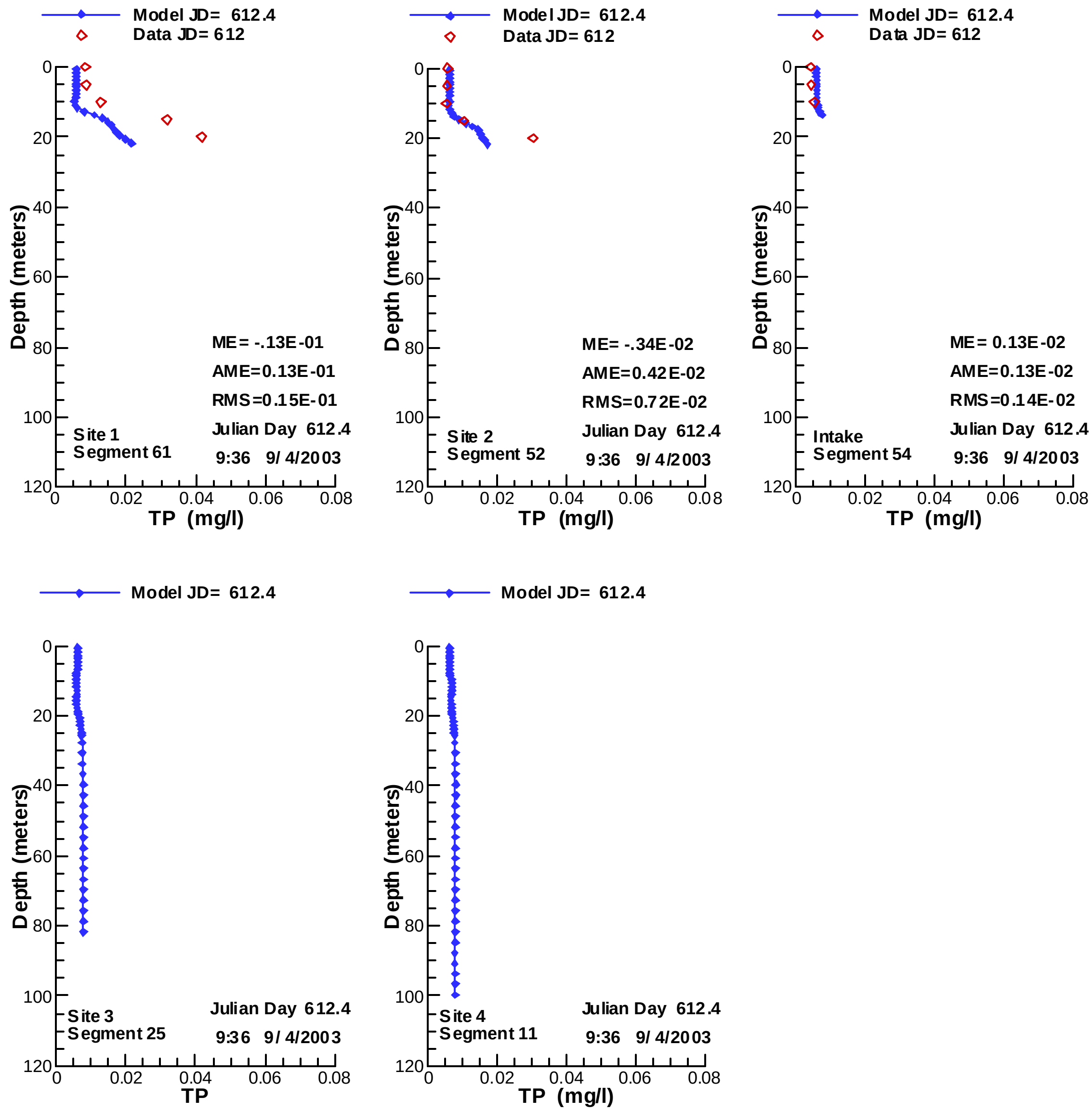

Figure 503. Vertical profiles of TP compared with data for 9/ 4/2003.

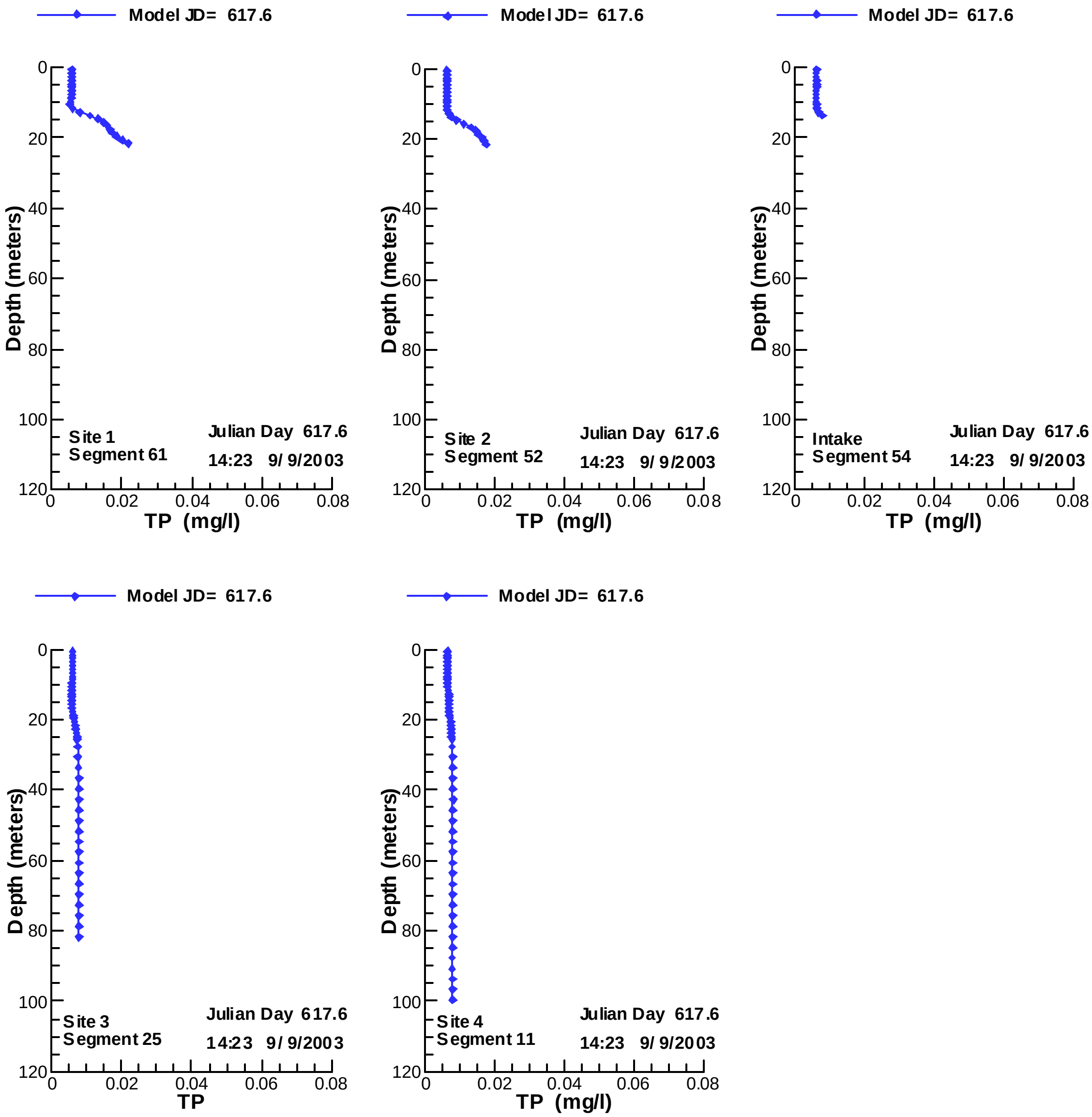

Figure 504. Vertical profiles of TP compared with data for 9/ 9/2003.

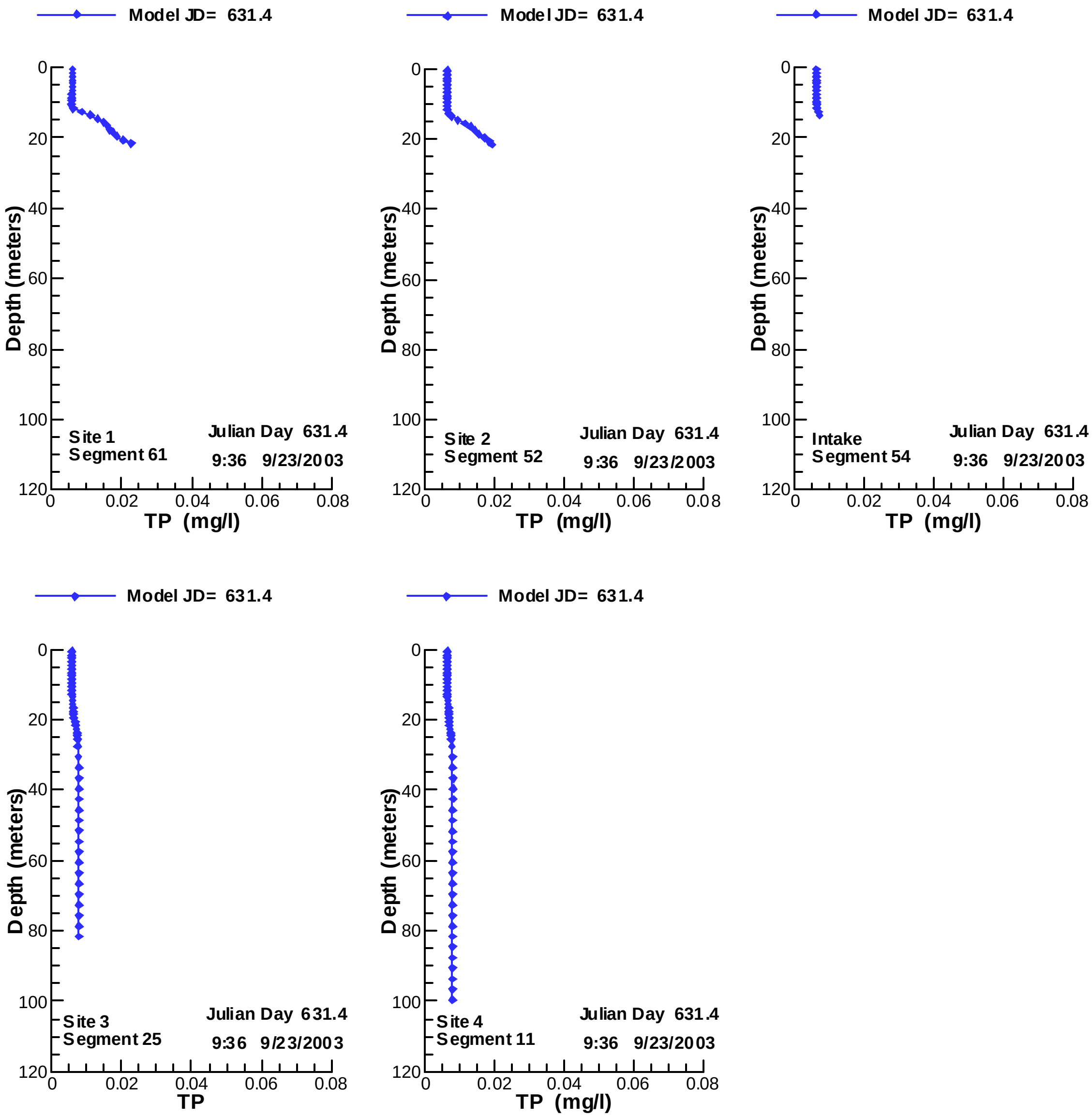

Figure 505. Vertical profiles of TP compared with data for 9/23/2003.

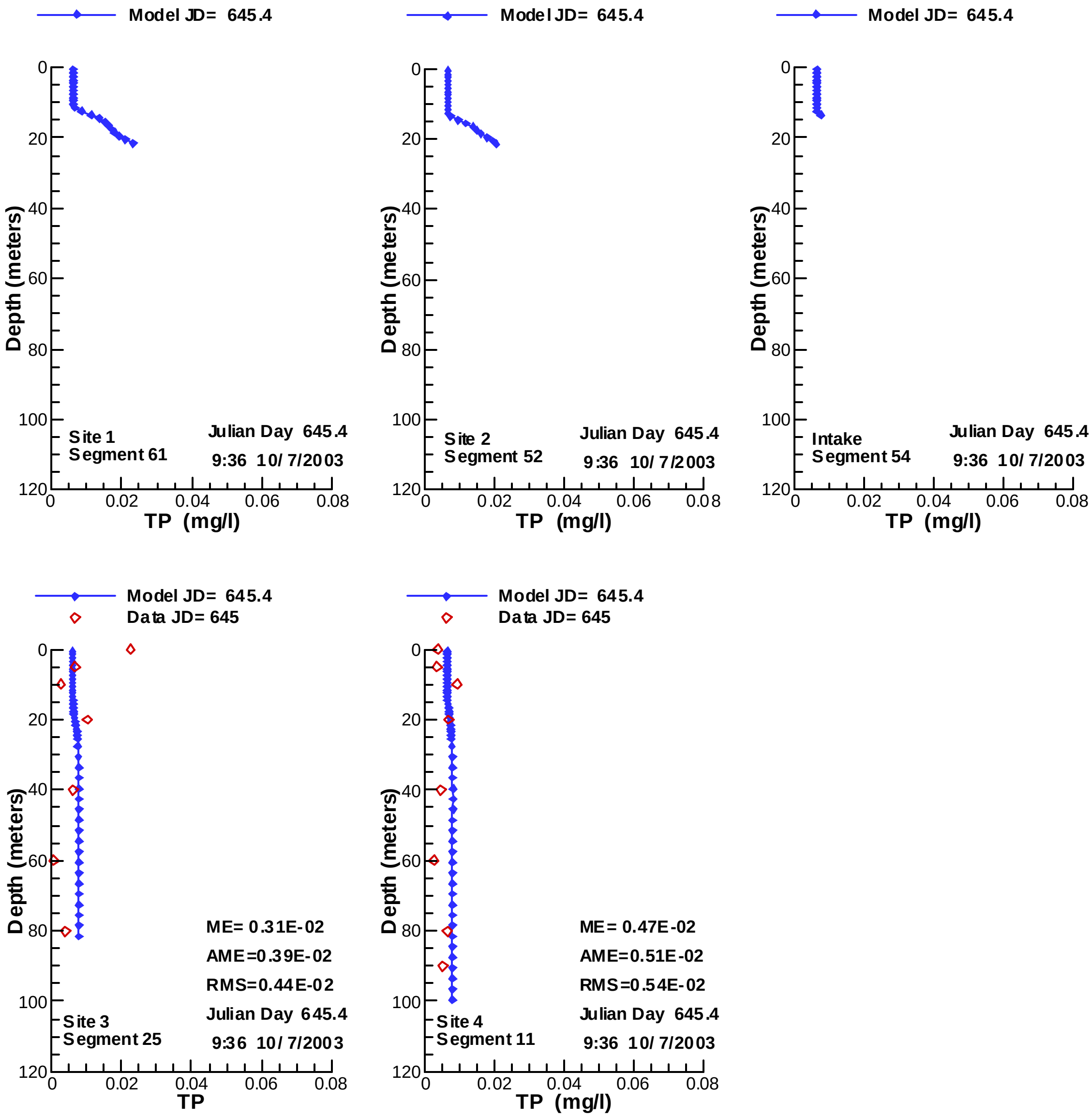

Figure 506. Vertical profiles of TP compared with data for 10/ 7/2003.

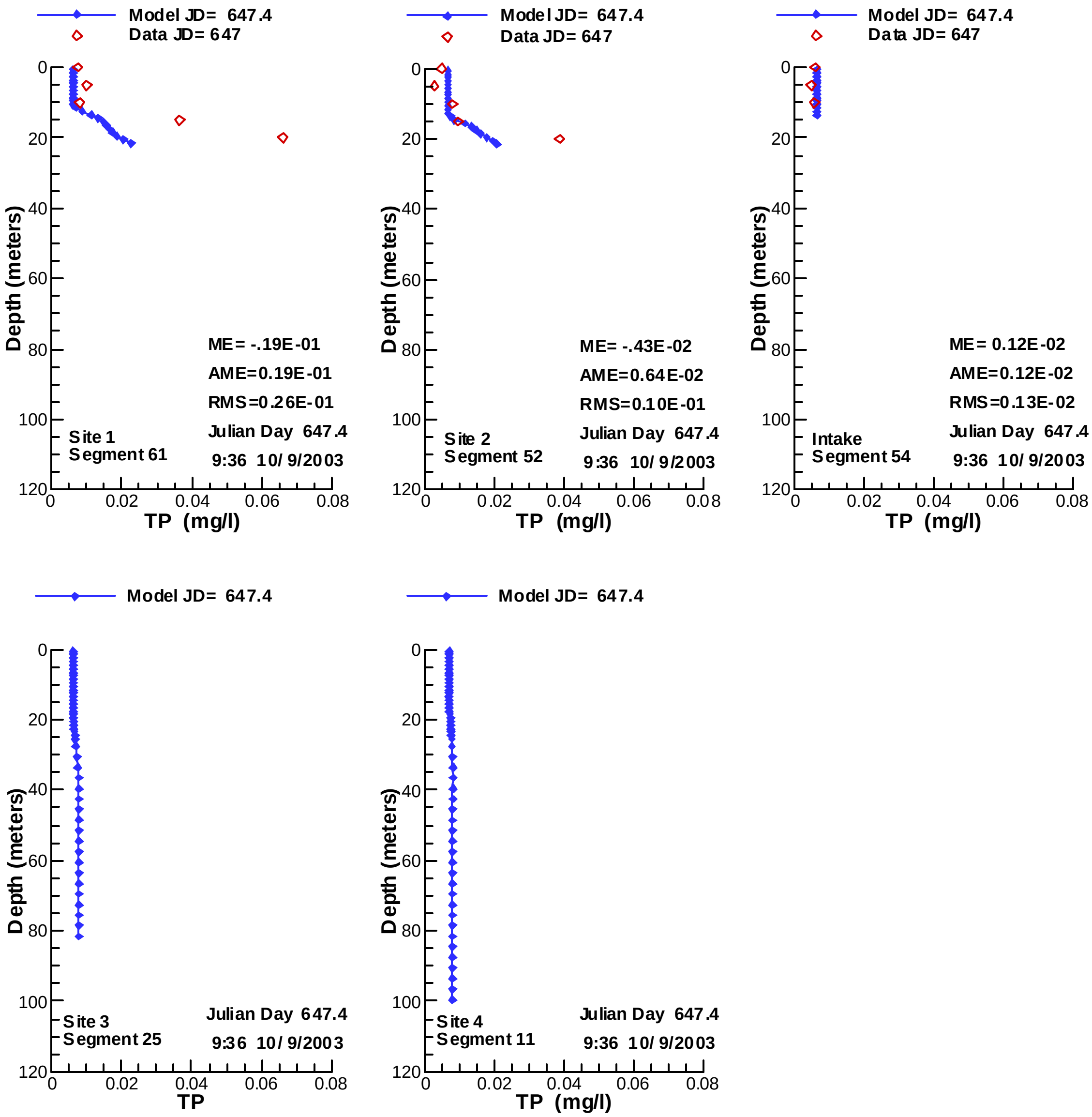

Figure 507. Vertical profiles of TP compared with data for 10/ 9/2003.

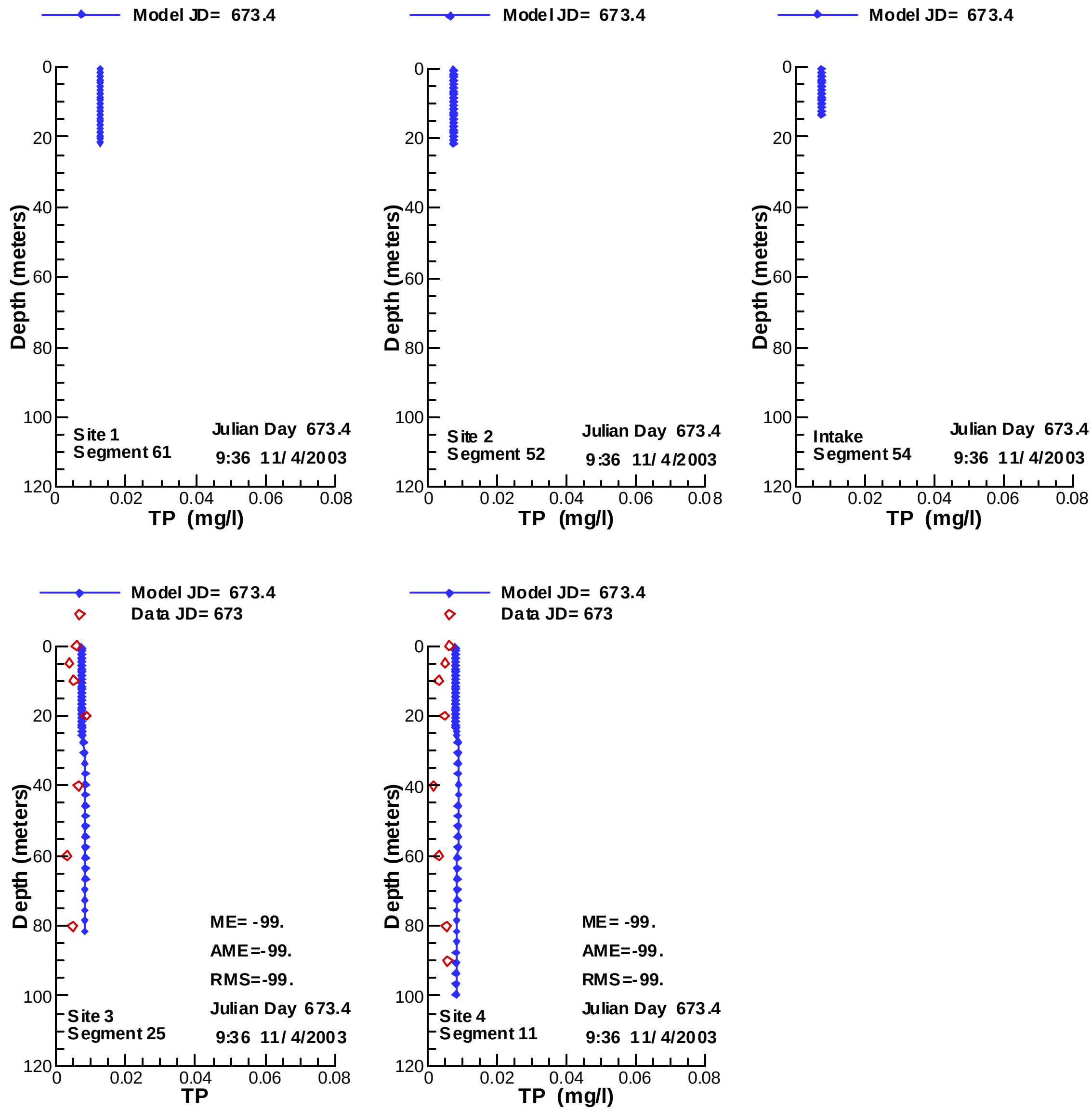

Figure 508. Vertical profiles of TP compared with data for 11/ 4/2003.

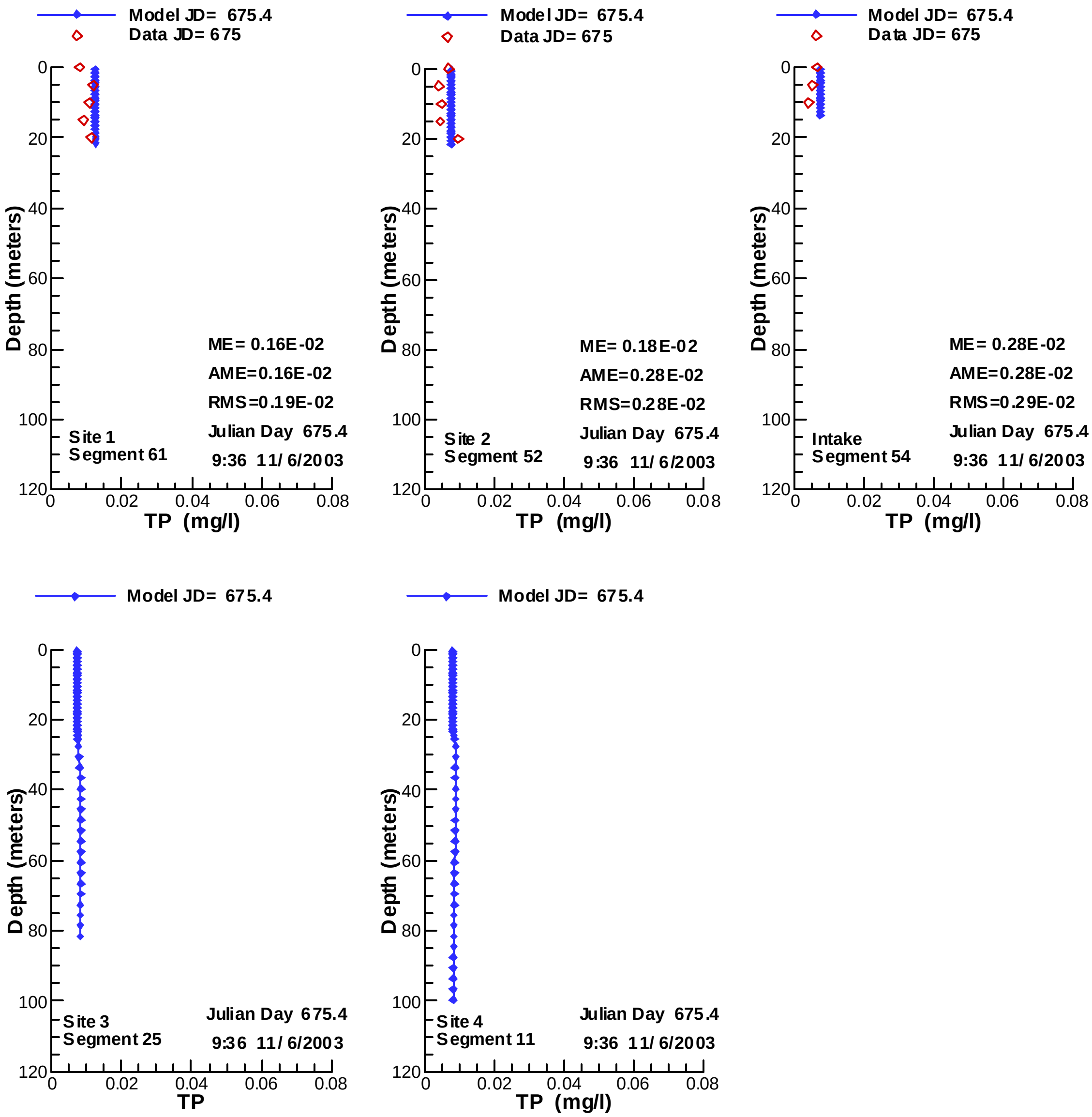

Figure 509. Vertical profiles of TP compared with data for 11/ 6/2003.

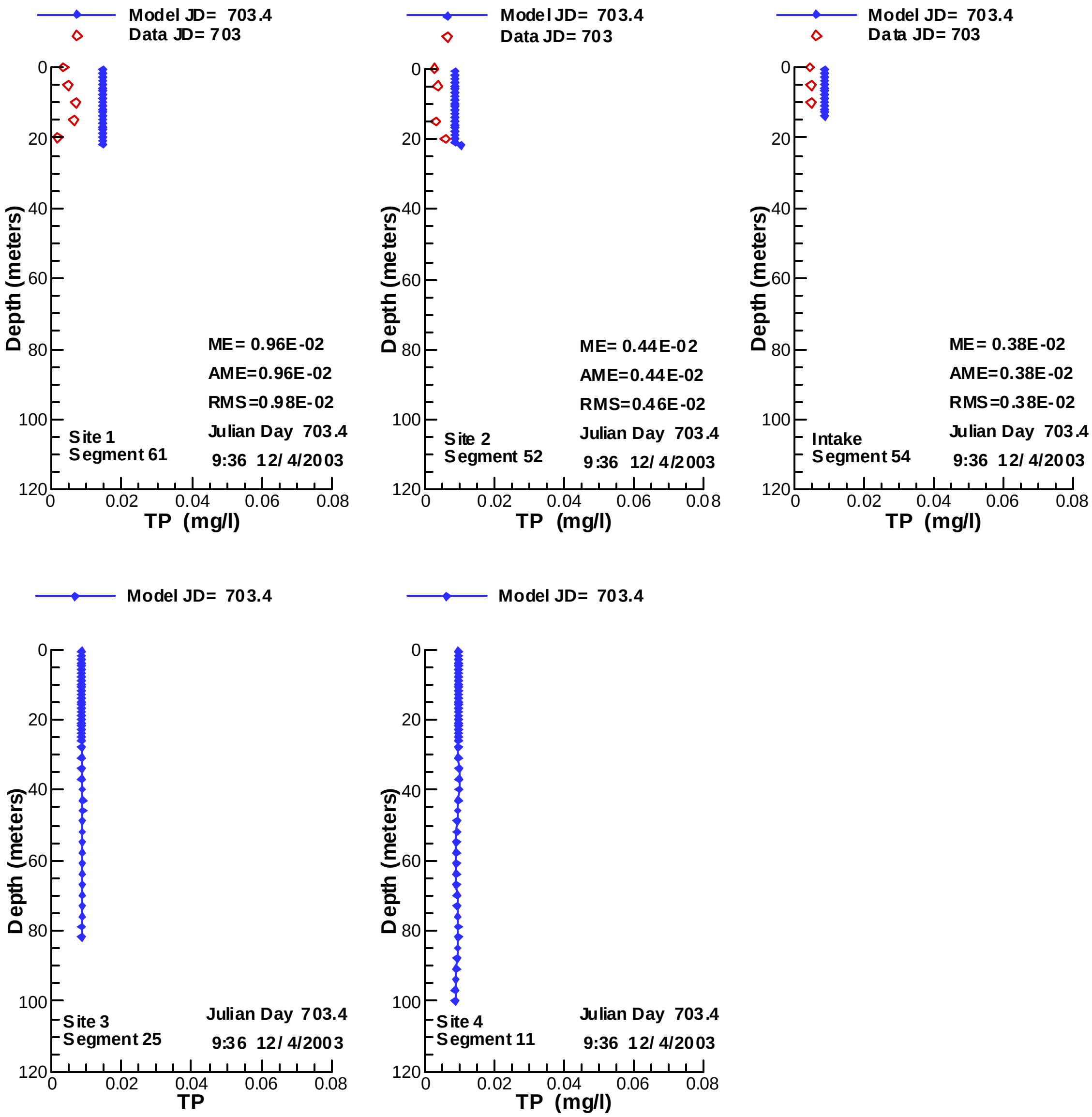

Figure 510. Vertical profiles of TP compared with data for 12/ 4/2003.

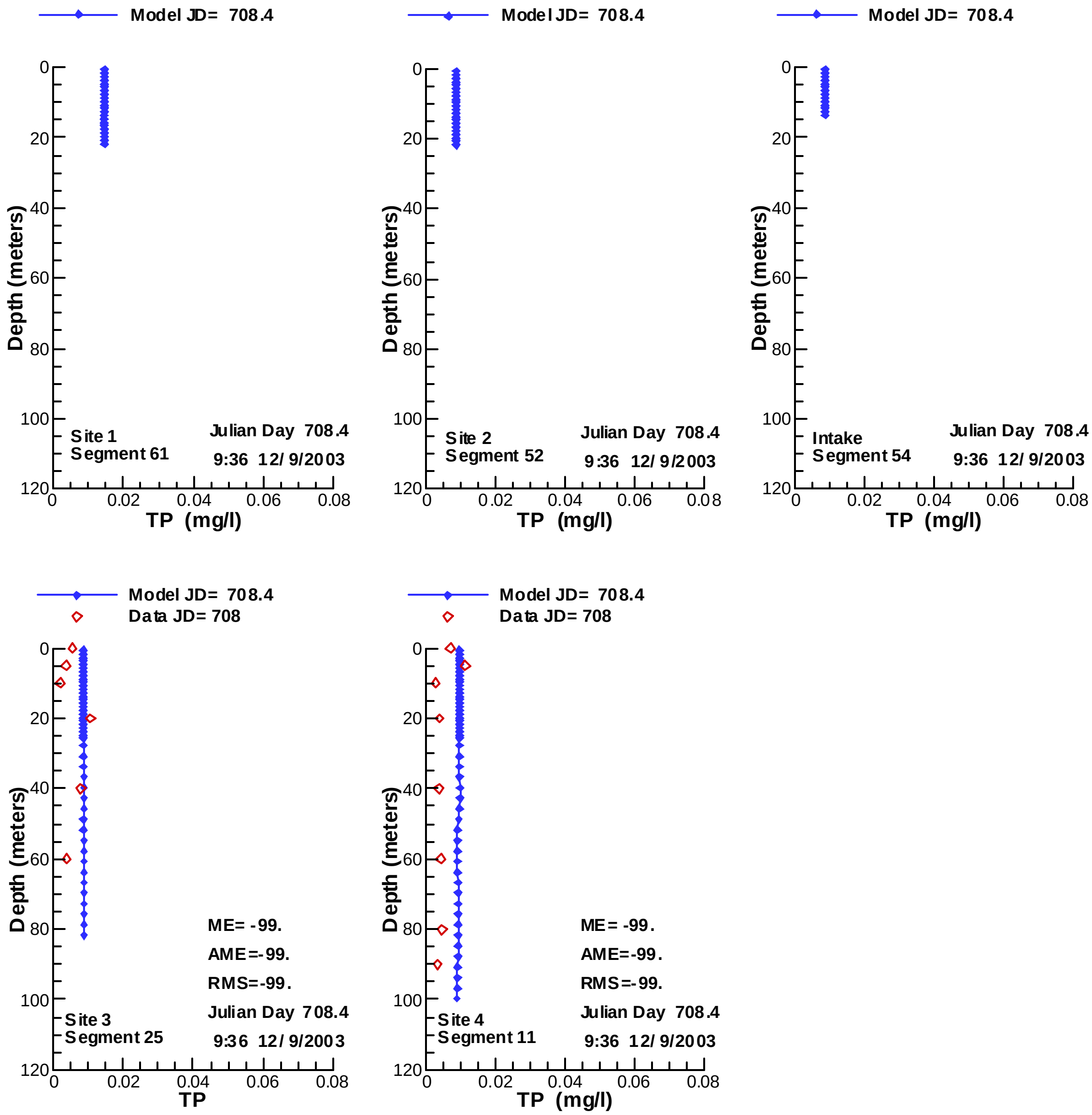

Figure 511. Vertical profiles of TP compared with data for 12/ 9/2003.

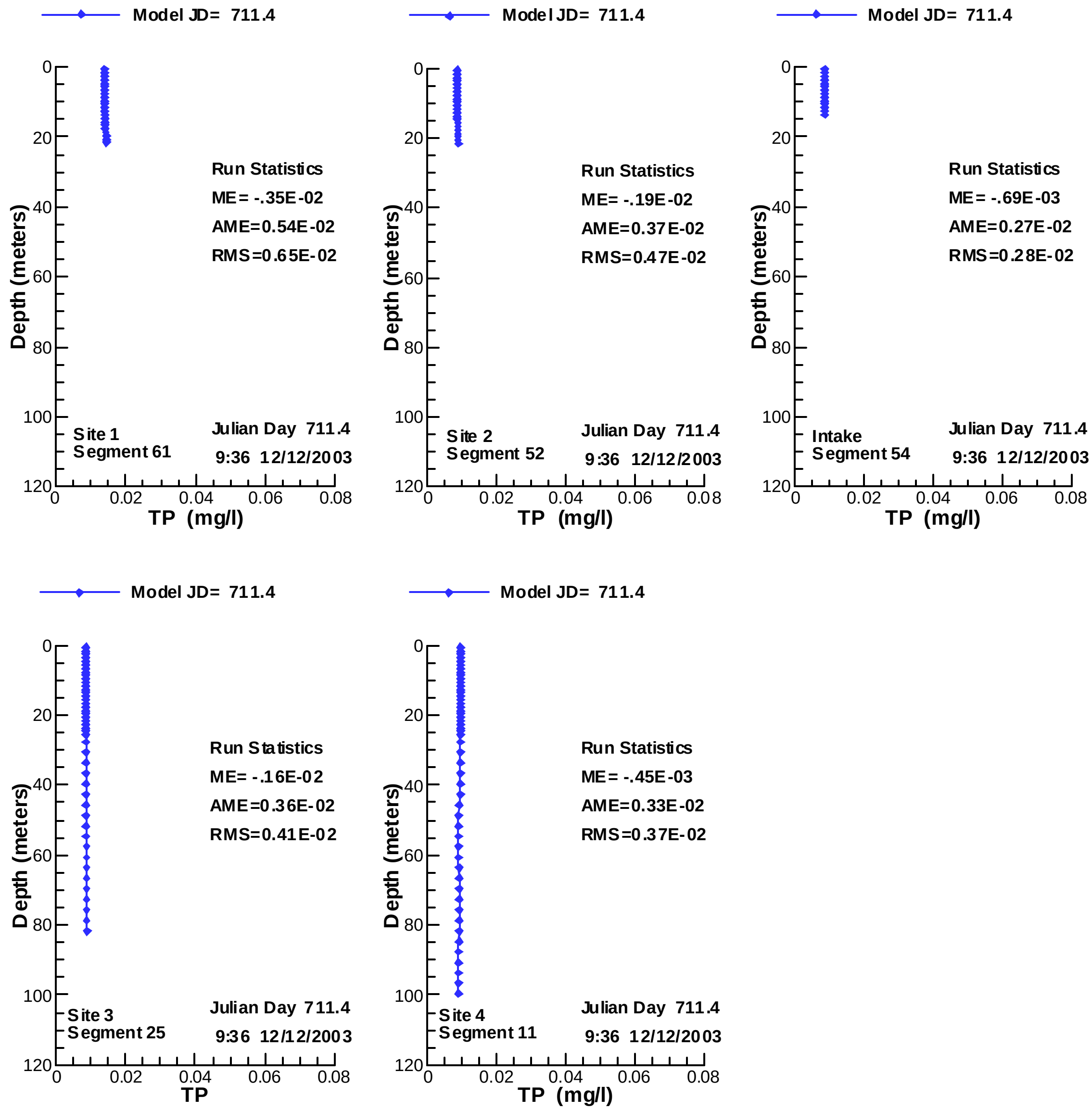

Figure 512. Vertical profiles of TP compared with data for 12/12/2003.

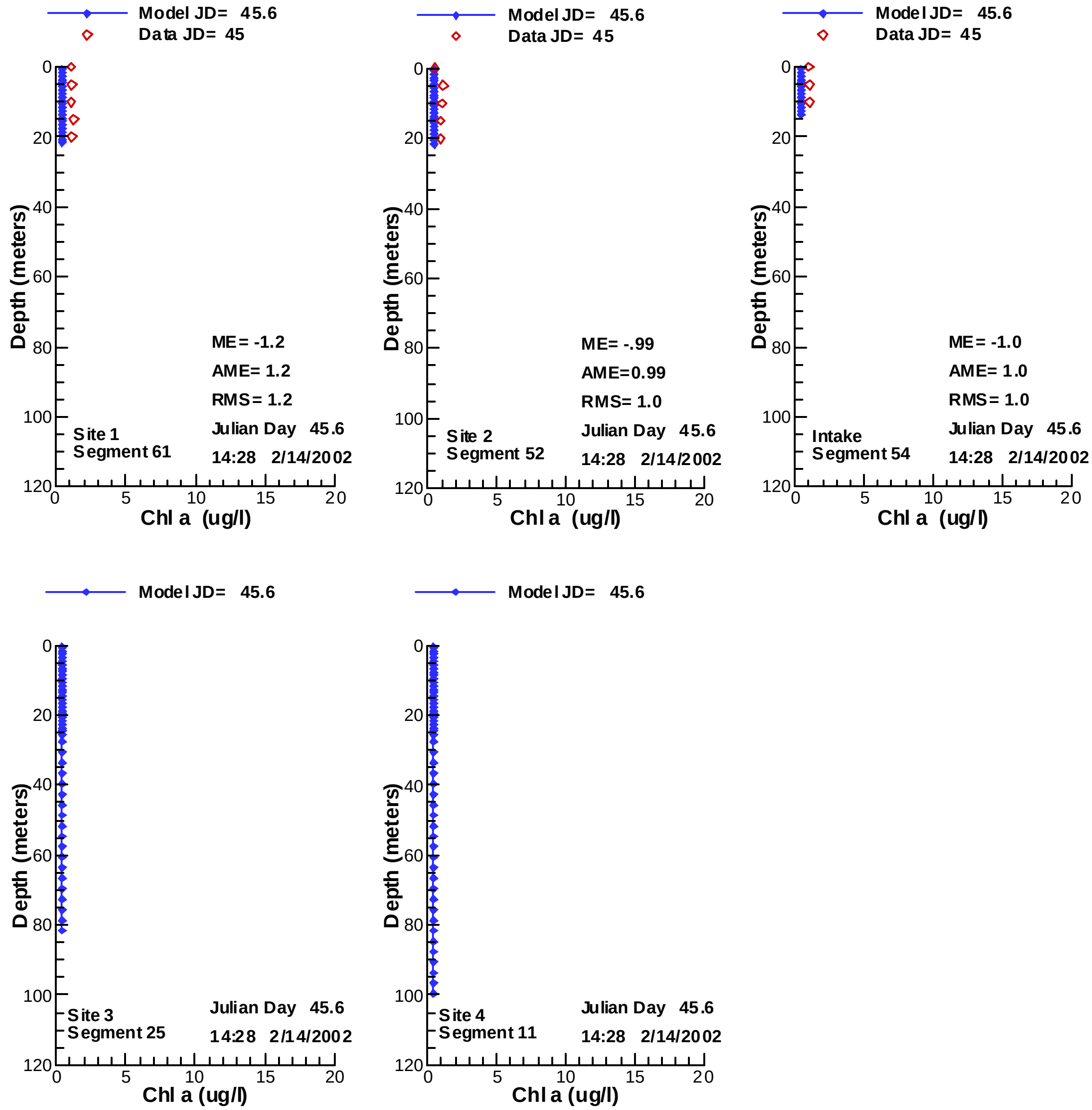

Figure 513. Vertical profiles of Chlorophyll a compared with data for 2/14/2002.

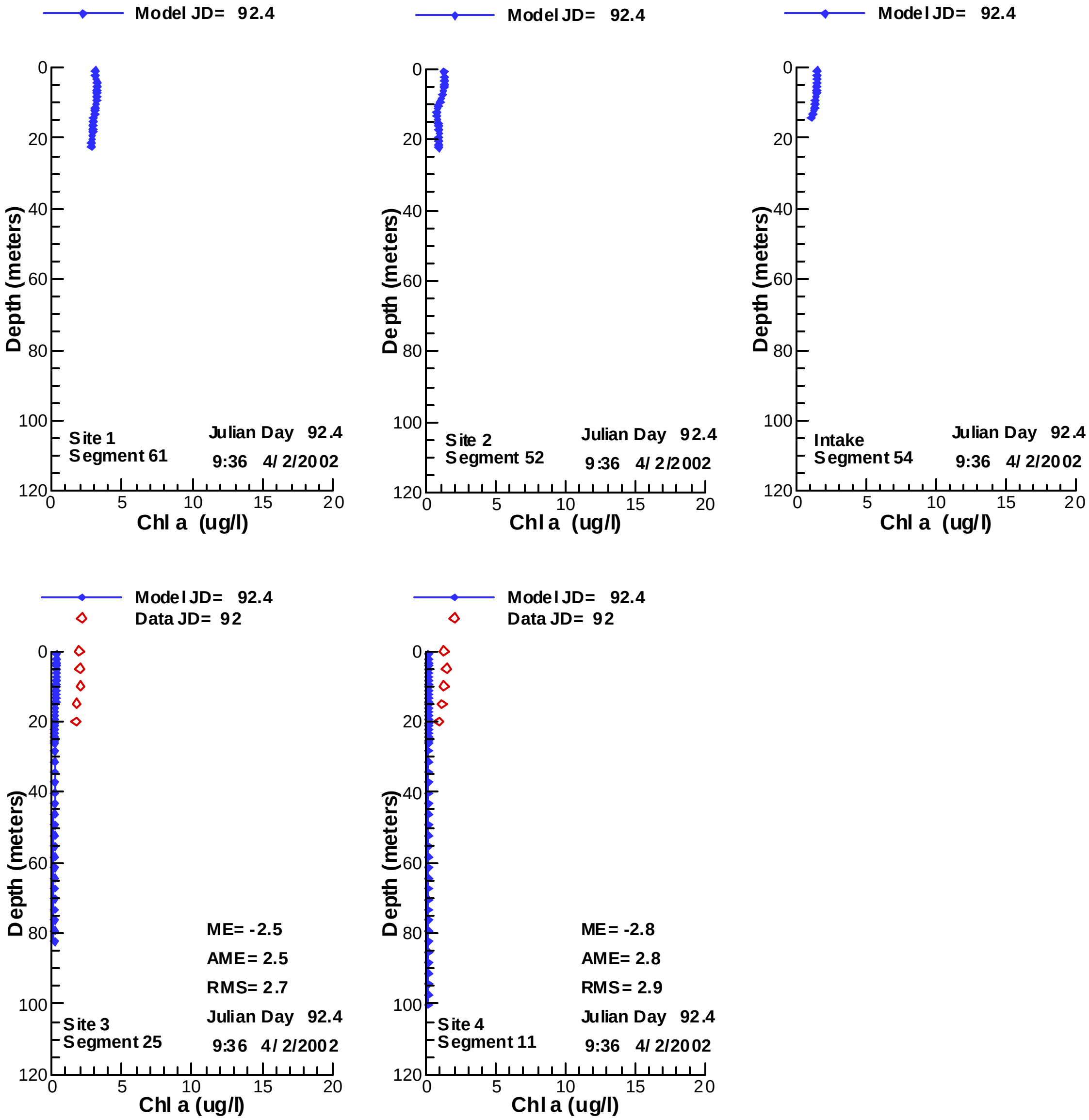

Figure 514. Vertical profiles of Chlorophyll a compared with data for 4/ 2/2002.

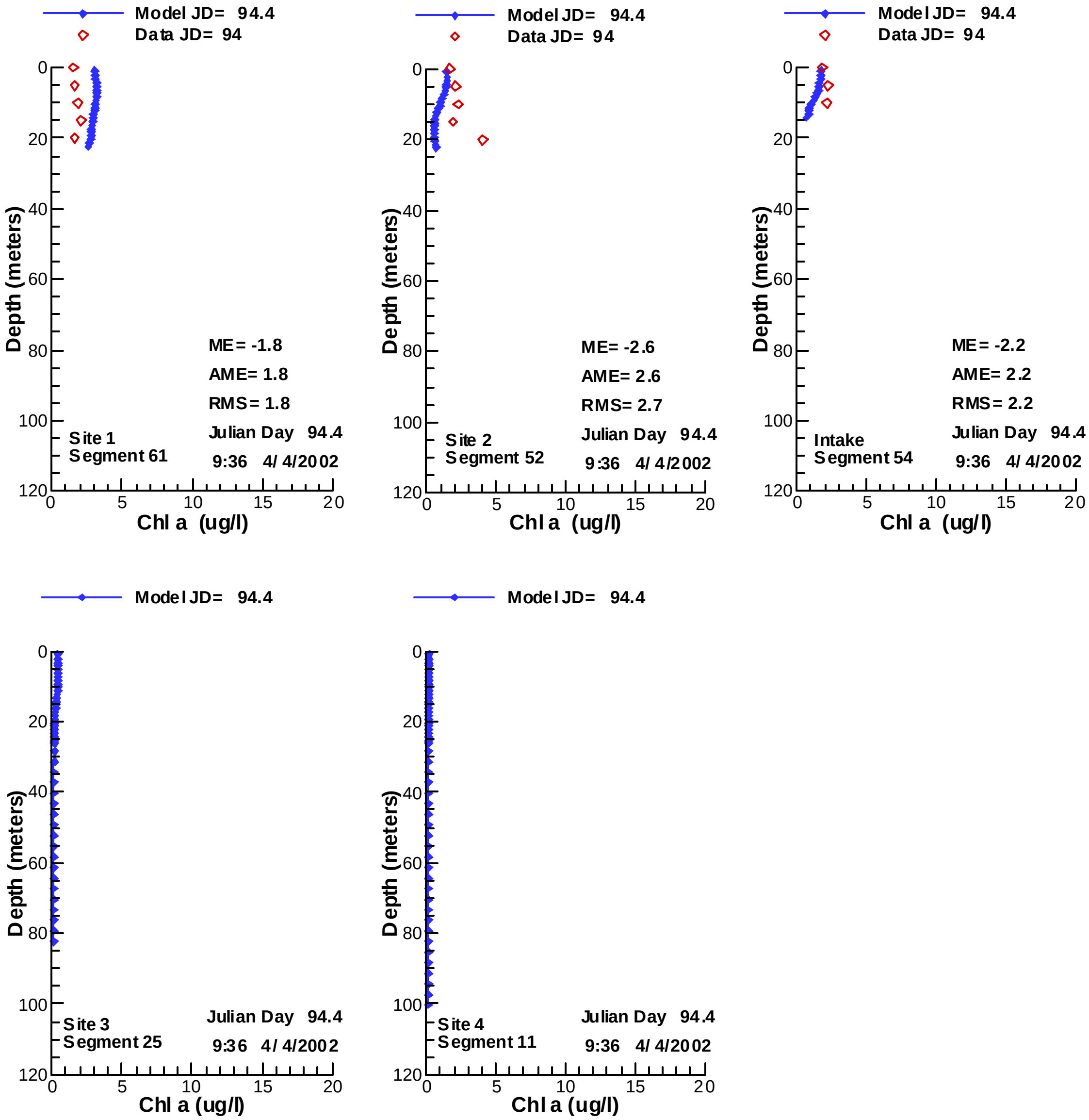

Figure 515. Vertical profiles of Chlorophyll a compared with data for 4/ 4/2002.

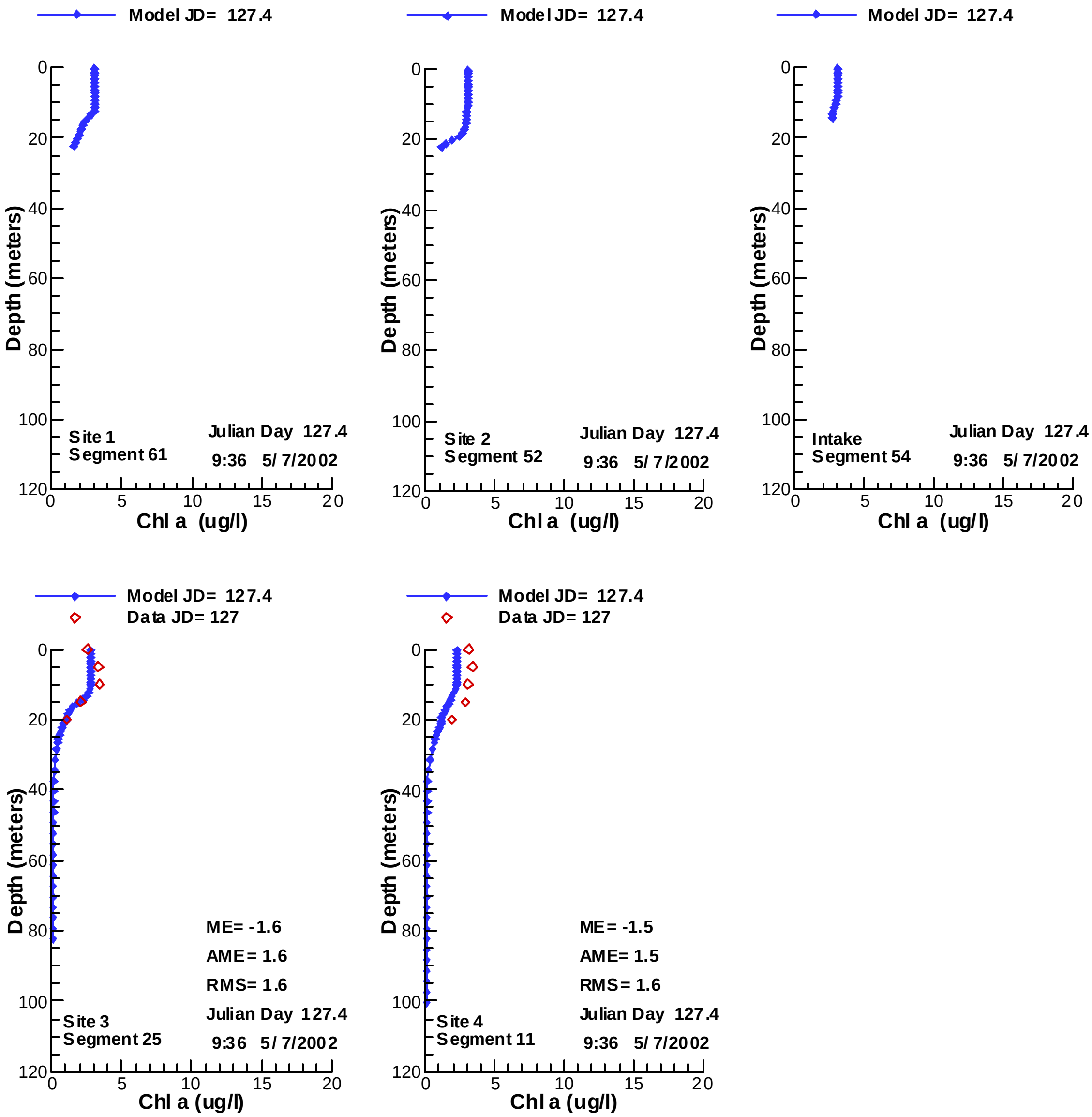

Figure 516. Vertical profiles of Chlorophyll a compared with data for 5/ 7/2002.

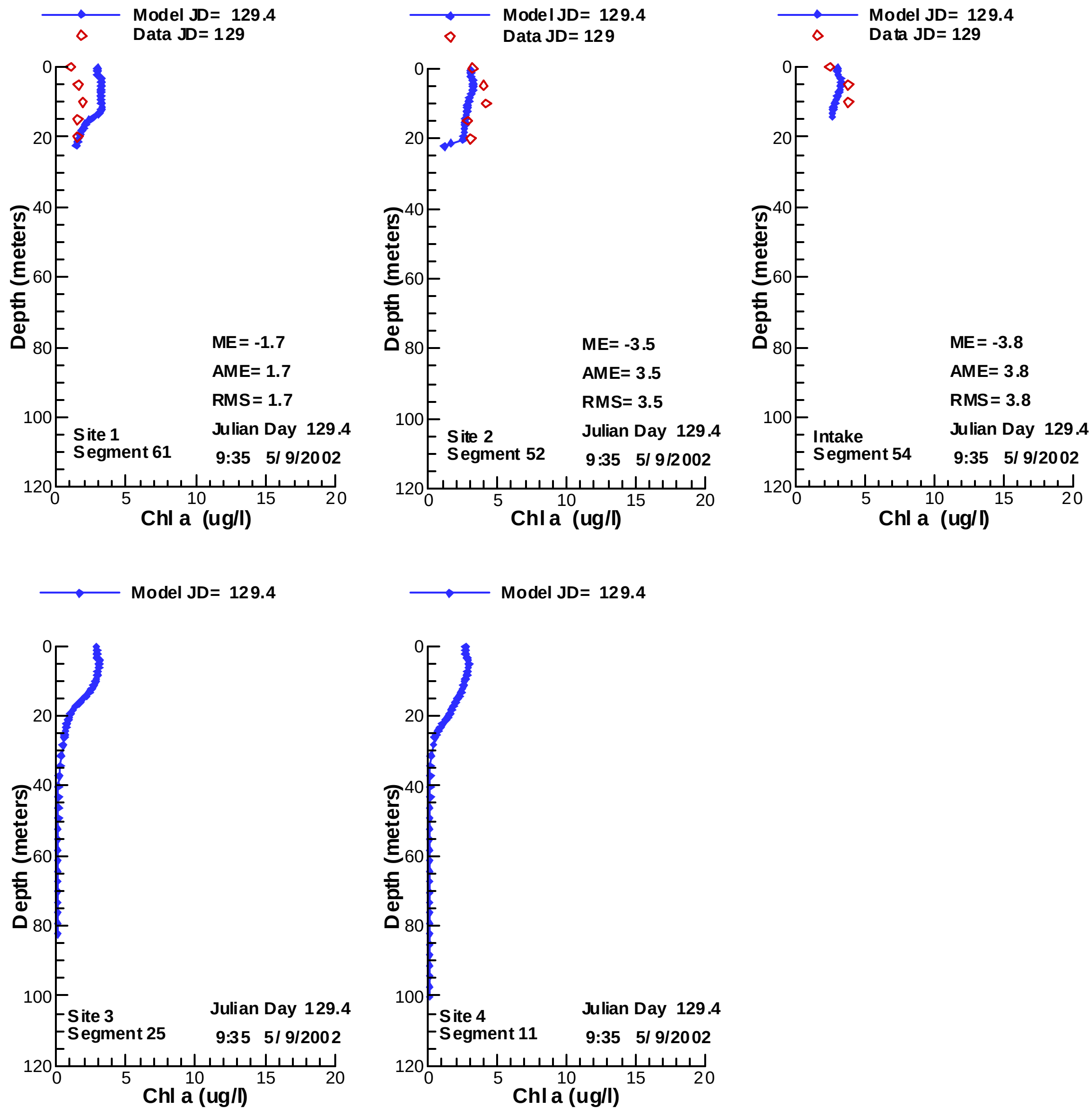

Figure 517. Vertical profiles of Chlorophyll a compared with data for 5/ 9/2002.

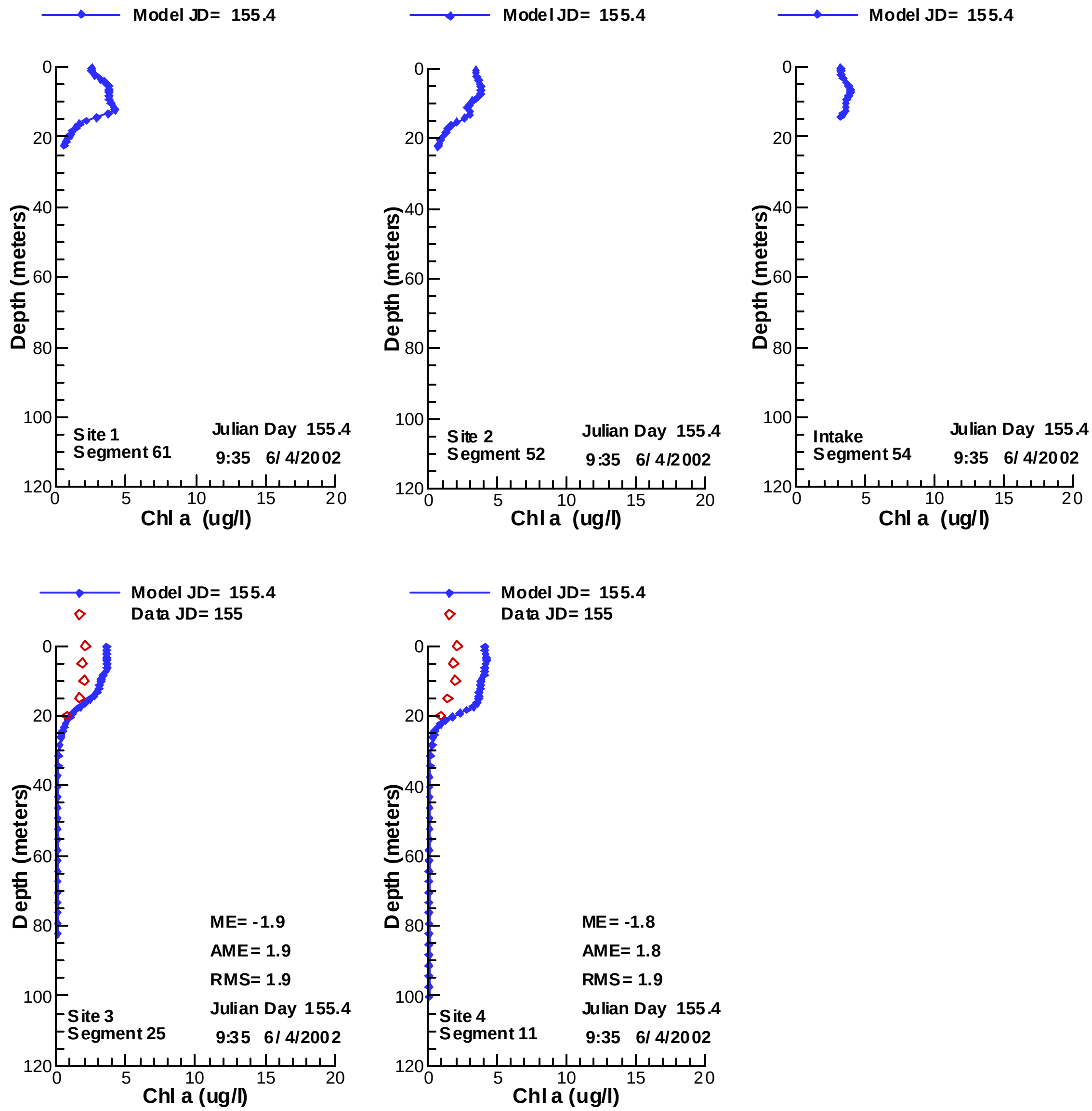

Figure 518. Vertical profiles of Chlorophyll a compared with data for 6/ 4/2002.

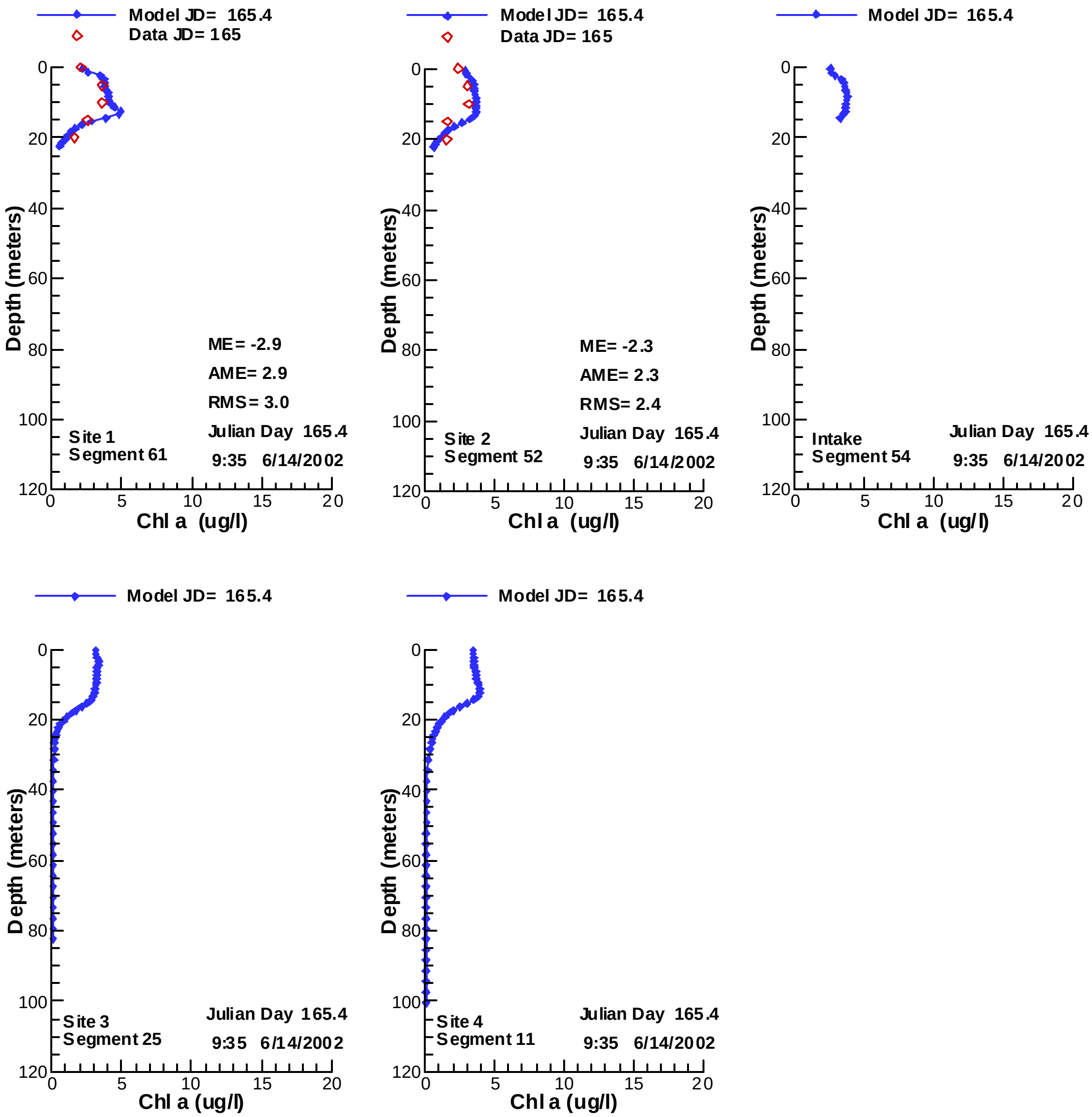

Figure 519. Vertical profiles of Chlorophyll a compared with data for 6/14/2002.

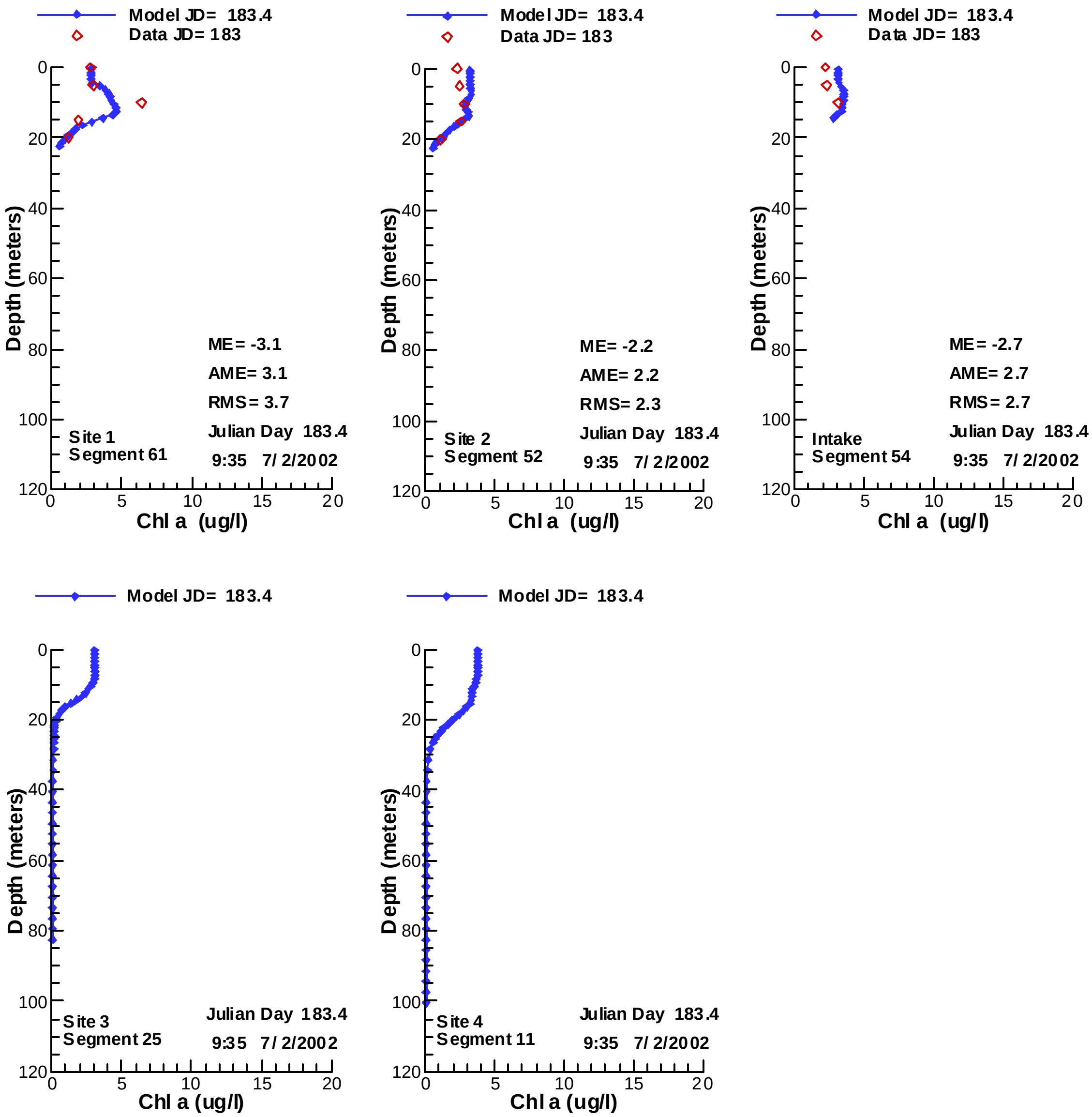

Figure 520. Vertical profiles of Chlorophyll a compared with data for 7/ 2/2002.

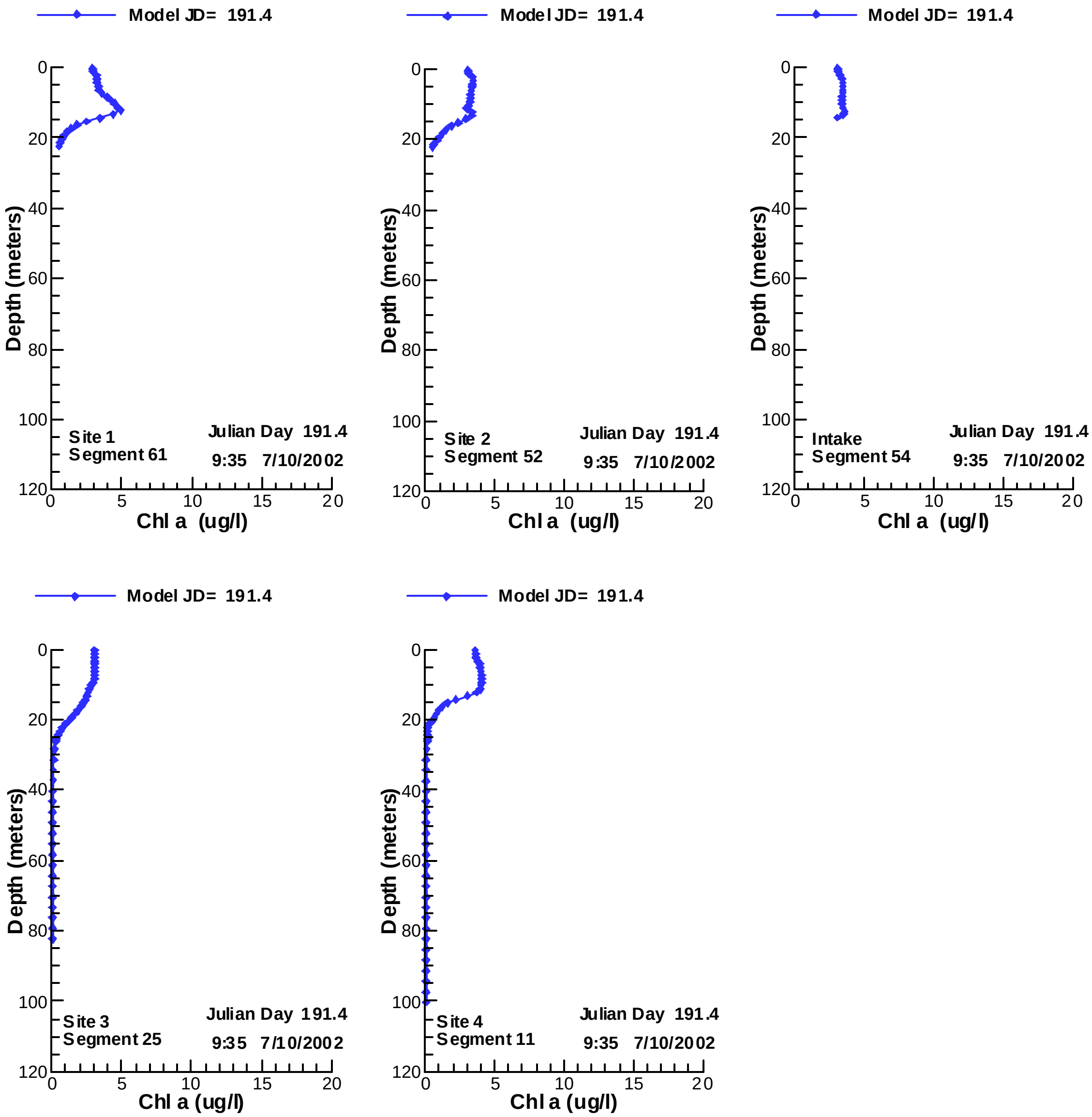

Figure 521. Vertical profiles of Chlorophyll a compared with data for 7/10/2002.

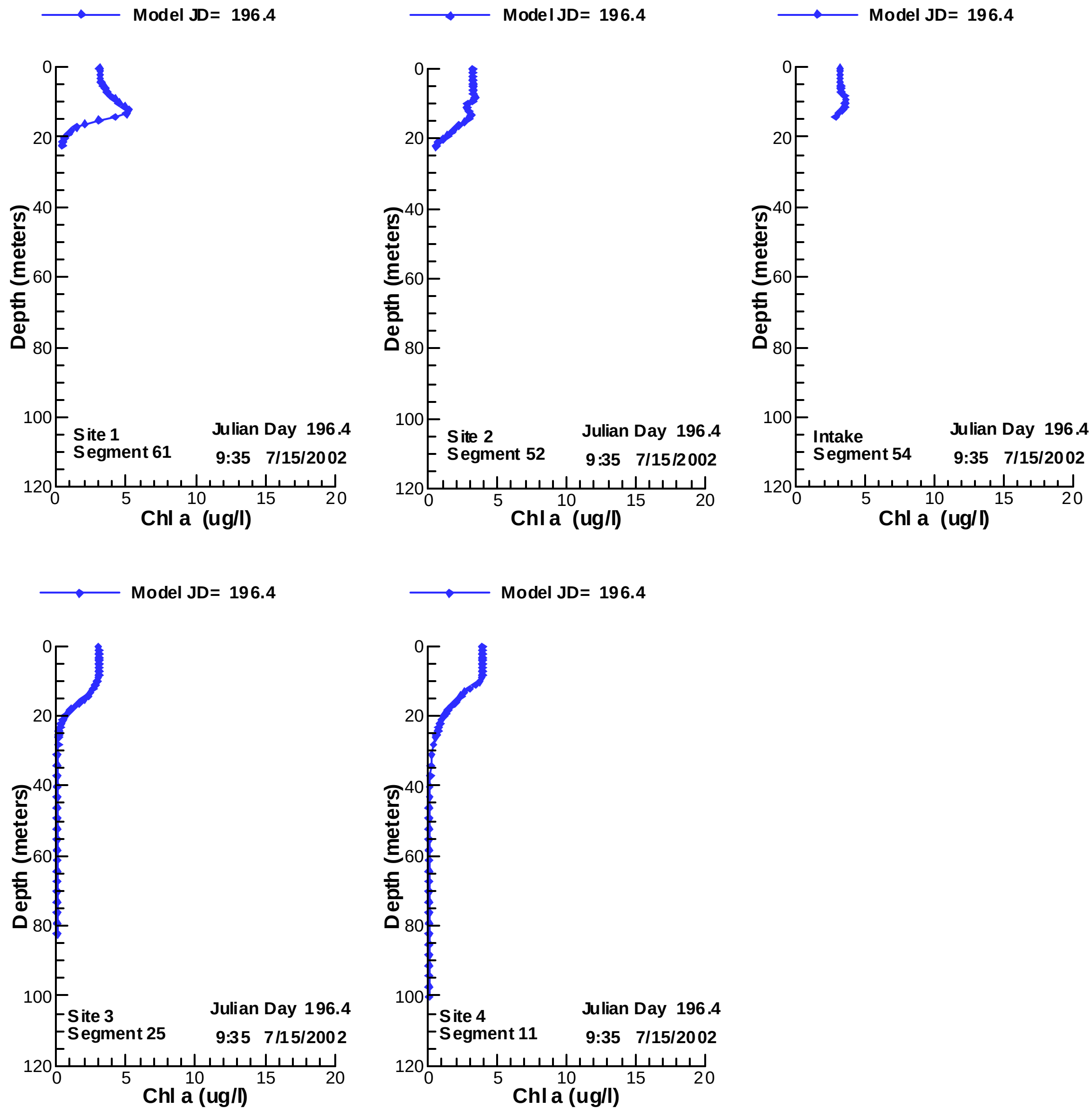

Figure 522. Vertical profiles of Chlorophyll a compared with data for 7/15/2002.

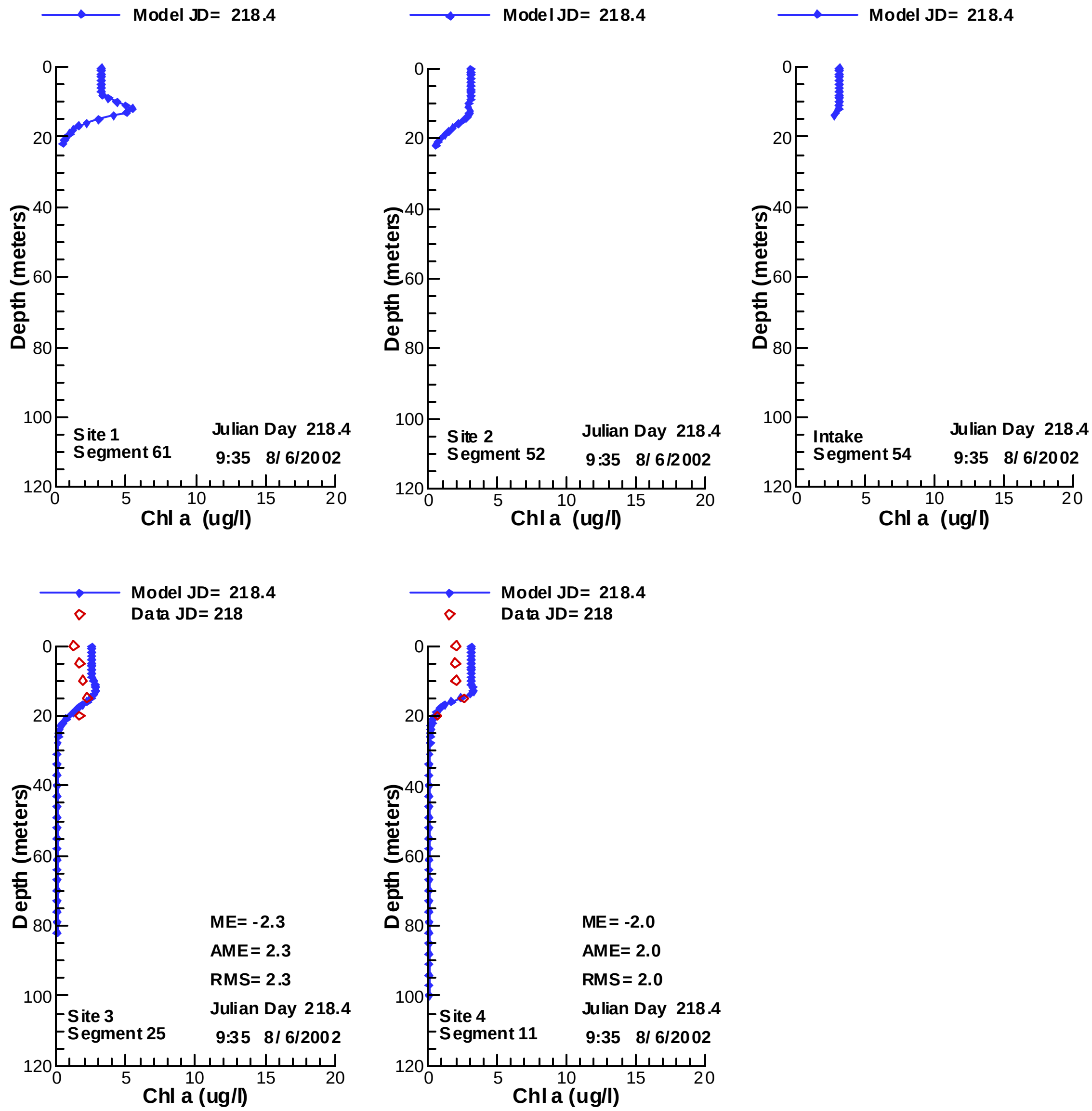

Figure 523. Vertical profiles of Chlorophyll a compared with data for 8/ 6/2002.

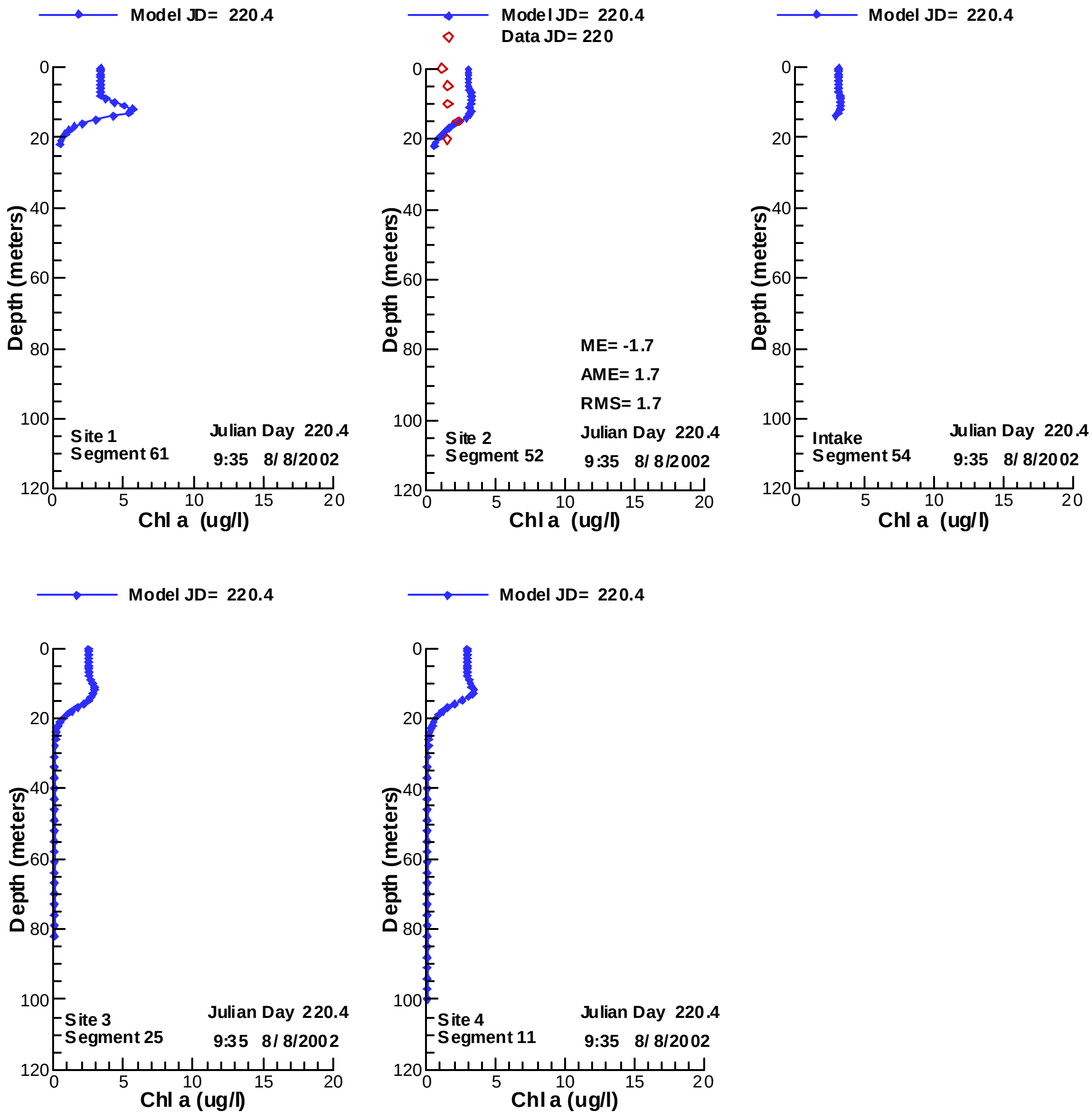

Figure 524. Vertical profiles of Chlorophyll a compared with data for 8/ 8/2002.

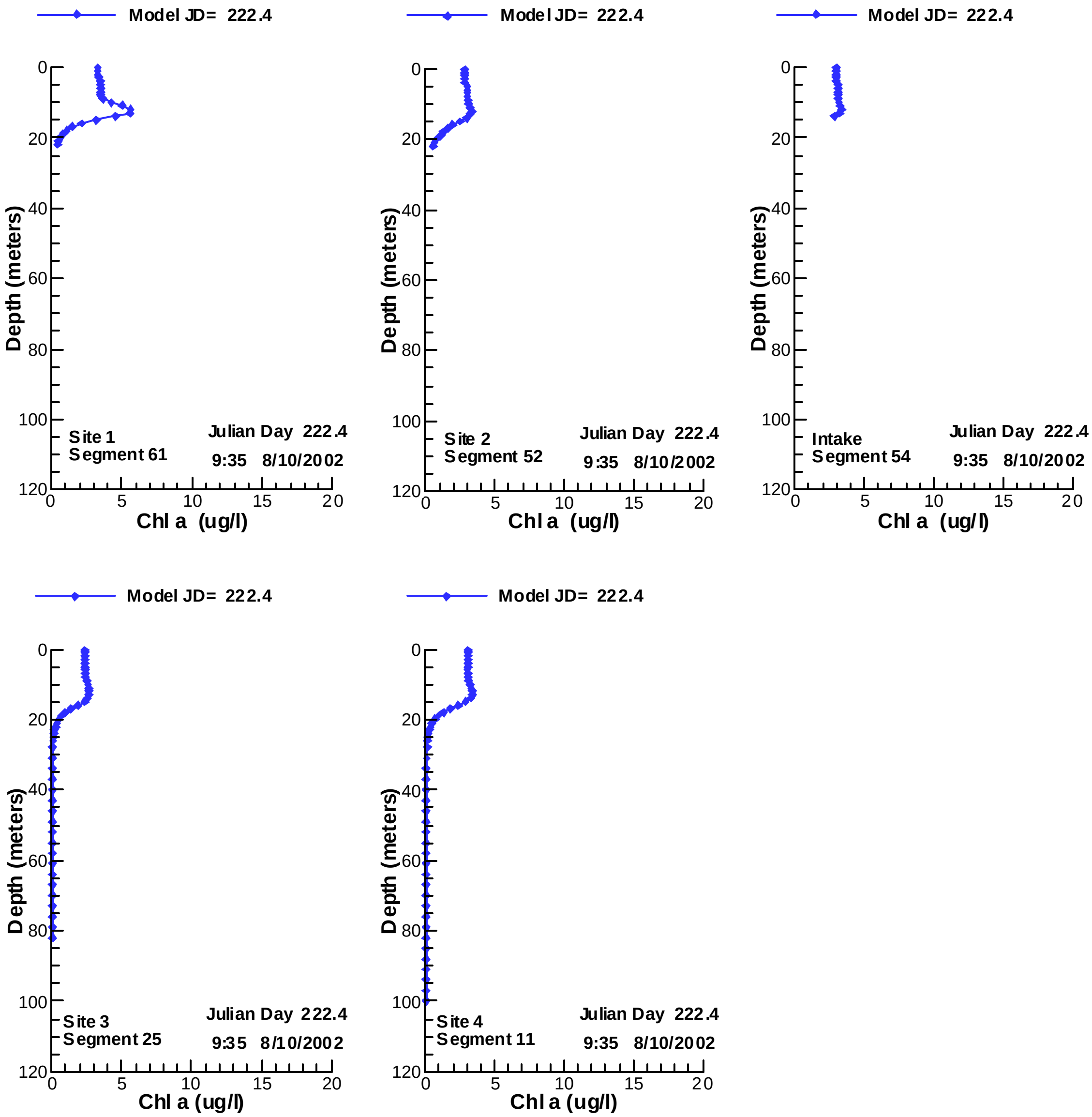

Figure 525. Vertical profiles of Chlorophyll a compared with data for 8/10/2002.

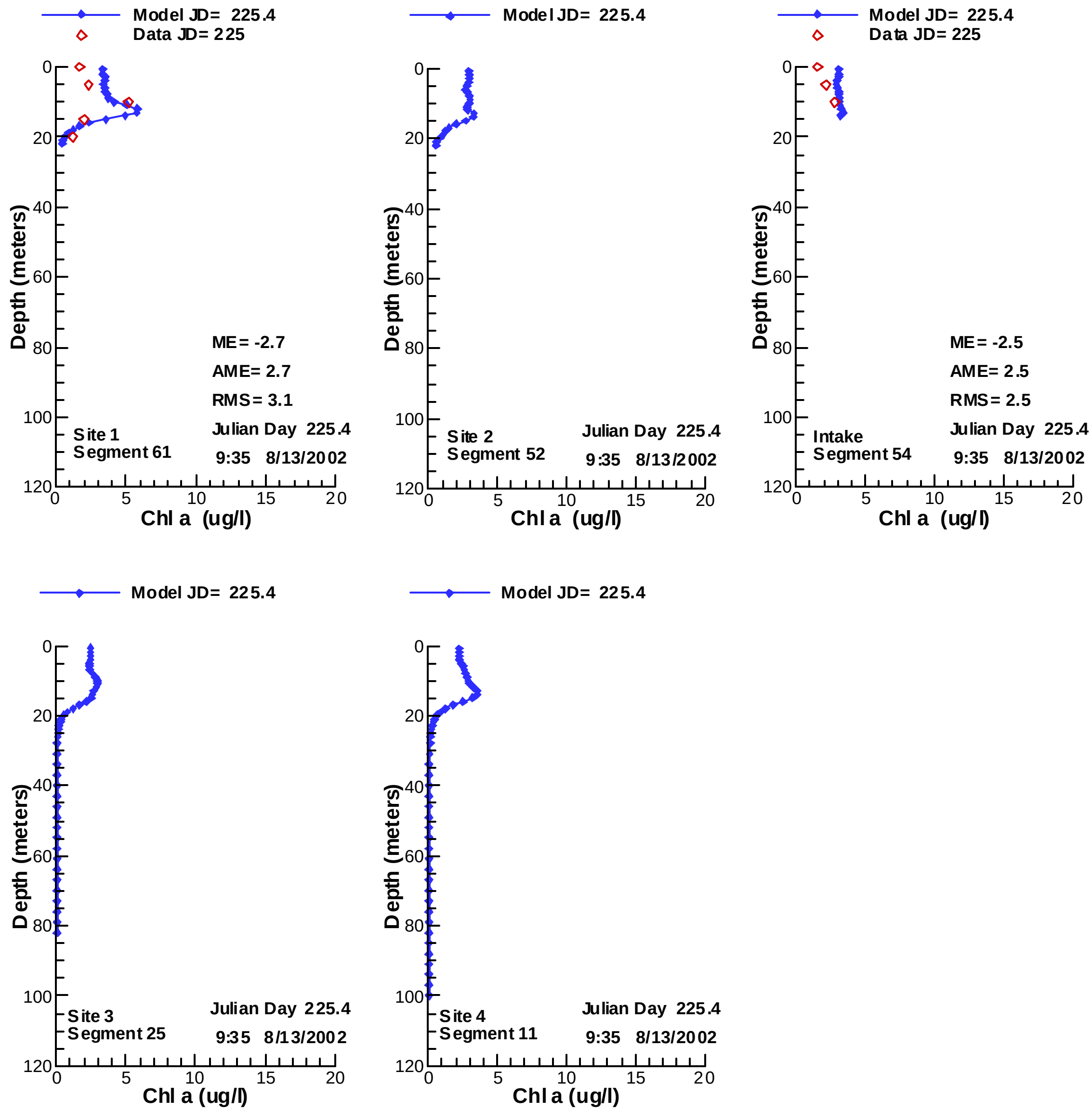

Figure 526. Vertical profiles of Chlorophyll a compared with data for 8/13/2002.

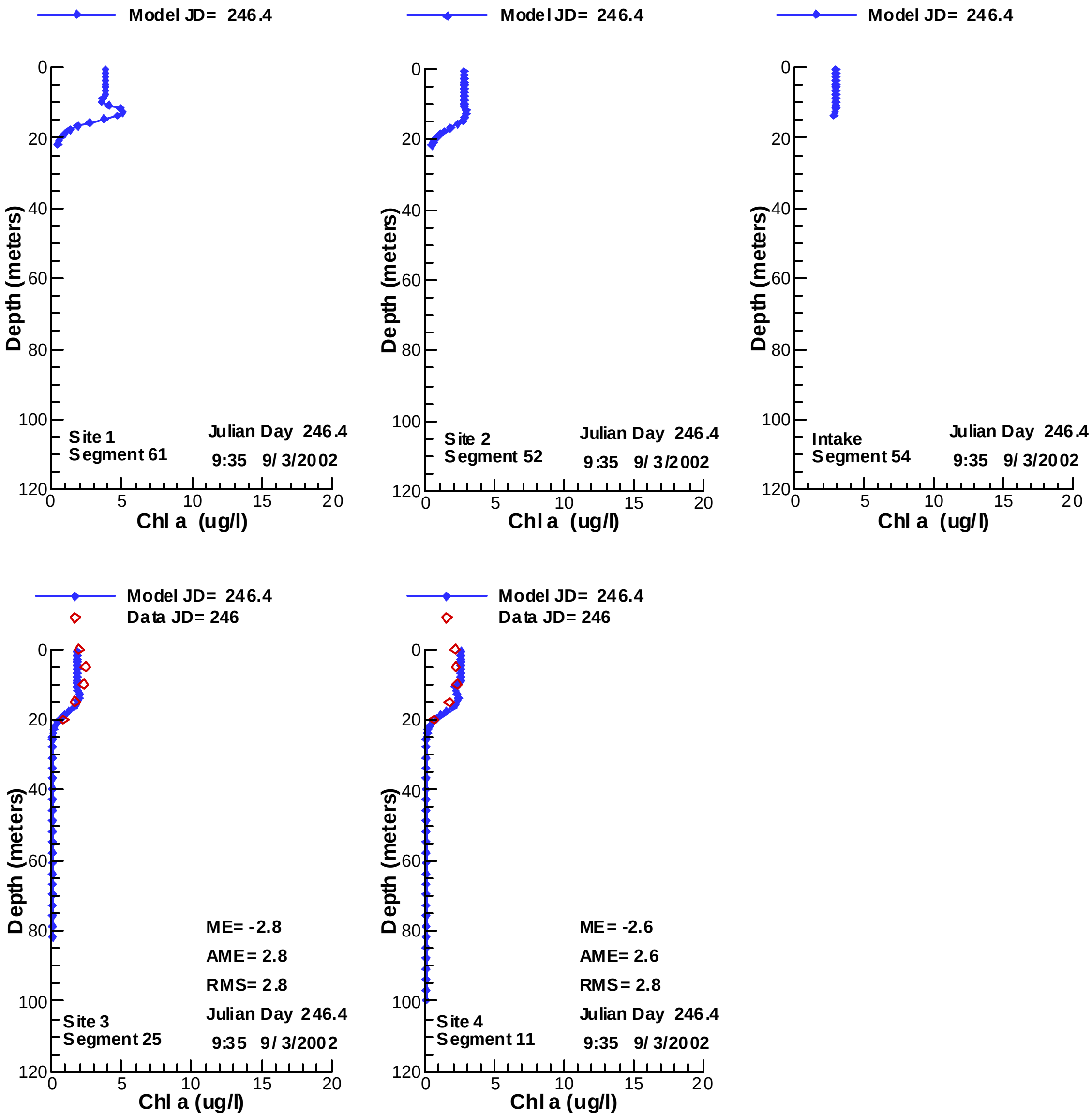

Figure 527. Vertical profiles of Chlorophyll a compared with data for 9/ 3/2002.

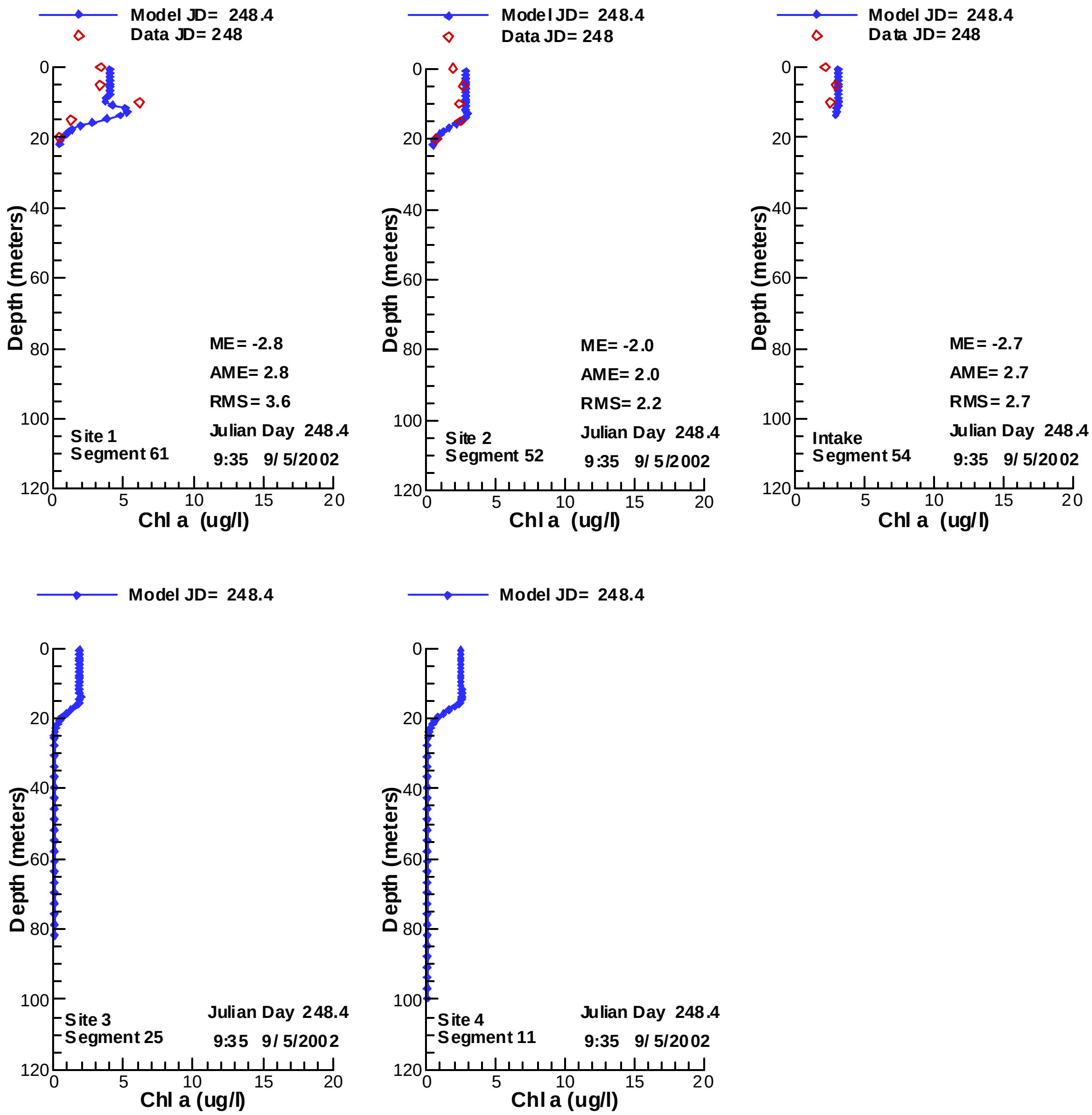

Figure 528. Vertical profiles of Chlorophyll a compared with data for 9/ 5/2002.

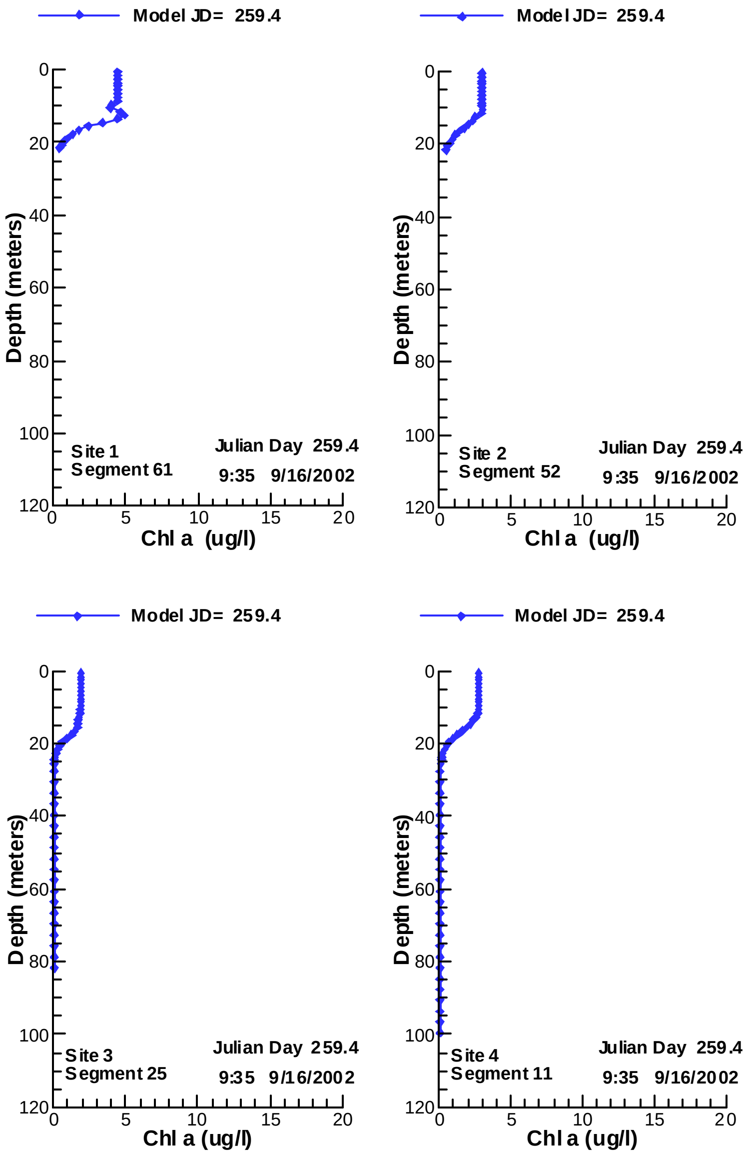

Figure 529. Vertical profiles of Chlorophyll a compared with data for 9/16/2002.

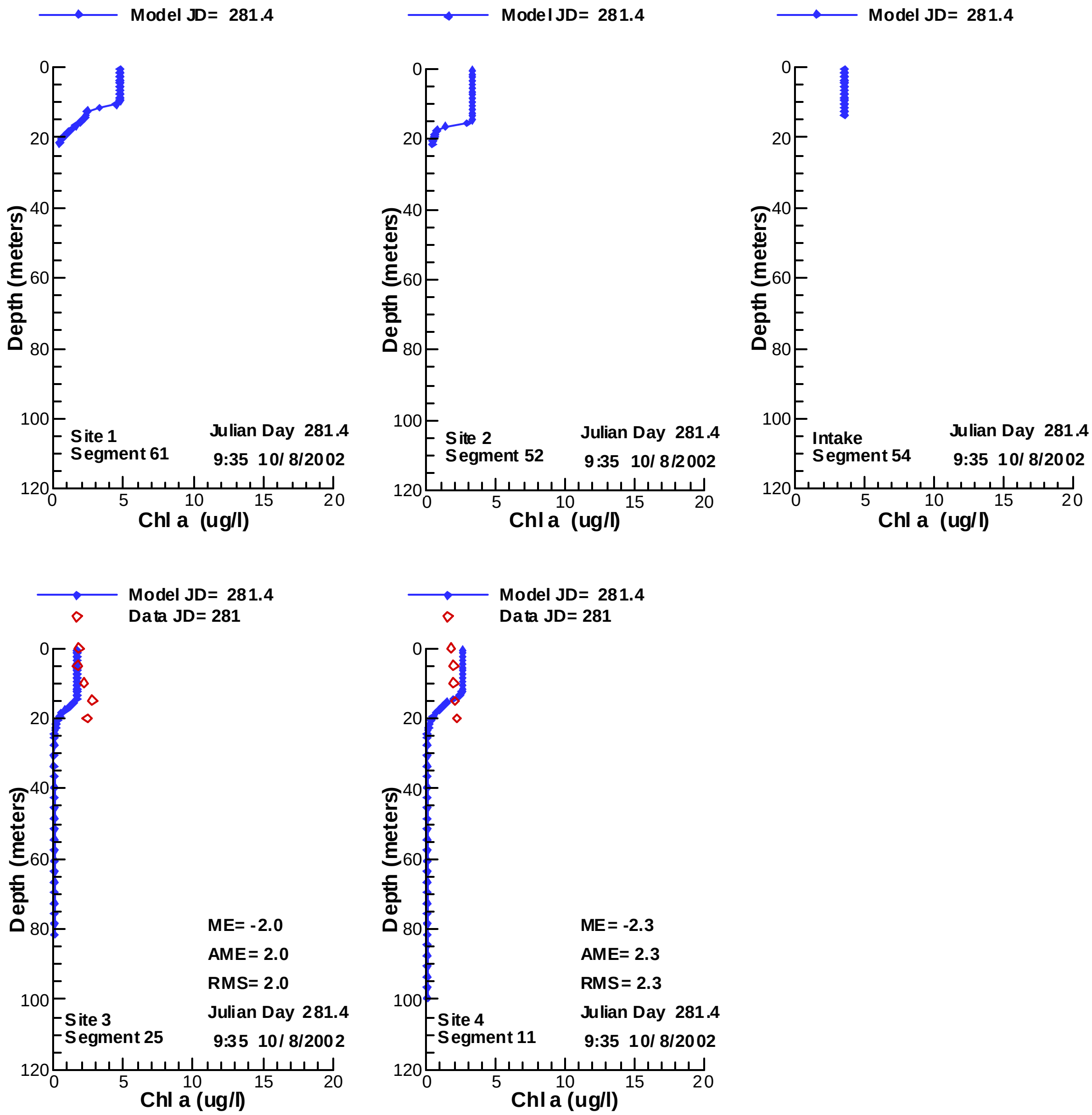

Figure 530. Vertical profiles of Chlorophyll a compared with data for 10/ 8/2002.

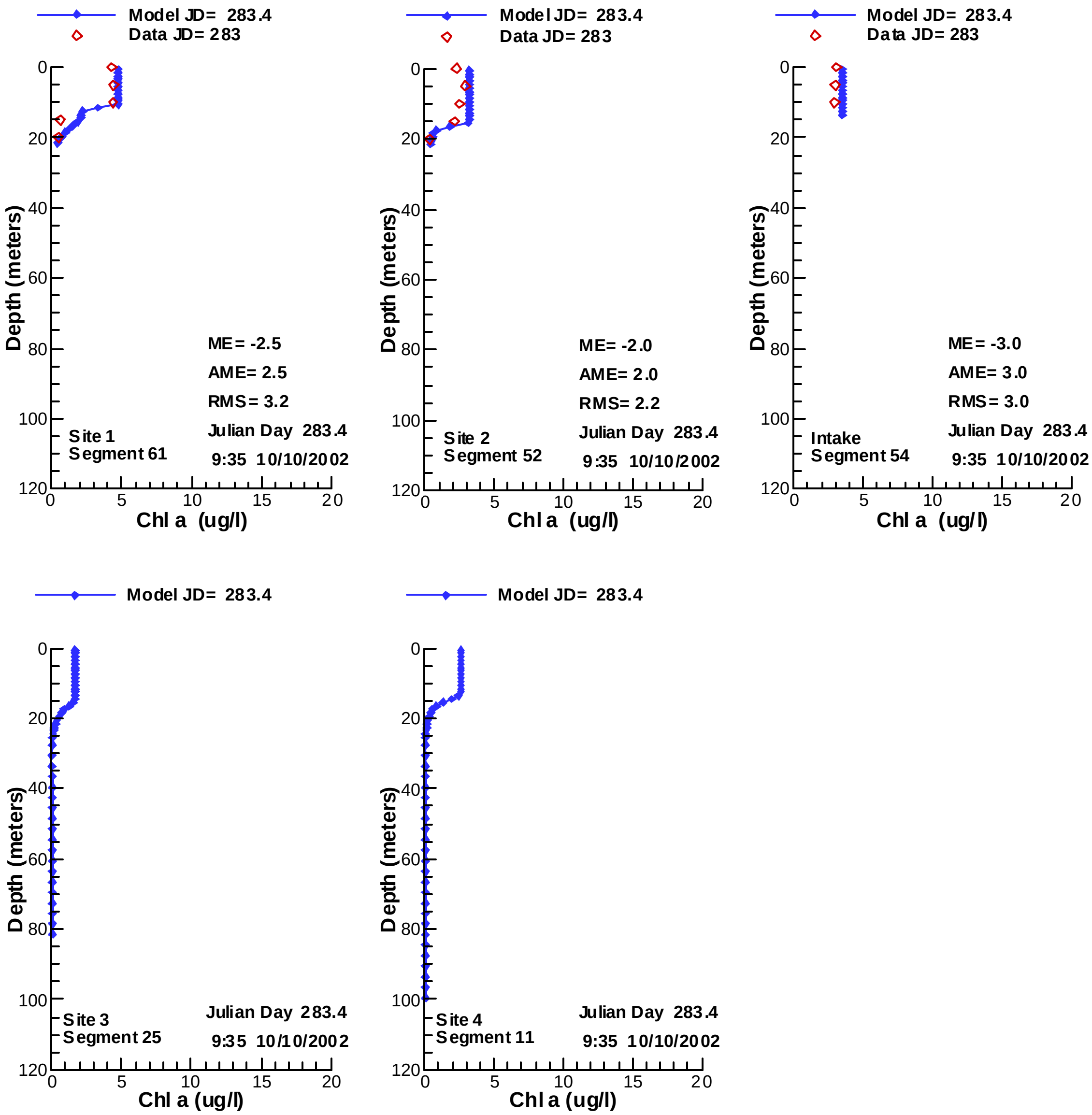

Figure 531. Vertical profiles of Chlorophyll a compared with data for 10/10/2002.

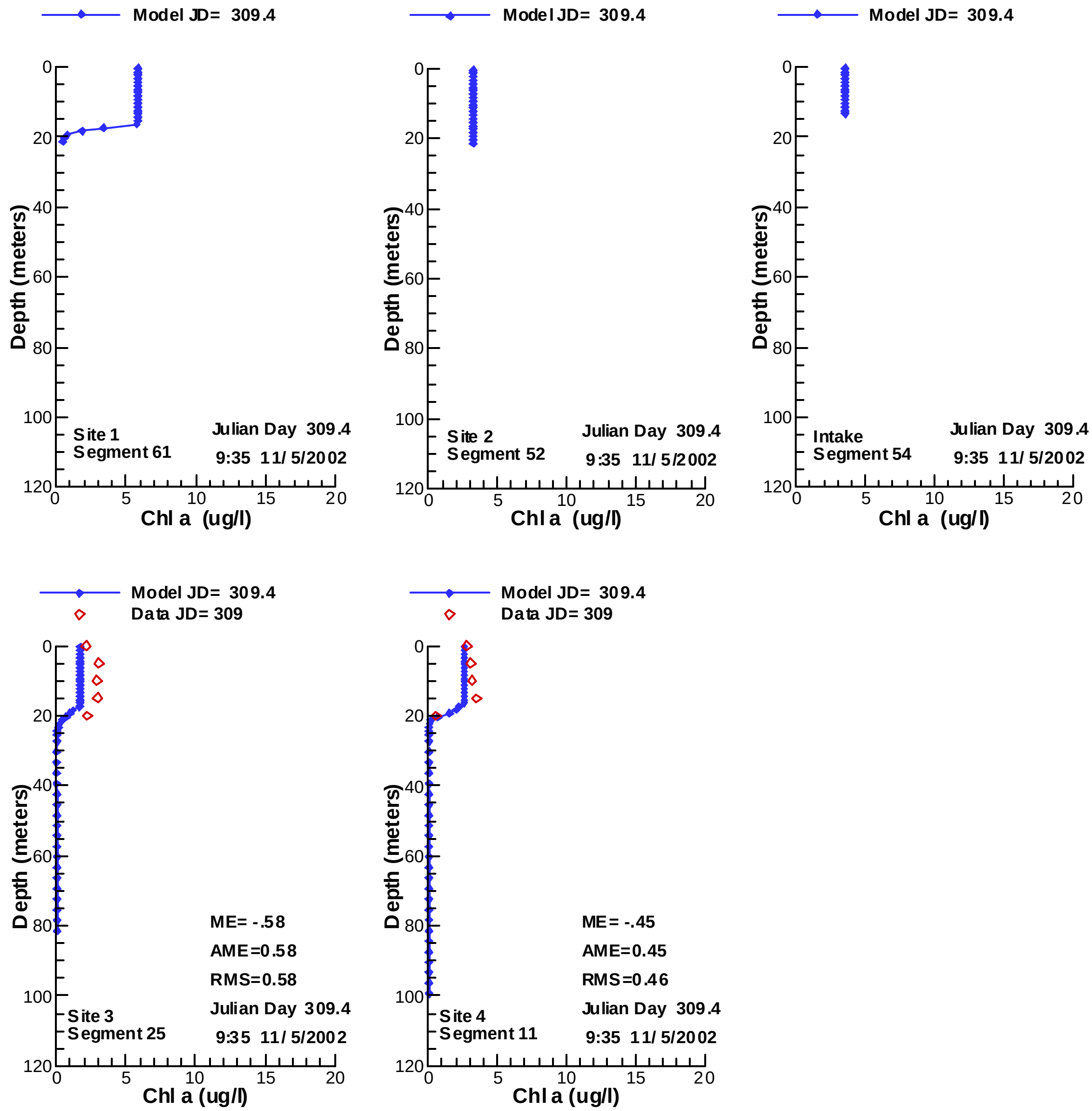

Figure 532. Vertical profiles of Chlorophyll a compared with data for 11/ 5/2002.

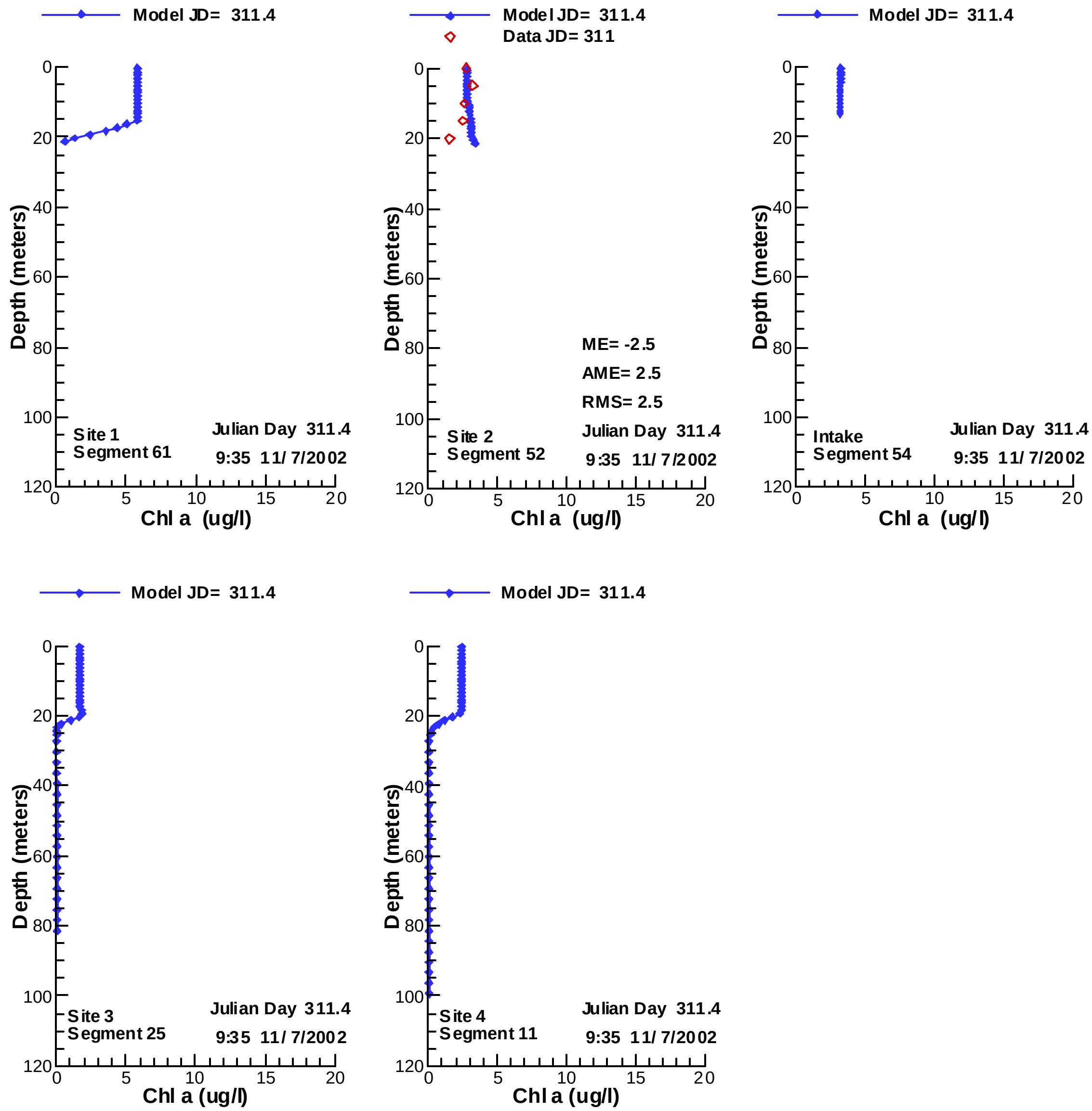

Figure 533. Vertical profiles of Chlorophyll a compared with data for 11/ 7/2002.

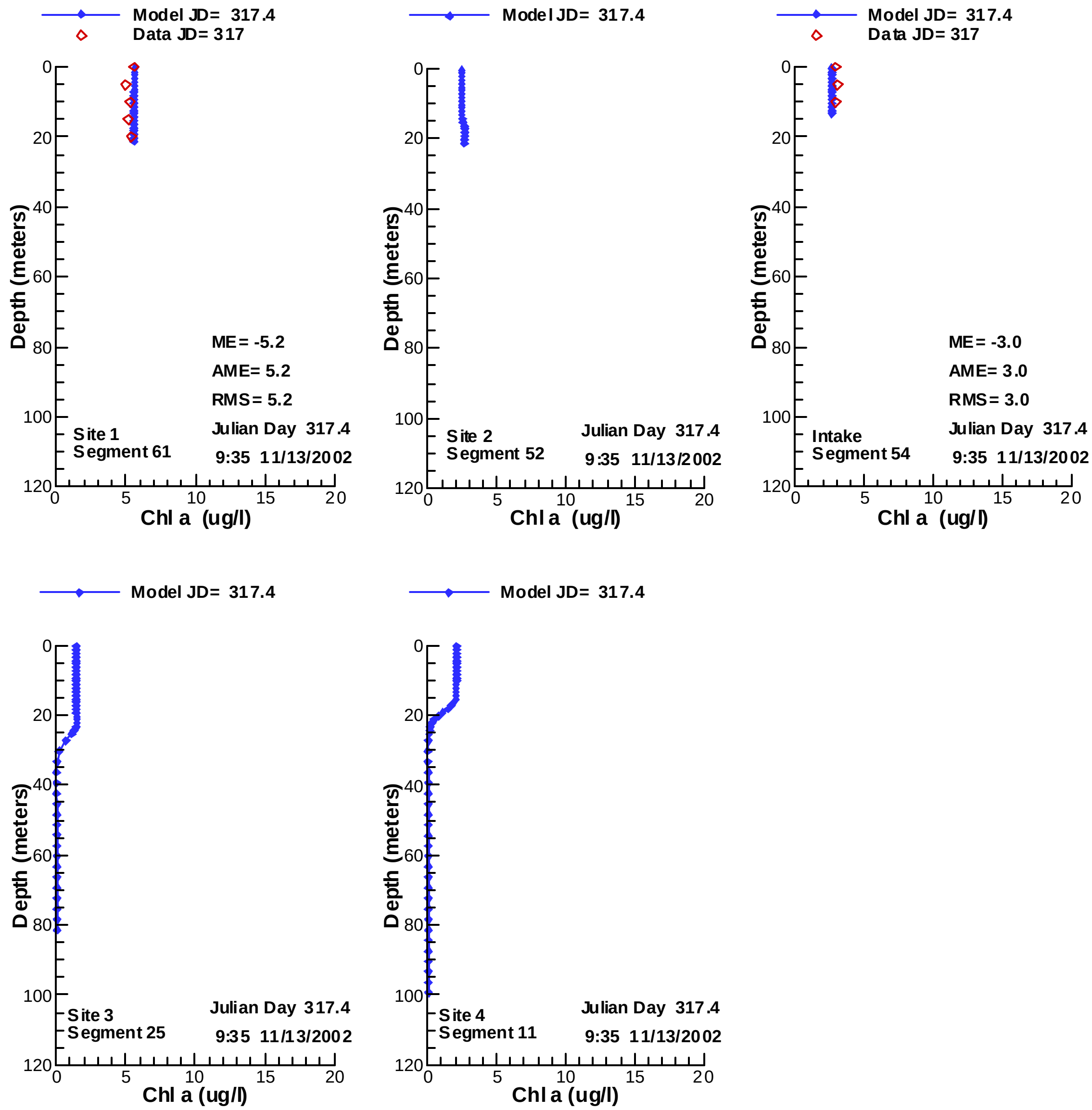

Figure 534. Vertical profiles of Chlorophyll a compared with data for 11/13/2002.

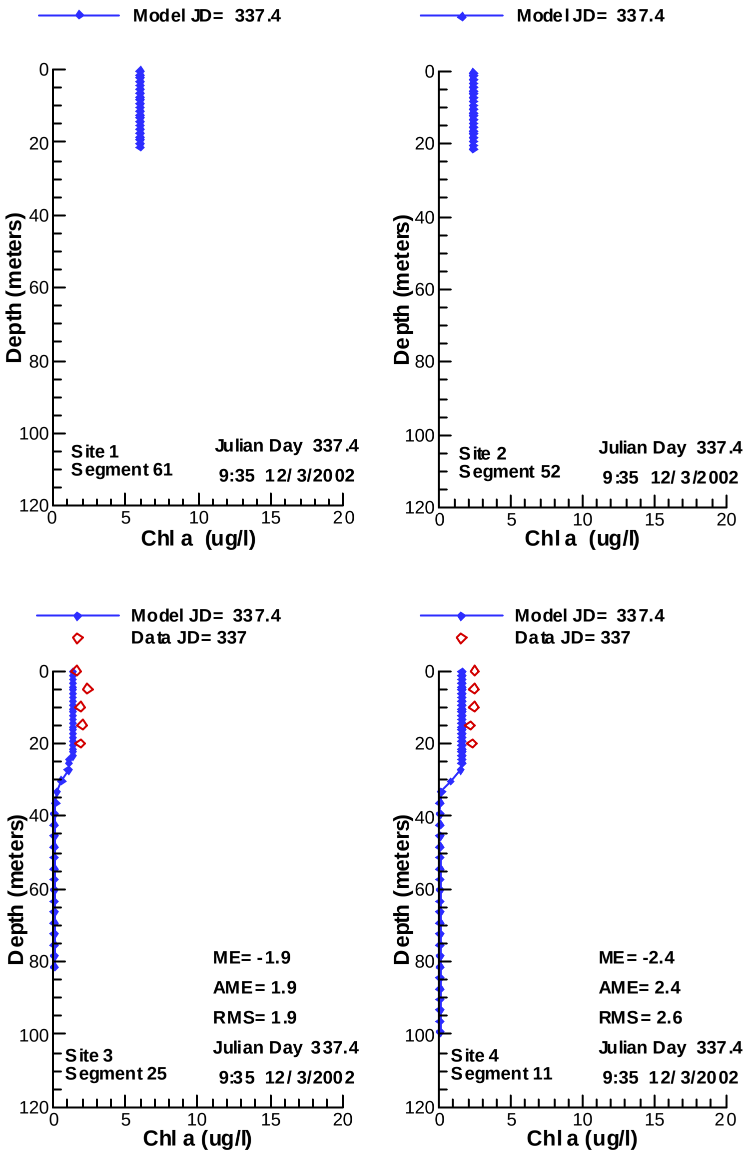

Figure 535. Vertical profiles of Chlorophyll a compared with data for 12/ 3/2002.

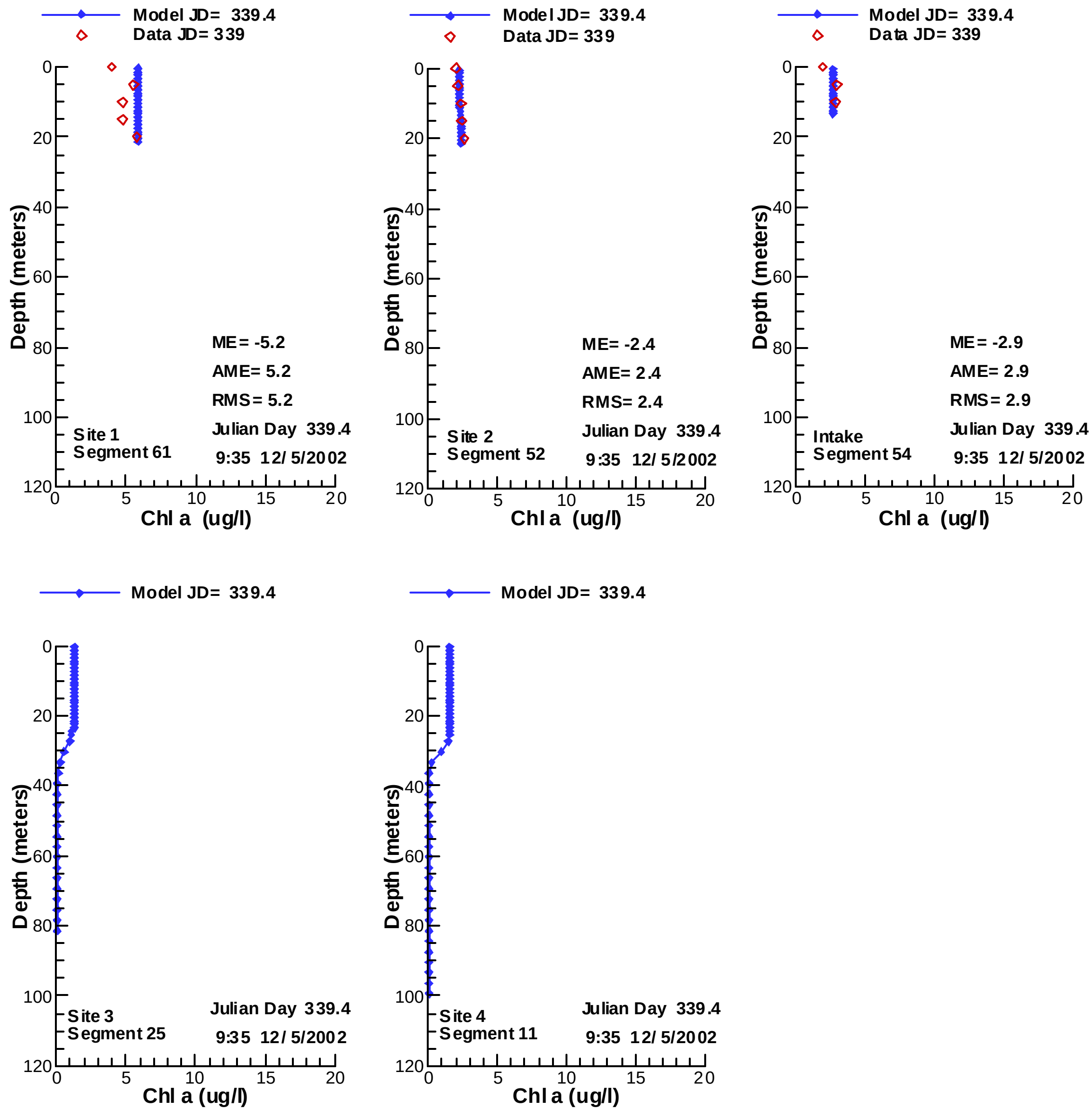

Figure 536. Vertical profiles of Chlorophyll a compared with data for 12/ 5/2002.

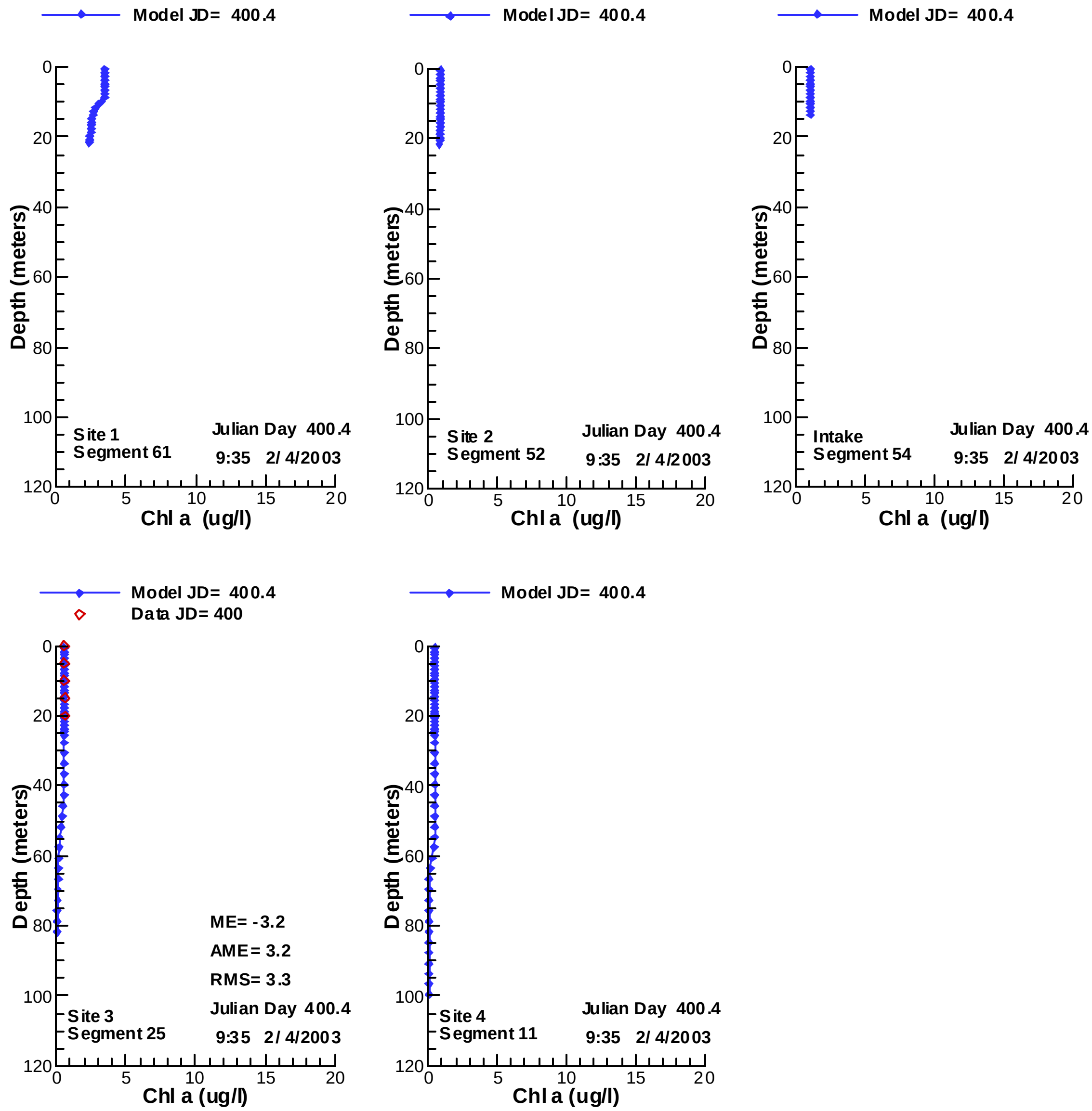

Figure 537. Vertical profiles of Chlorophyll a compared with data for 2/ 4/2003.

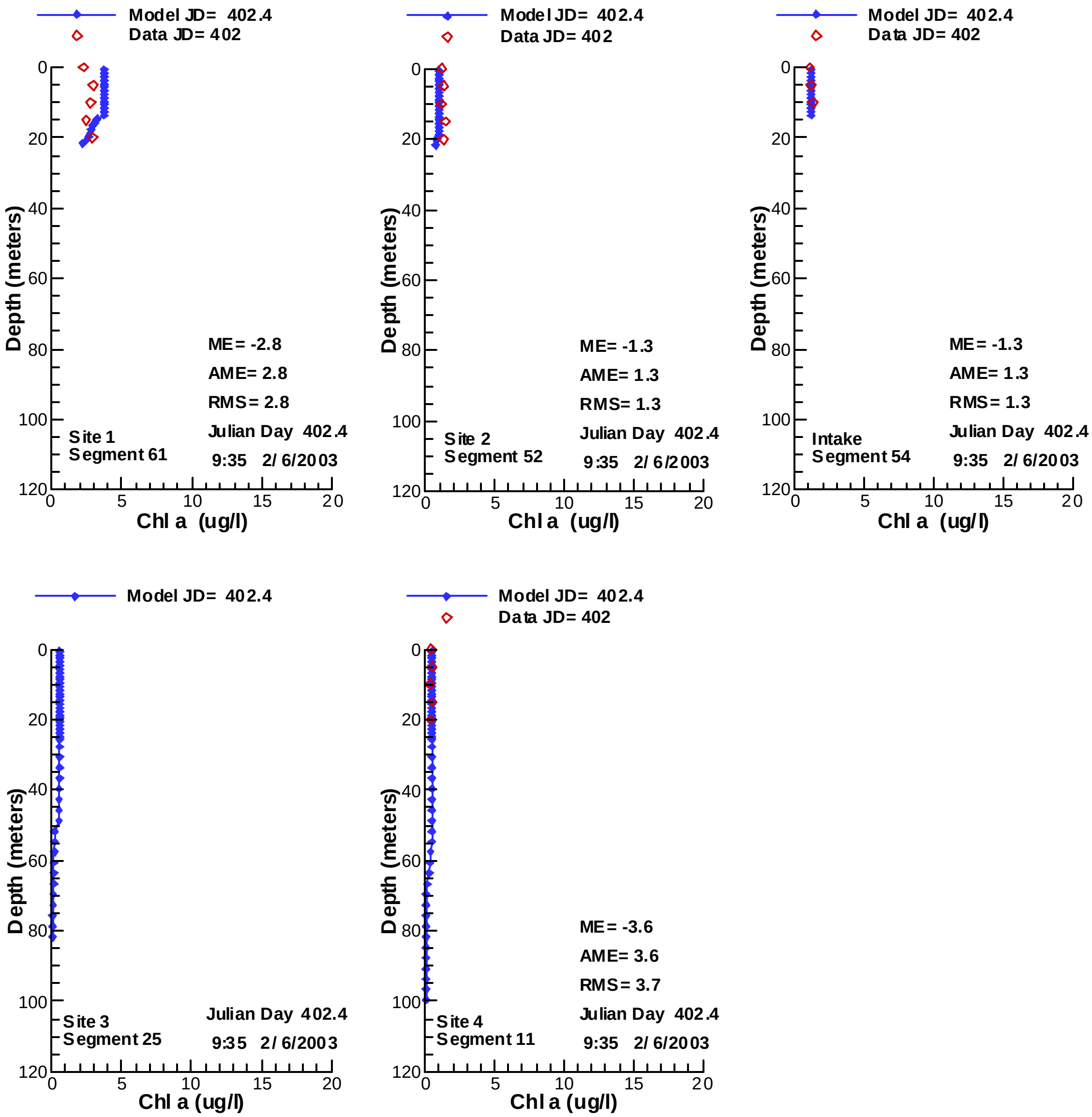

Figure 538. Vertical profiles of Chlorophyll a compared with data for 2/ 6/2003.

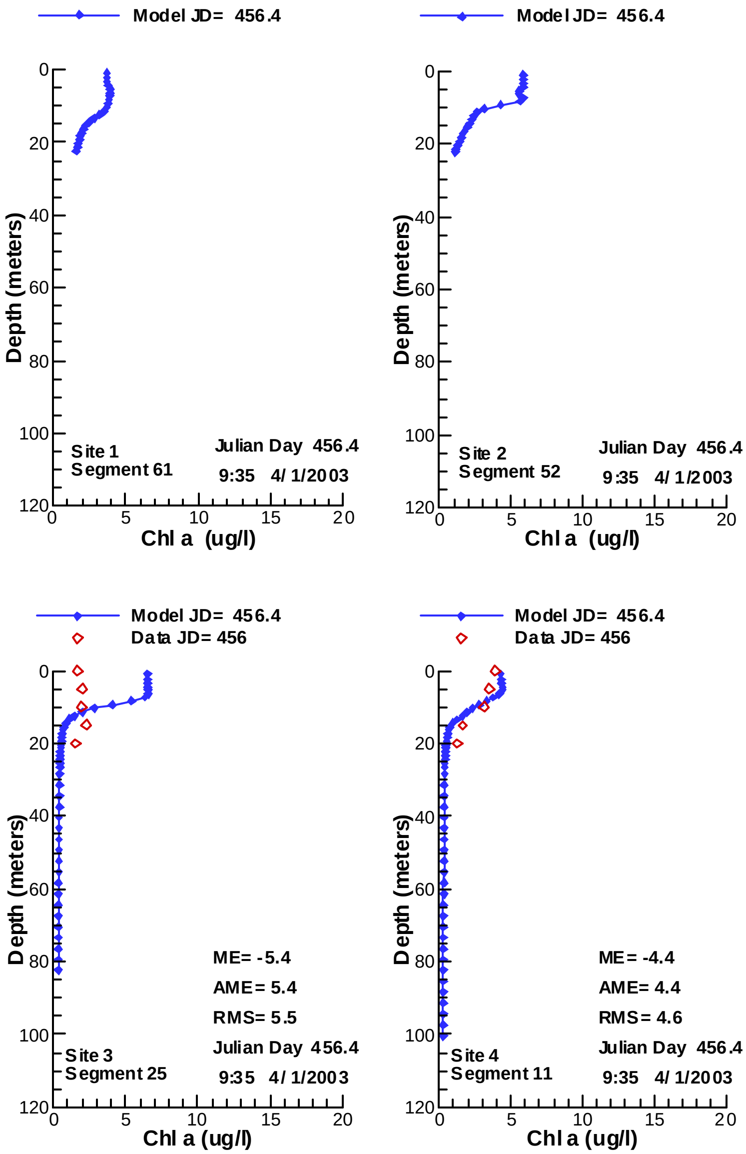

Figure 539. Vertical profiles of Chlorophyll a compared with data for 4/ 1/2003.

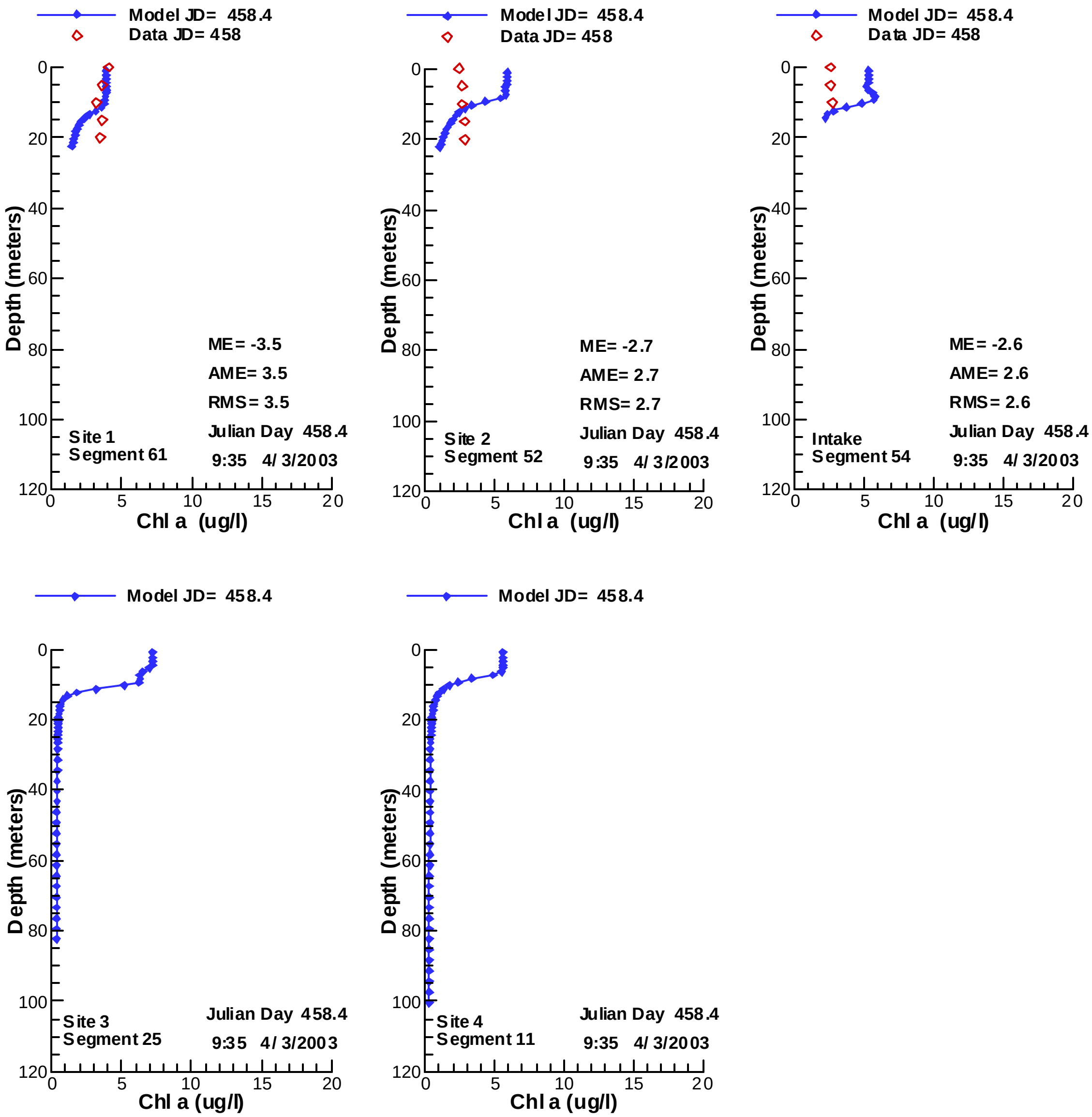

Figure 540. Vertical profiles of Chlorophyll a compared with data for 4/ 3/2003.

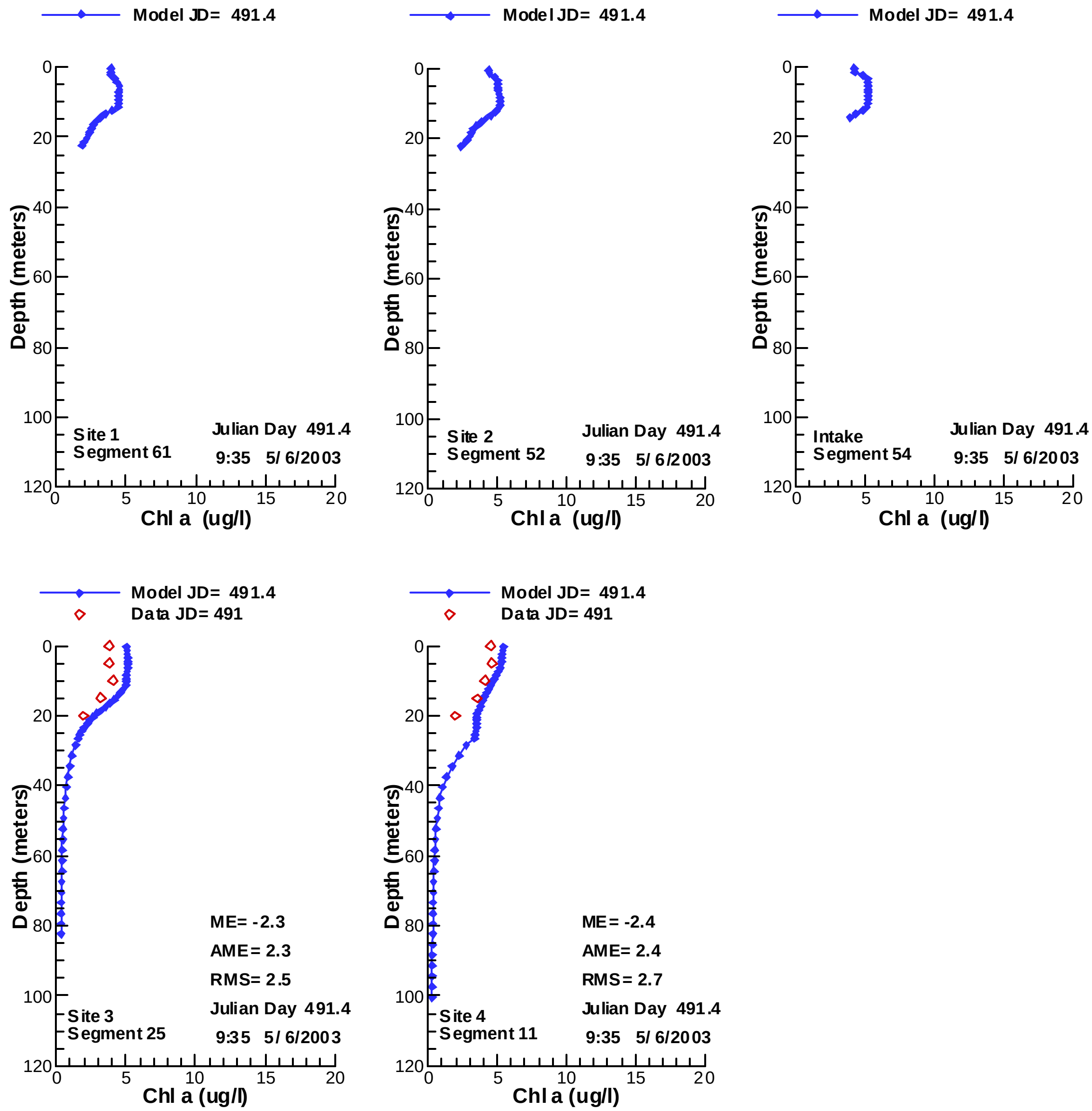

Figure 541. Vertical profiles of Chlorophyll a compared with data for 5/ 6/2003.

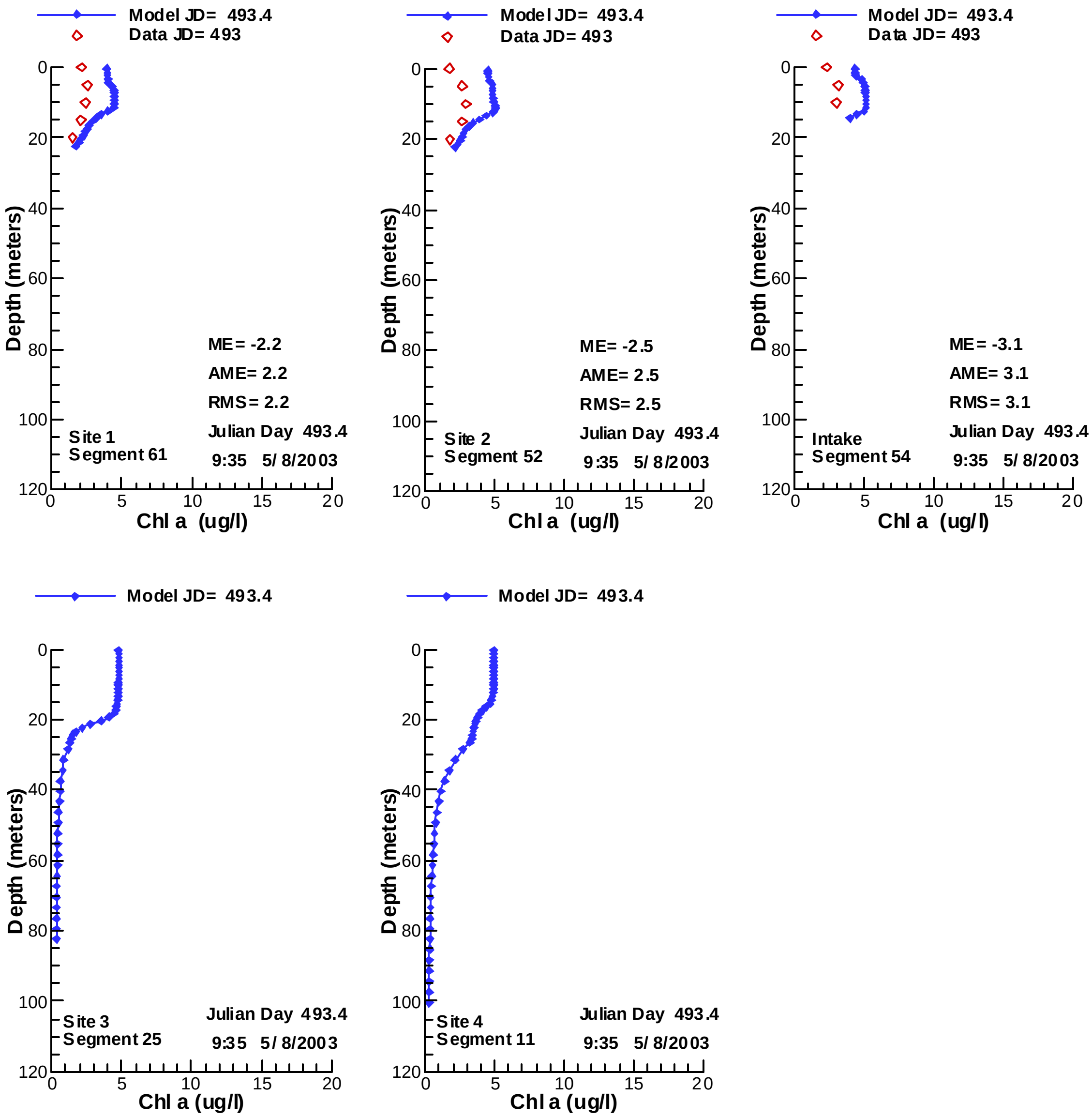

Figure 542. Vertical profiles of Chlorophyll a compared with data for 5/ 8/2003.

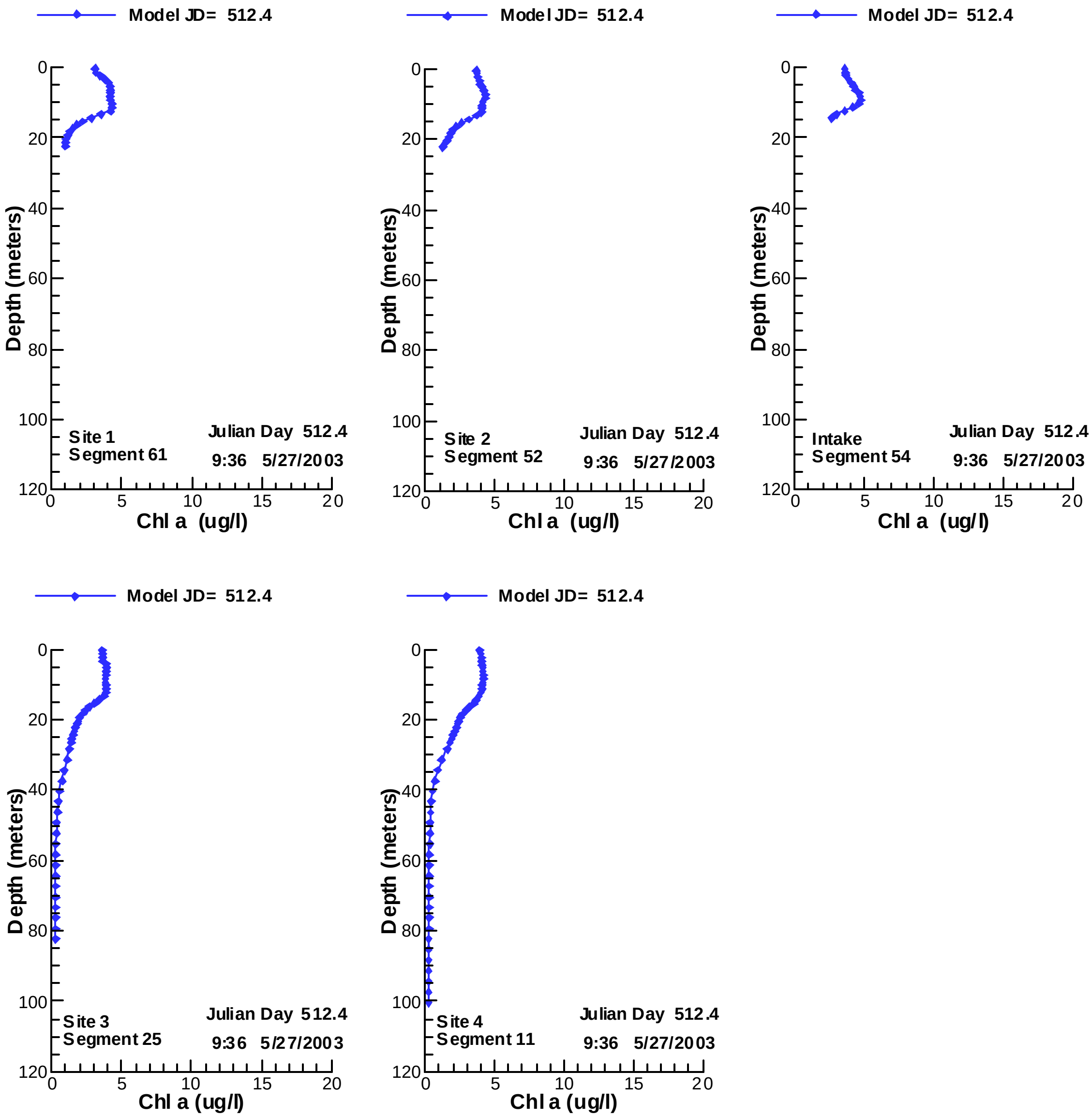

Figure 543. Vertical profiles of Chlorophyll a compared with data for 5/27/2003.

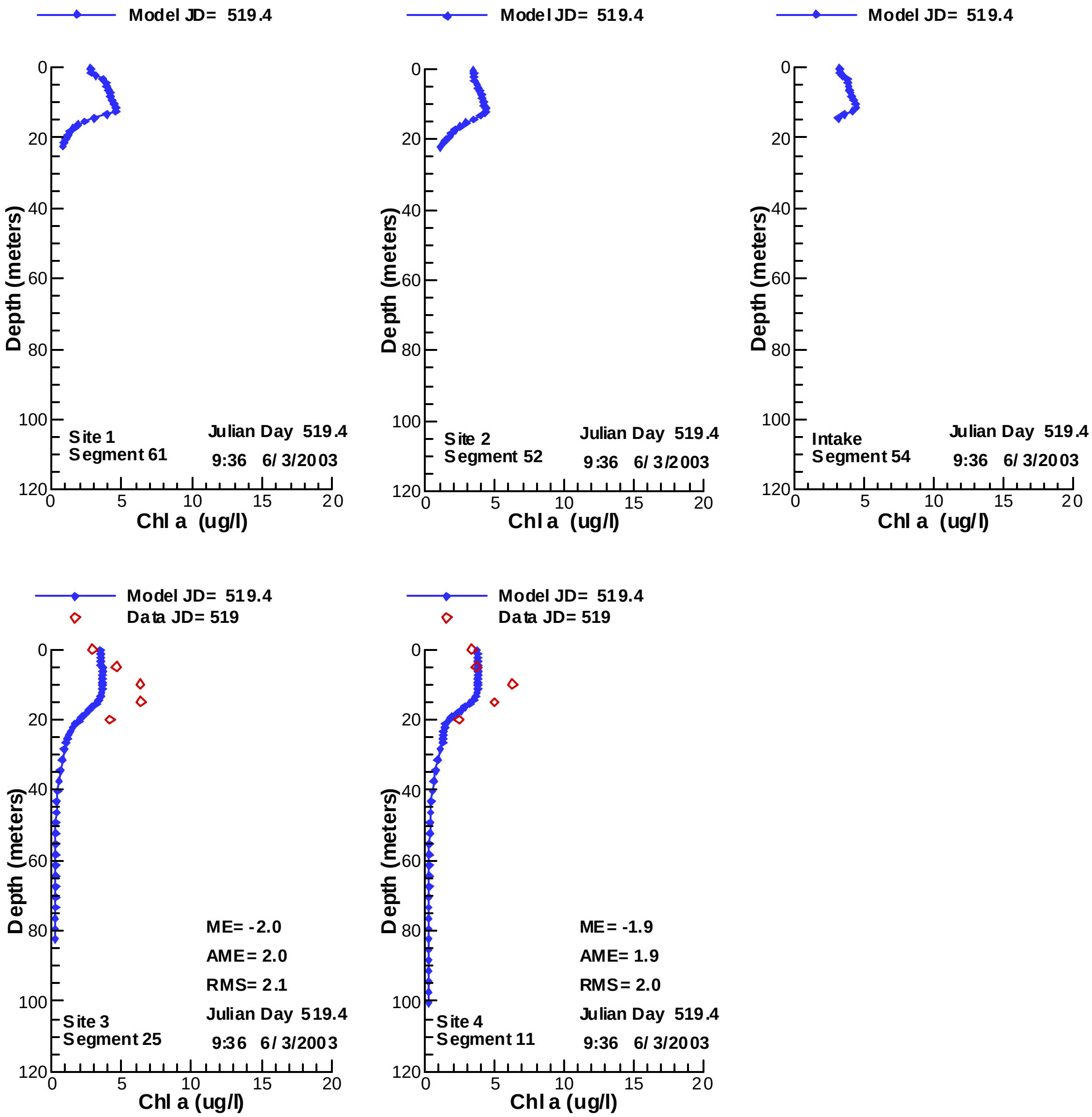

Figure 544. Vertical profiles of Chlorophyll a compared with data for 6/ 3/2003.

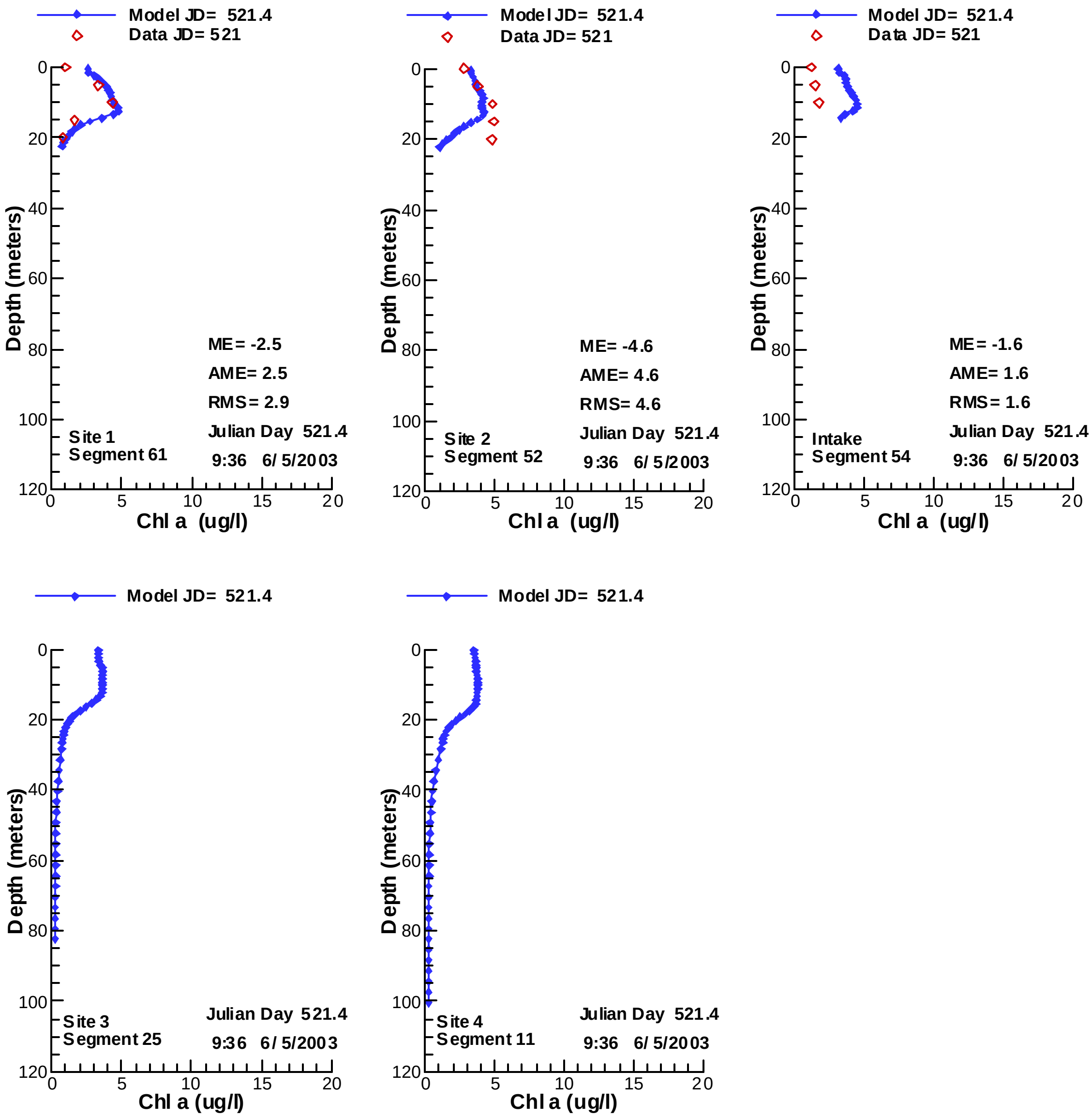

Figure 545. Vertical profiles of Chlorophyll a compared with data for 6/ 5/2003.

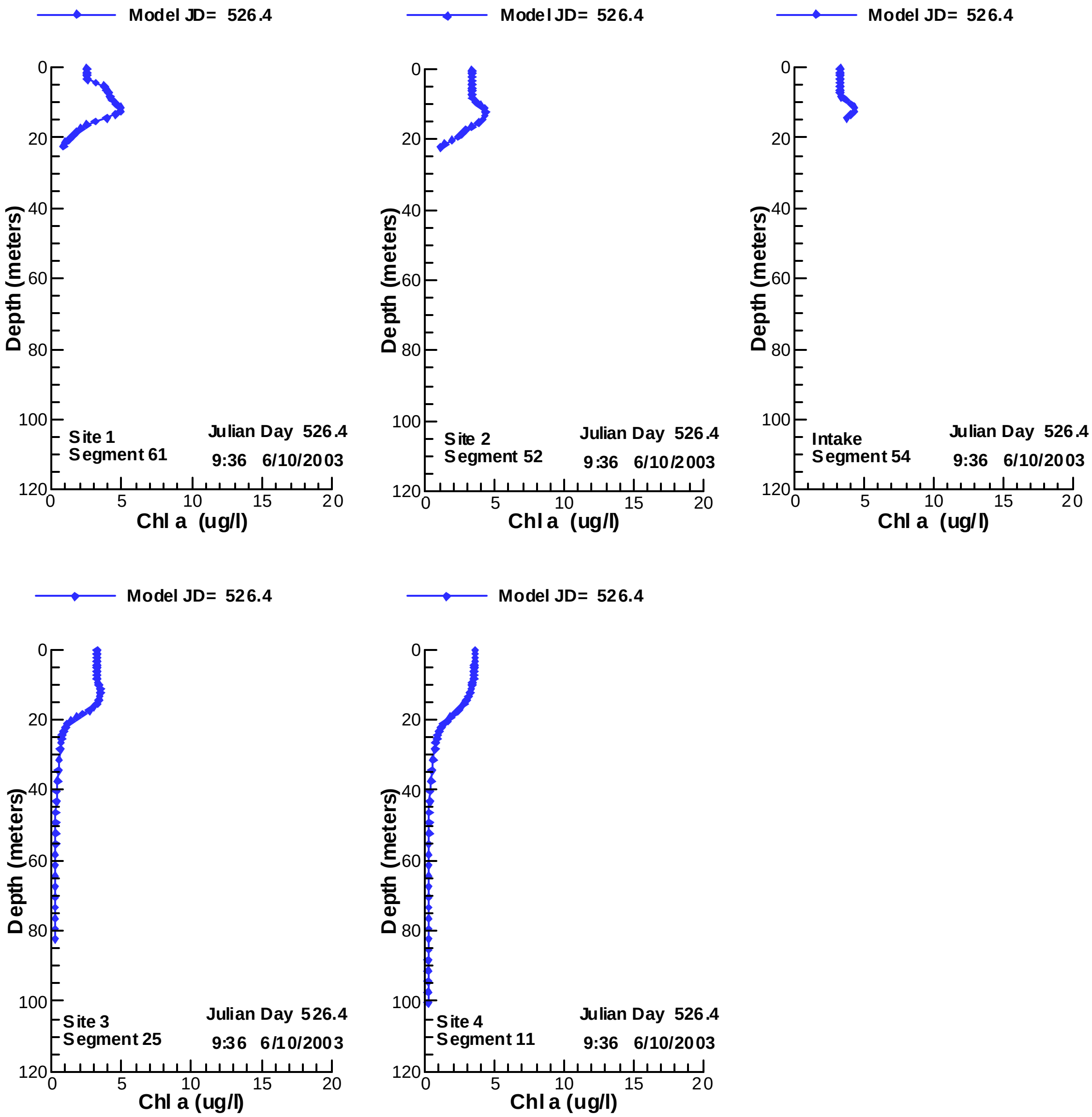

Figure 546. Vertical profiles of Chlorophyll a compared with data for 6/10/2003.

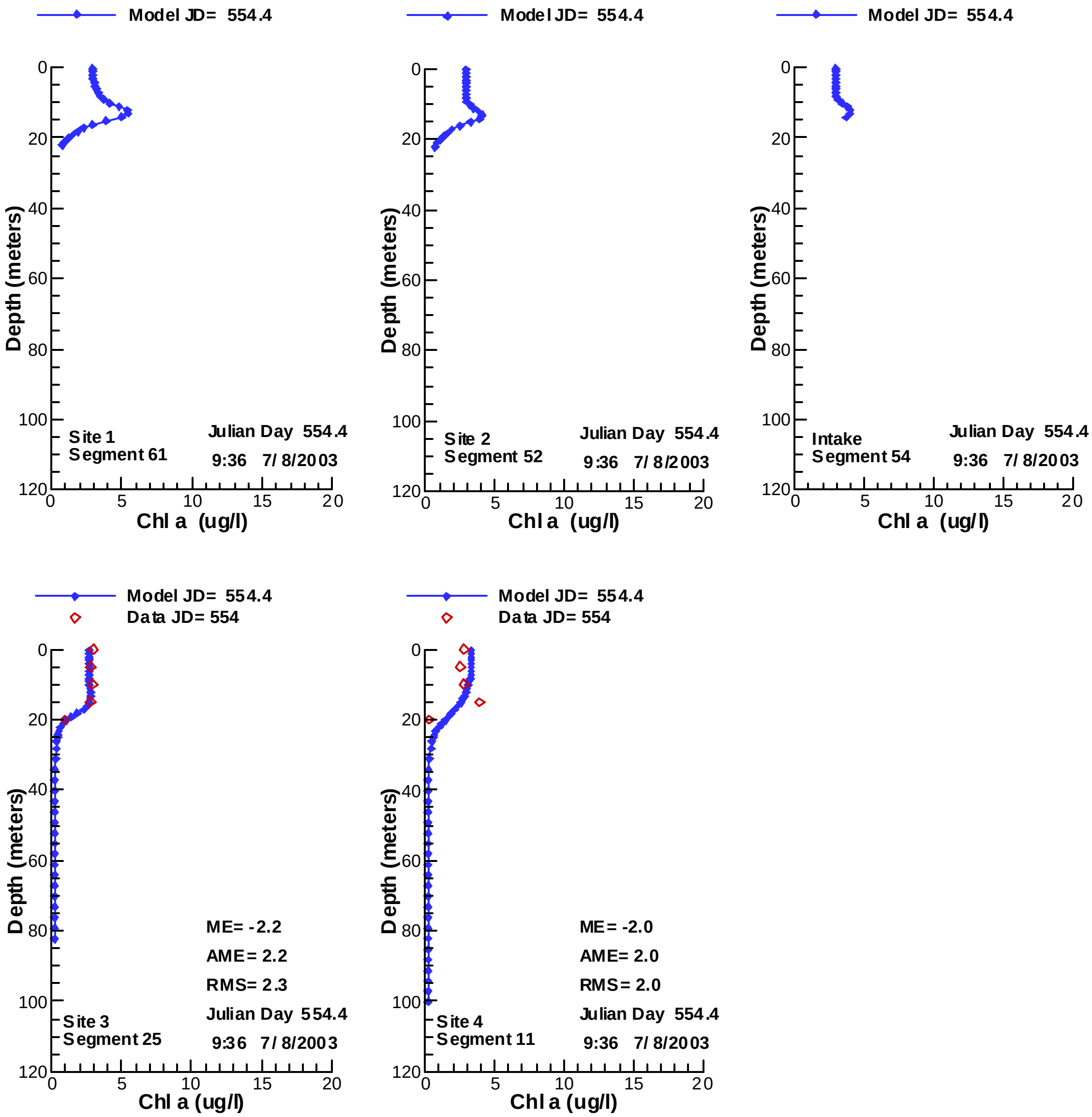

Figure 547. Vertical profiles of Chlorophyll a compared with data for 7/ 8/2003.

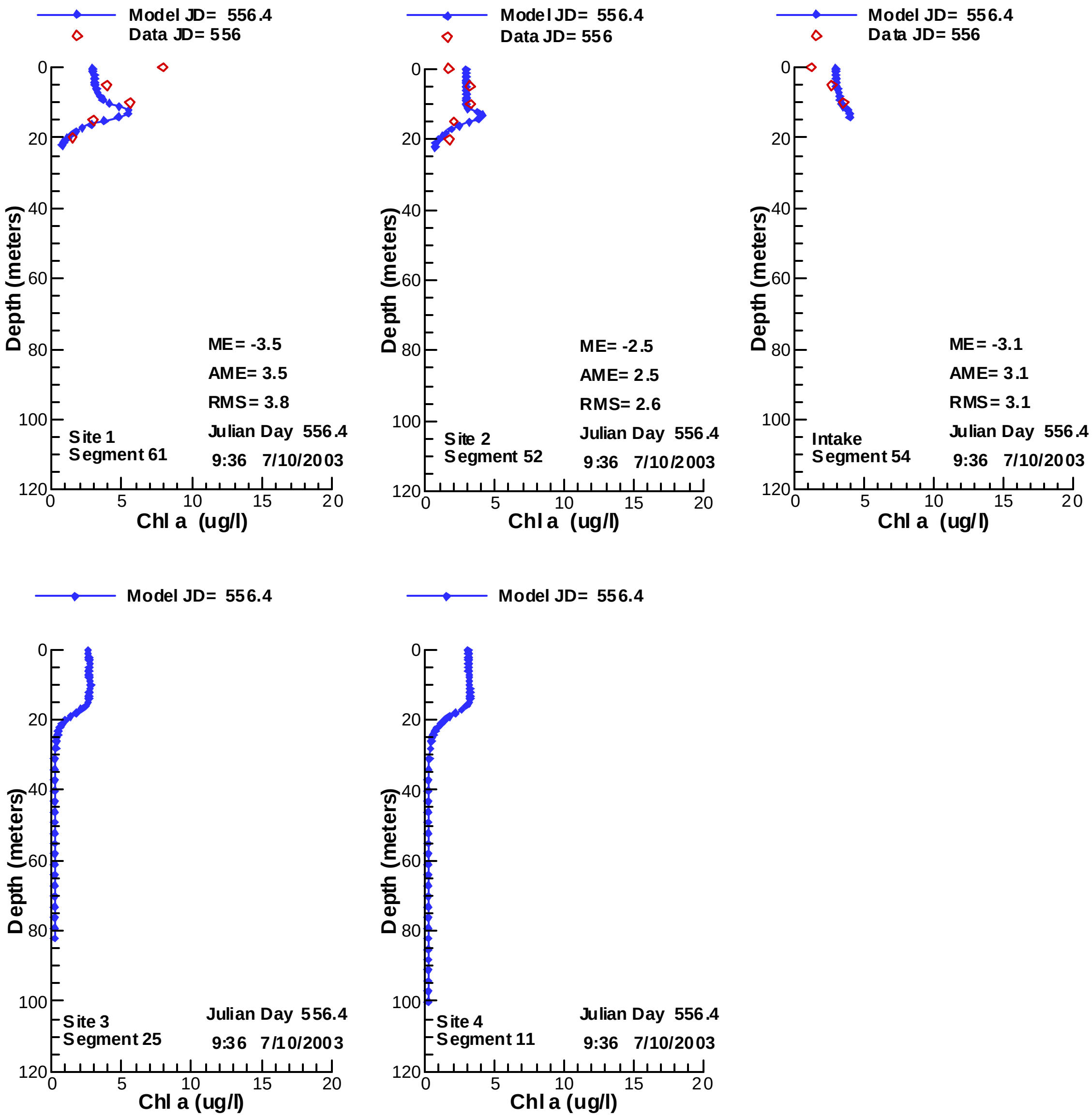

Figure 548. Vertical profiles of Chlorophyll a compared with data for 7/10/2003.

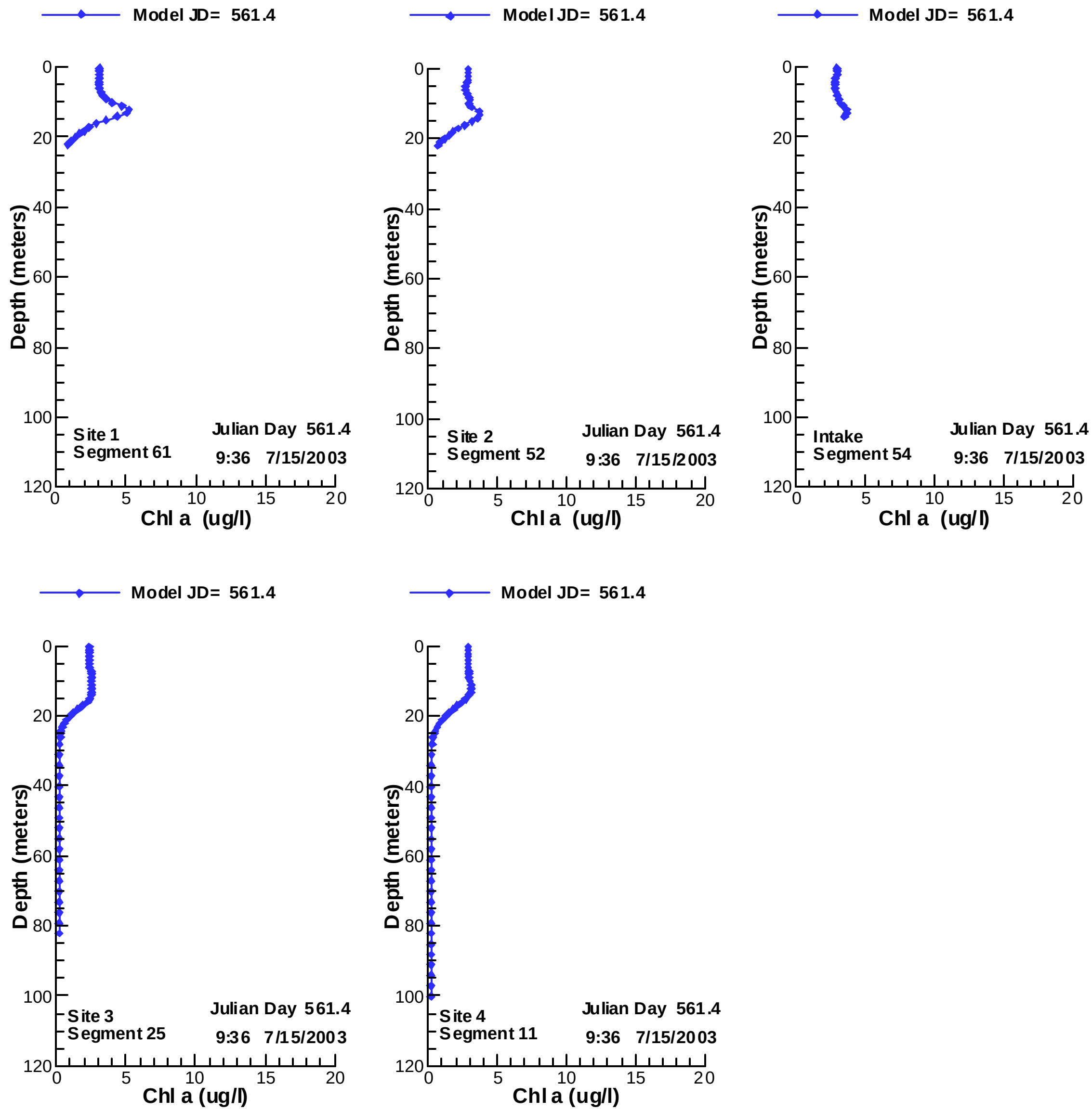

Figure 549. Vertical profiles of Chlorophyll a compared with data for 7/15/2003.

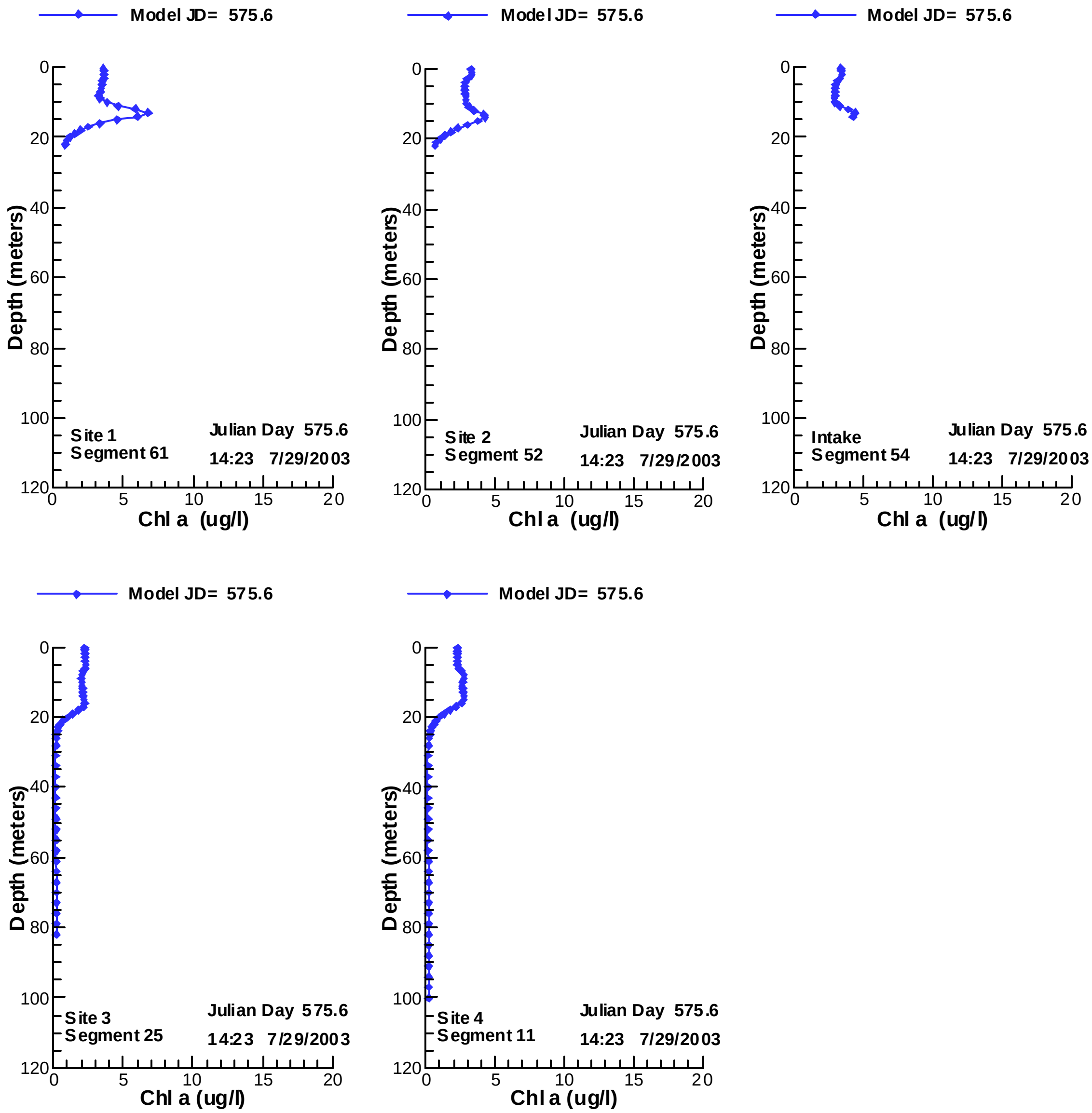

Figure 550. Vertical profiles of Chlorophyll a compared with data for 7/29/2003.

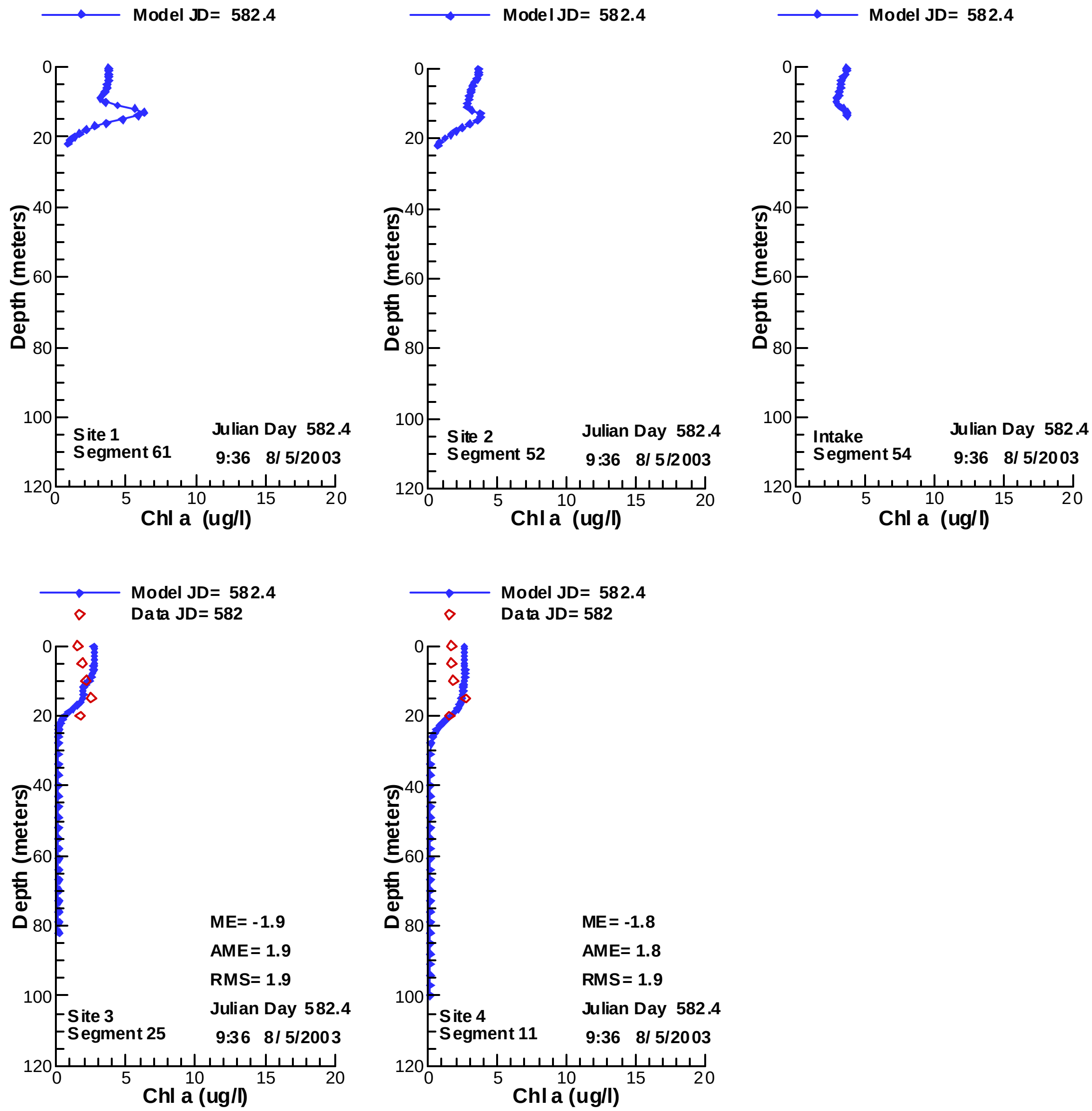

Figure 551. Vertical profiles of Chlorophyll a compared with data for 8/ 5/2003.

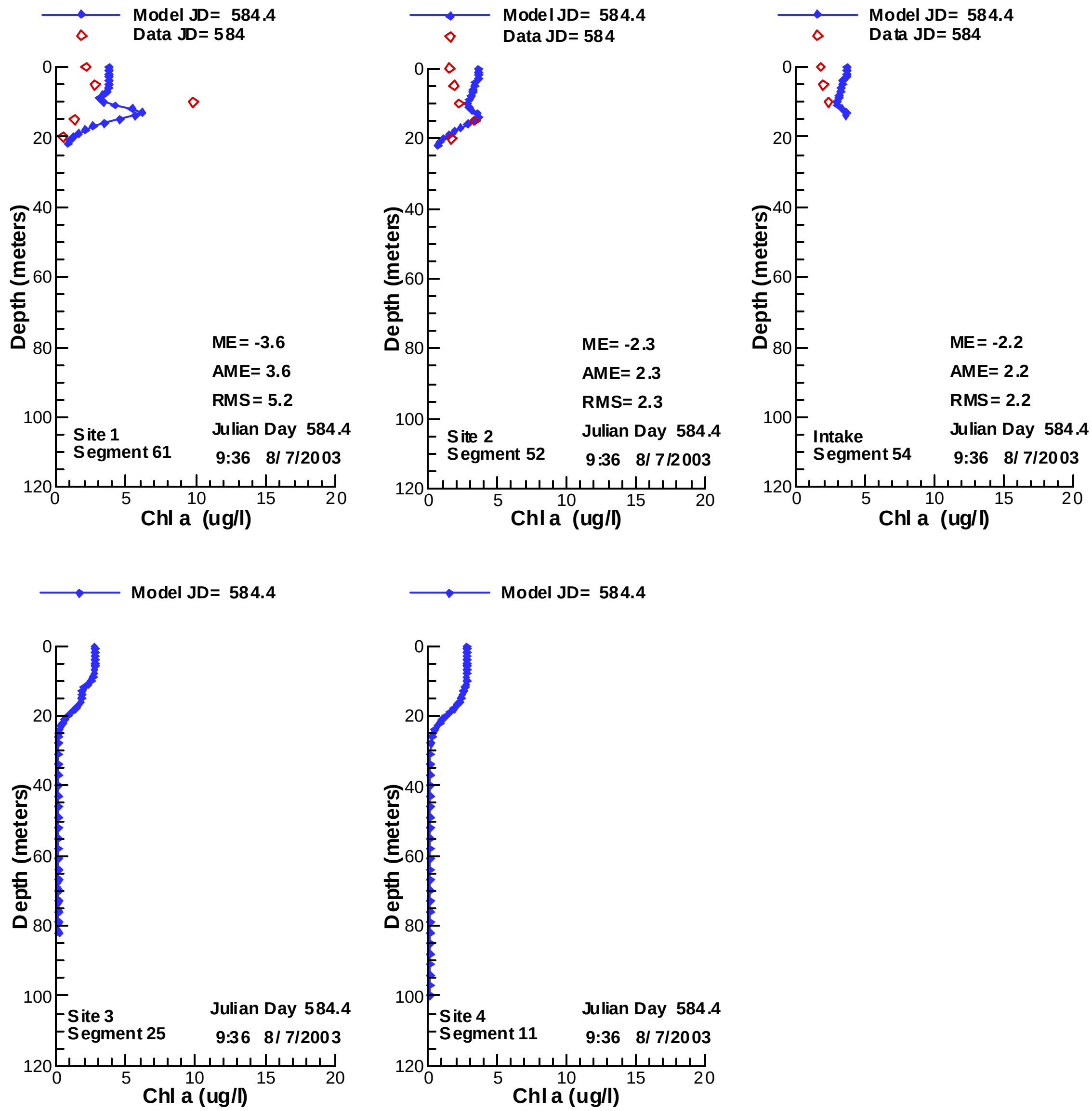

Figure 552. Vertical profiles of Chlorophyll a compared with data for 8/ 7/2003.

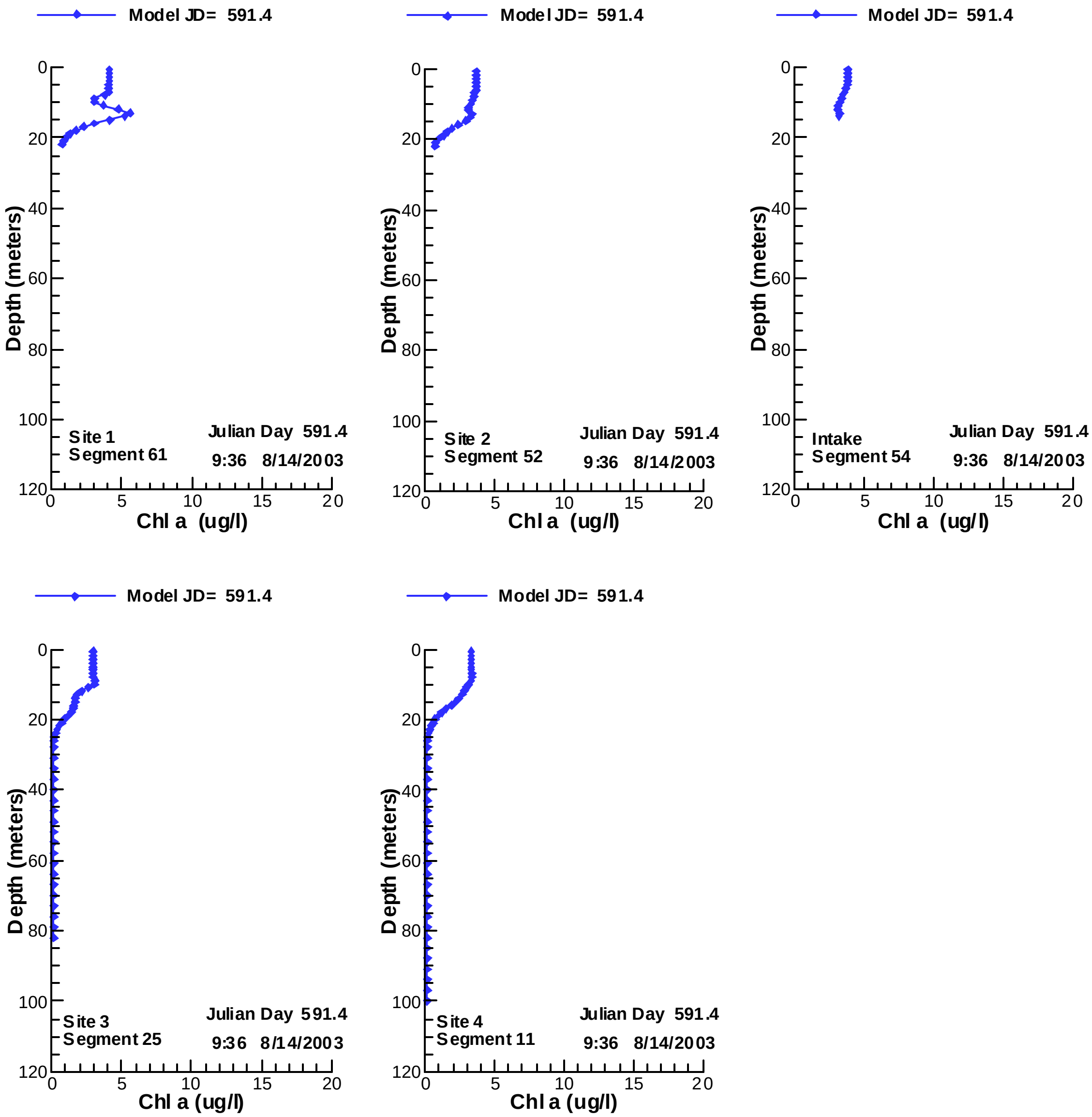

Figure 553. Vertical profiles of Chlorophyll a compared with data for 8/14/2003.

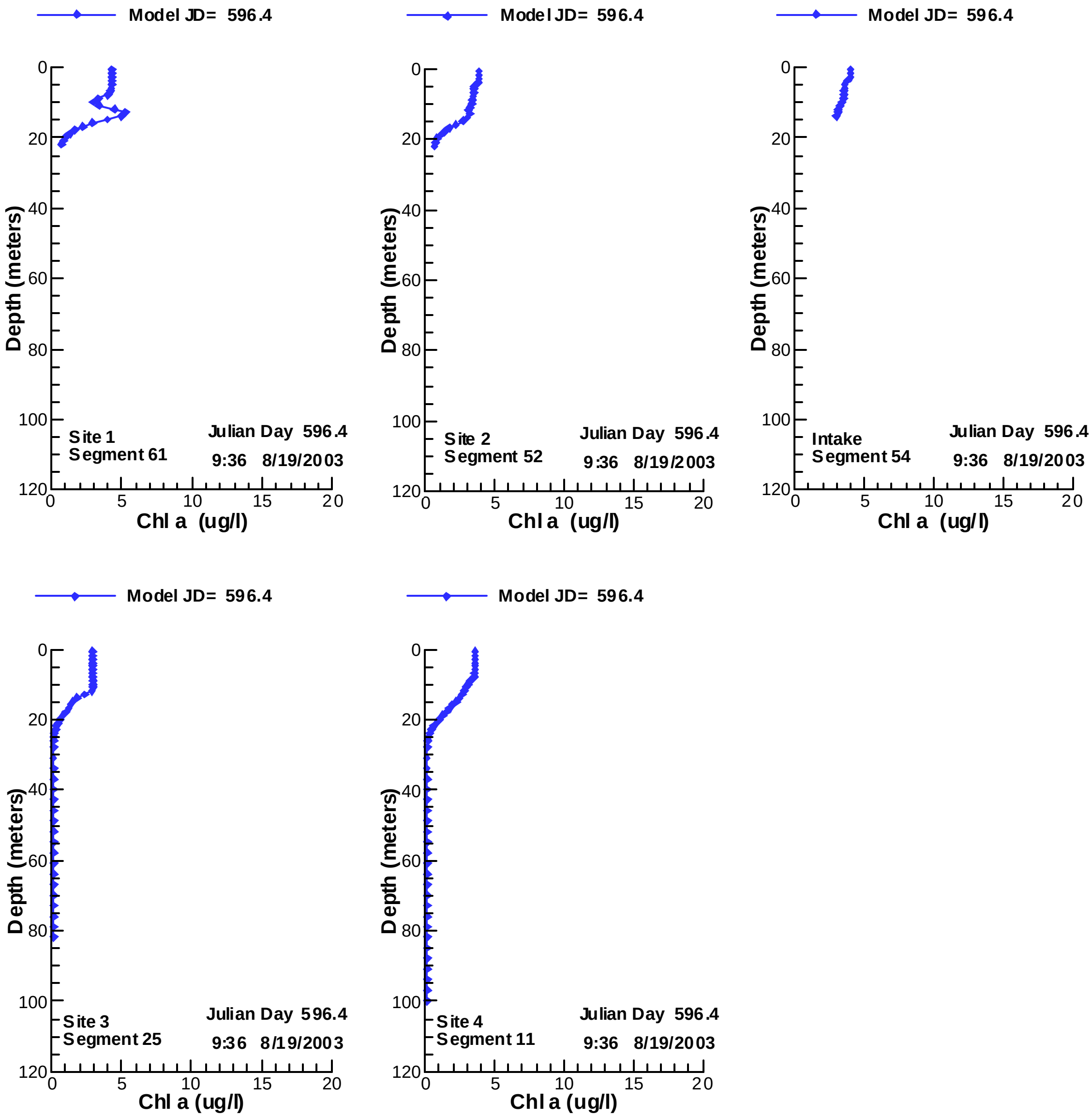

Figure 554. Vertical profiles of Chlorophyll a compared with data for 8/19/2003.

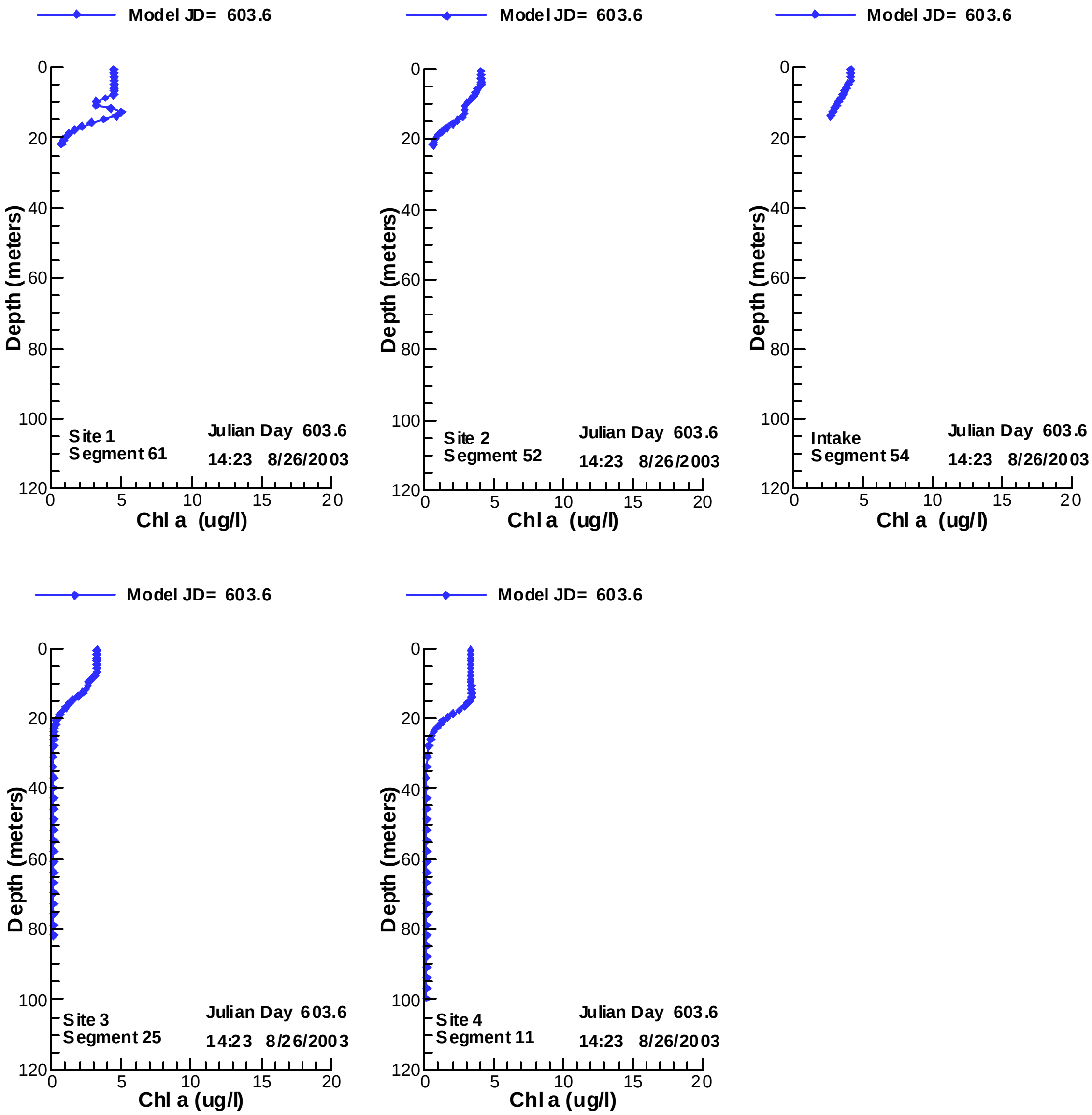

Figure 555. Vertical profiles of Chlorophyll a compared with data for 8/26/2003.

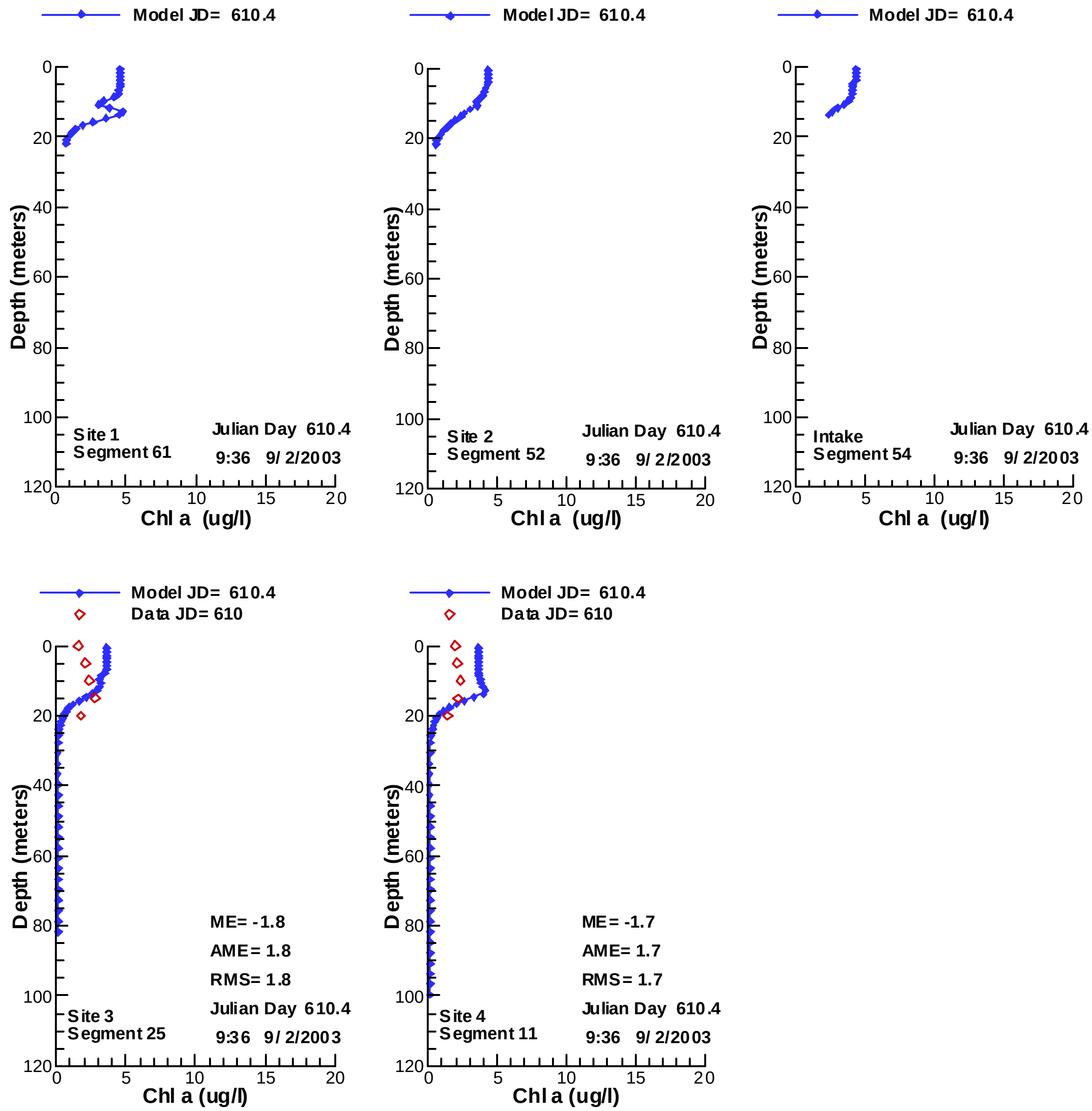

Figure 556. Vertical profiles of Chlorophyll a compared with data for 9/ 2/2003.

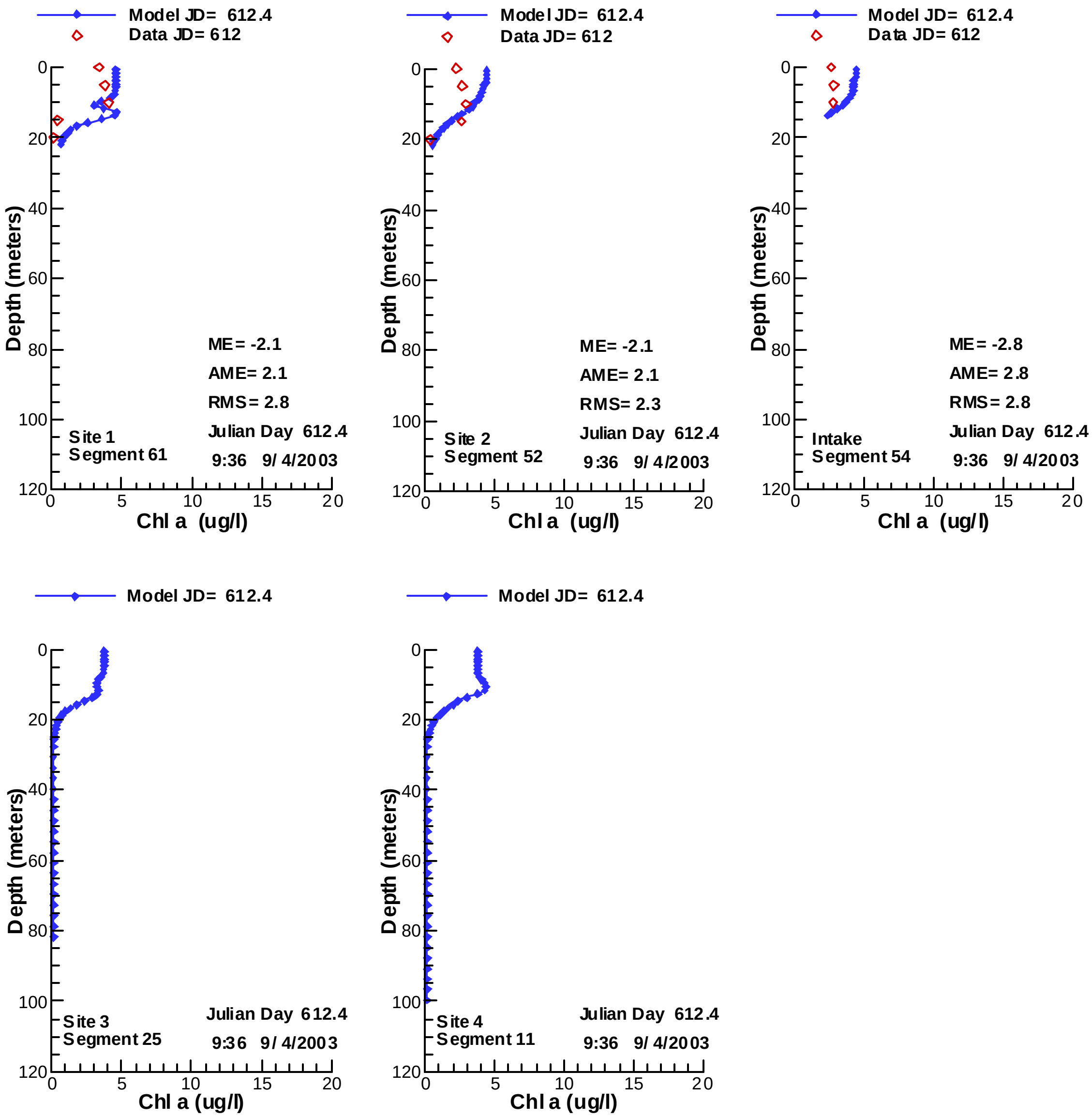

Figure 557. Vertical profiles of Chlorophyll a compared with data for 9/ 4/2003.

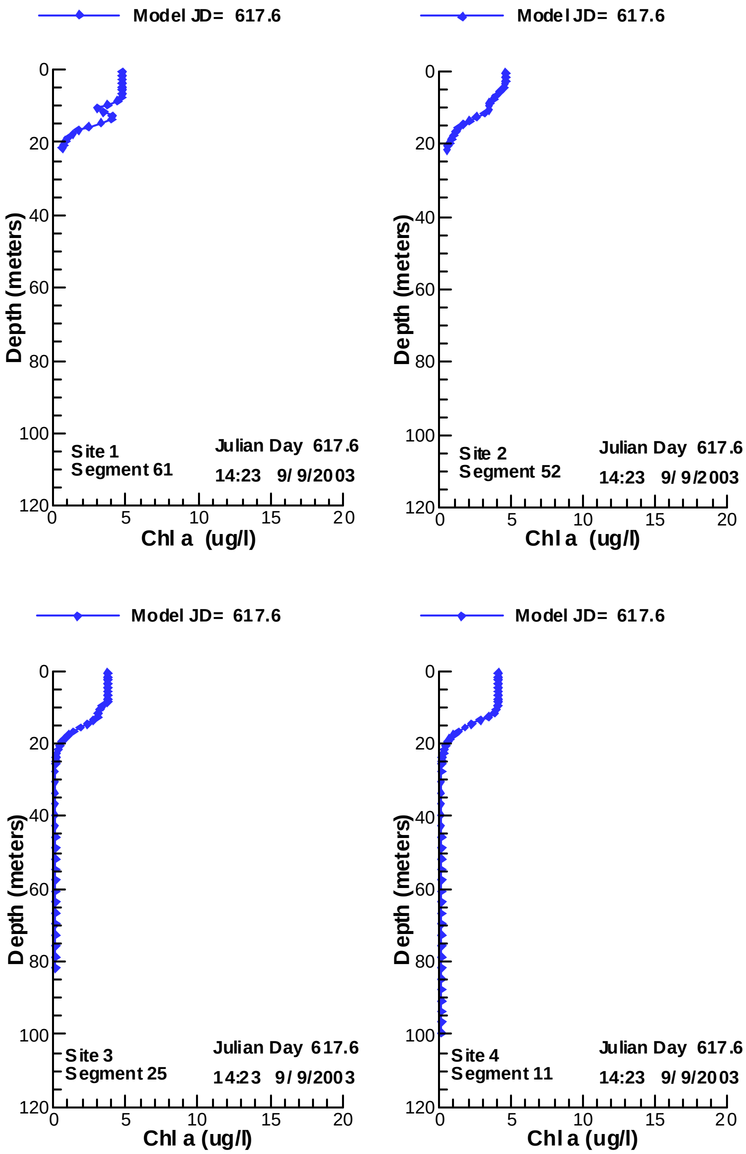

Figure 558. Vertical profiles of Chlorophyll a compared with data for 9/ 9/2003.

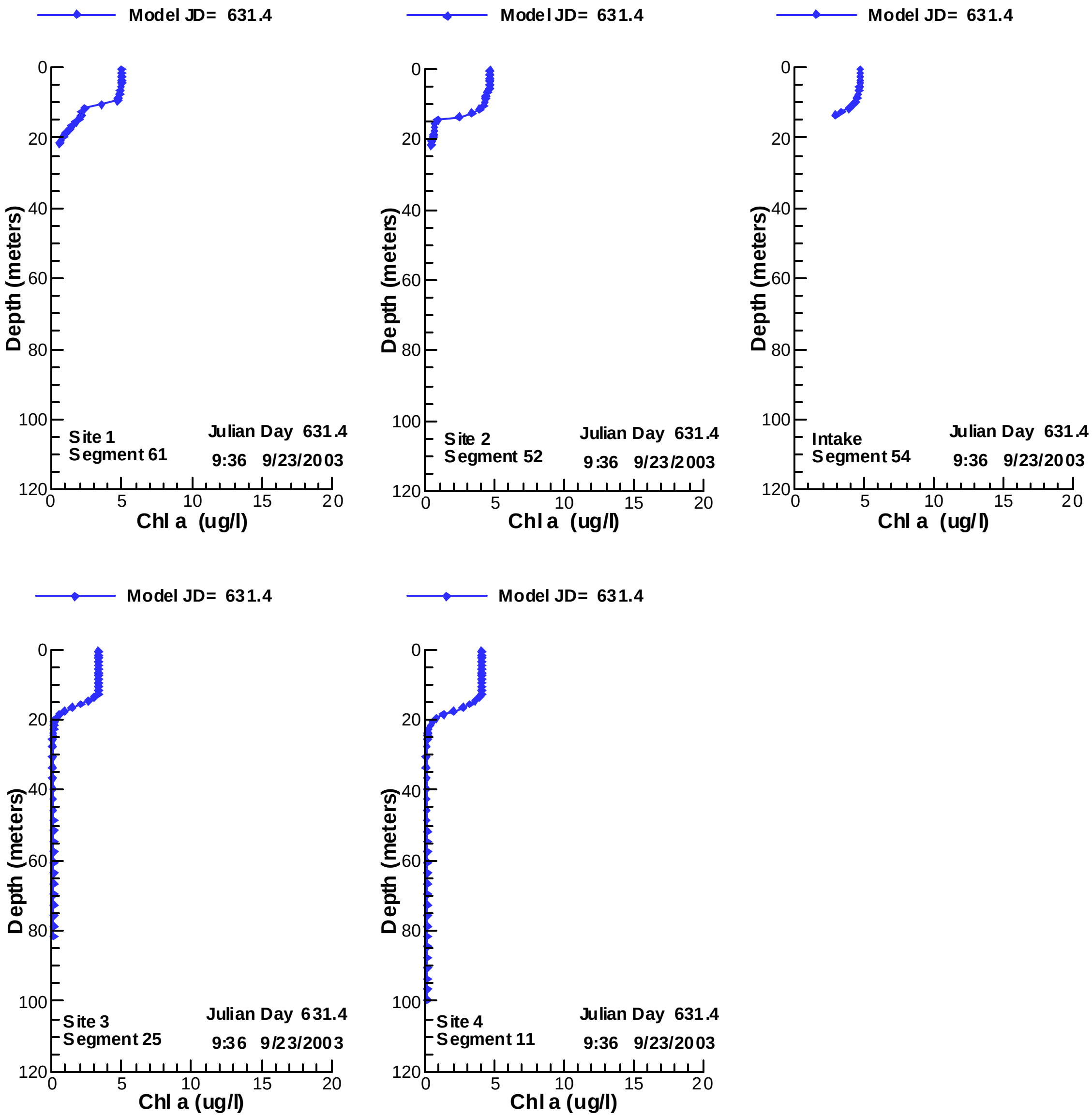

Figure 559. Vertical profiles of Chlorophyll a compared with data for 9/23/2003.

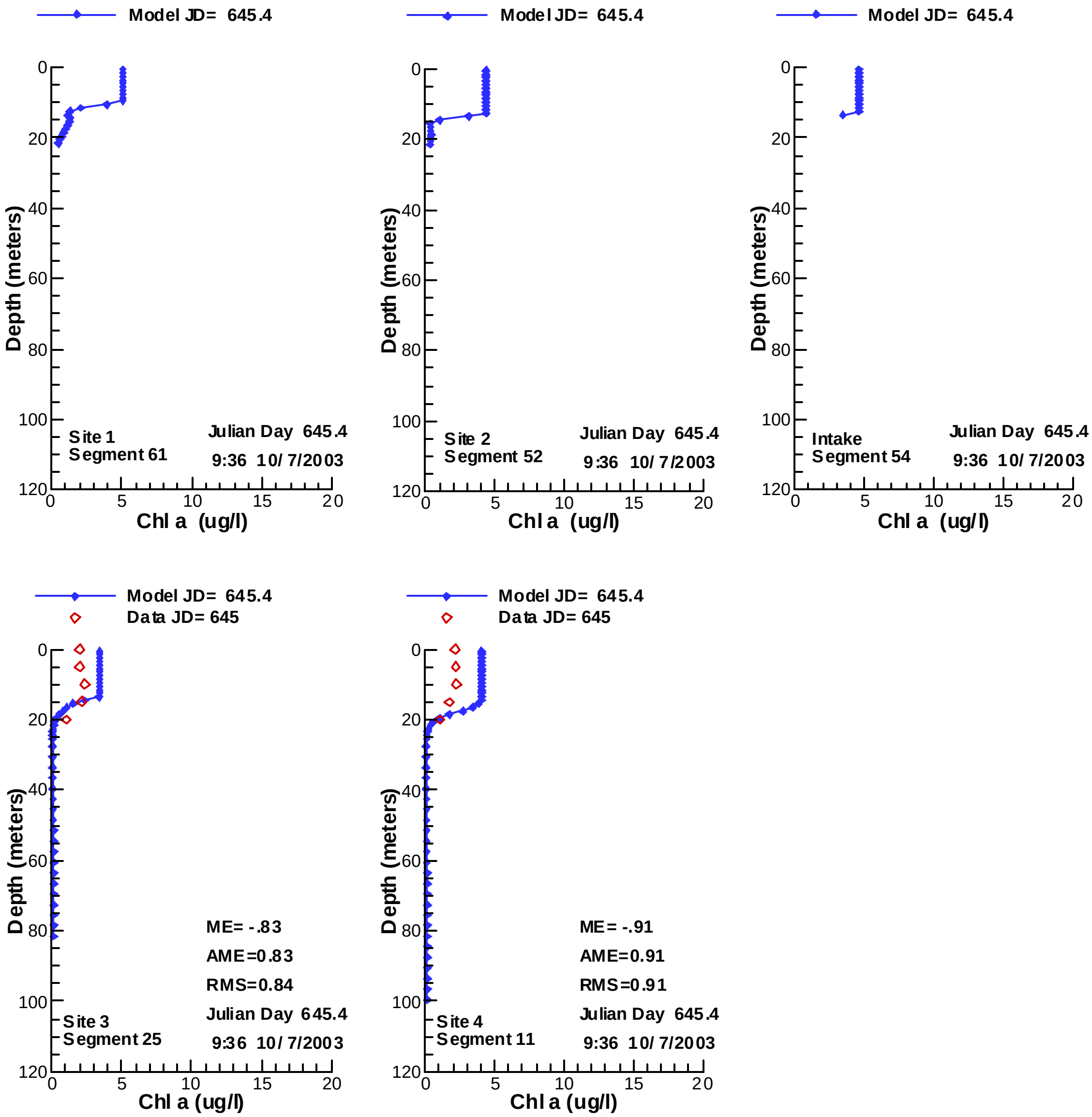

Figure 560. Vertical profiles of Chlorophyll a compared with data for 10/ 7/2003.

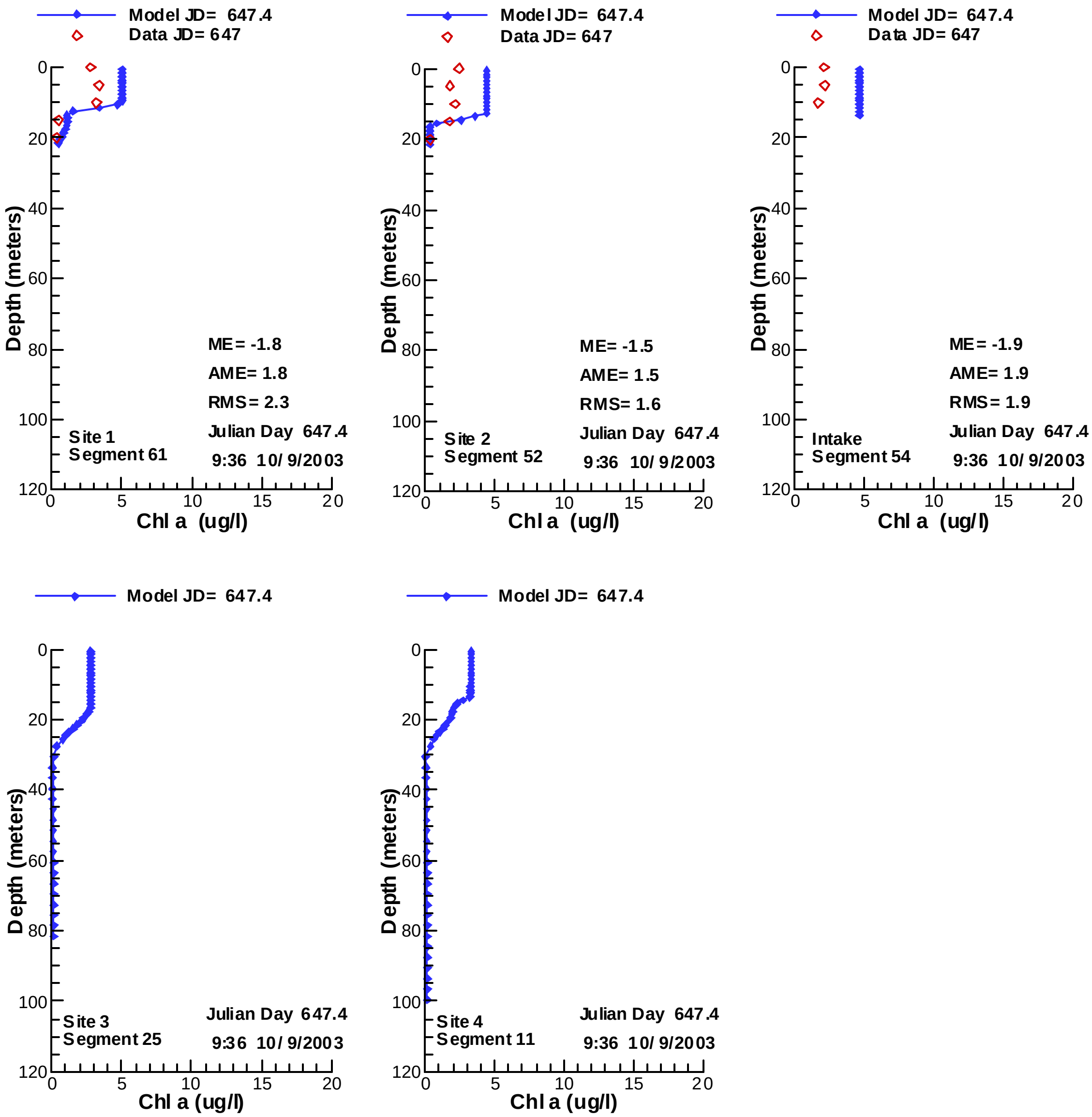

Figure 561. Vertical profiles of Chlorophyll a compared with data for 10/ 9/2003.

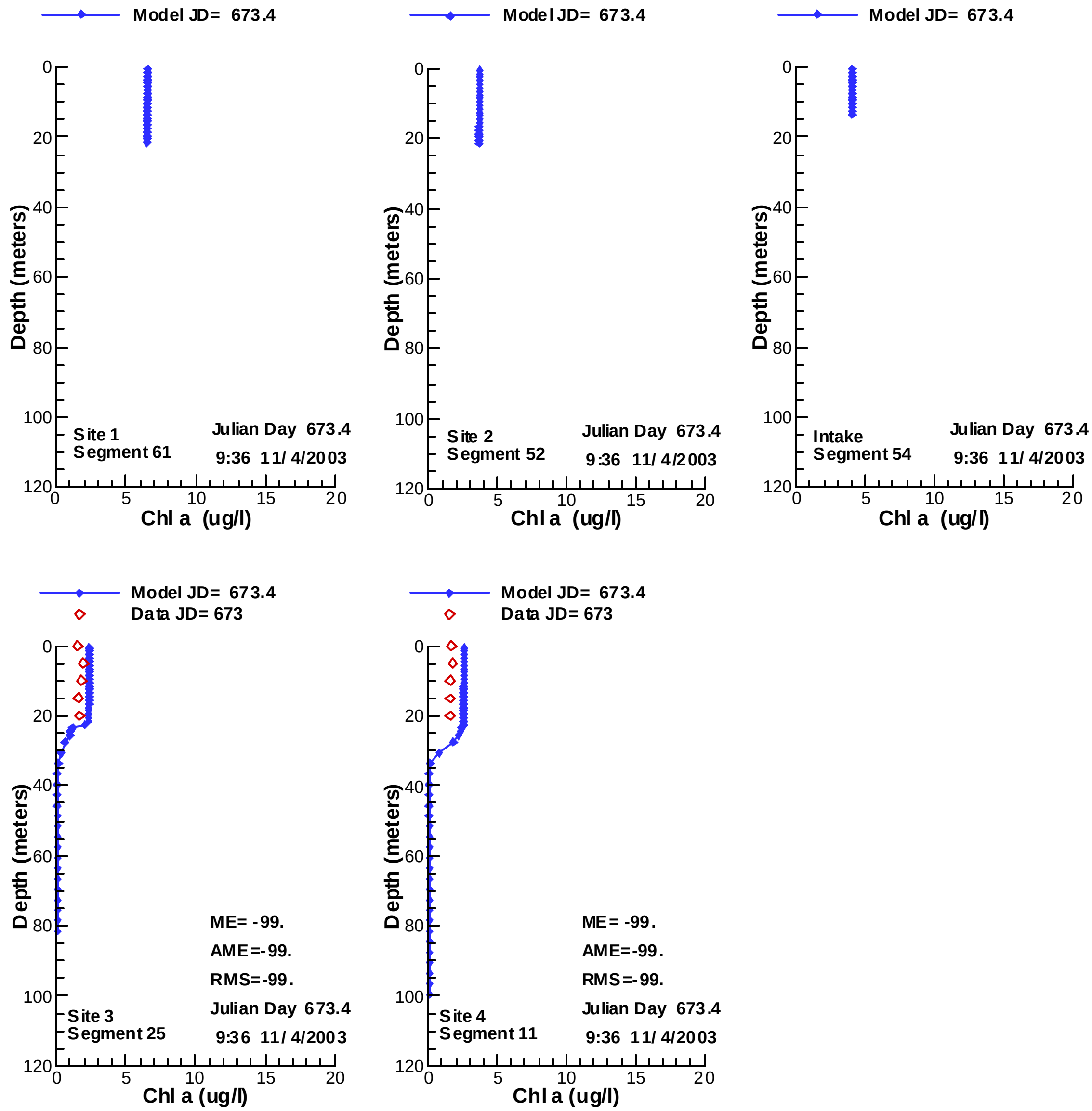

Figure 562. Vertical profiles of Chlorophyll a compared with data for 11/ 4/2003.

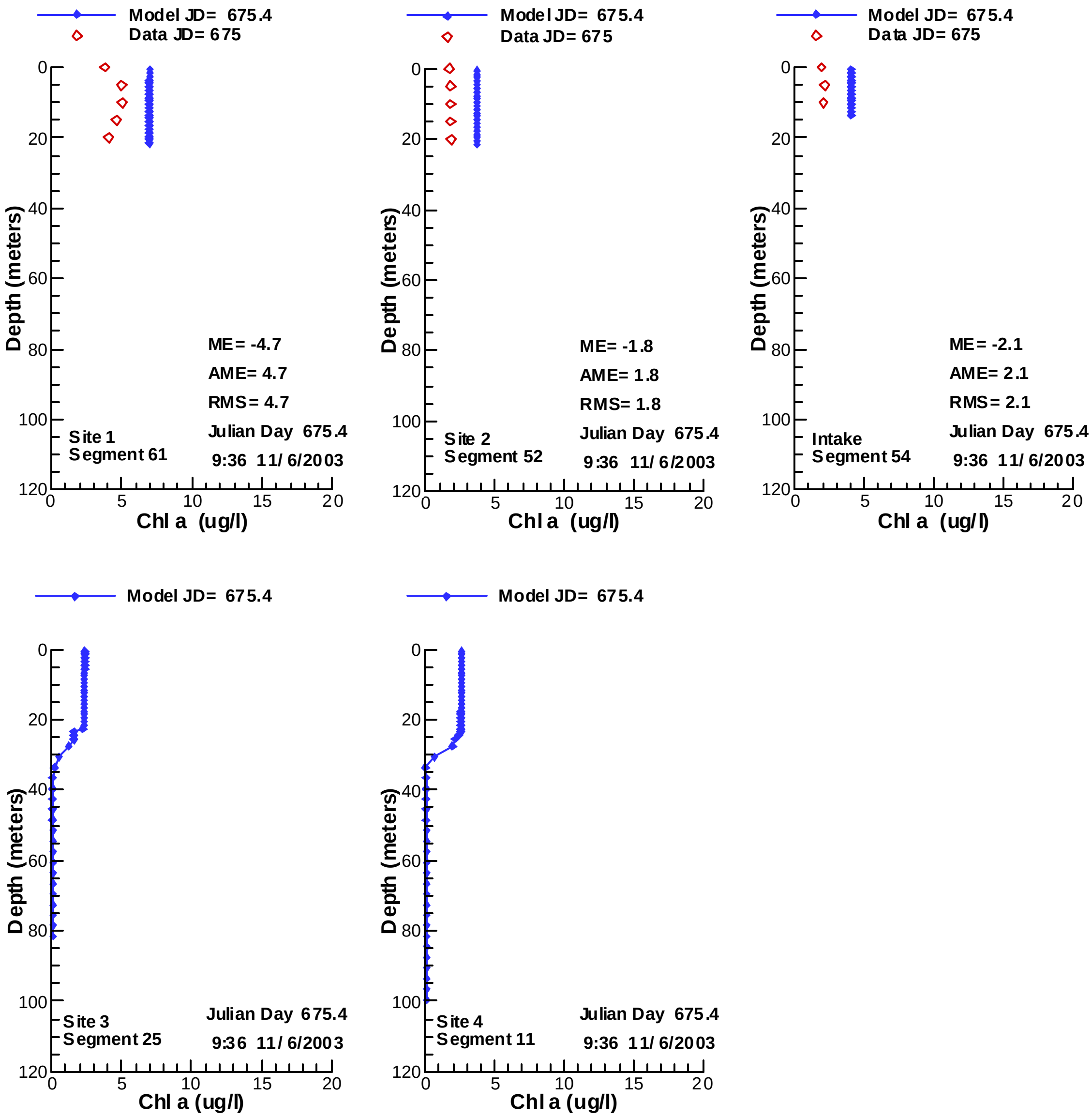

Figure 563. Vertical profiles of Chlorophyll a compared with data for 11/ 6/2003.

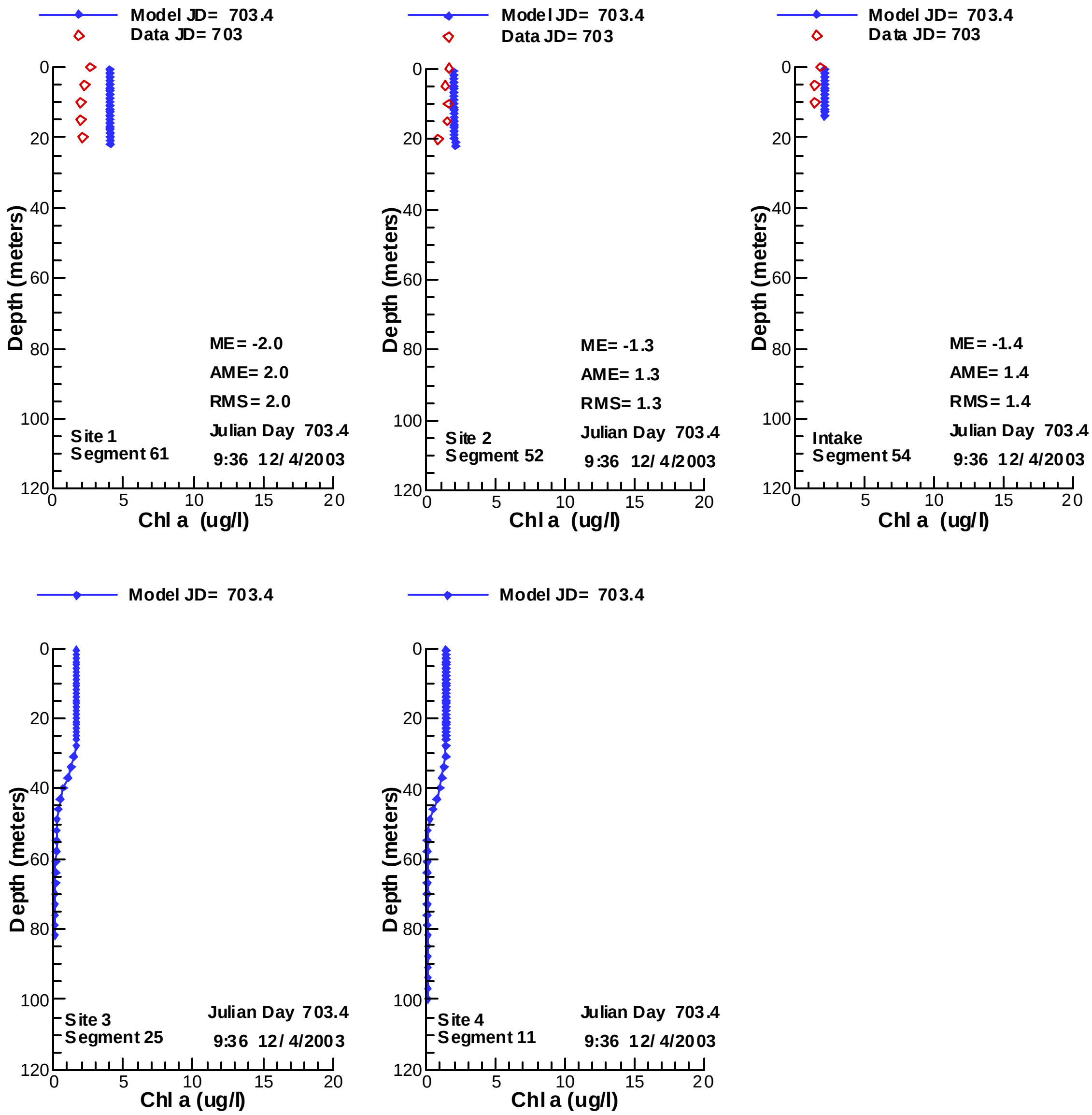

Figure 564. Vertical profiles of Chlorophyll a compared with data for 12/ 4/2003.

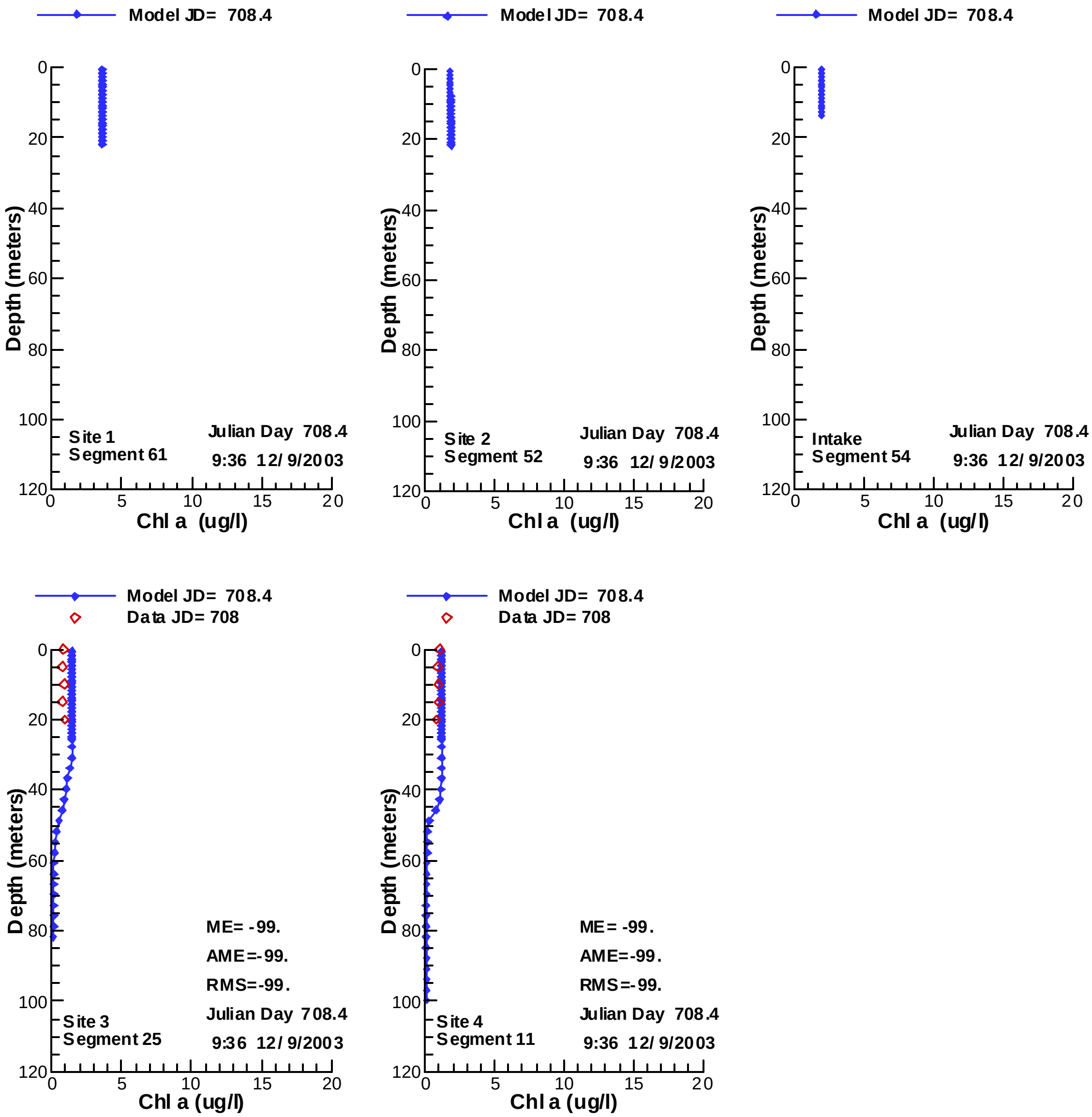

Figure 565. Vertical profiles of Chlorophyll a compared with data for 12/ 9/2003.

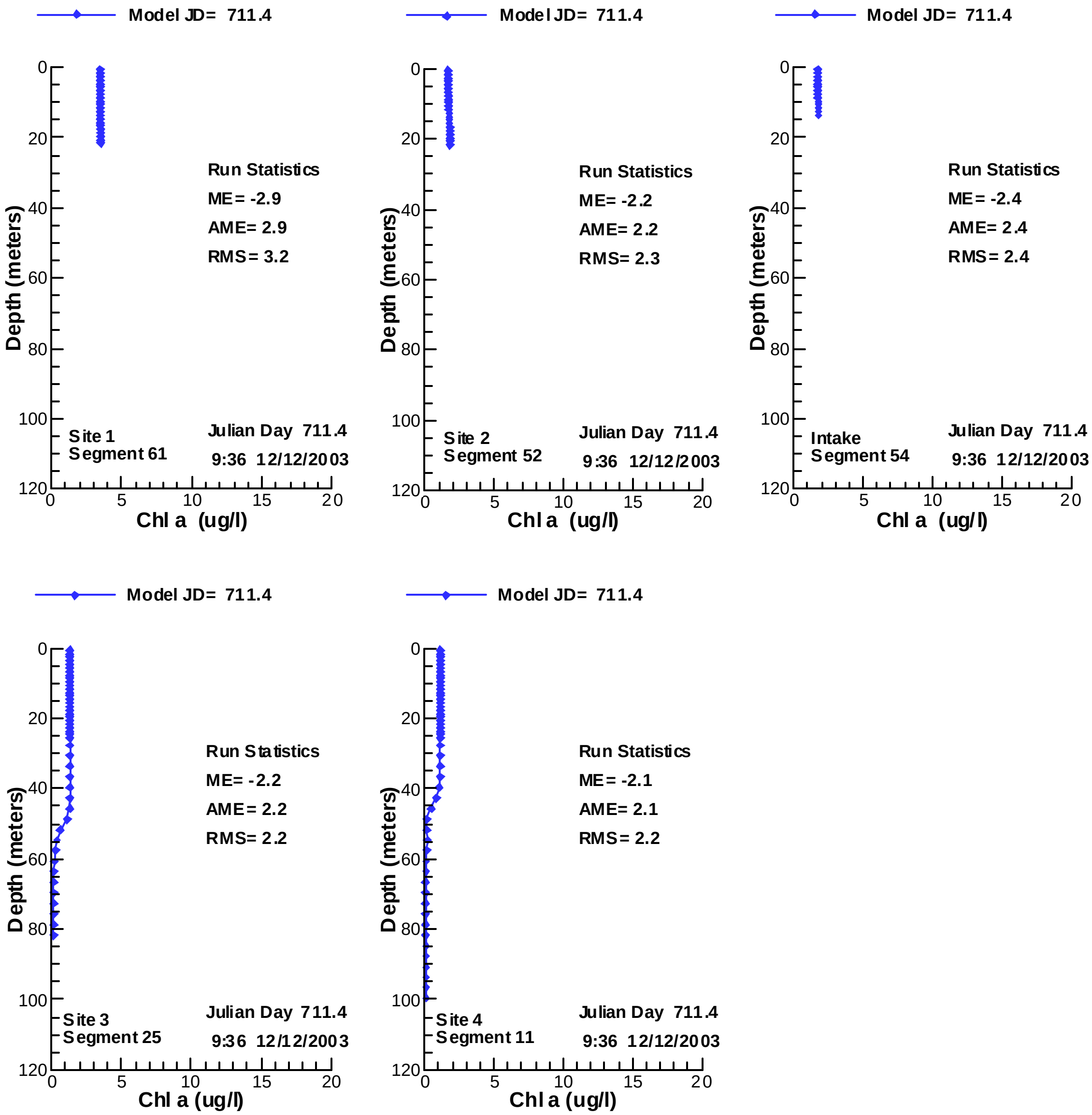

Figure 566. Vertical profiles of Chlorophyll a compared with data for 12/12/2003.

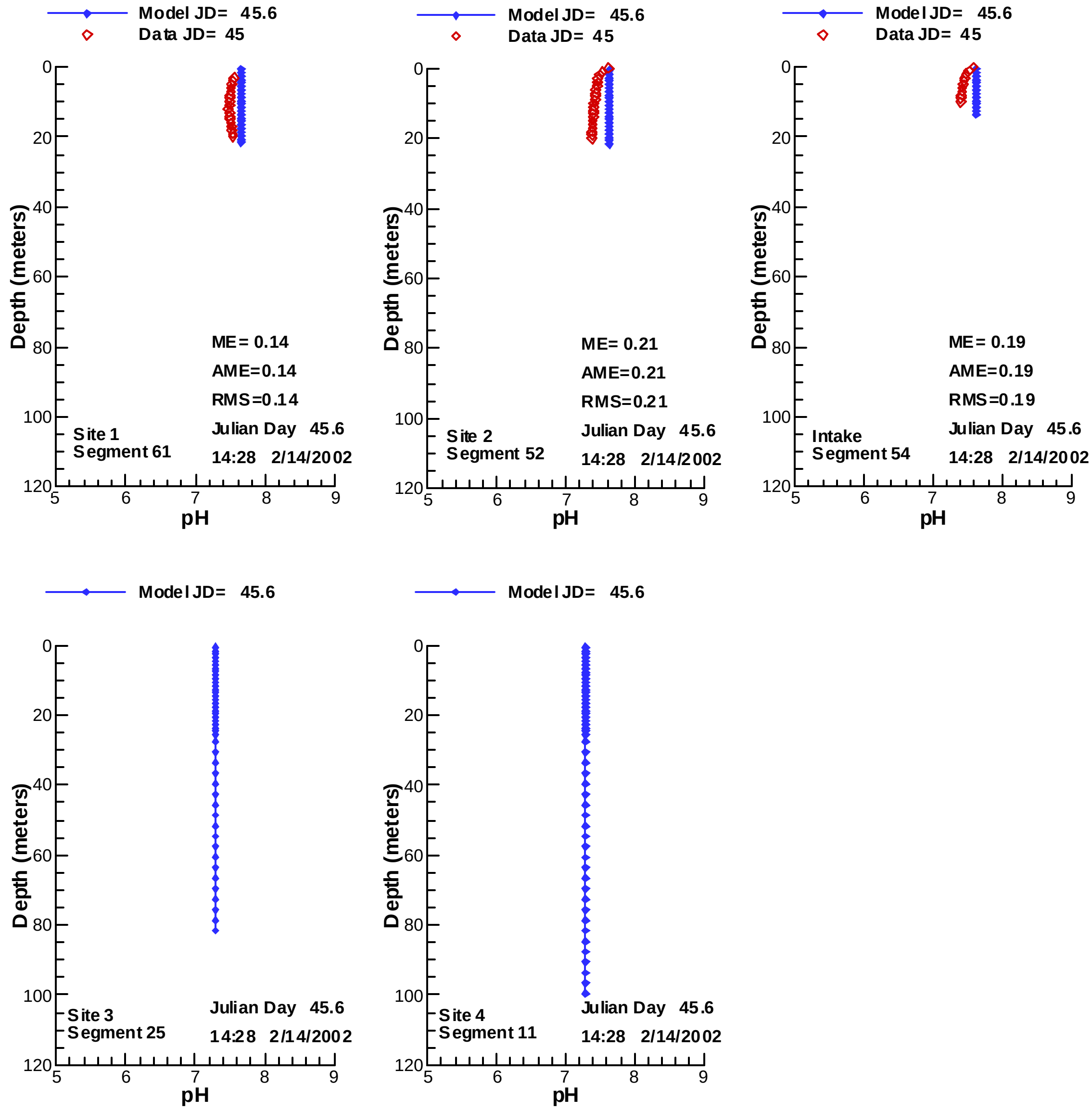

Figure 567. Vertical profiles of pH compared with data for 2/14/2002.

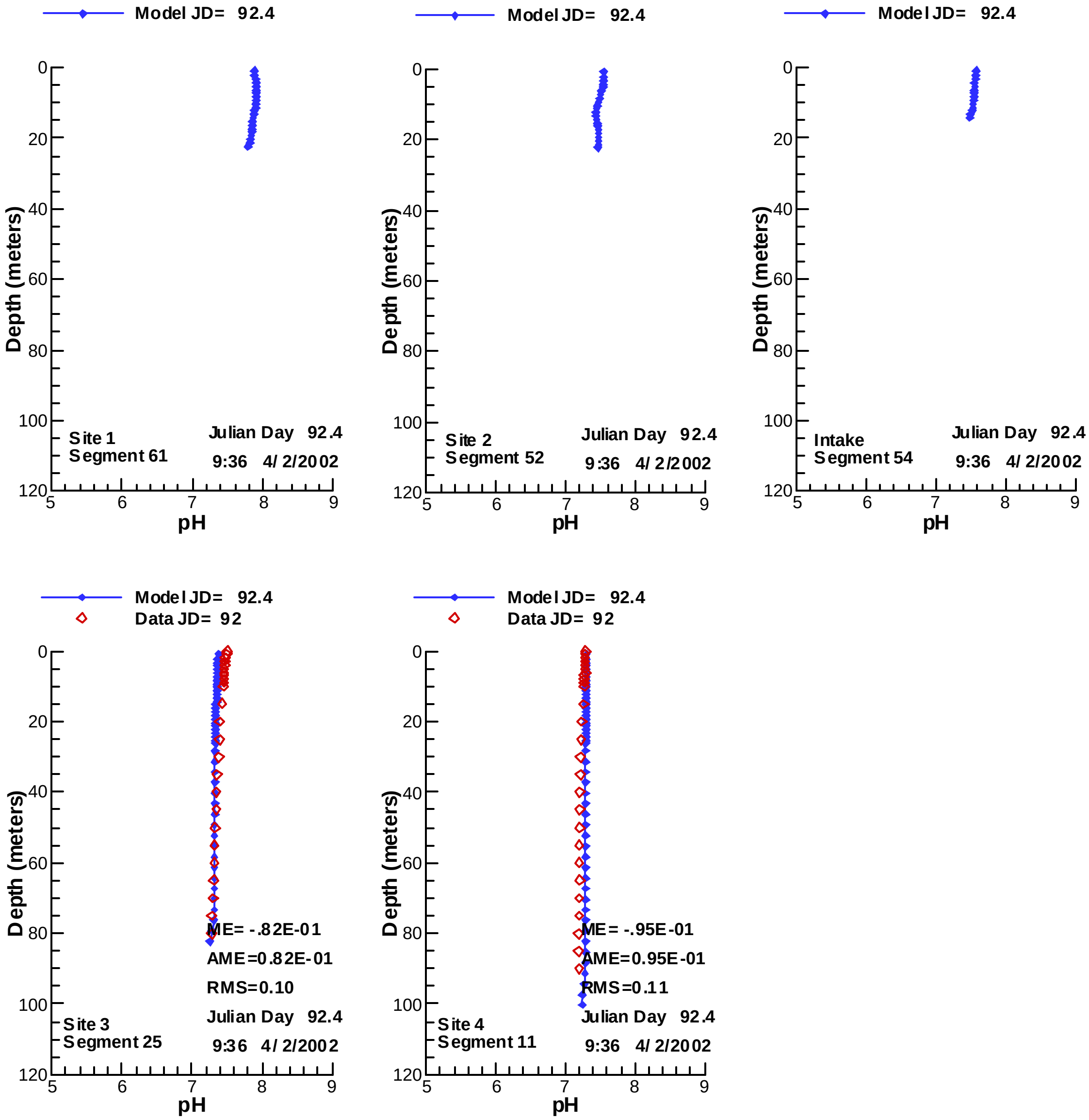

Figure 568. Vertical profiles of pH compared with data for 4/ 2/2002.

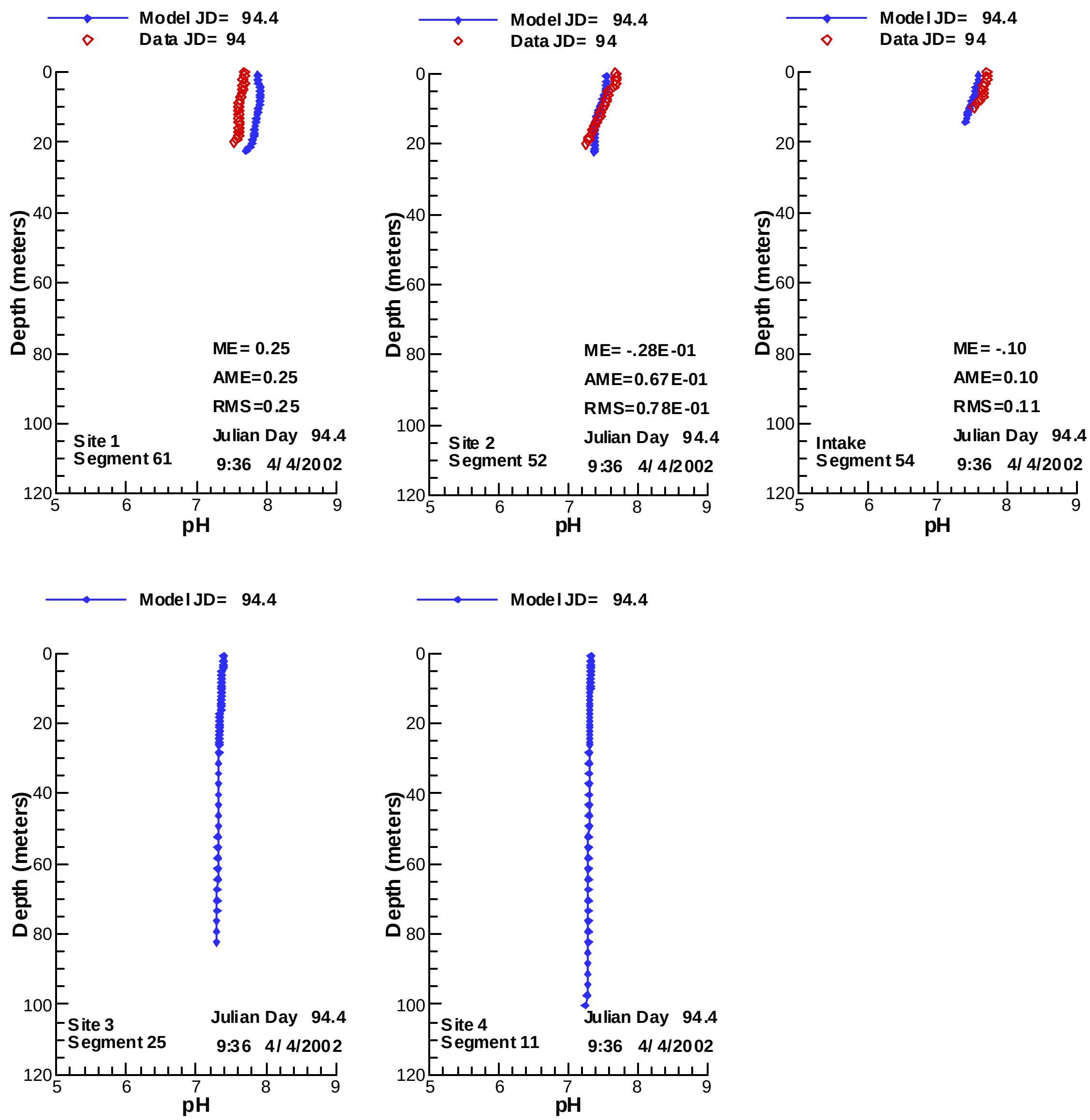

Figure 569. Vertical profiles of pH compared with data for 4/ 4/2002.

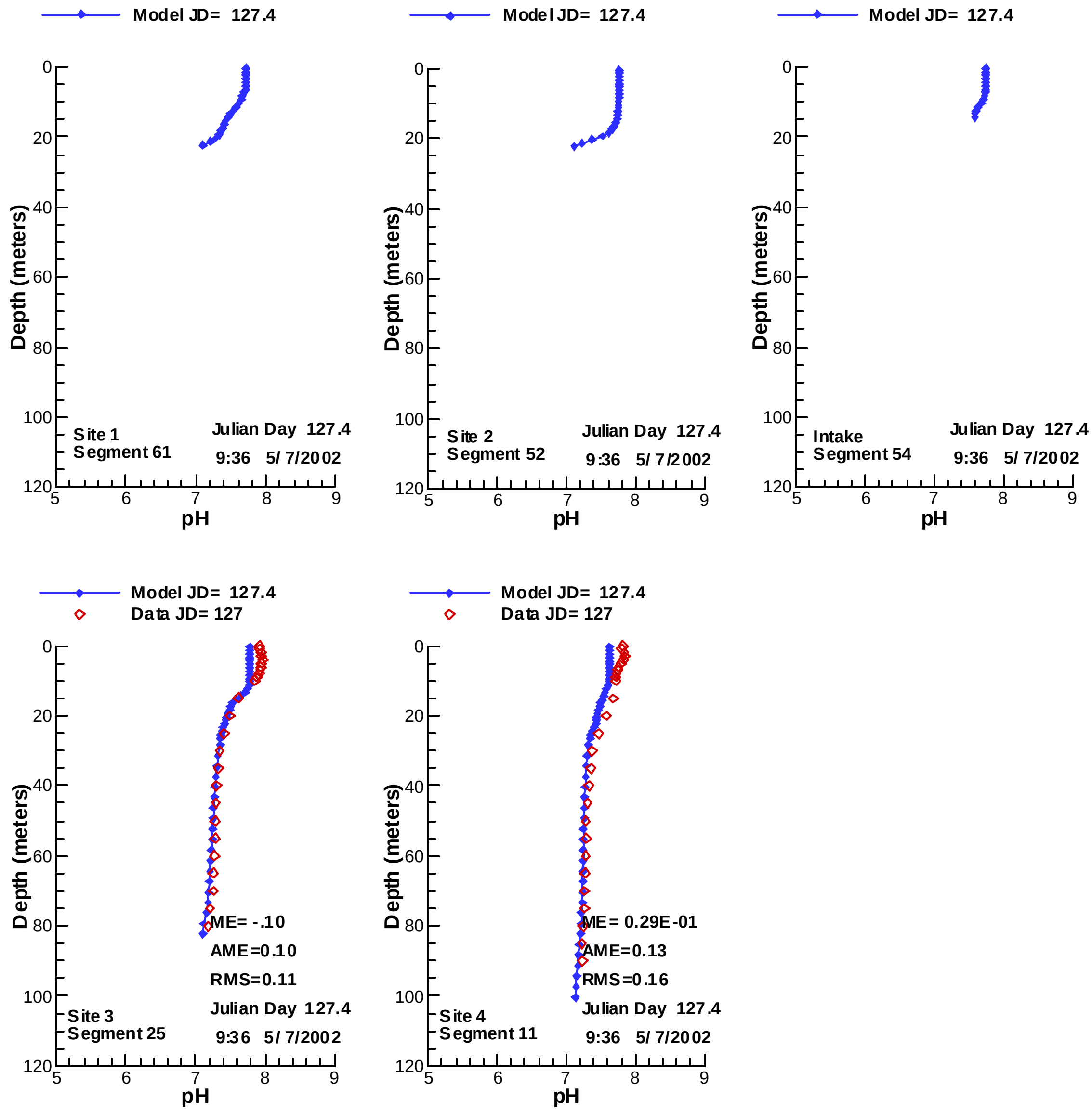

Figure 570. Vertical profiles of pH compared with data for 5/ 7/2002.

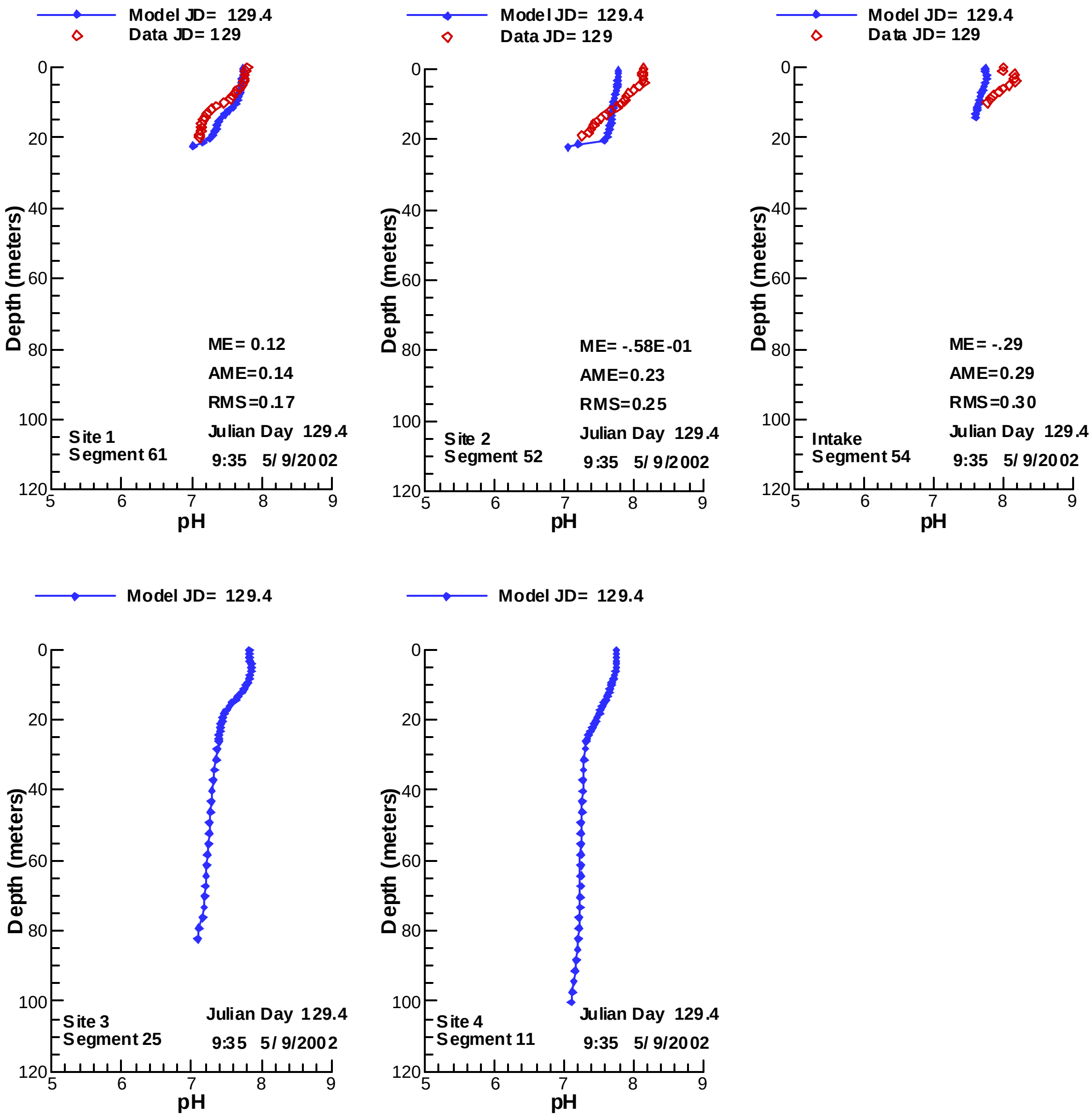

Figure 571. Vertical profiles of pH compared with data for 5/ 9/2002.

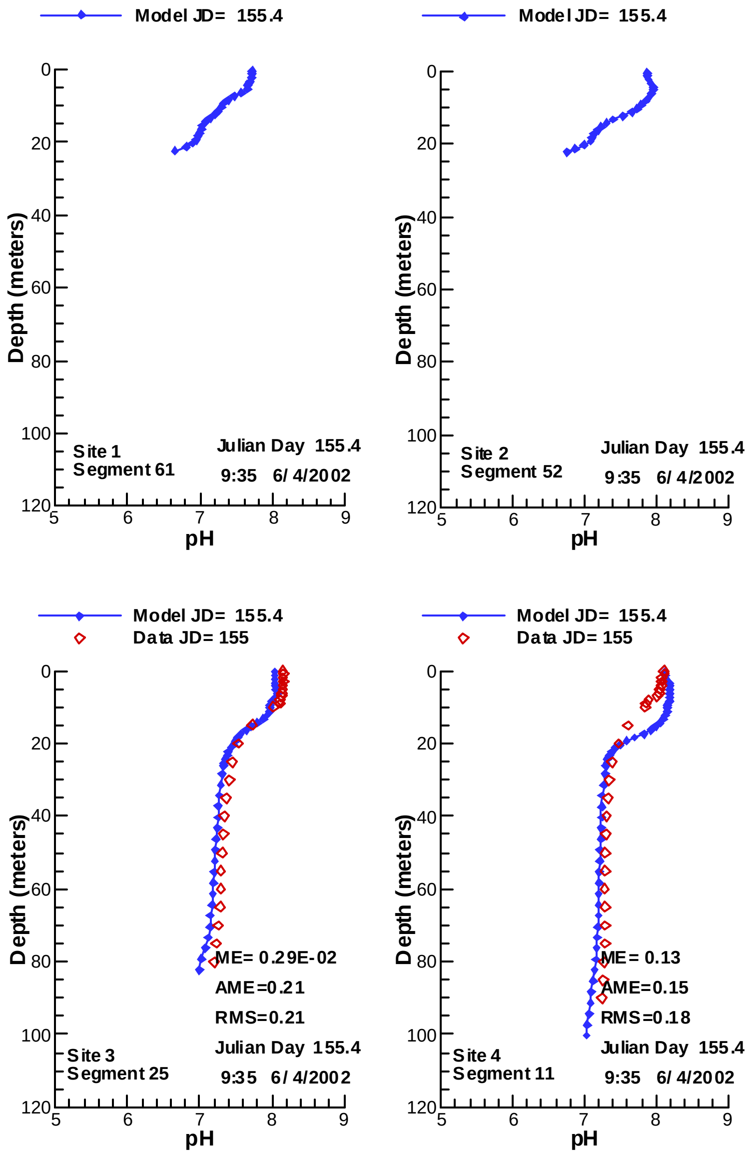

Figure 572. Vertical profiles of pH compared with data for 6/ 4/2002.

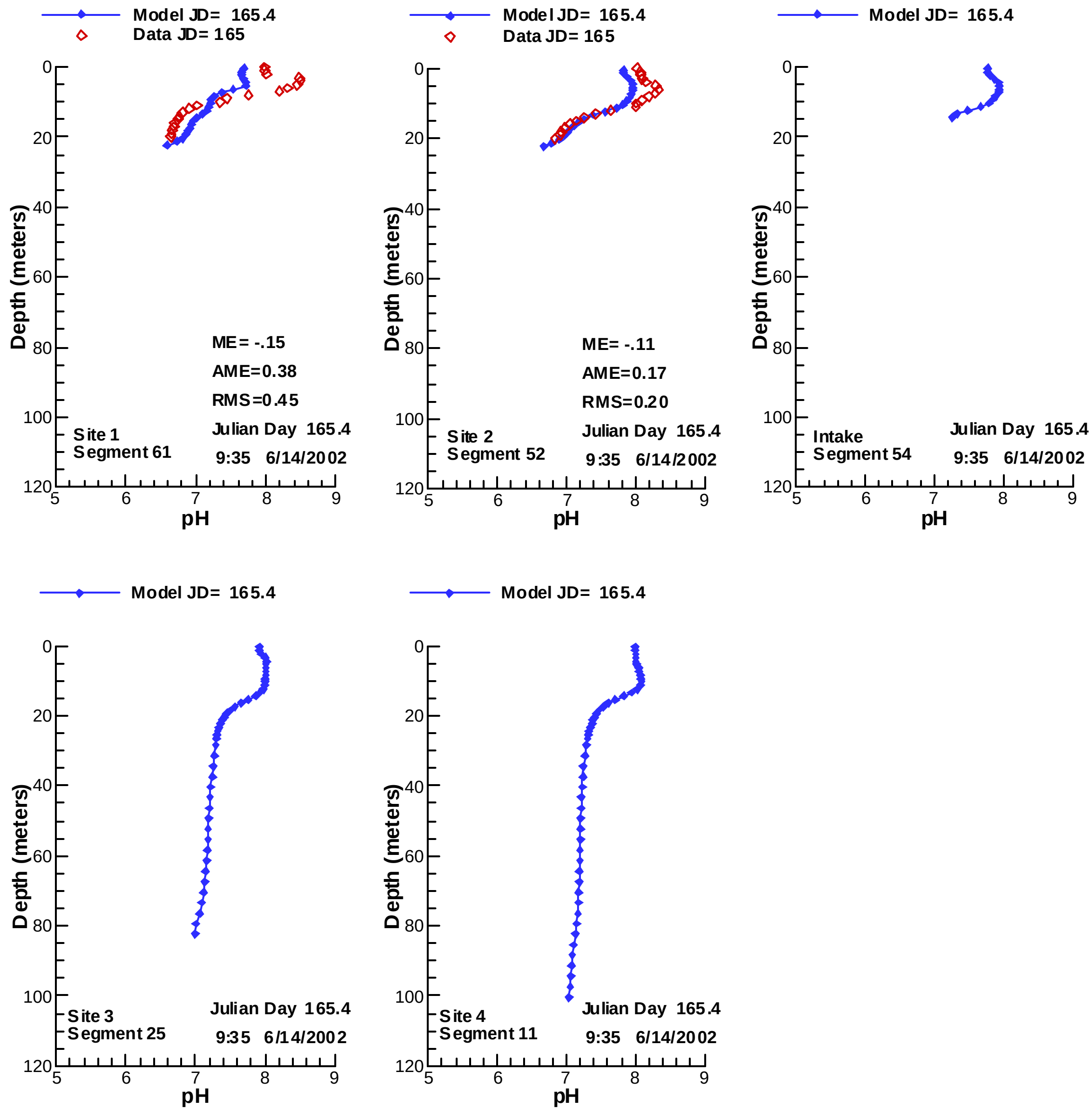

Figure 573. Vertical profiles of pH compared with data for 6/14/2002.

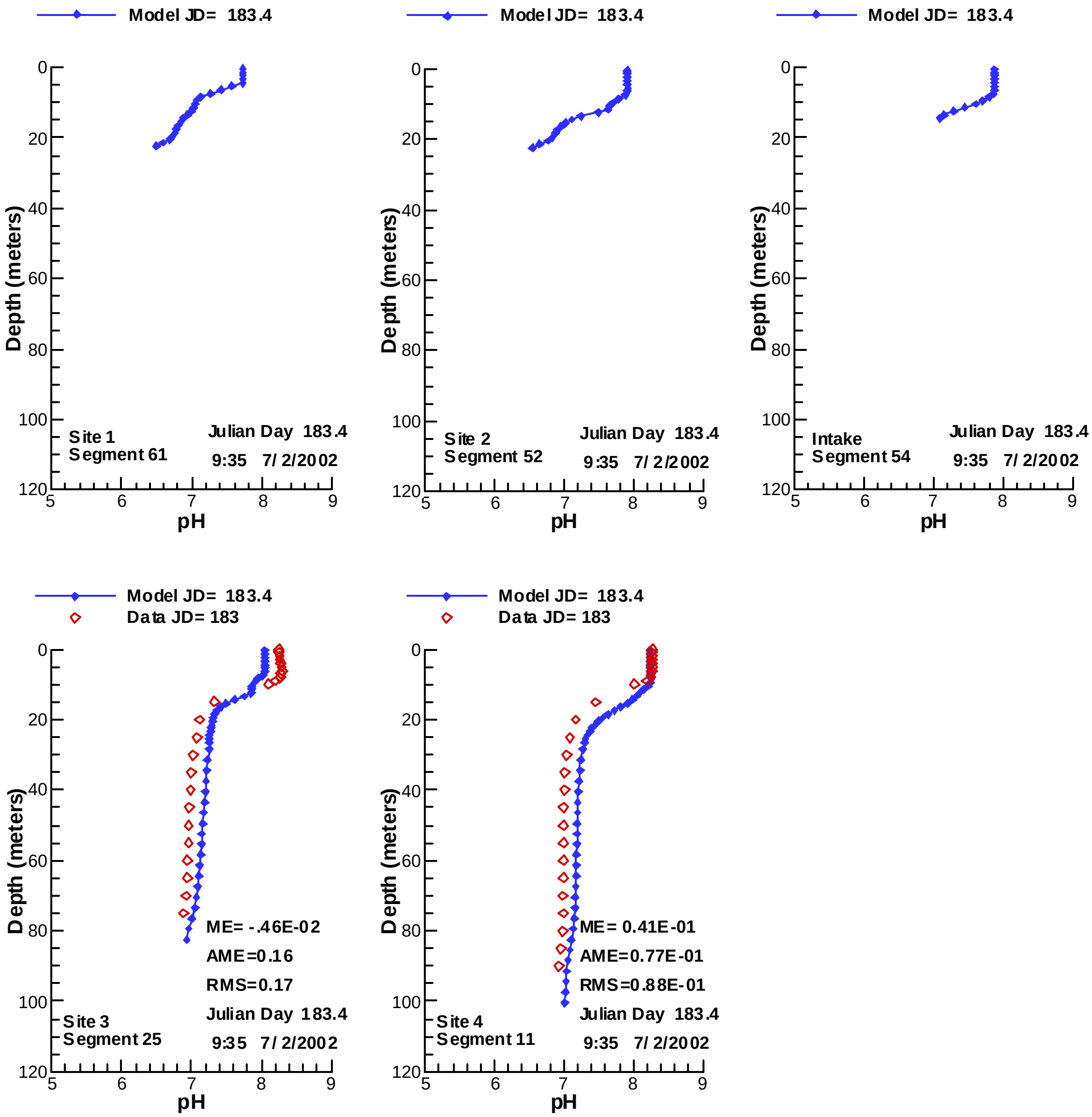

Figure 574. Vertical profiles of pH compared with data for 7/ 2/2002.

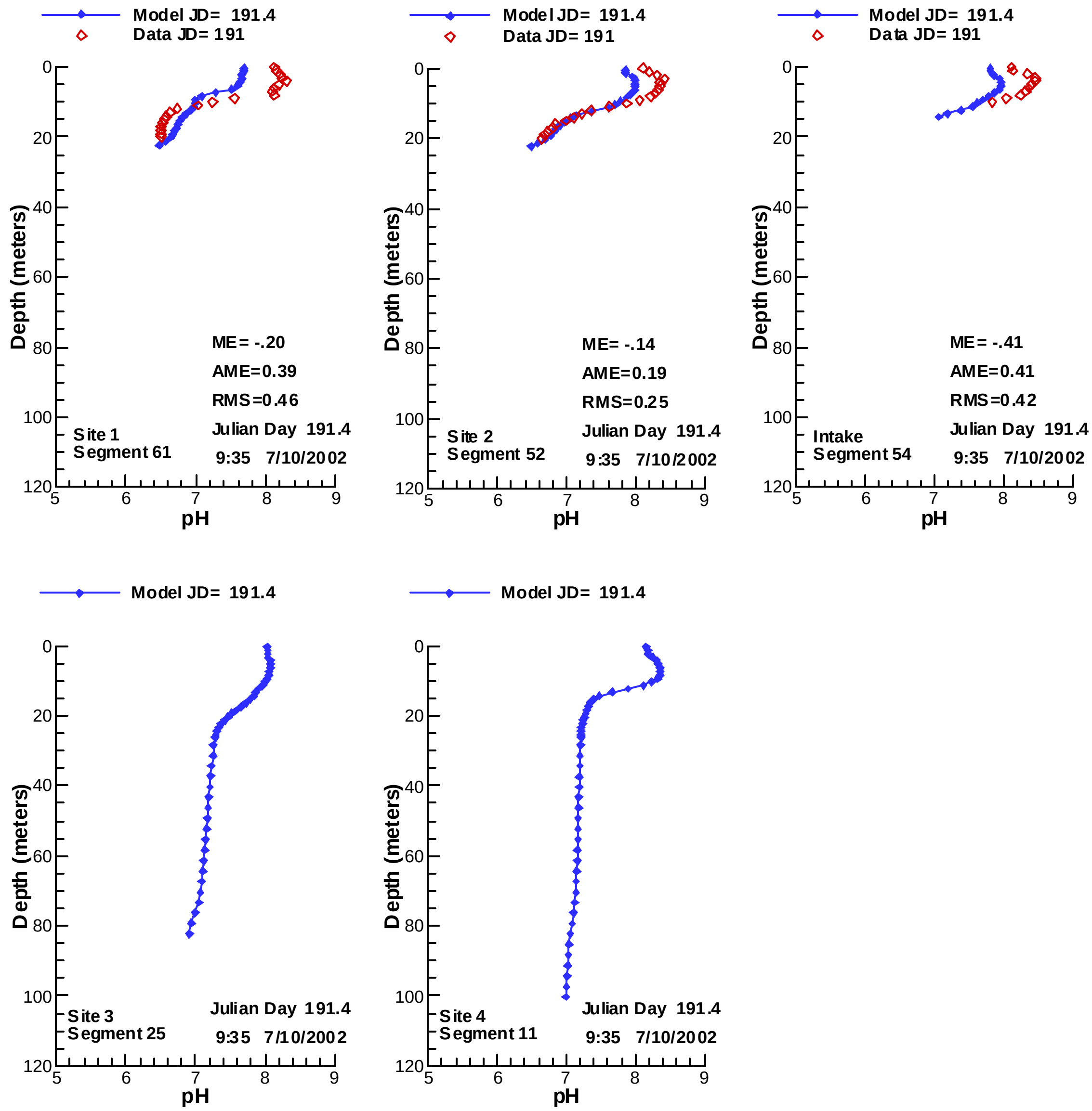

Figure 575. Vertical profiles of pH compared with data for 7/10/2002.

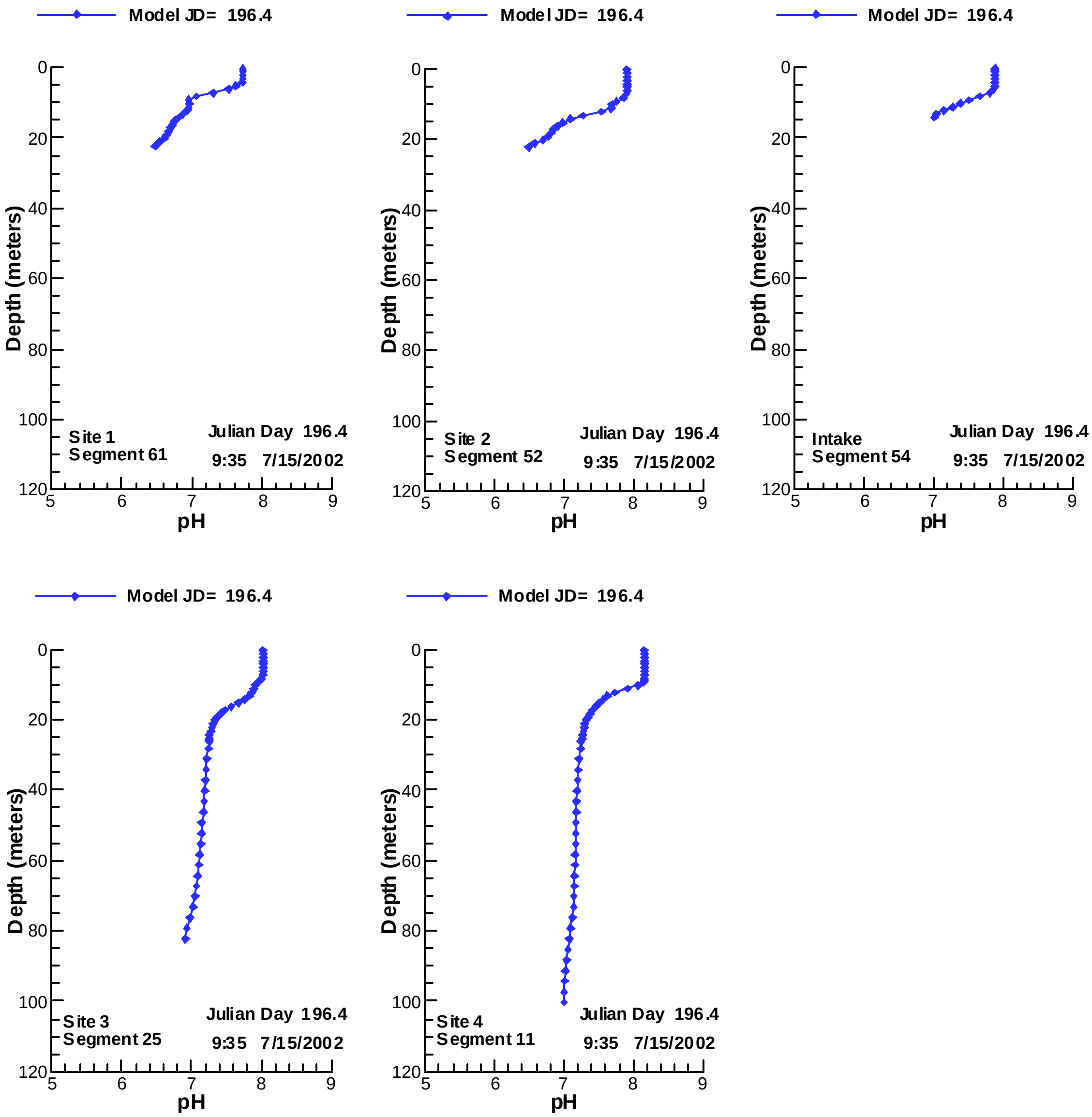

Figure 576. Vertical profiles of pH compared with data for 7/15/2002.

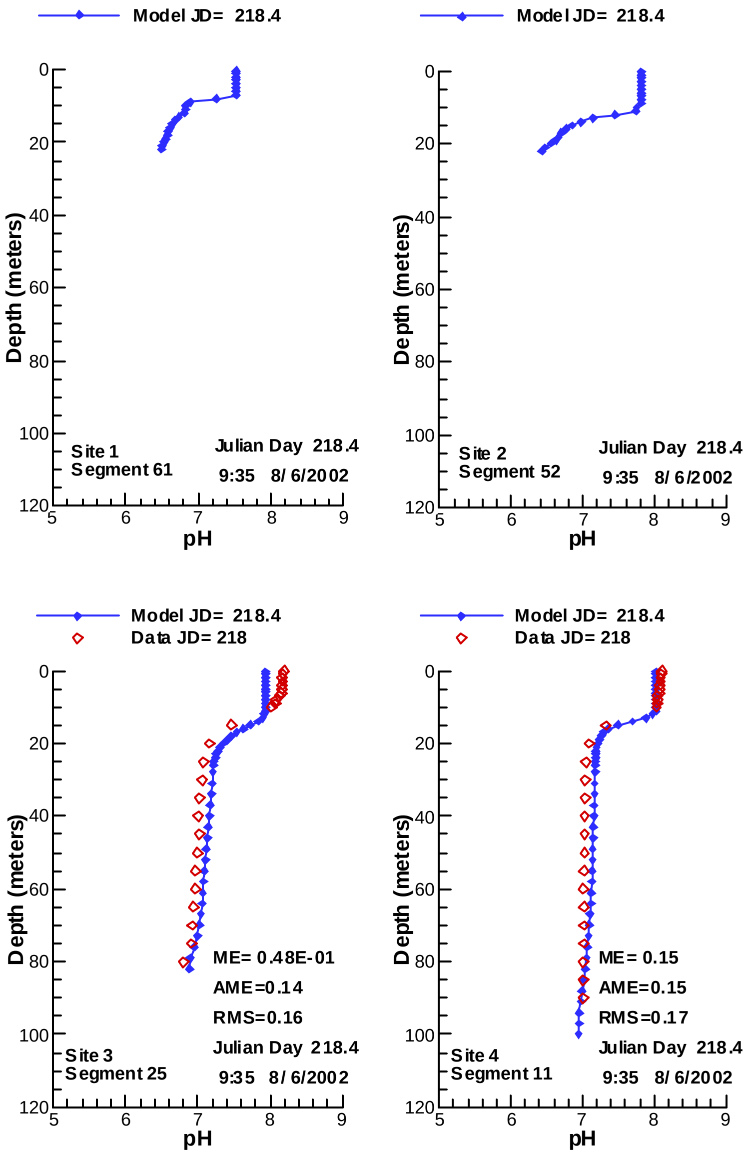

Figure 577. Vertical profiles of pH compared with data for 8/ 6/2002.

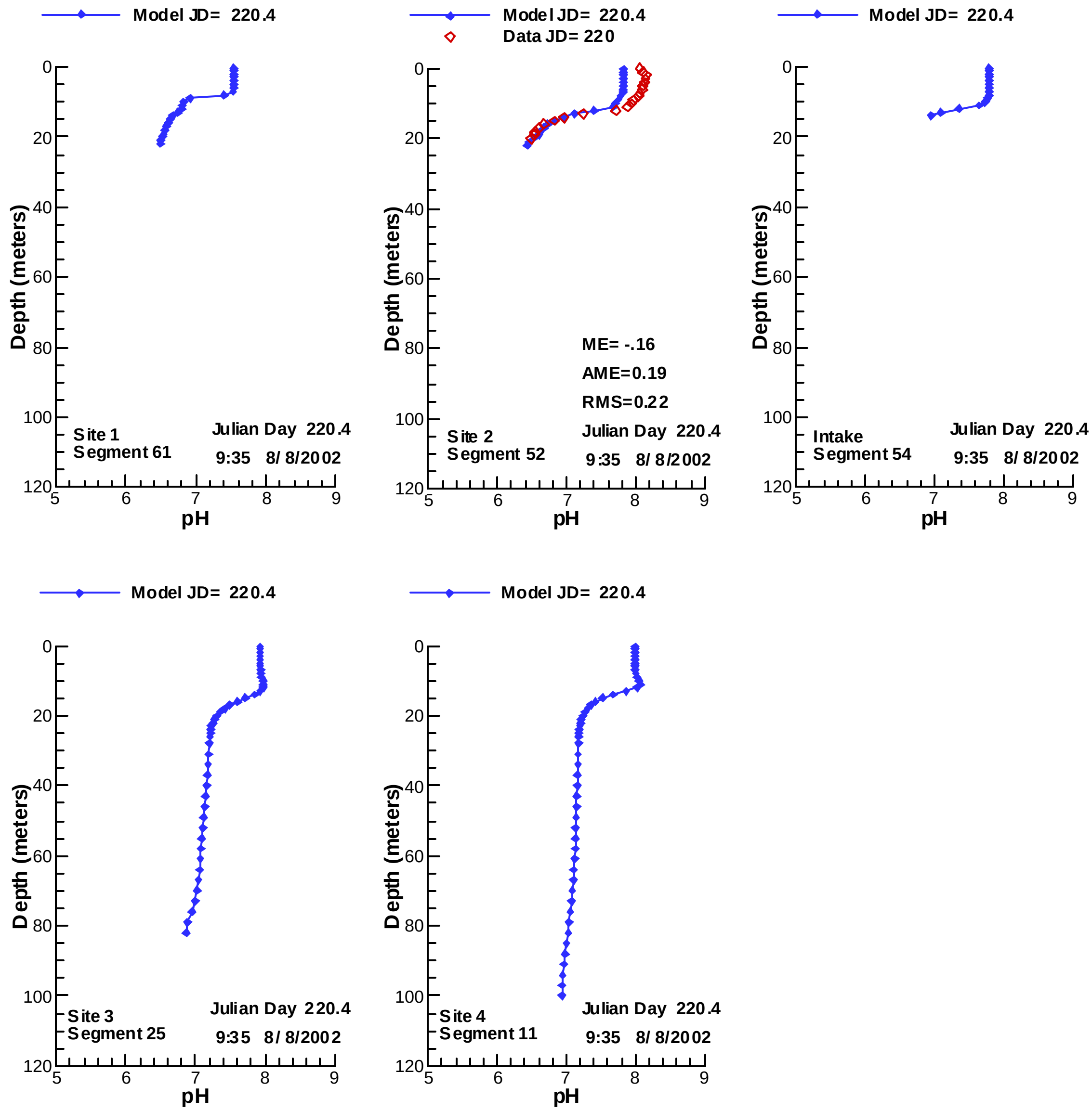

Figure 578. Vertical profiles of pH compared with data for 8/ 8/2002.

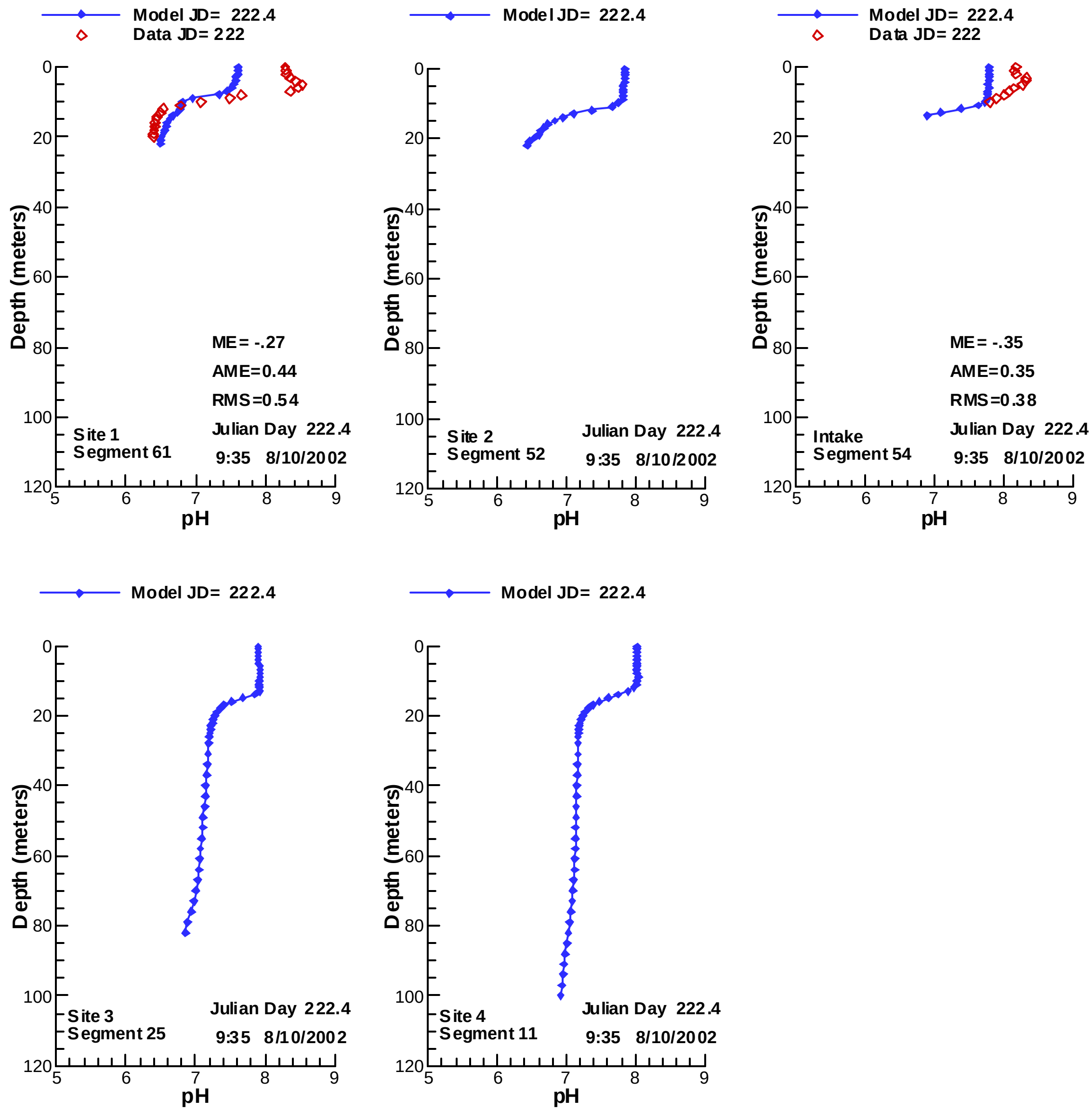

Figure 579. Vertical profiles of pH compared with data for 8/10/2002.

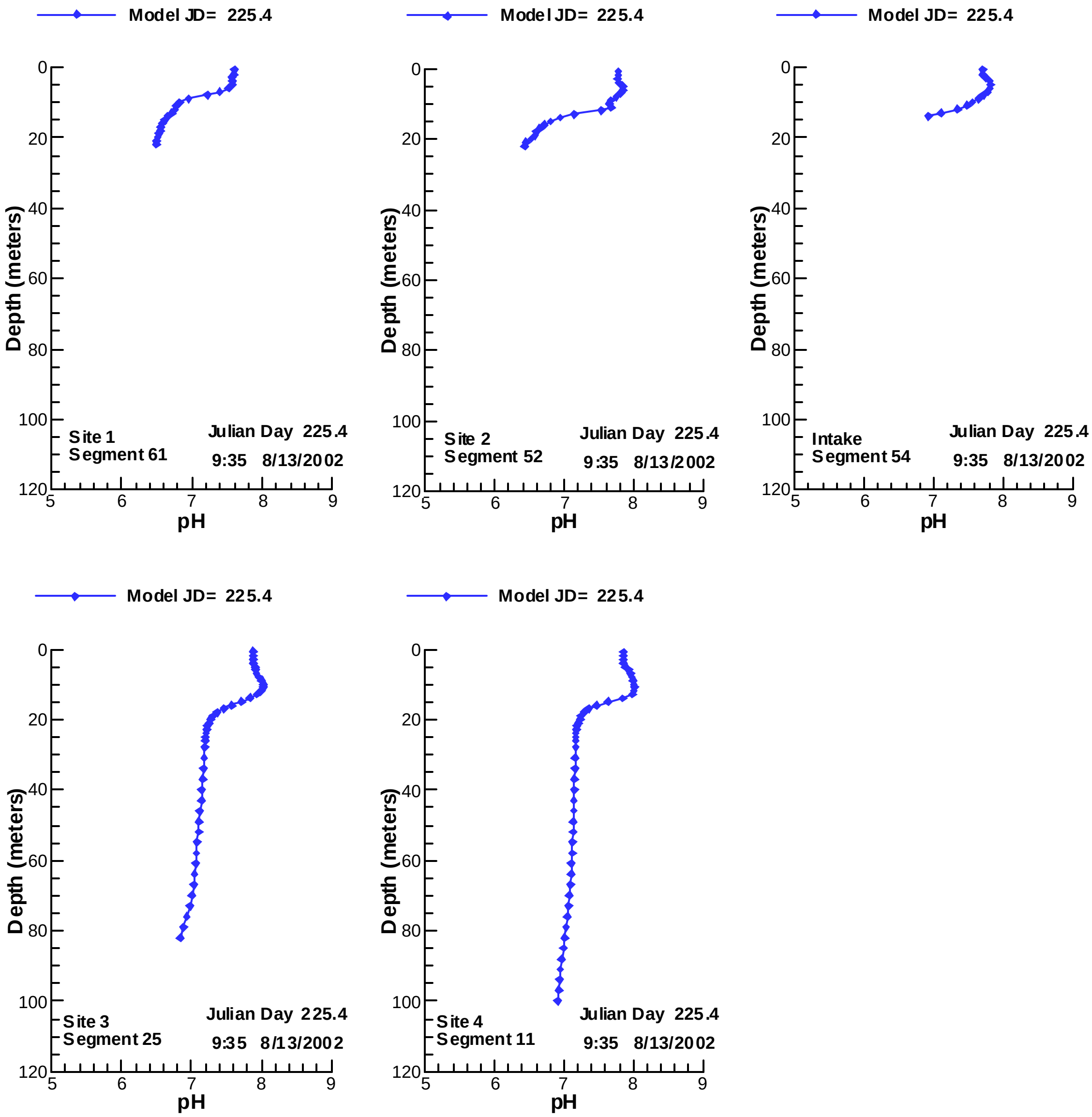

Figure 580. Vertical profiles of pH compared with data for 8/13/2002.

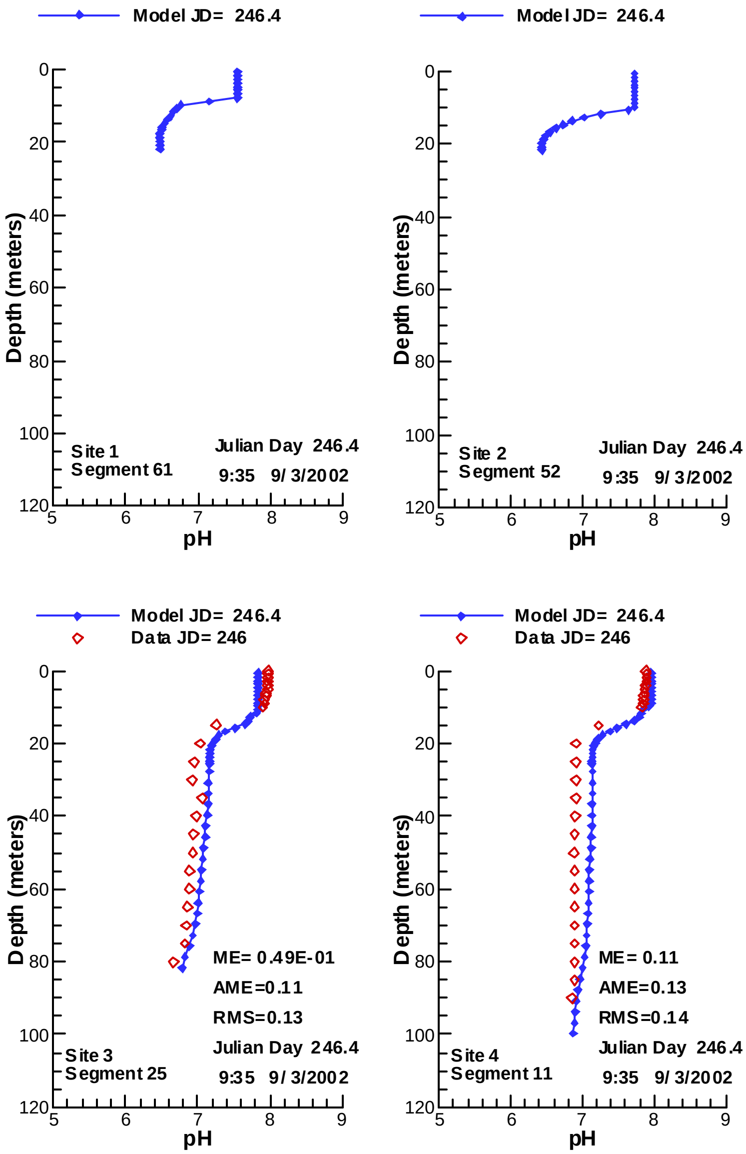

Figure 581. Vertical profiles of pH compared with data for 9/ 3/2002.

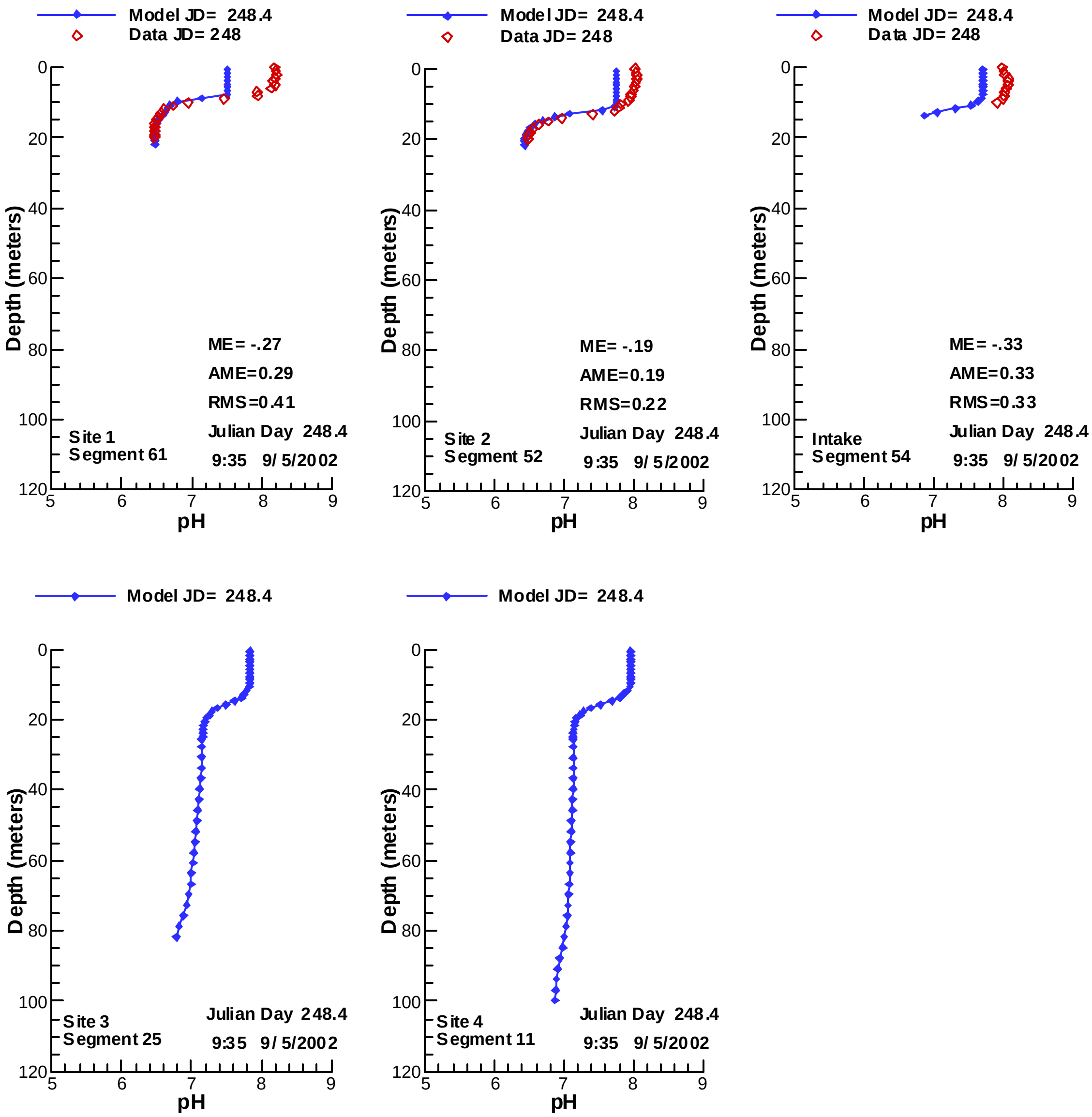

Figure 582. Vertical profiles of pH compared with data for 9/ 5/2002.

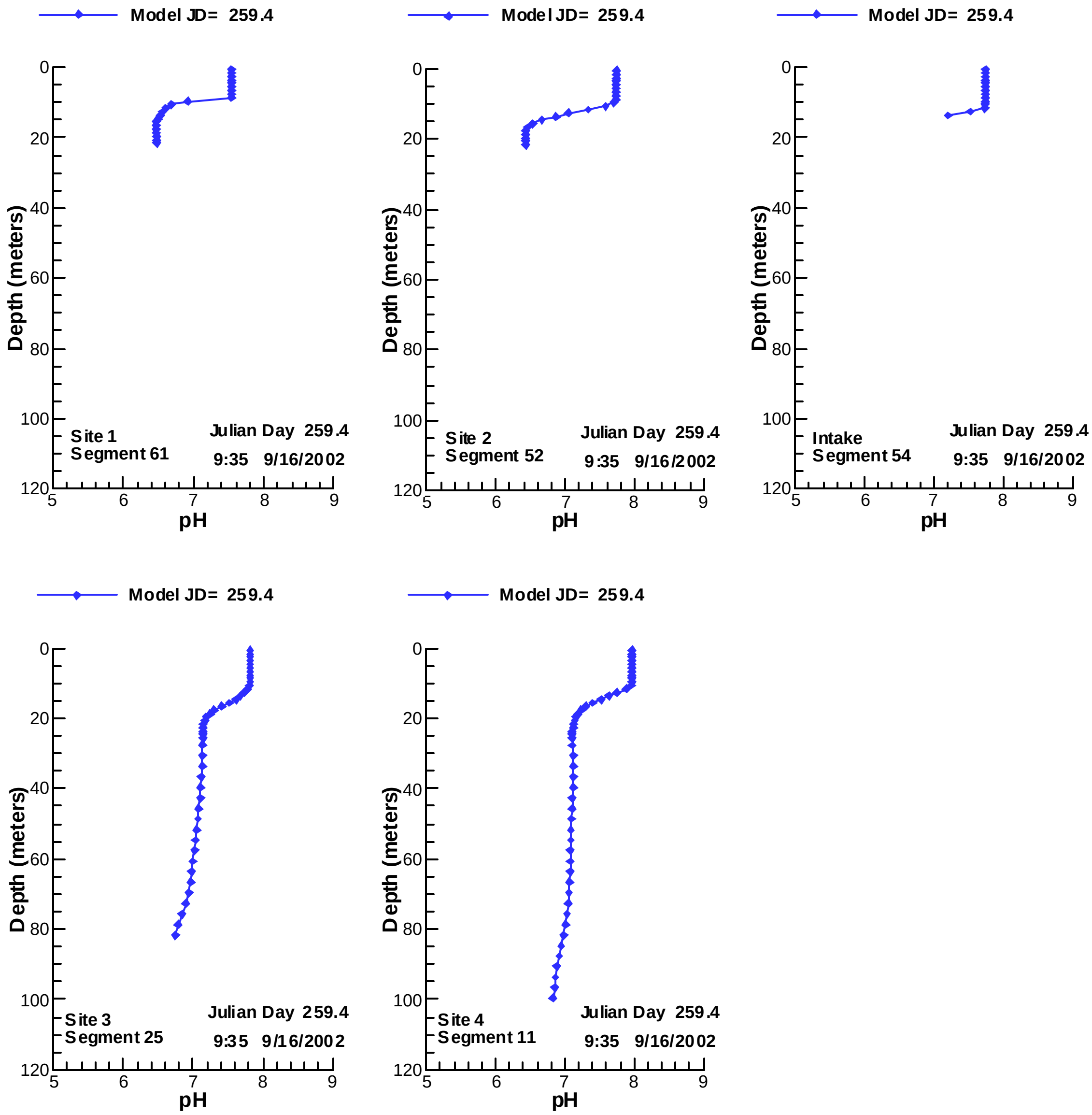

Figure 583. Vertical profiles of pH compared with data for 9/16/2002.

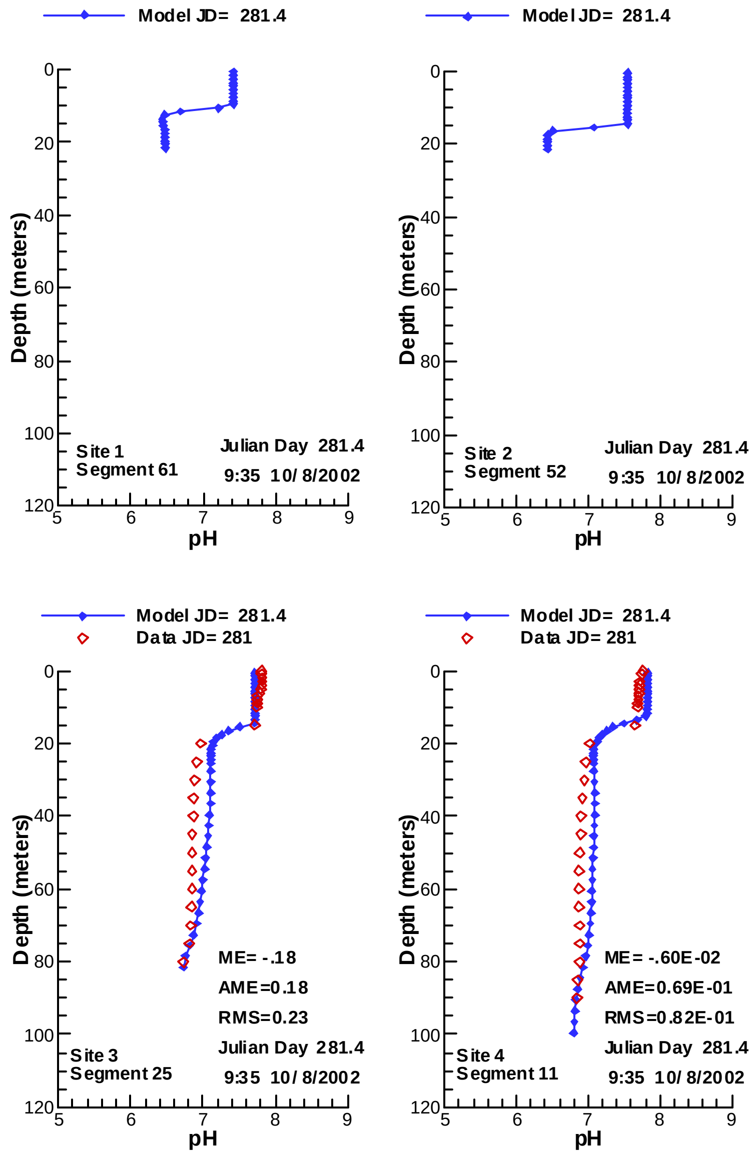

Figure 584. Vertical profiles of pH compared with data for 10/ 8/2002.

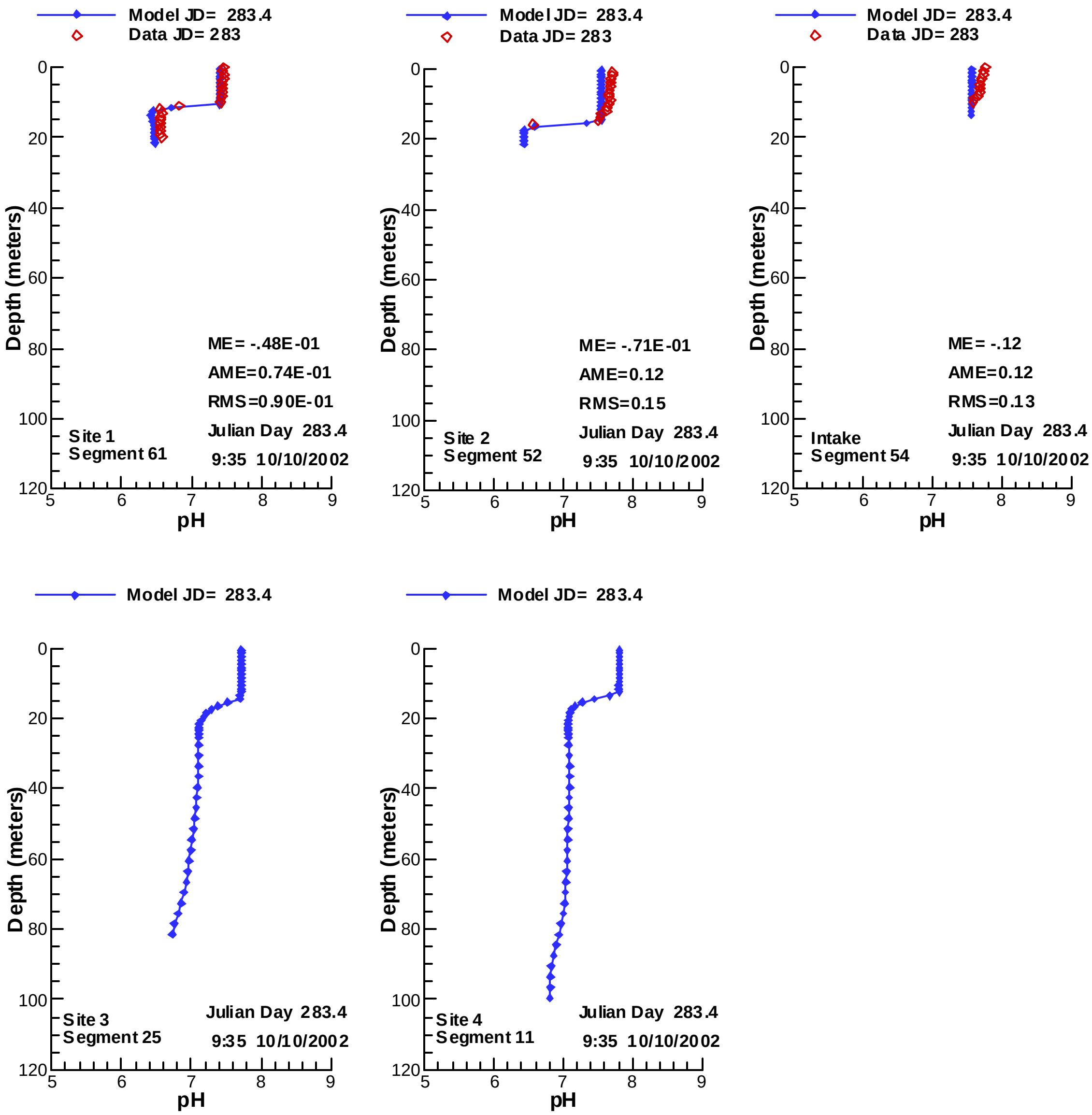

Figure 585. Vertical profiles of pH compared with data for 10/10/2002.

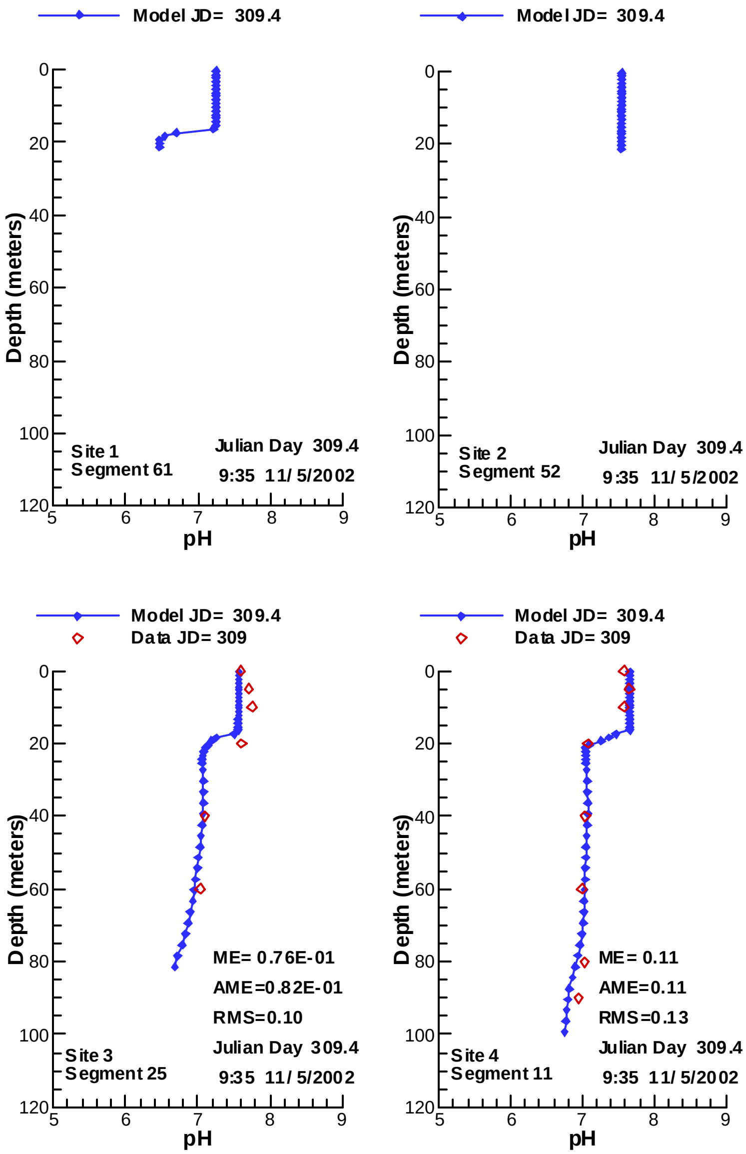

Figure 586. Vertical profiles of pH compared with data for 11/ 5/2002.

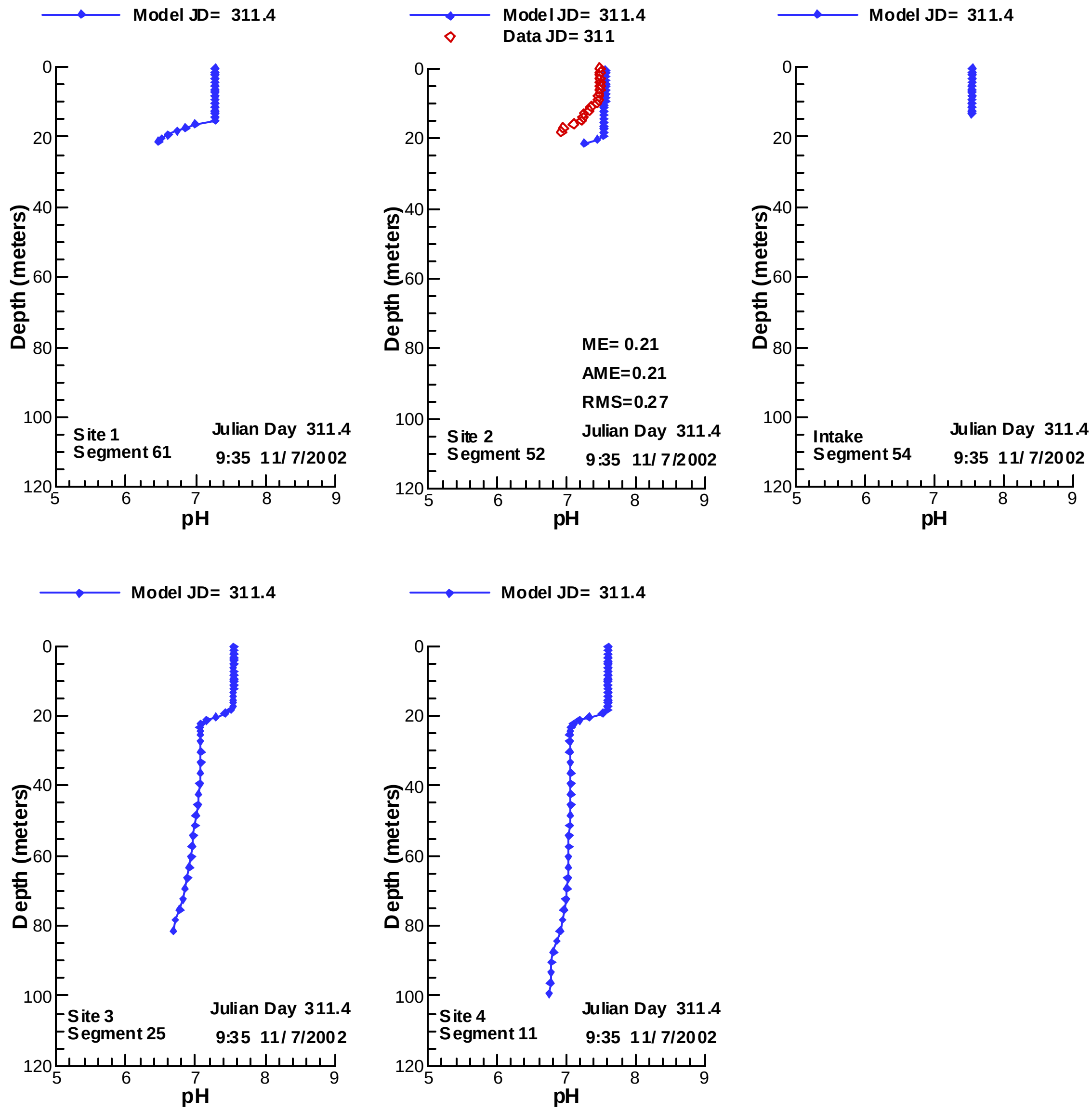

Figure 587. Vertical profiles of pH compared with data for 11/ 7/2002.

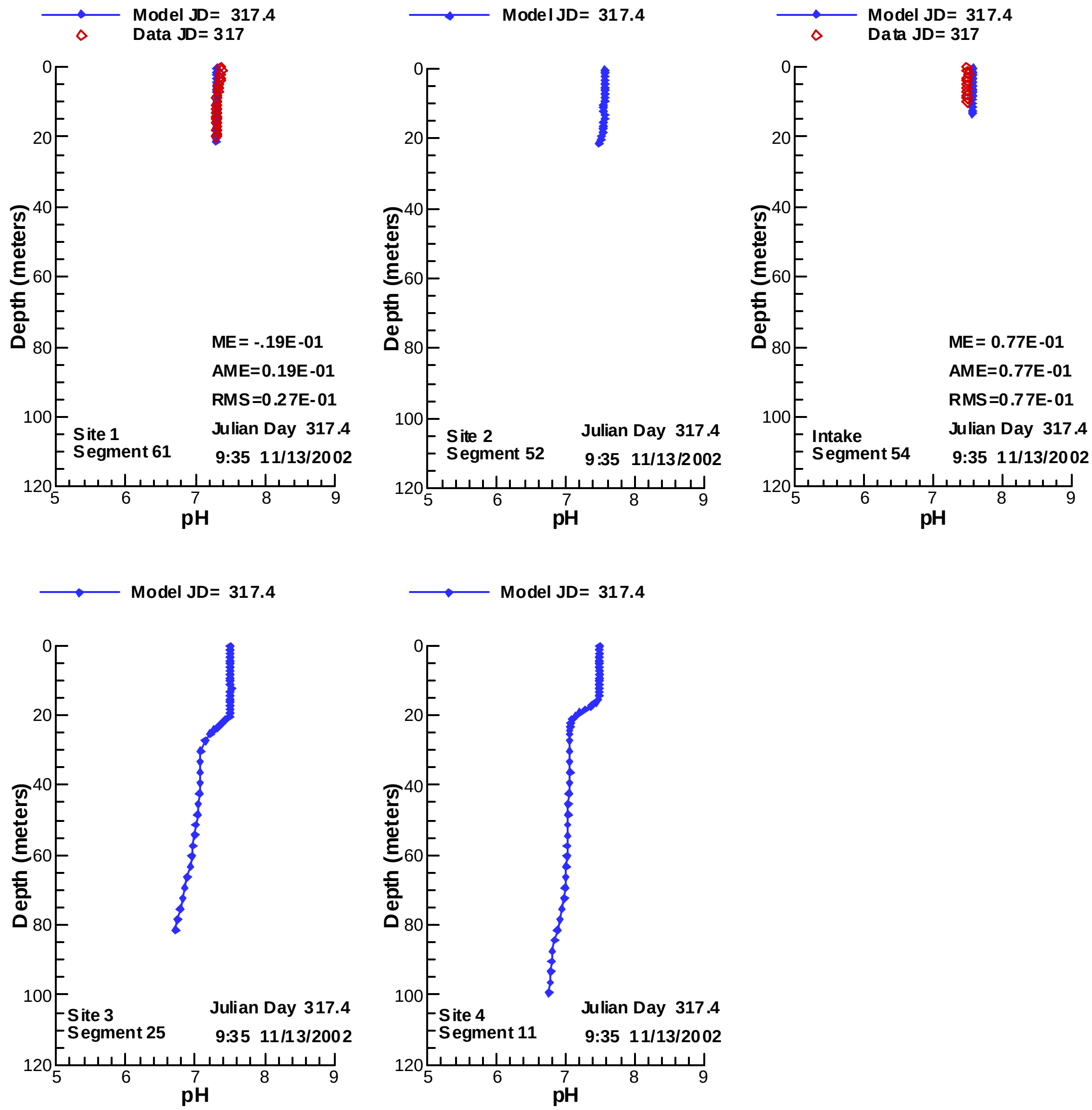

Figure 588. Vertical profiles of pH compared with data for 11/13/2002.

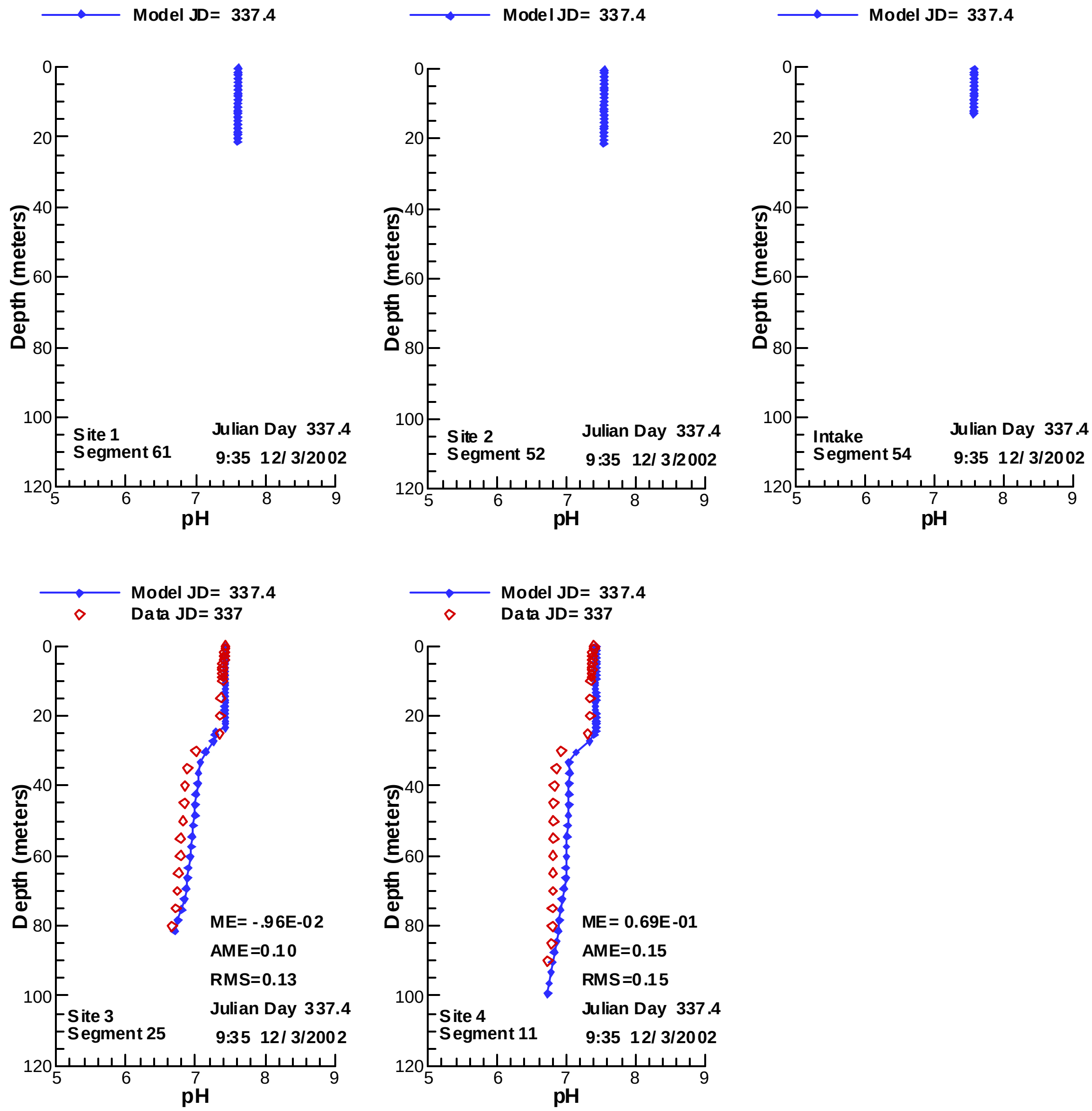

Figure 589. Vertical profiles of pH compared with data for 12/ 3/2002.

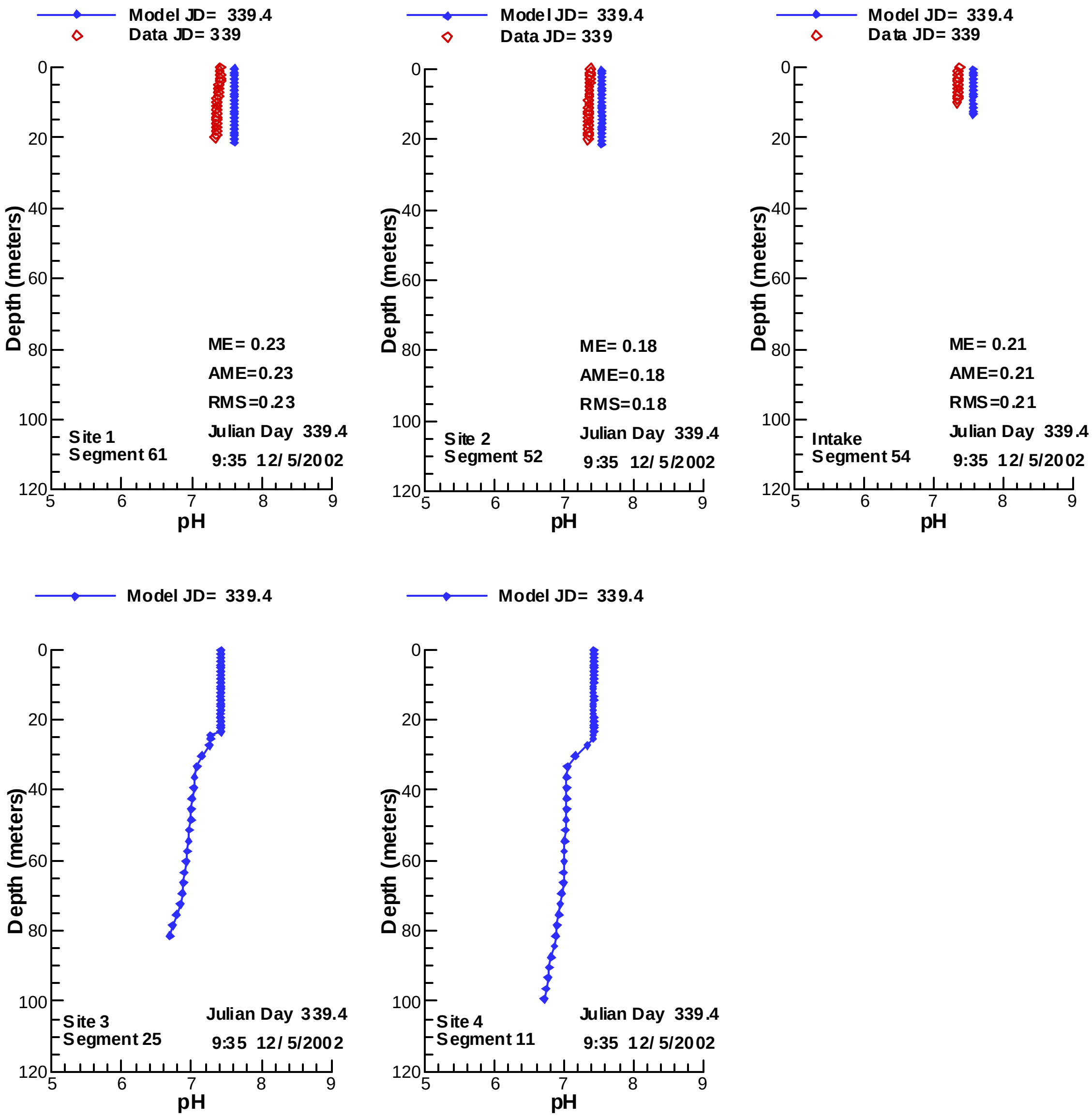

Figure 590. Vertical profiles of pH compared with data for 12/ 5/2002.

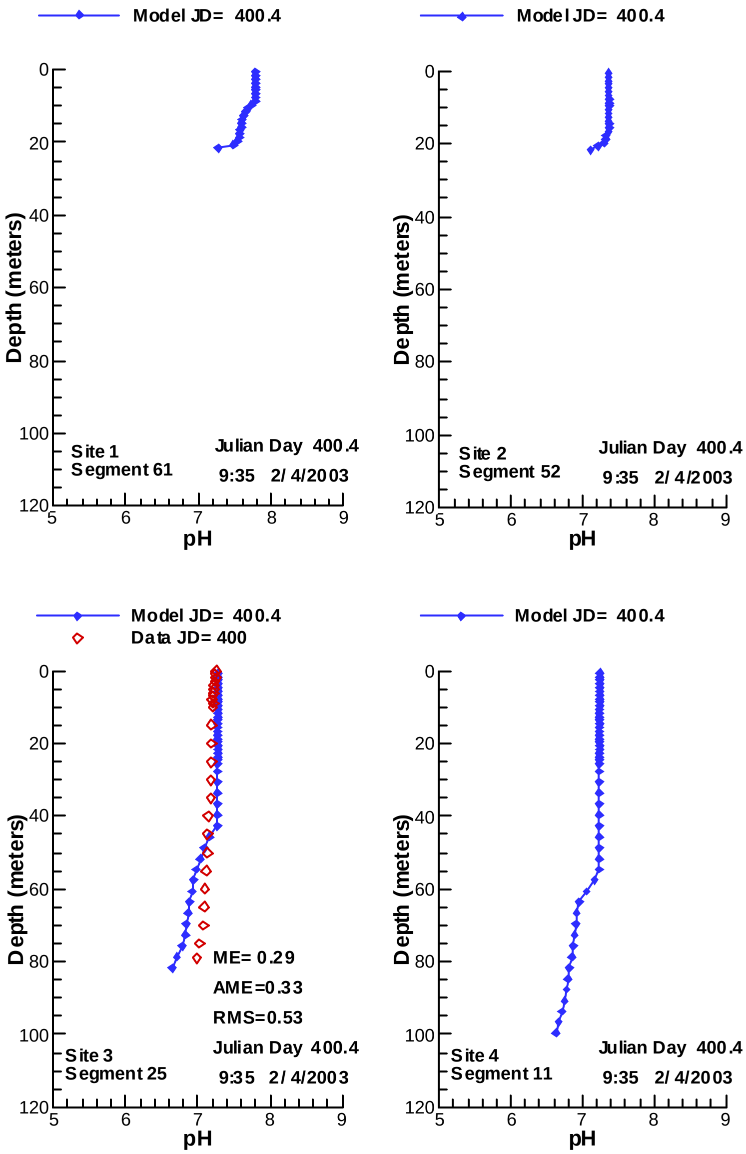

Figure 591. Vertical profiles of pH compared with data for 2/ 4/2003.

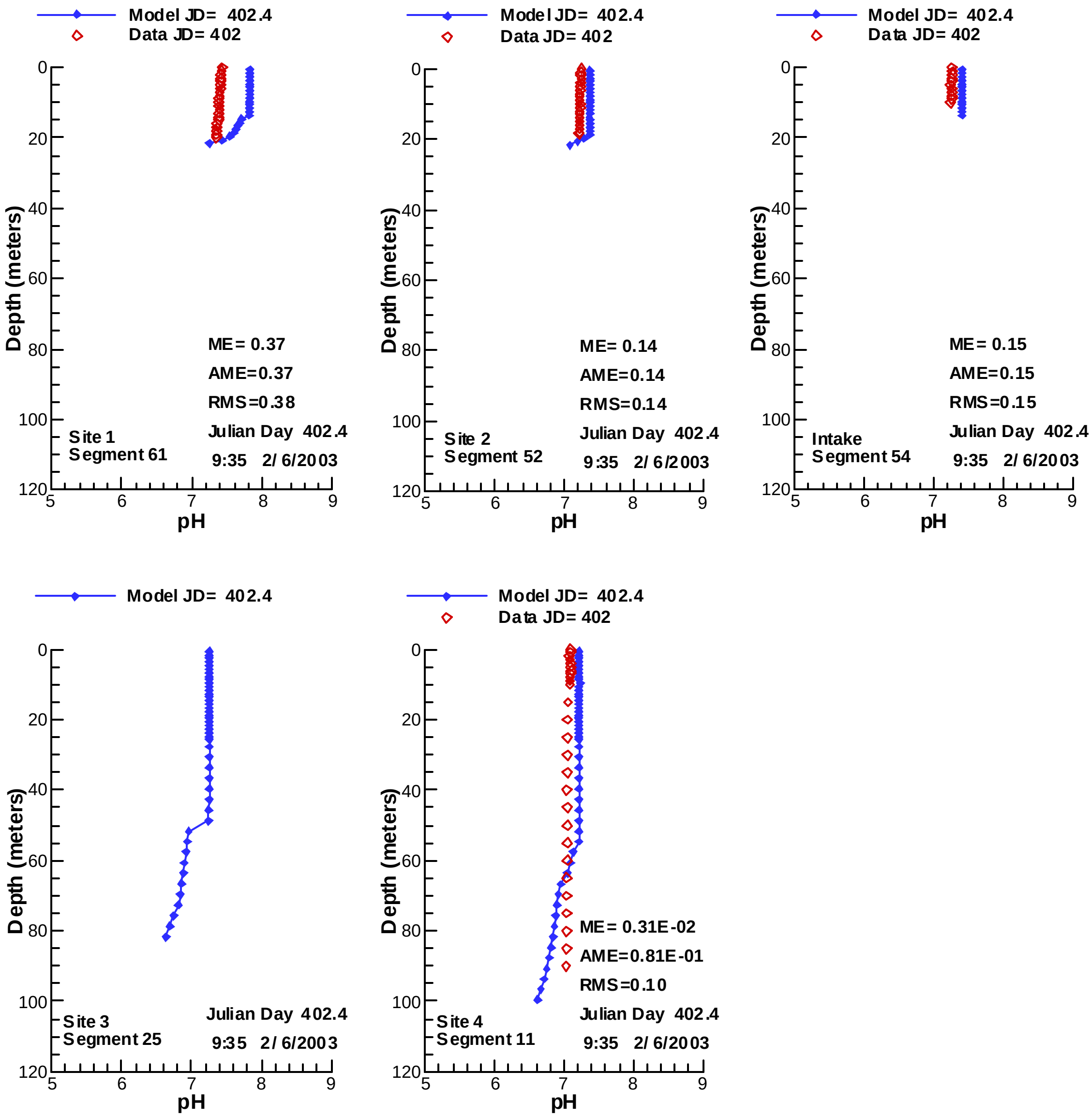

Figure 592. Vertical profiles of pH compared with data for 2/ 6/2003.

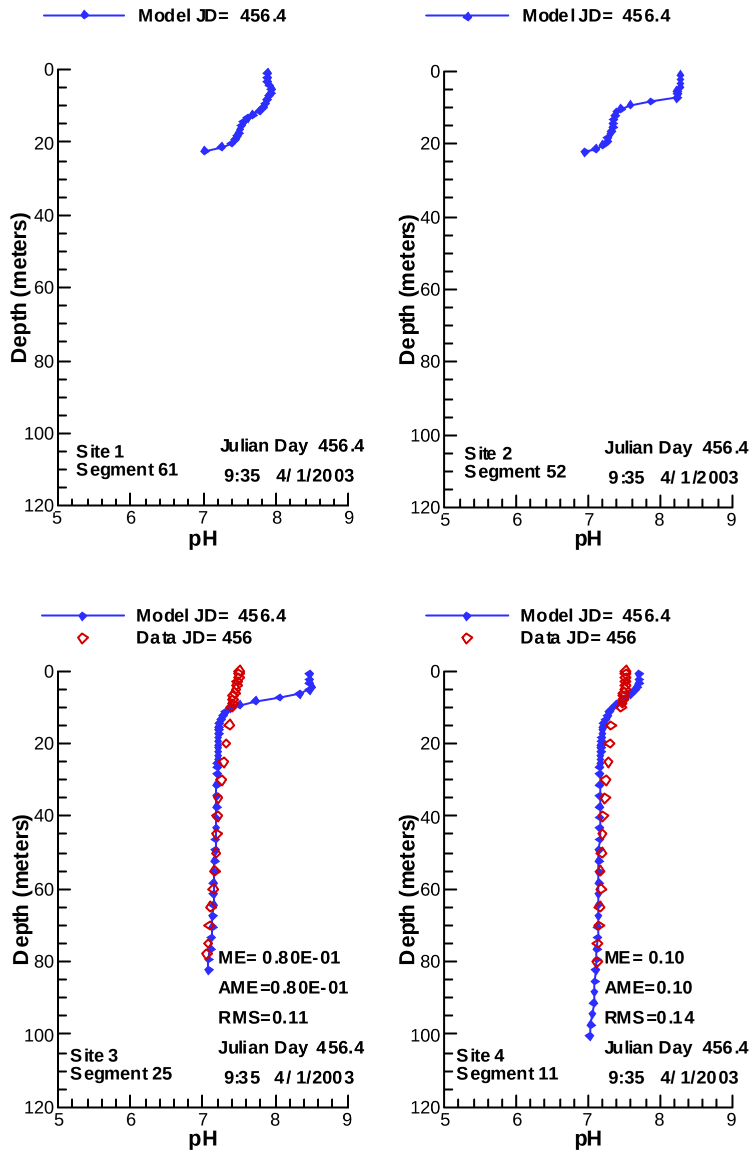

Figure 593. Vertical profiles of pH compared with data for 4/ 1/2003.

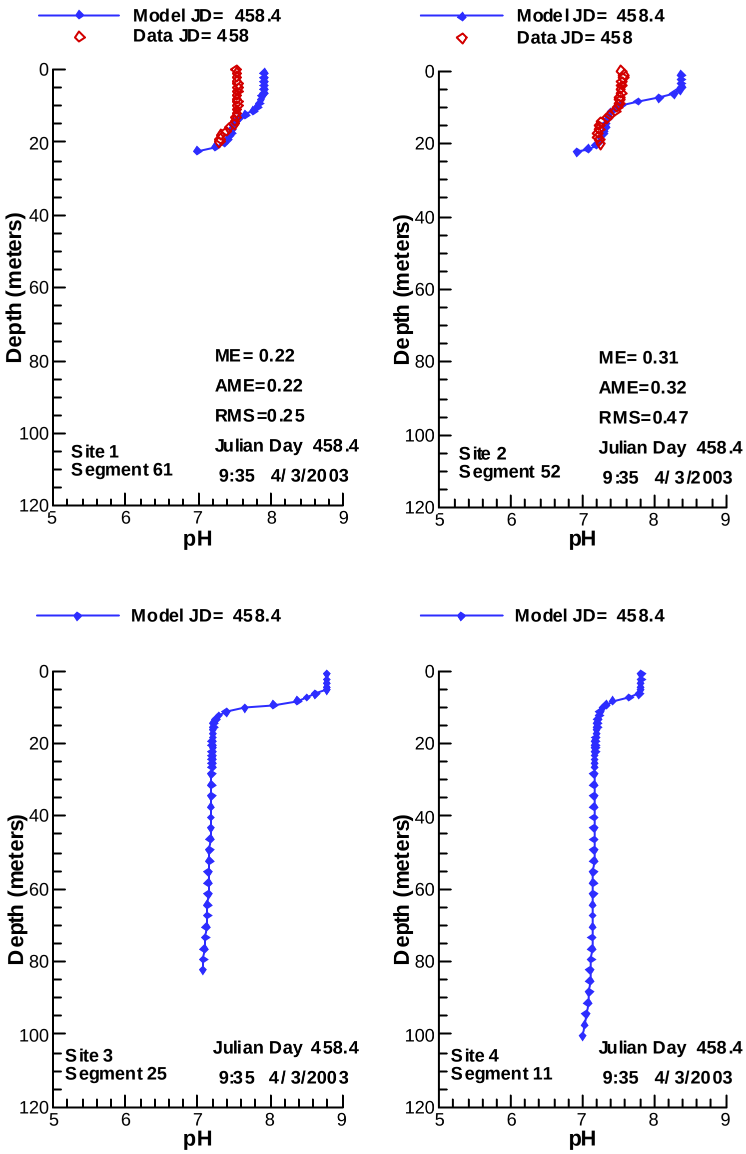

Figure 594. Vertical profiles of pH compared with data for 4/ 3/2003.

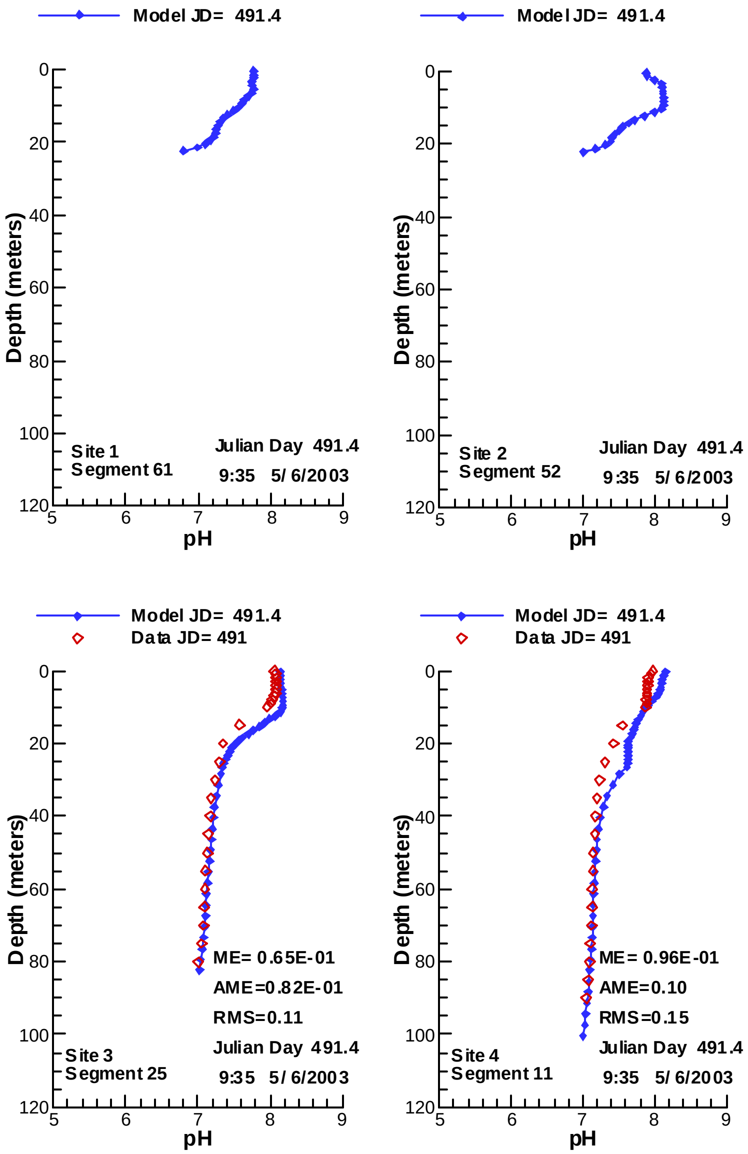

Figure 595. Vertical profiles of pH compared with data for 5/ 6/2003.

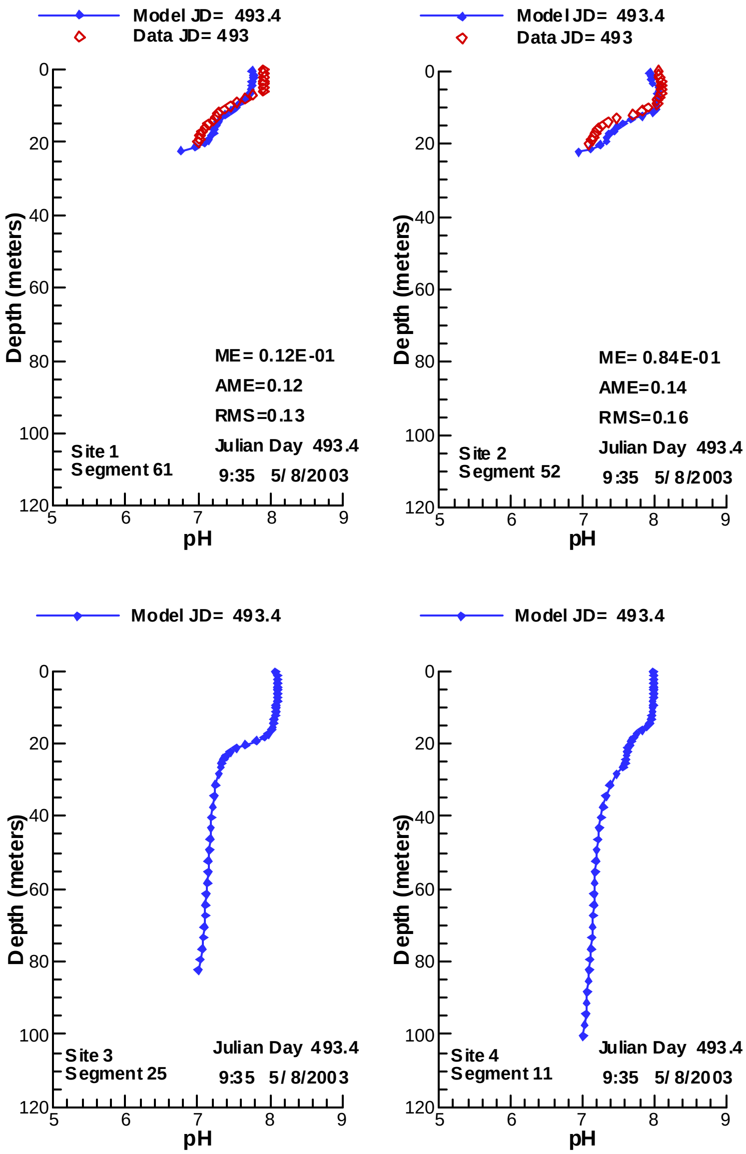

Figure 596. Vertical profiles of pH compared with data for 5/ 8/2003.

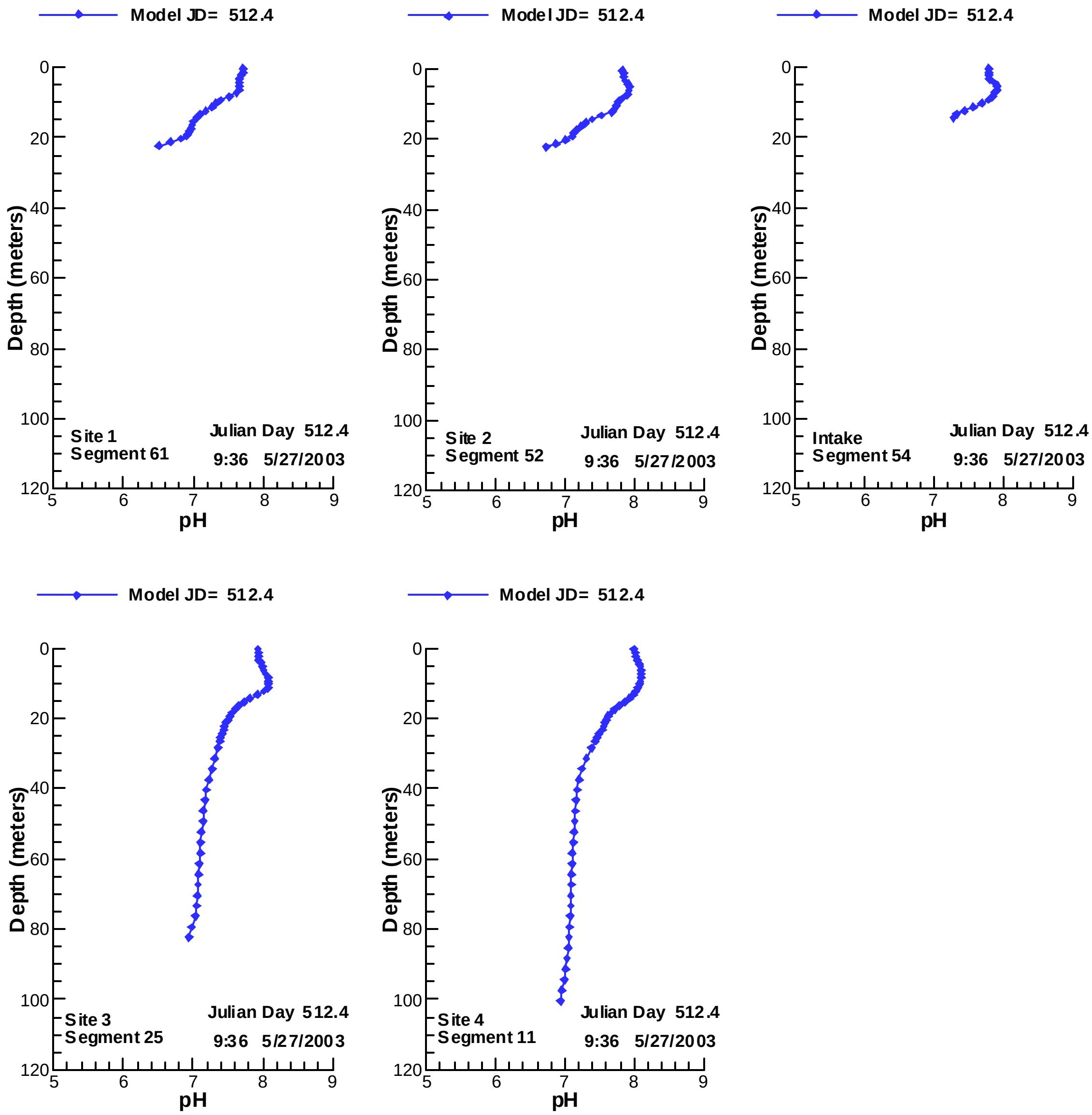

Figure 597. Vertical profiles of pH compared with data for 5/27/2003.

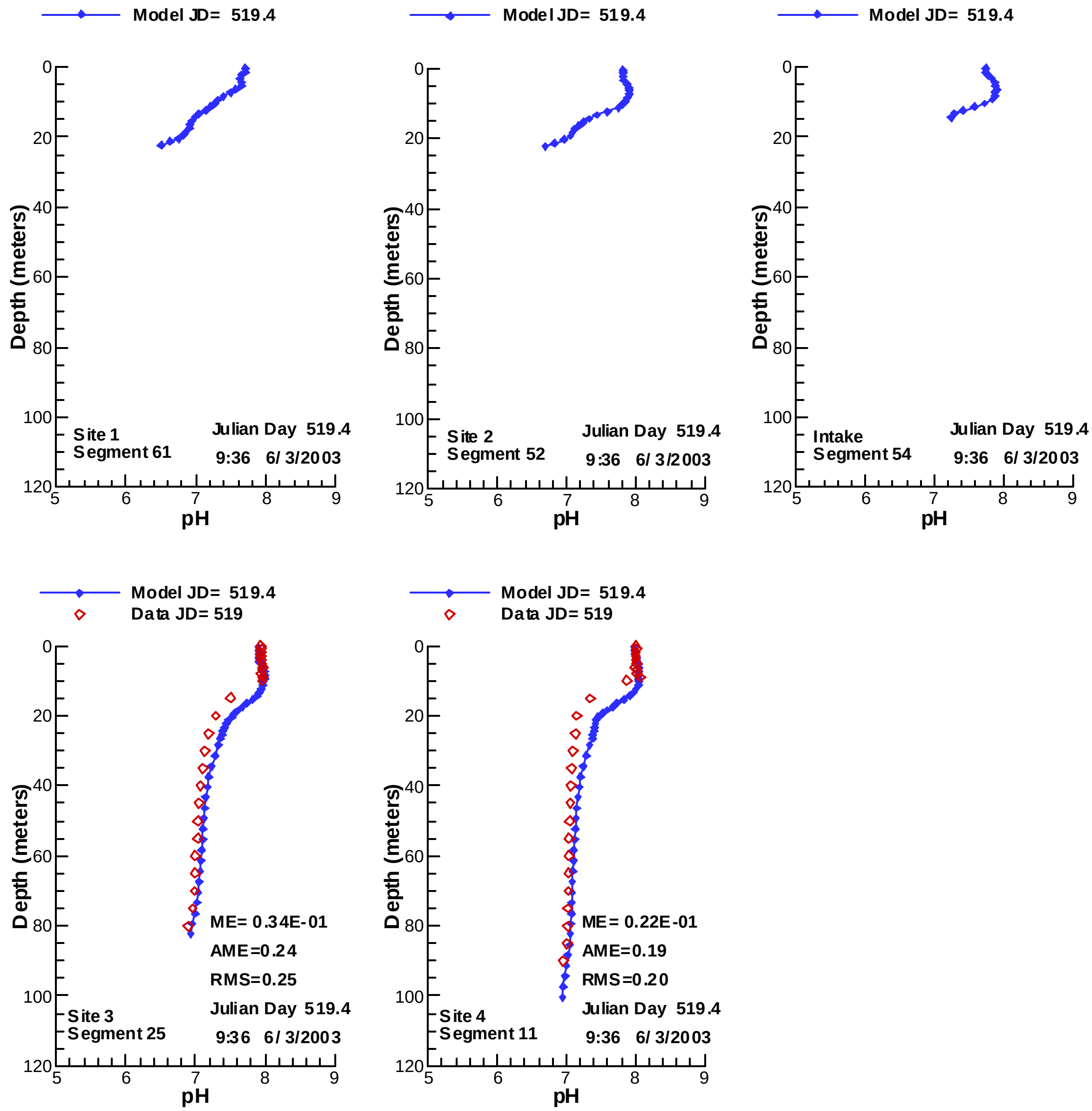

Figure 598. Vertical profiles of pH compared with data for 6/ 3/2003.

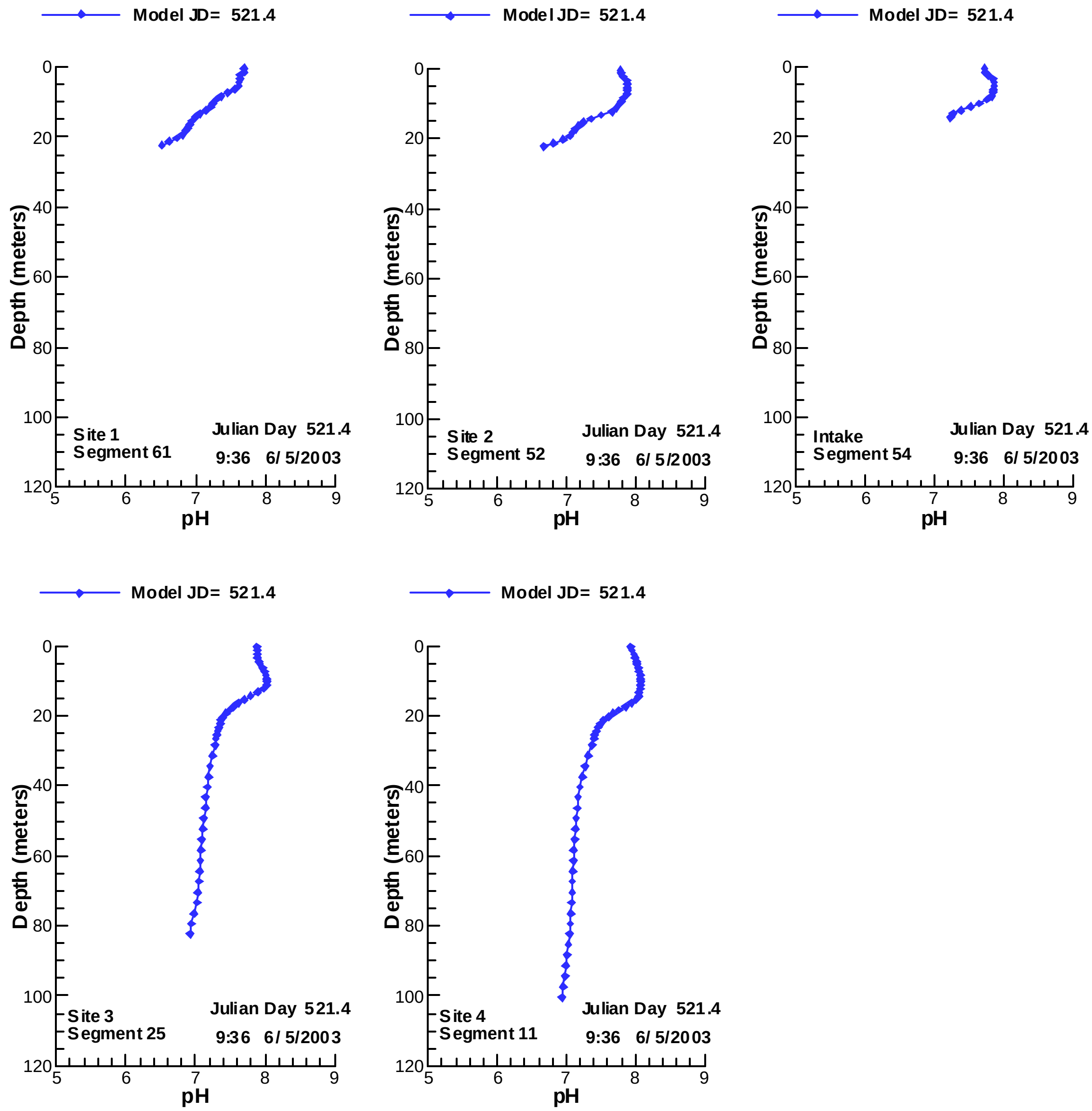

Figure 599. Vertical profiles of pH compared with data for 6/ 5/2003.

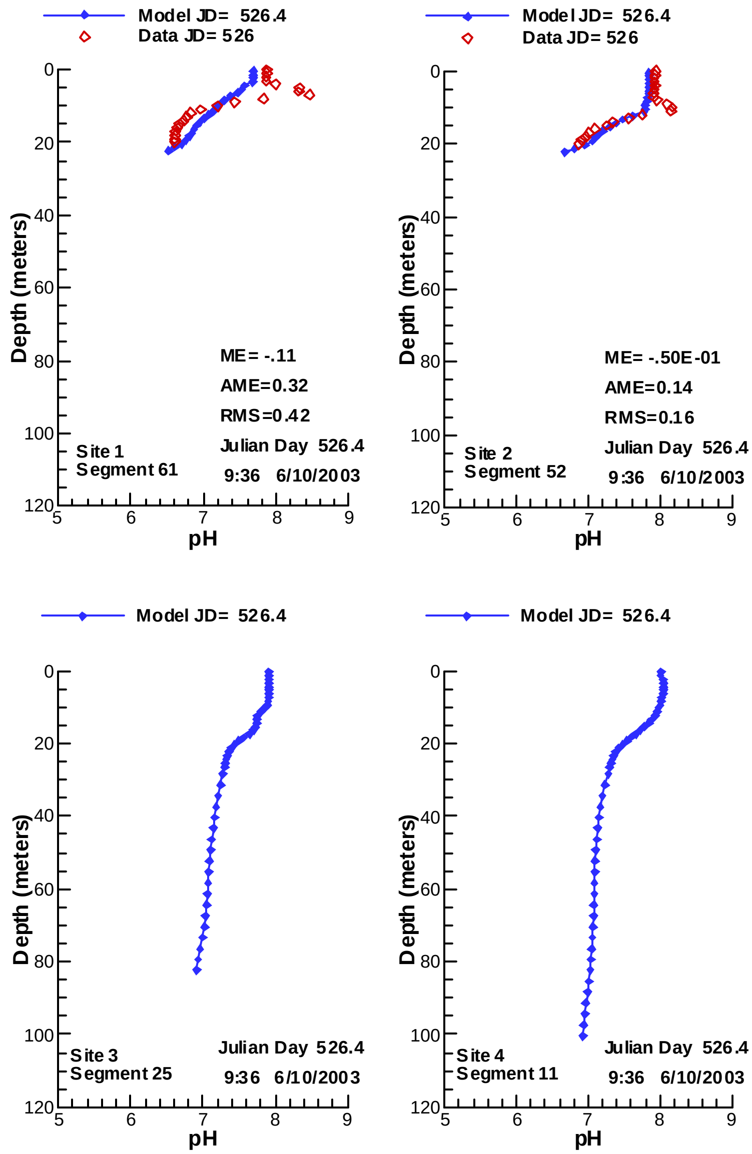

Figure 600. Vertical profiles of pH compared with data for 6/10/2003.

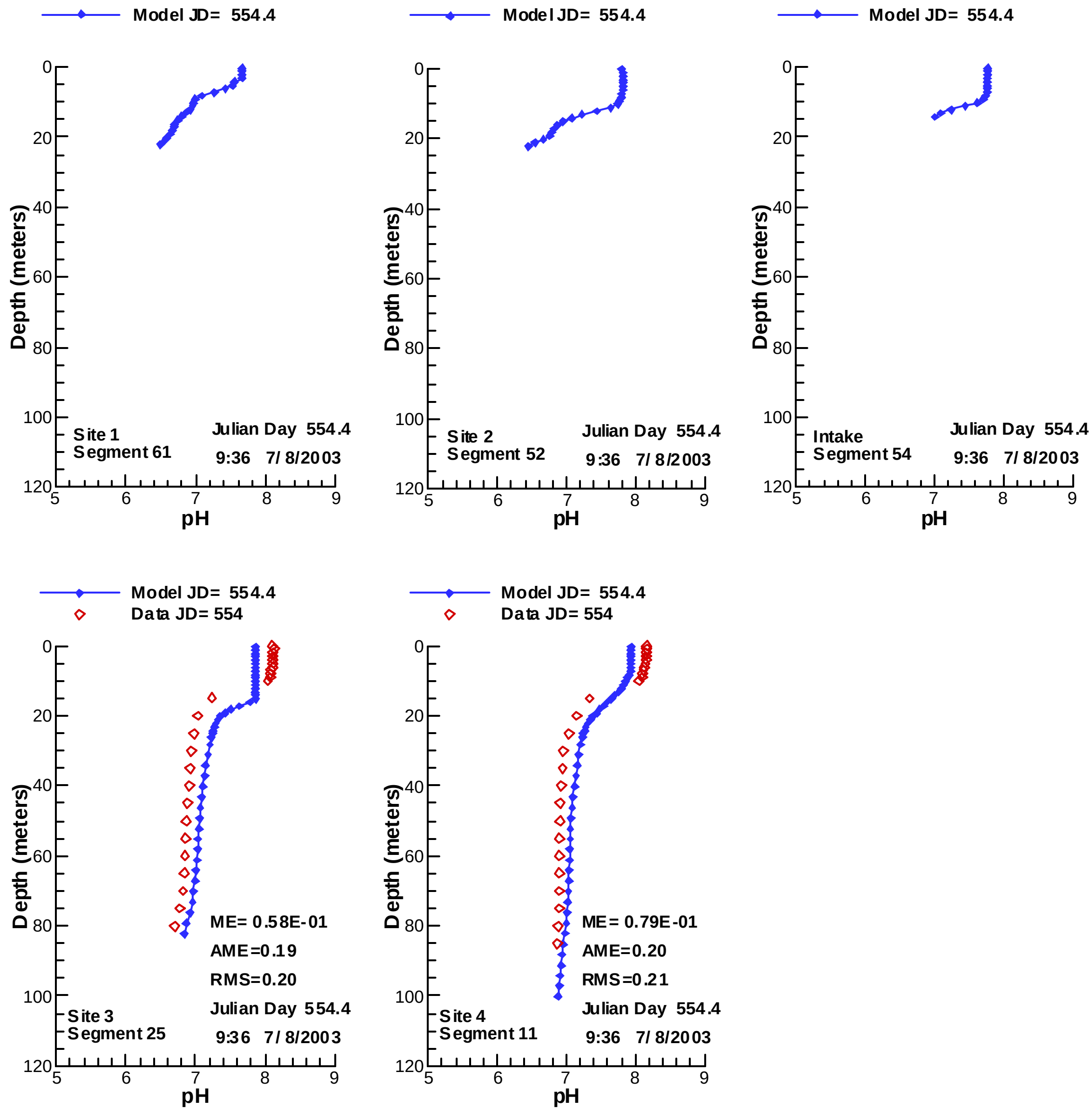

Figure 601. Vertical profiles of pH compared with data for 7/ 8/2003.

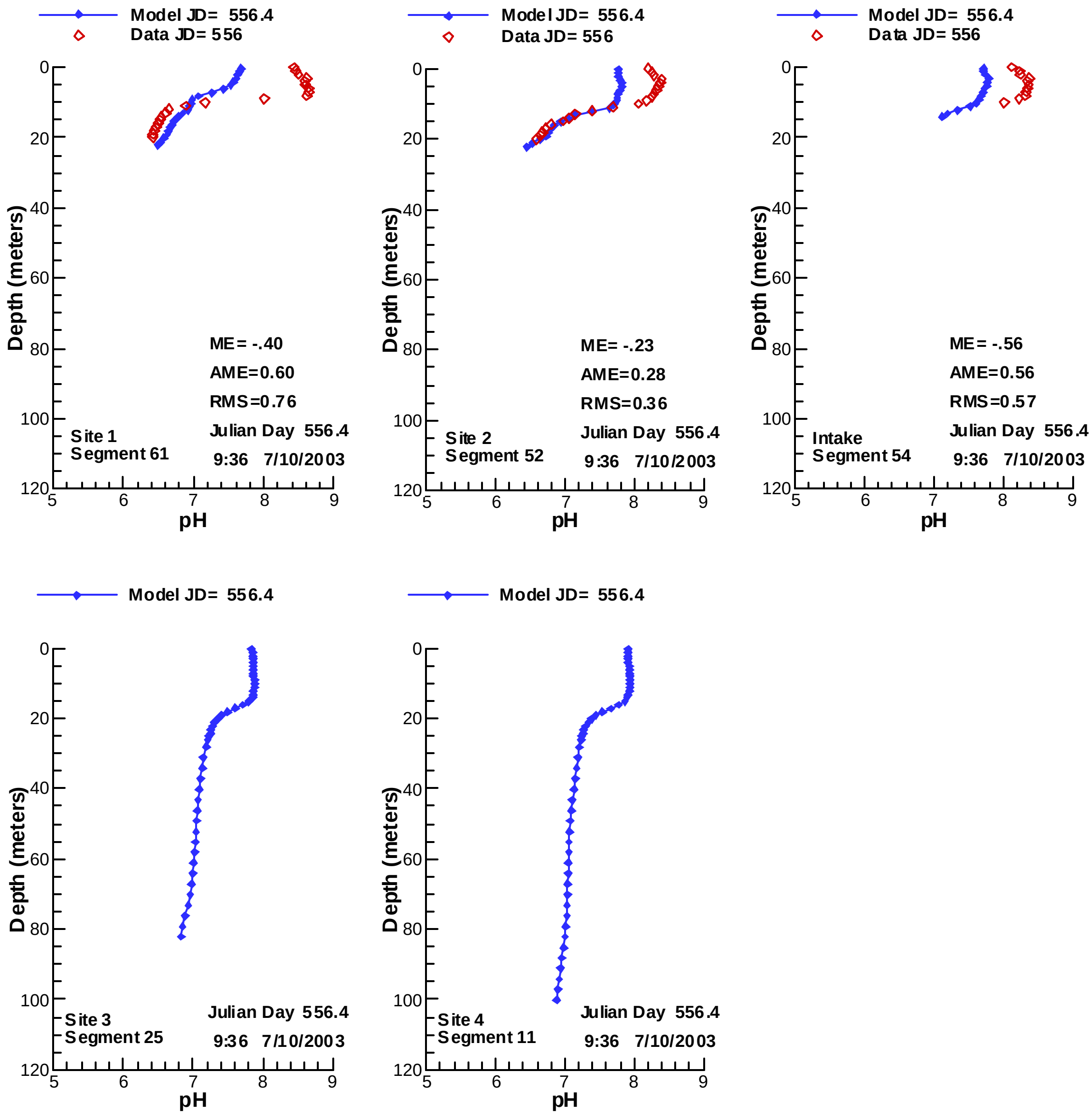

Figure 602. Vertical profiles of pH compared with data for 7/10/2003.

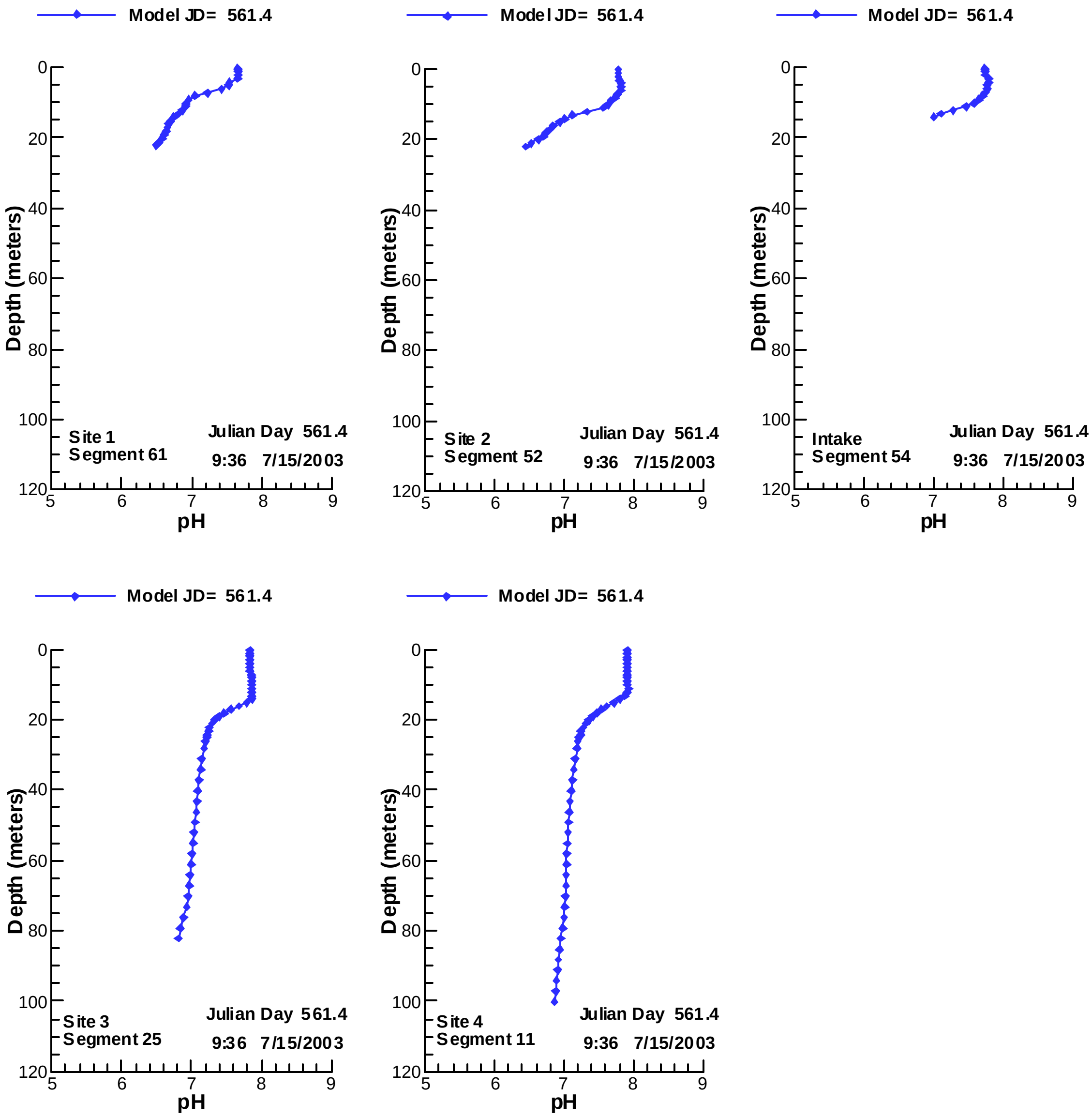

Figure 603. Vertical profiles of pH compared with data for 7/15/2003.

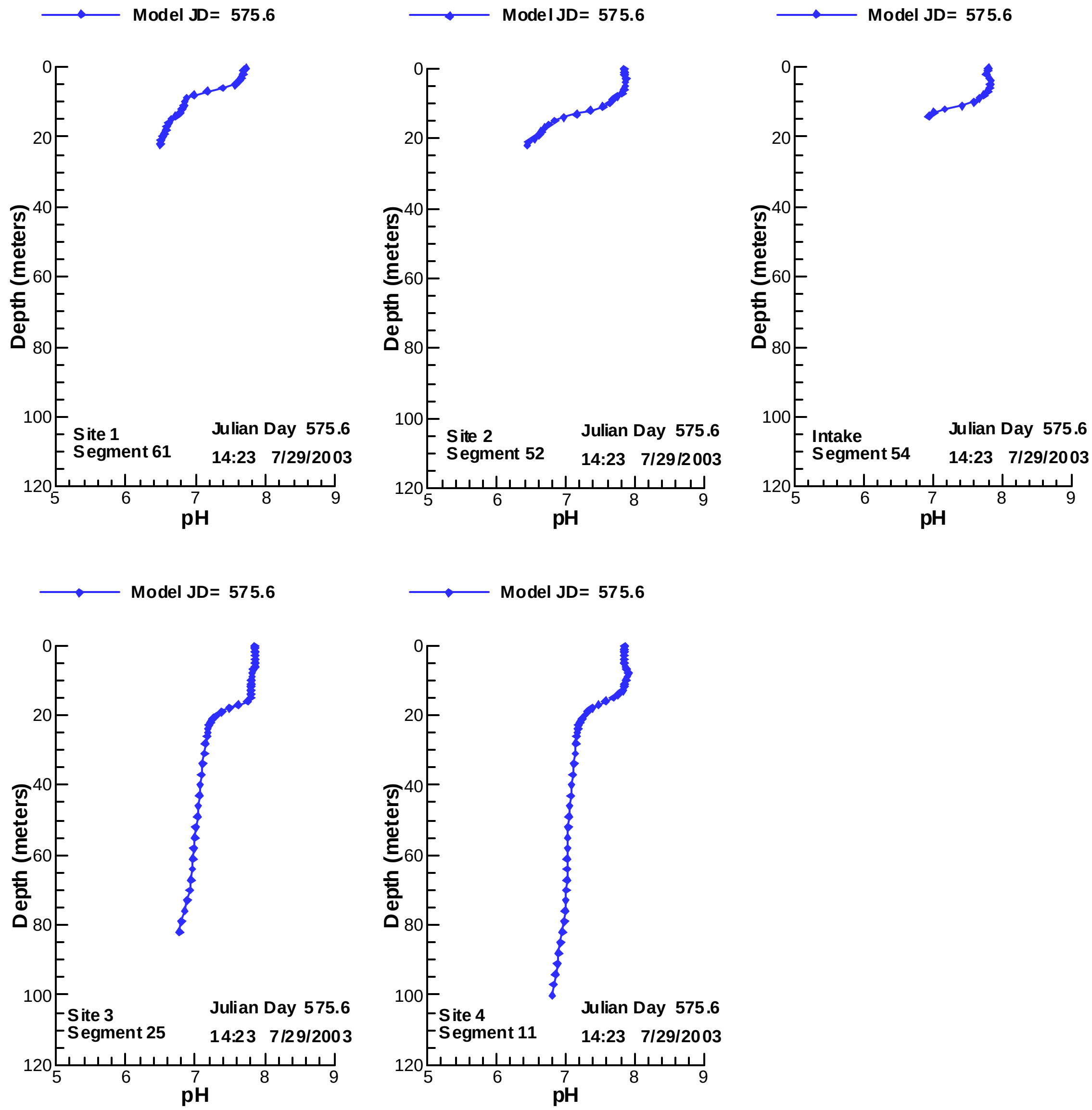

Figure 604. Vertical profiles of pH compared with data for 7/29/2003.

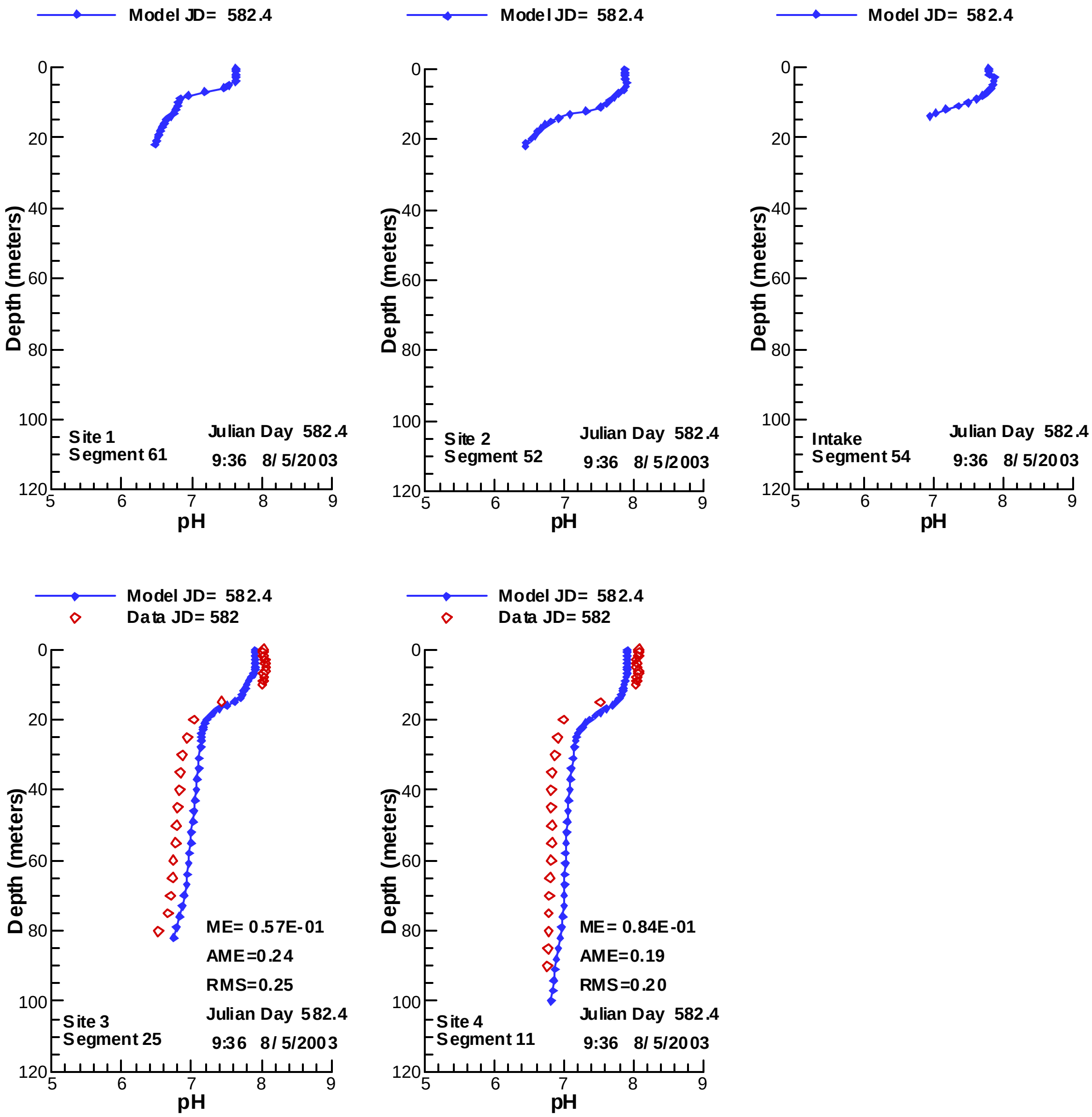

Figure 605. Vertical profiles of pH compared with data for 8/ 5/2003.

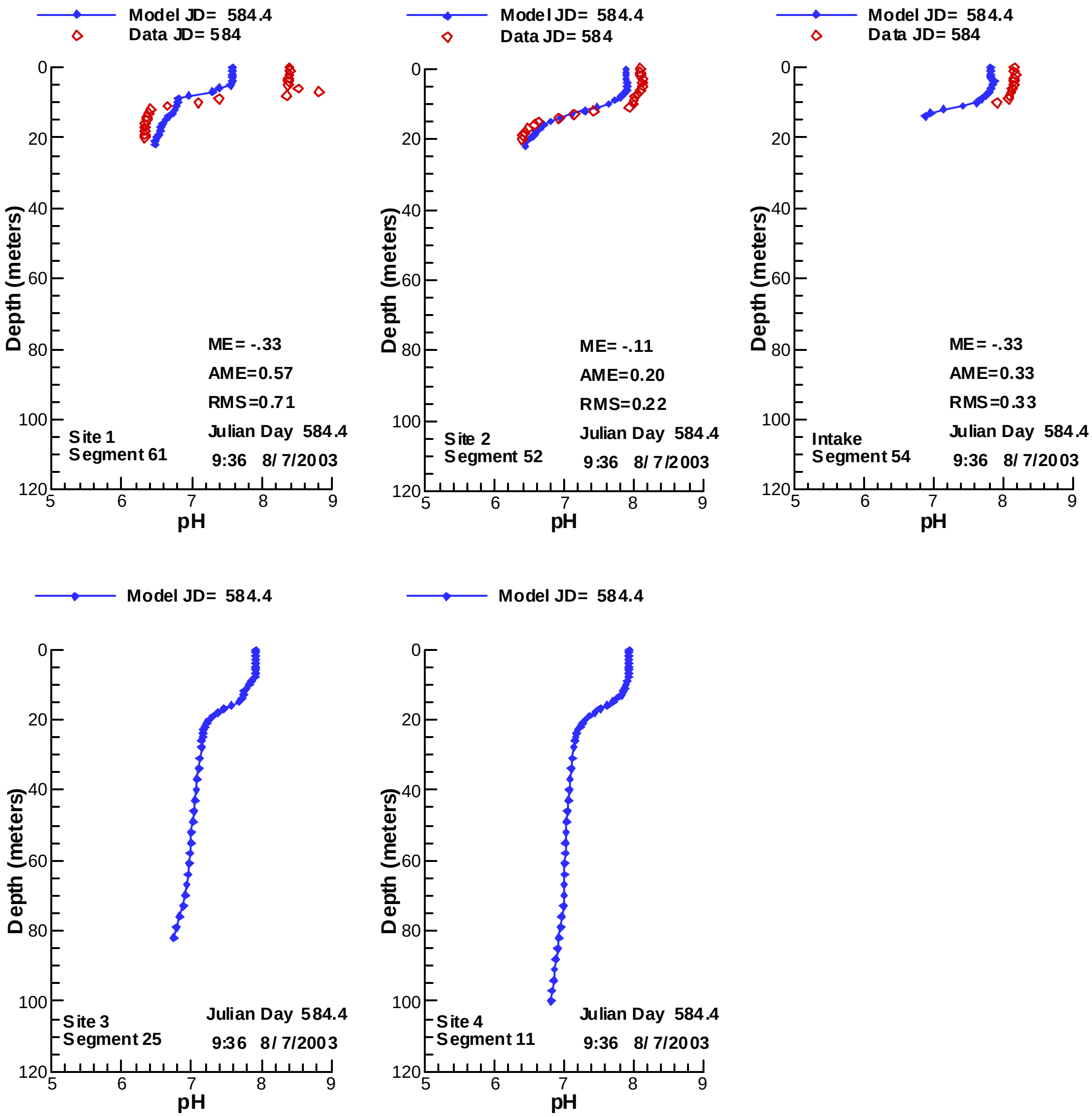

Figure 606. Vertical profiles of pH compared with data for 8/ 7/2003.

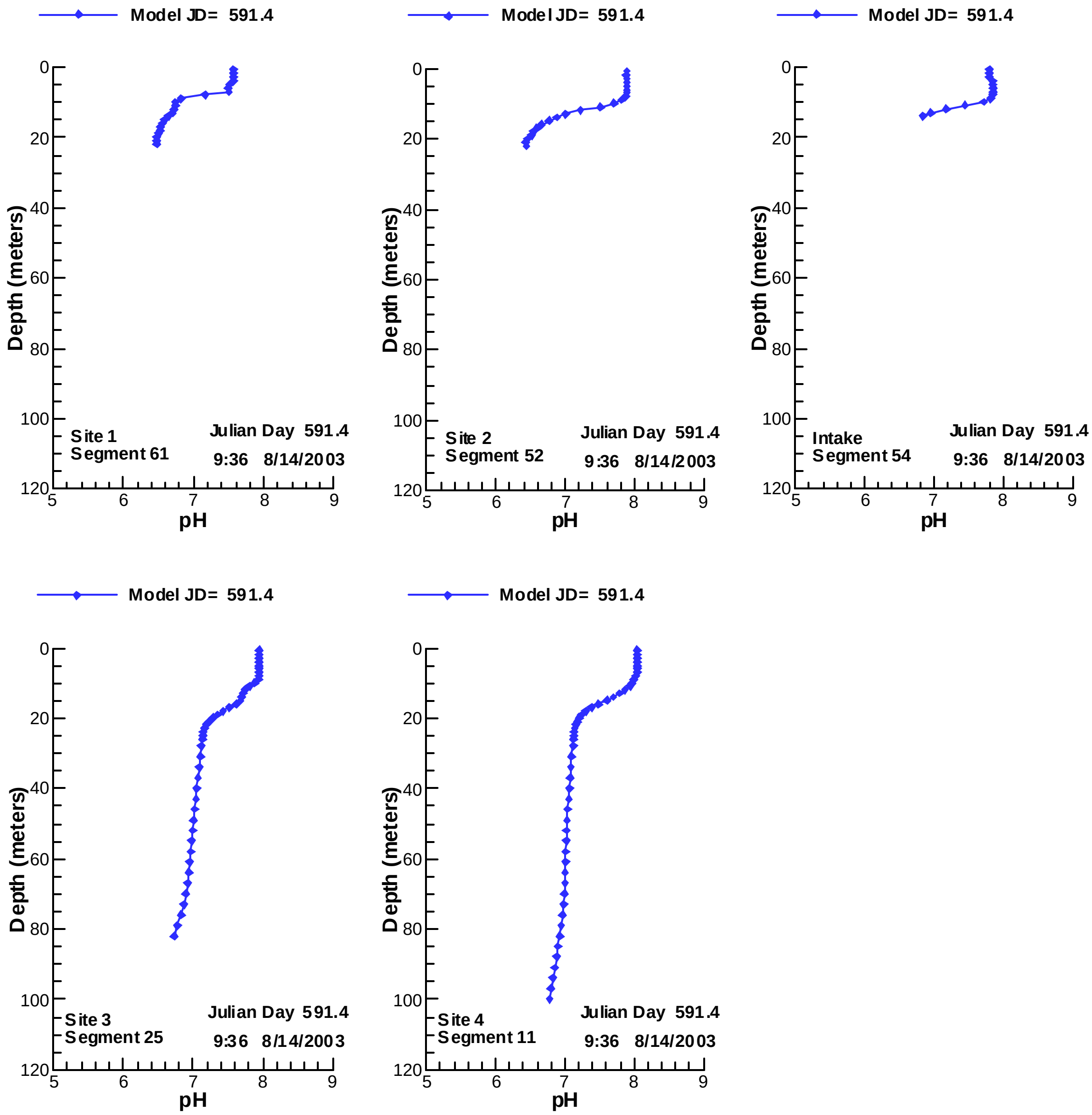

Figure 607. Vertical profiles of pH compared with data for 8/14/2003.

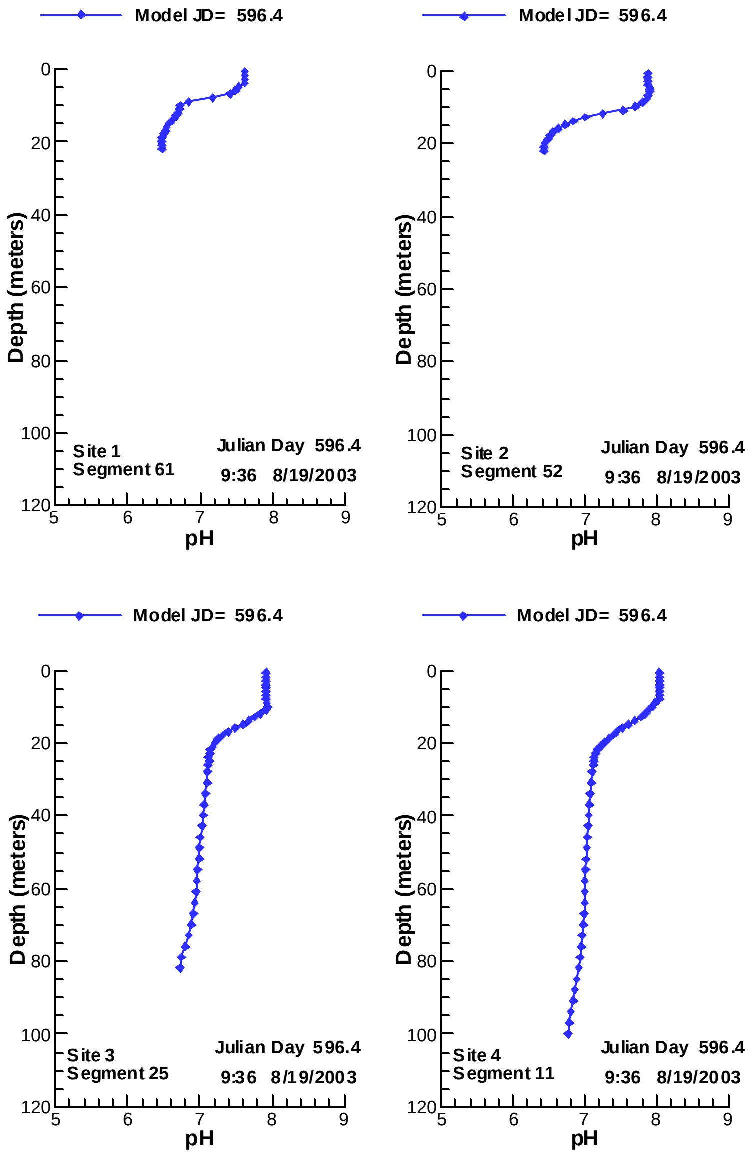

Figure 608. Vertical profiles of pH compared with data for 8/19/2003.

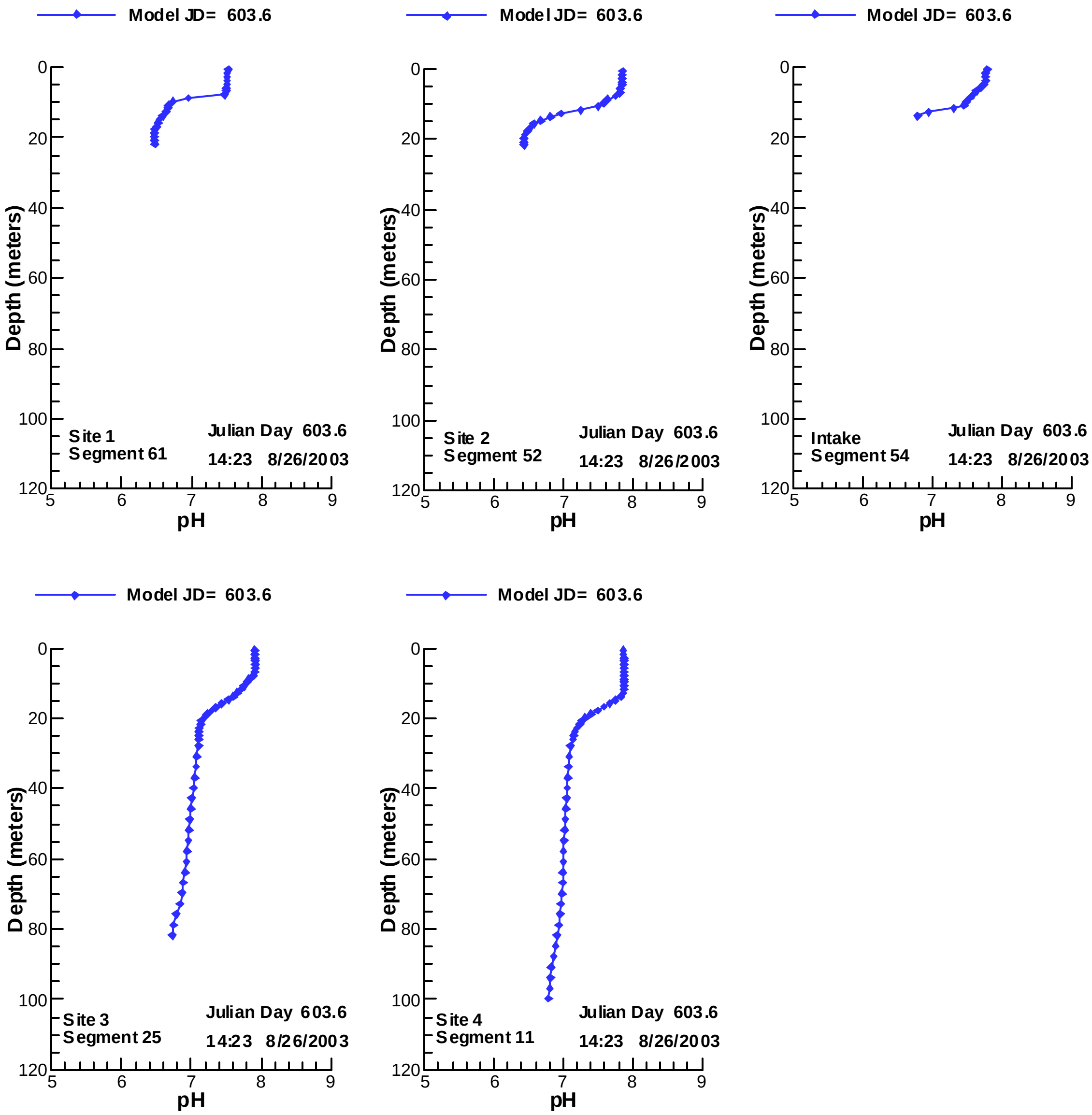

Figure 609. Vertical profiles of pH compared with data for 8/26/2003.

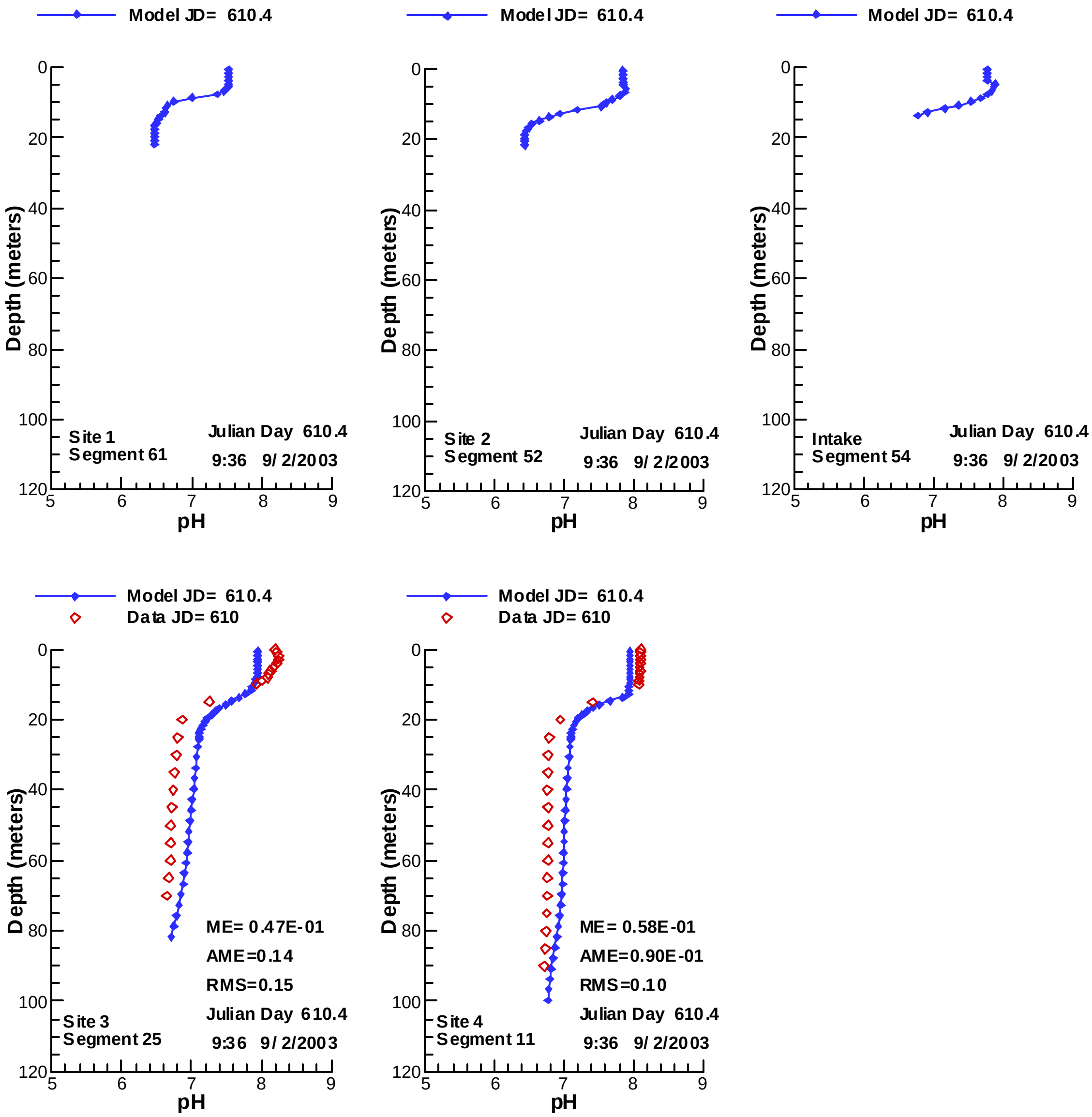

Figure 610. Vertical profiles of pH compared with data for 9/ 2/2003.

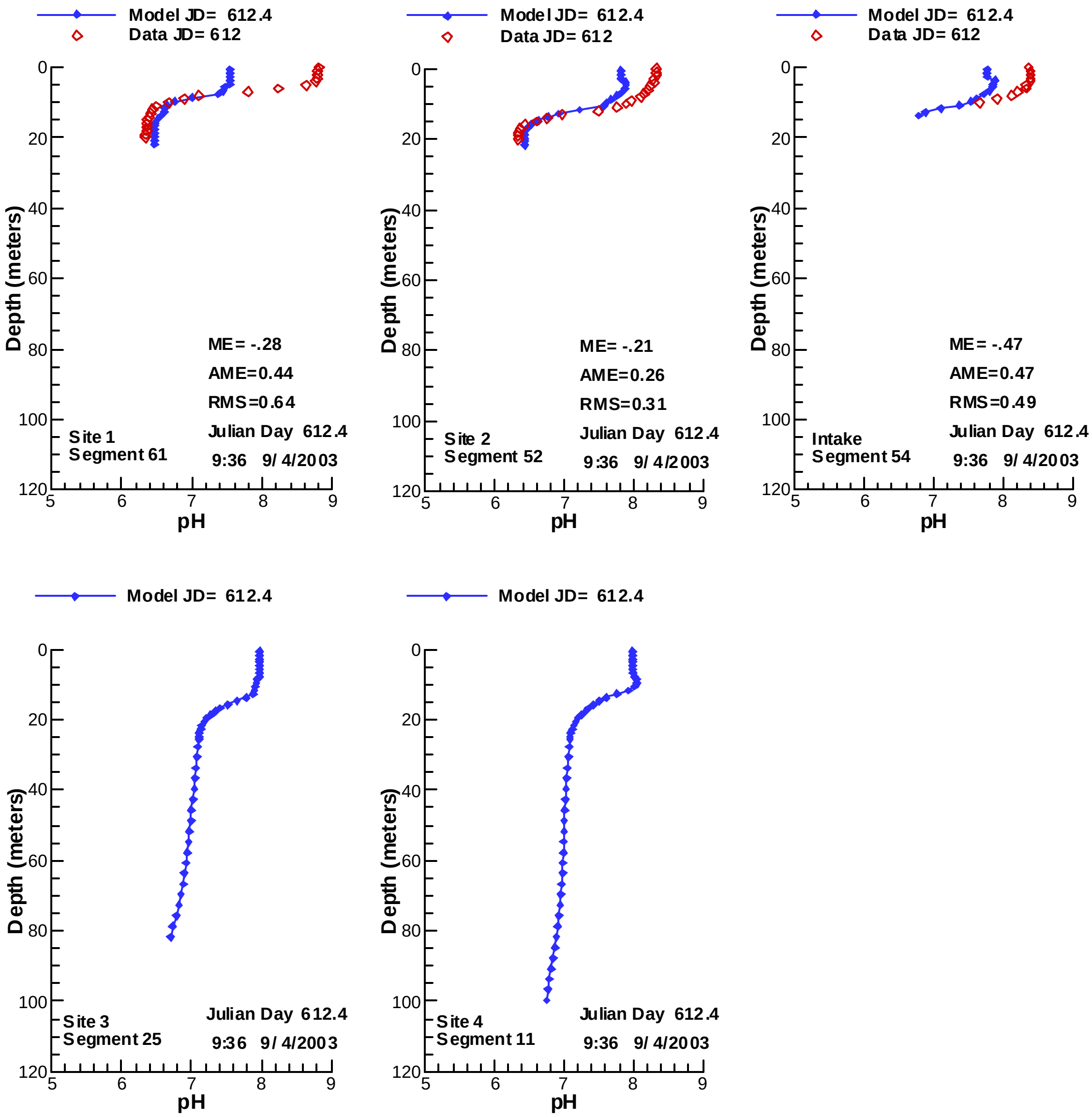

Figure 611. Vertical profiles of pH compared with data for 9/ 4/2003.

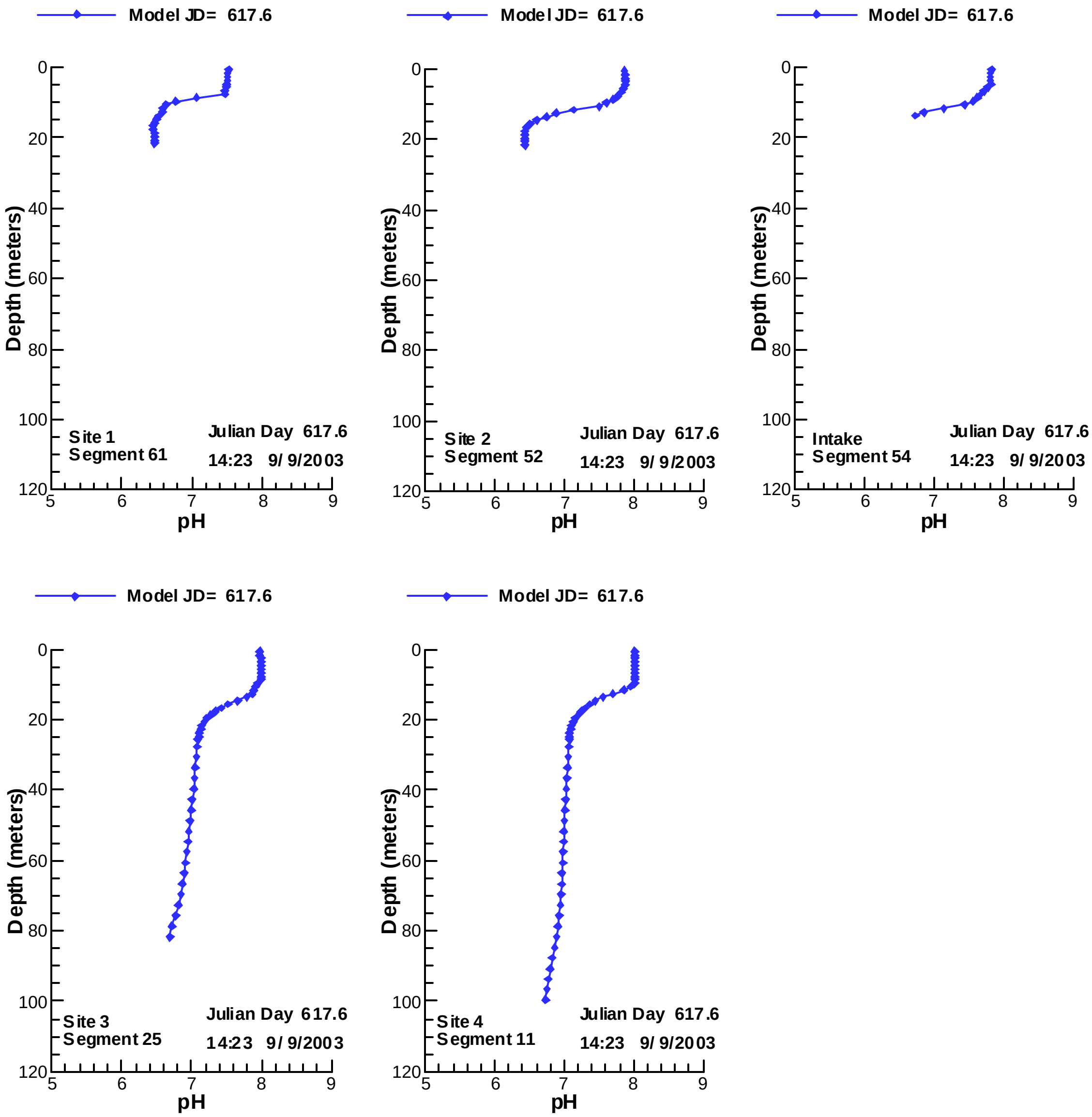

Figure 612. Vertical profiles of pH compared with data for 9/ 9/2003.

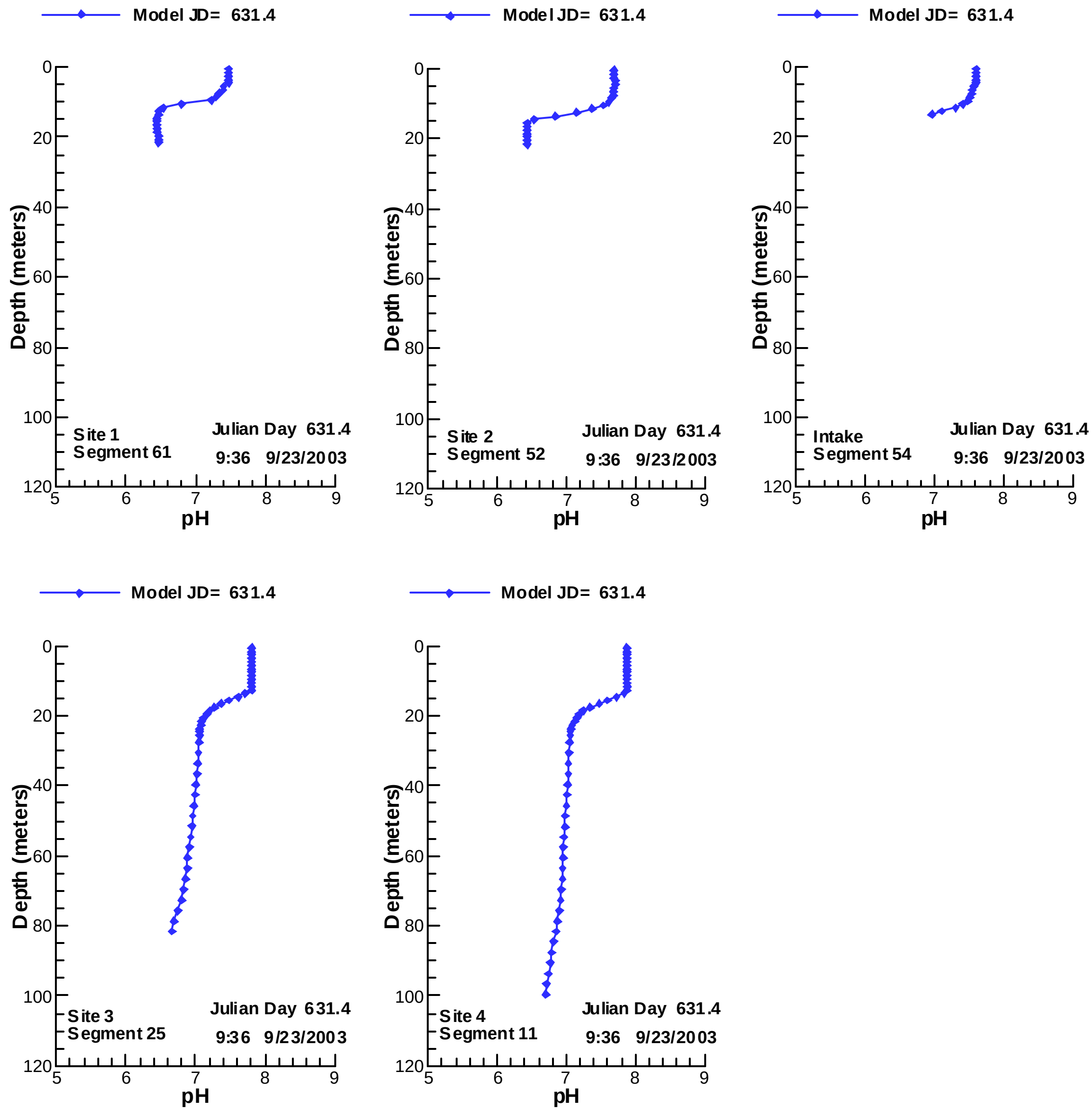

Figure 613. Vertical profiles of pH compared with data for 9/23/2003.

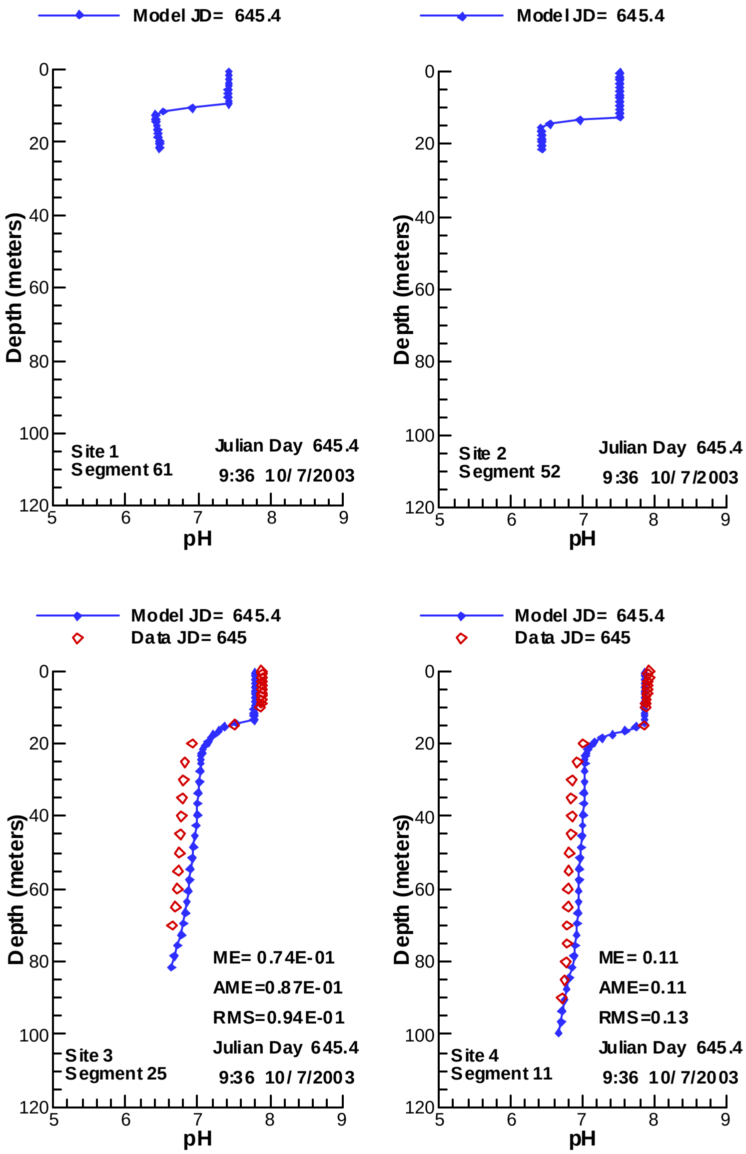

Figure 614. Vertical profiles of pH compared with data for 10/ 7/2003.

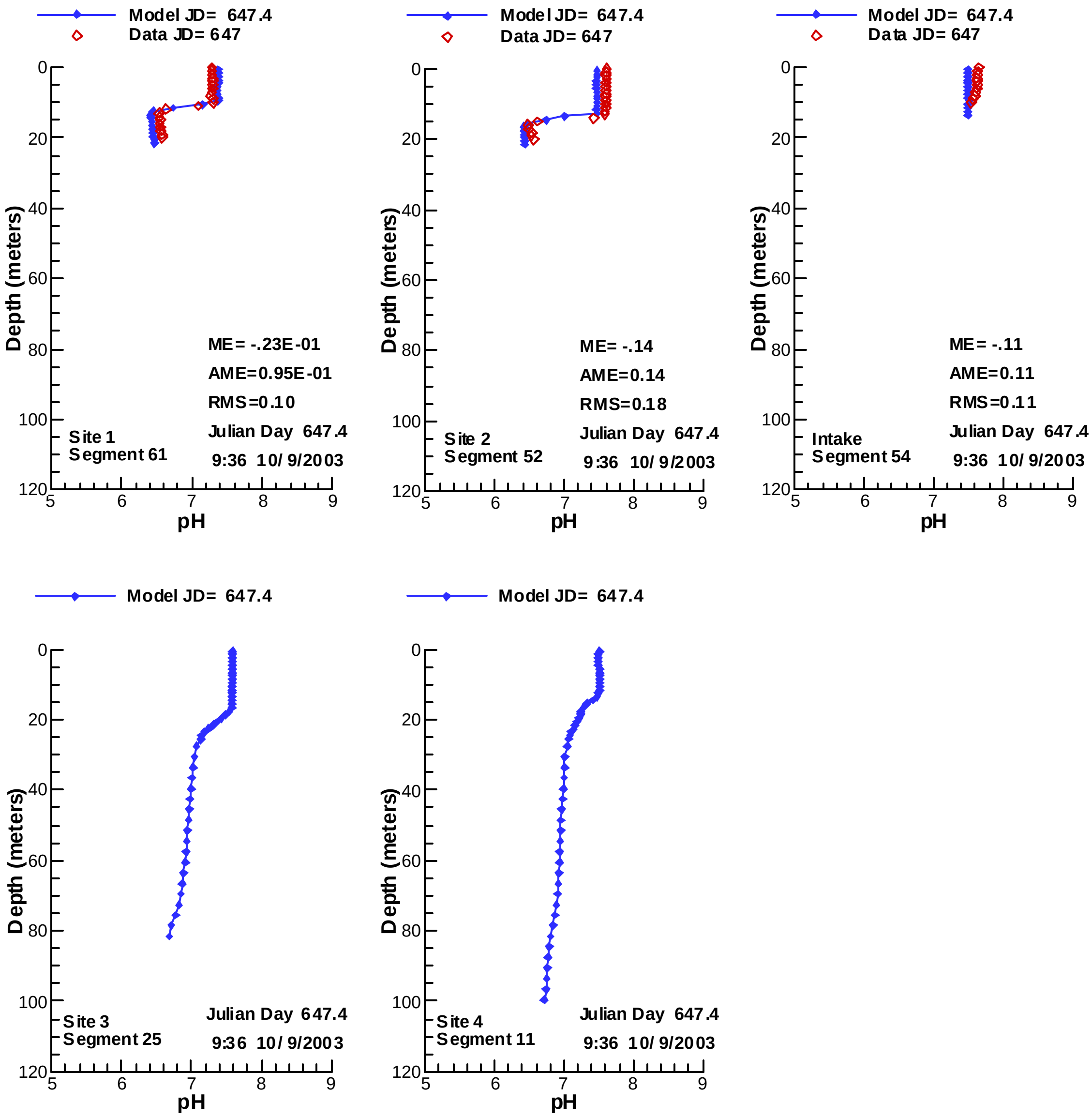

Figure 615. Vertical profiles of pH compared with data for 10/ 9/2003.

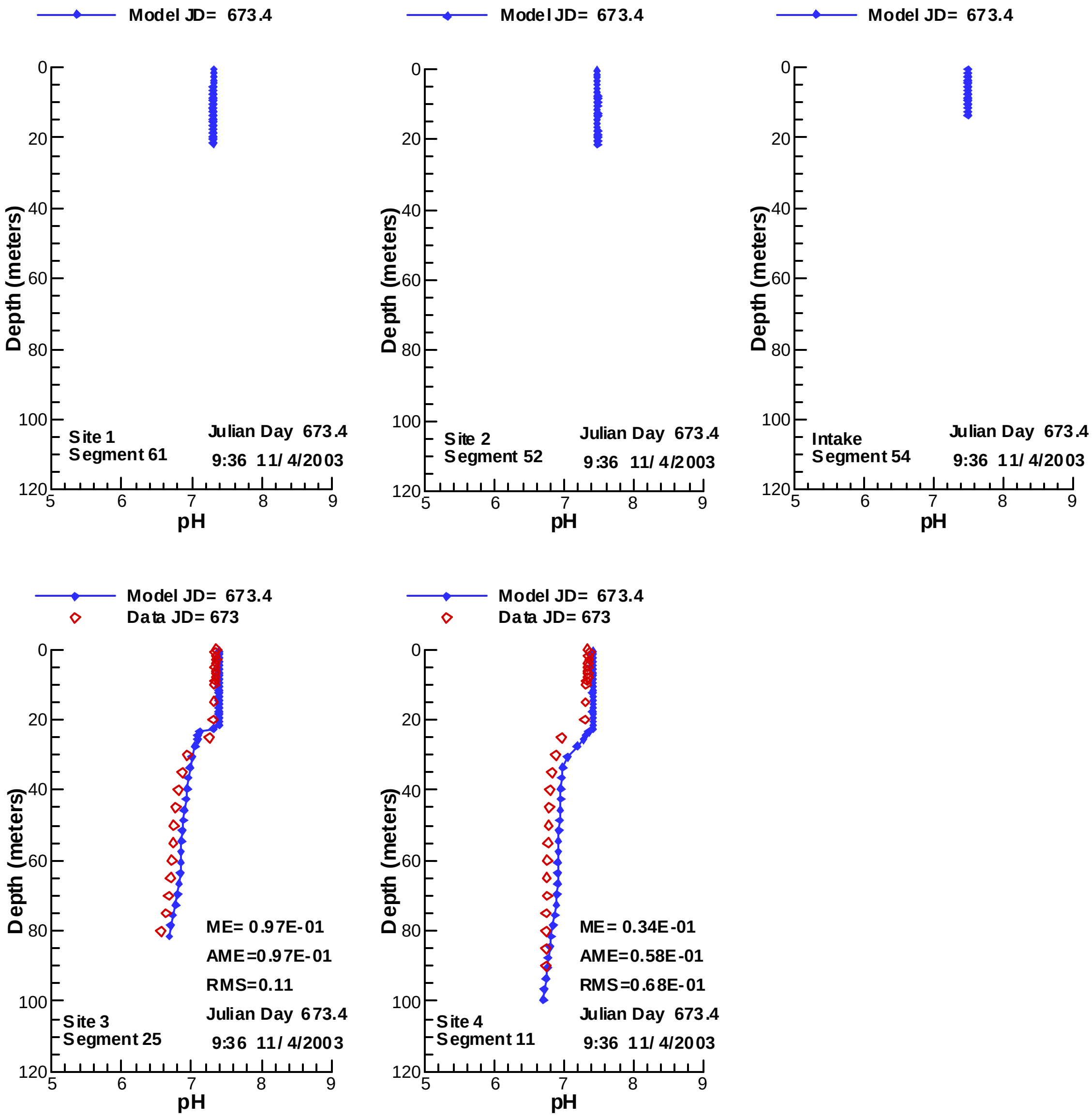

Figure 616. Vertical profiles of pH compared with data for 11/ 4/2003.

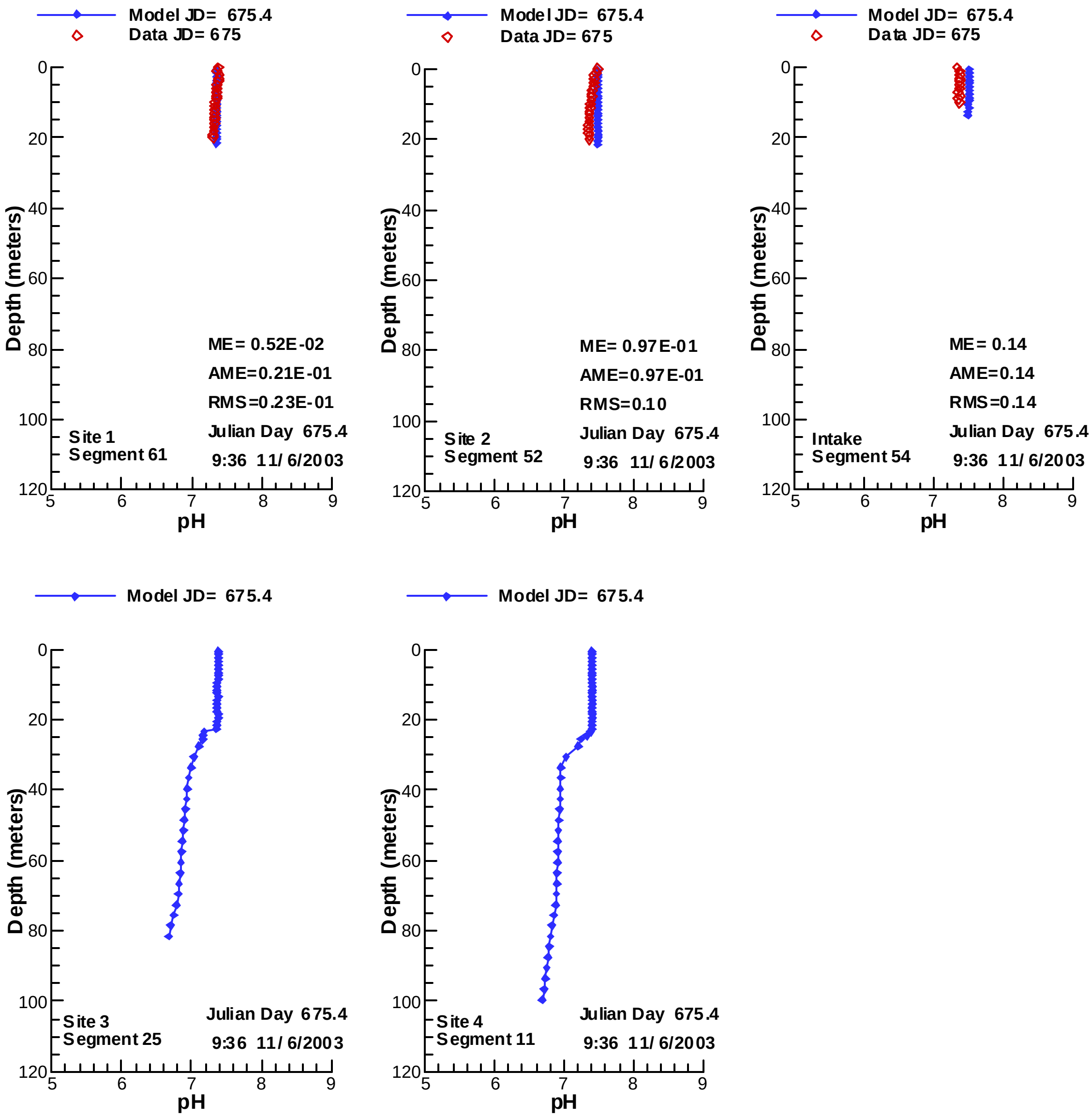

Figure 617. Vertical profiles of pH compared with data for 11/ 6/2003.

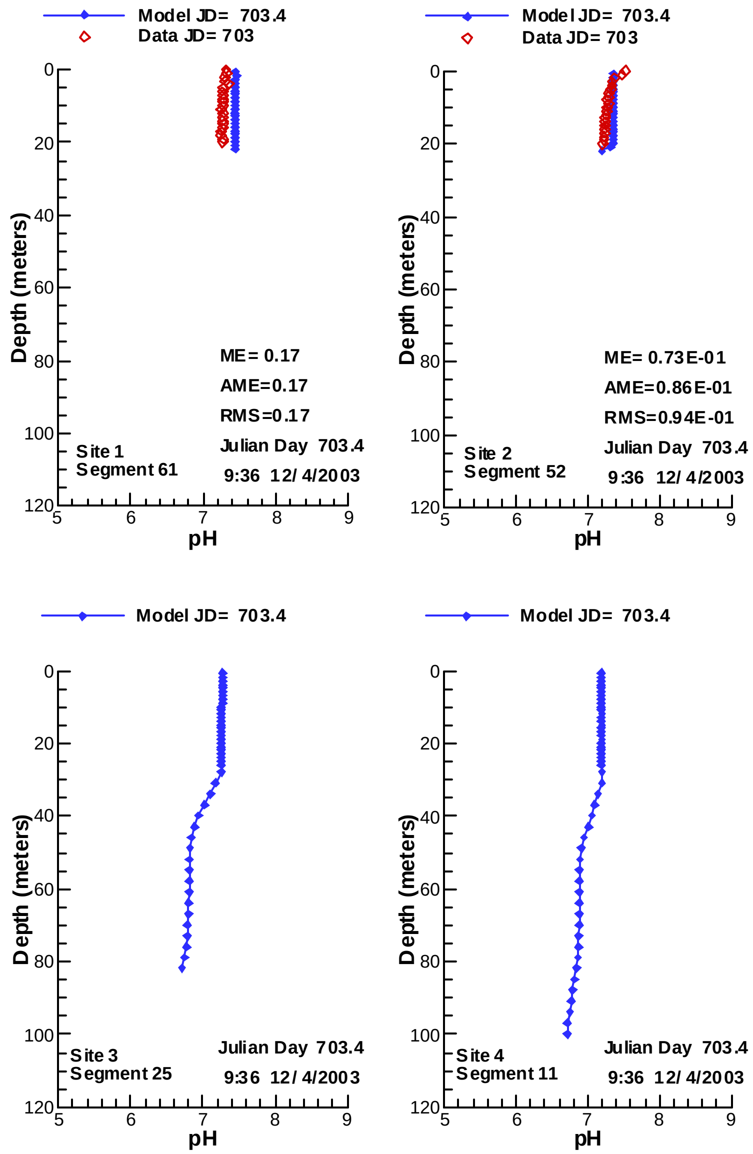

Figure 618. Vertical profiles of pH compared with data for 12/ 4/2003.

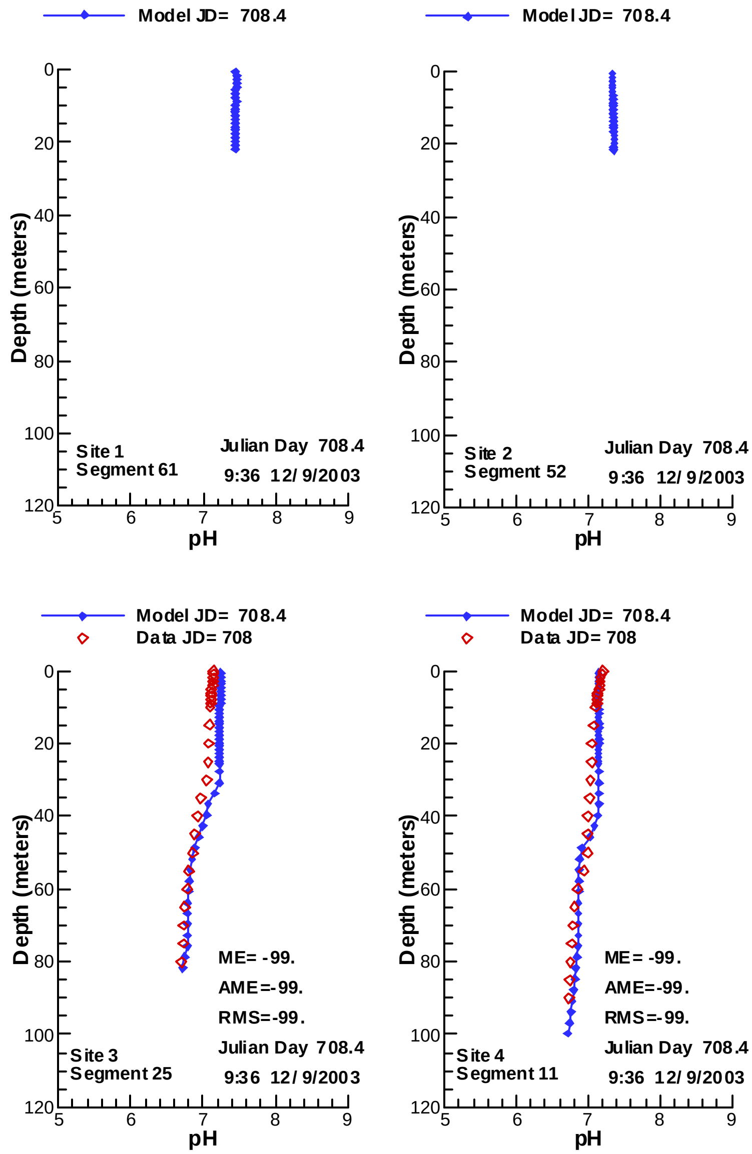

Figure 619. Vertical profiles of pH compared with data for 12/ 9/2003.

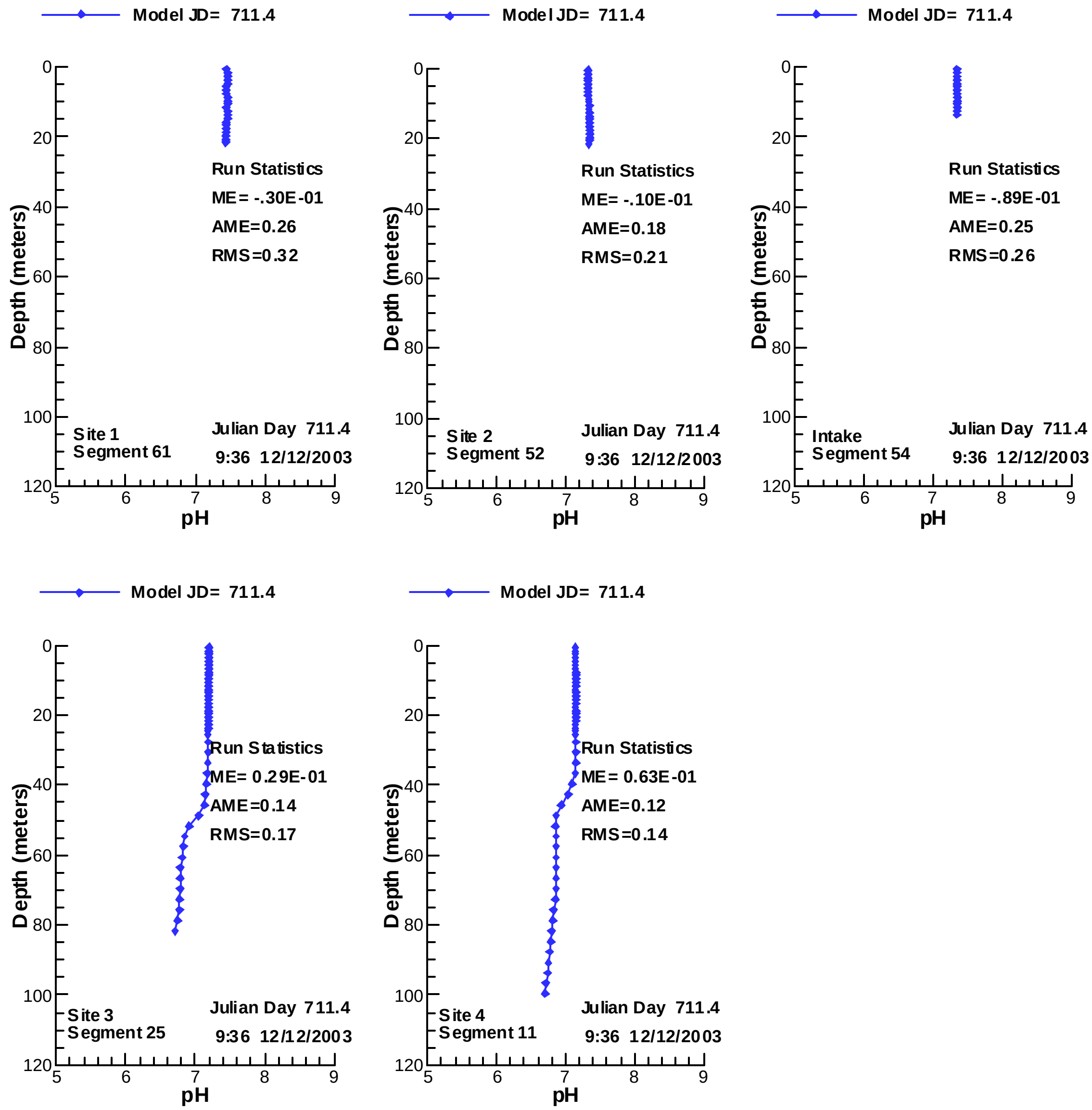

Figure 620. Vertical profiles of pH compared with data for 12/12/2003.

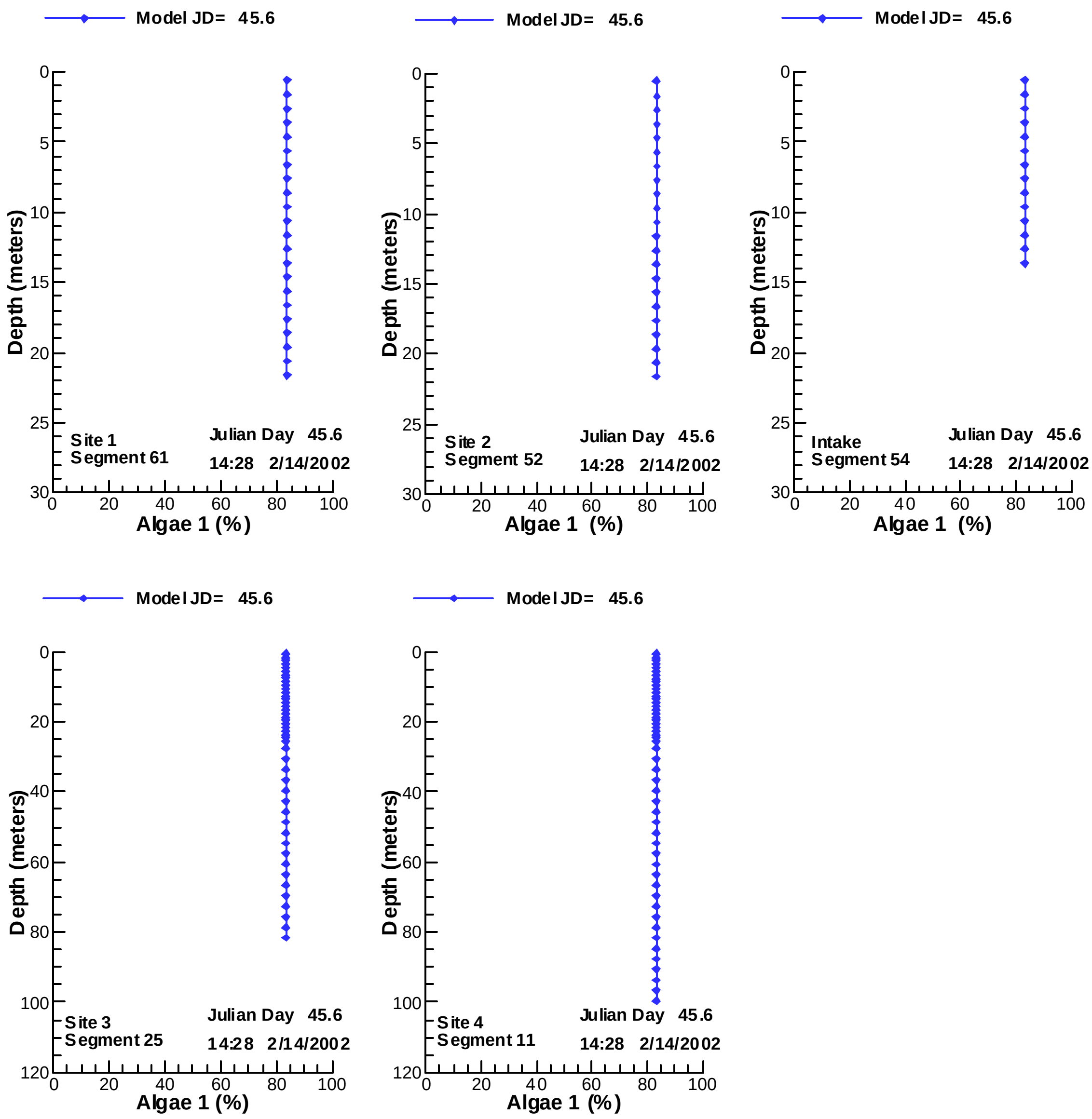

Figure 621. Vertical profiles of ALGAE 1 compared with data for 2/14/2002.

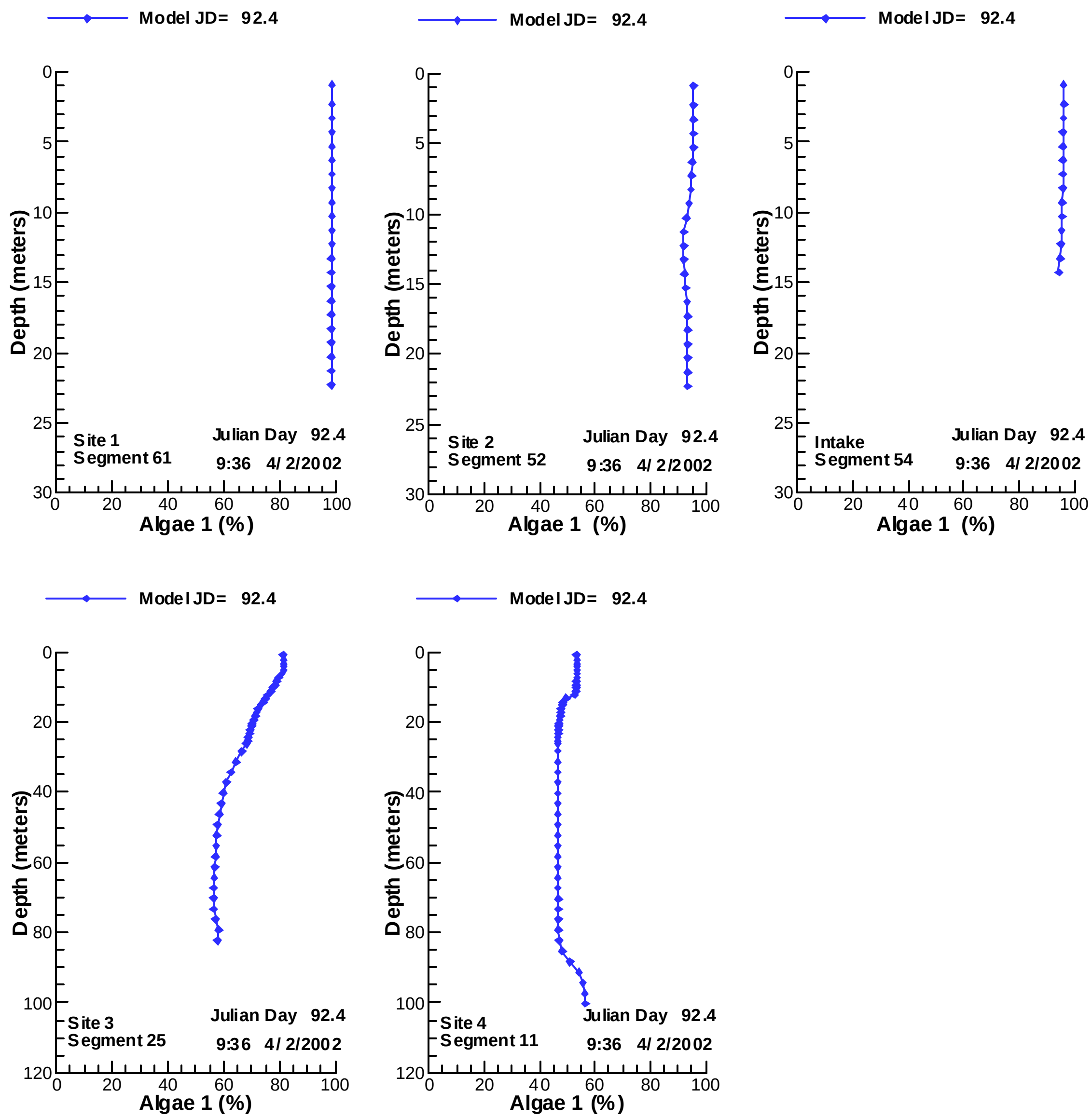

Figure 622. Vertical profiles of ALGAE 1 compared with data for 4/ 2/2002.

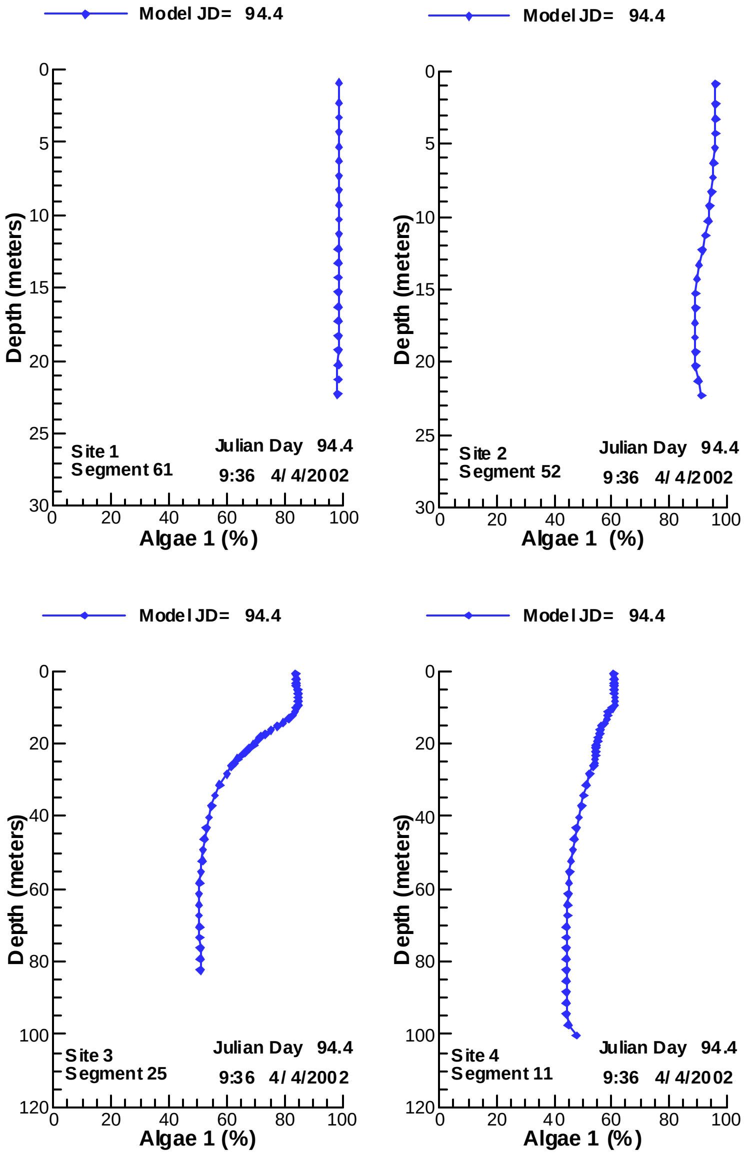

Figure 623. Vertical profiles of ALGAE 1 compared with data for 4/ 4/2002.

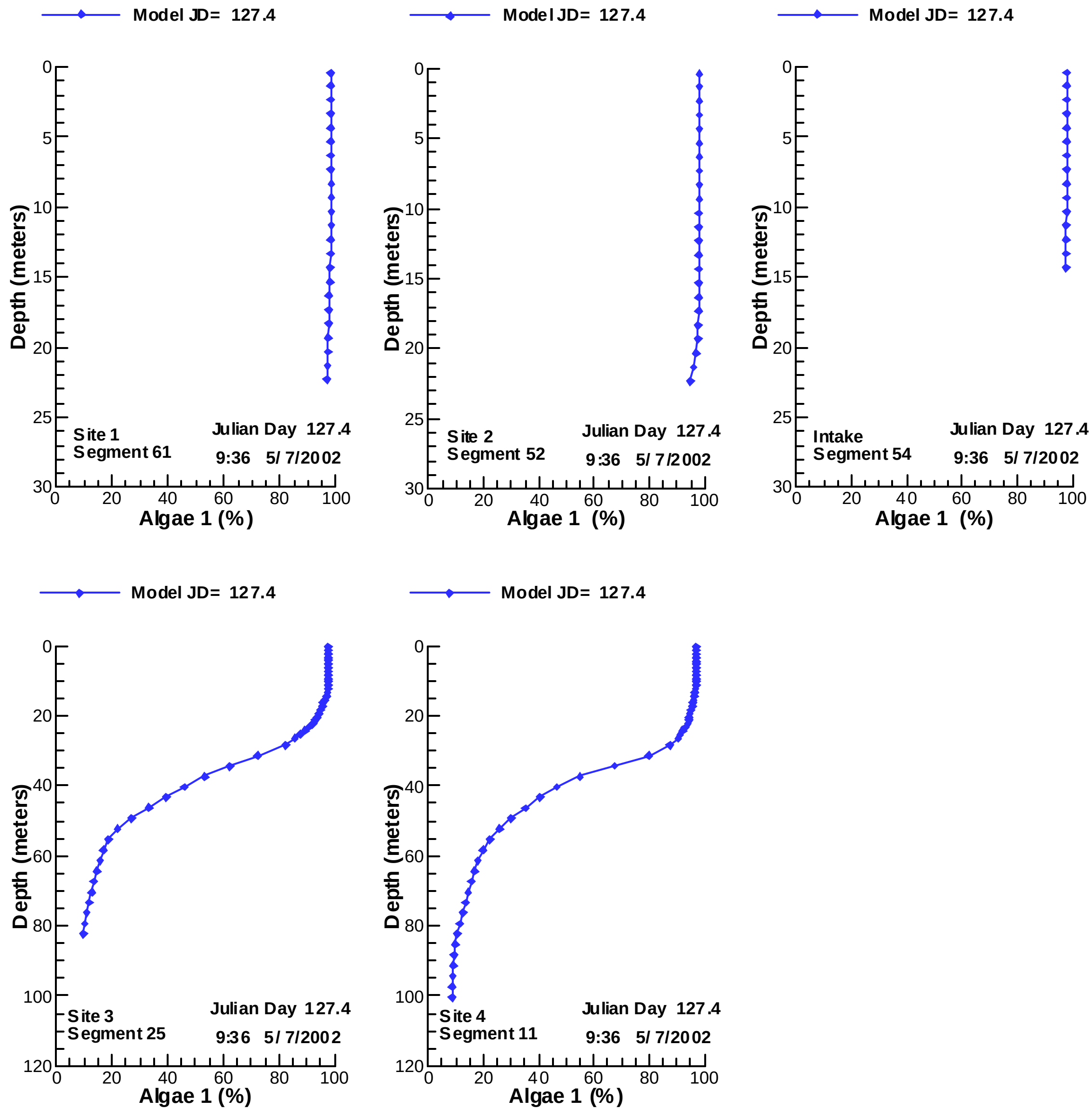

Figure 624. Vertical profiles of ALGAE 1 compared with data for 5/ 7/2002.

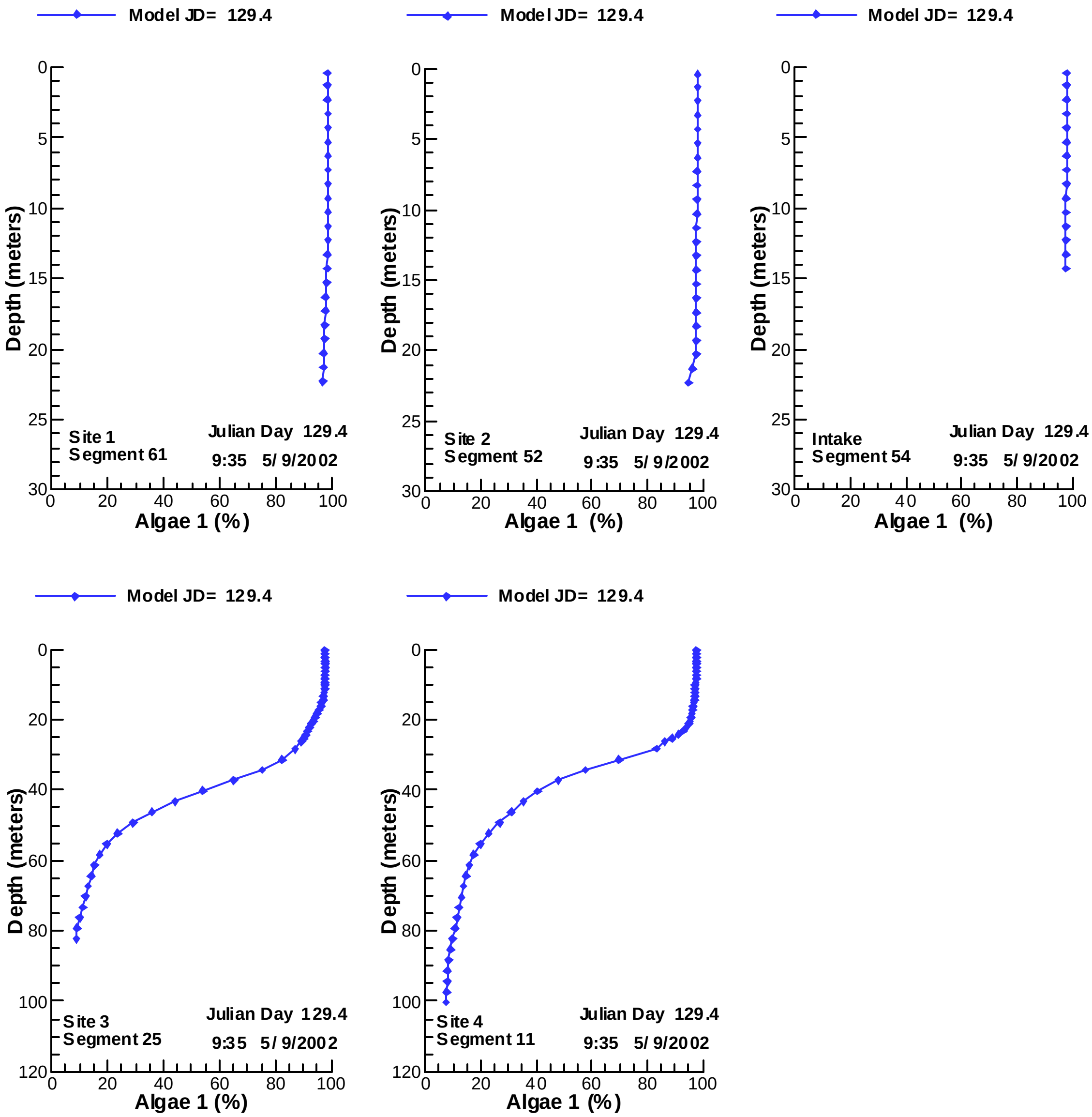

Figure 625. Vertical profiles of ALGAE 1 compared with data for 5/ 9/2002.

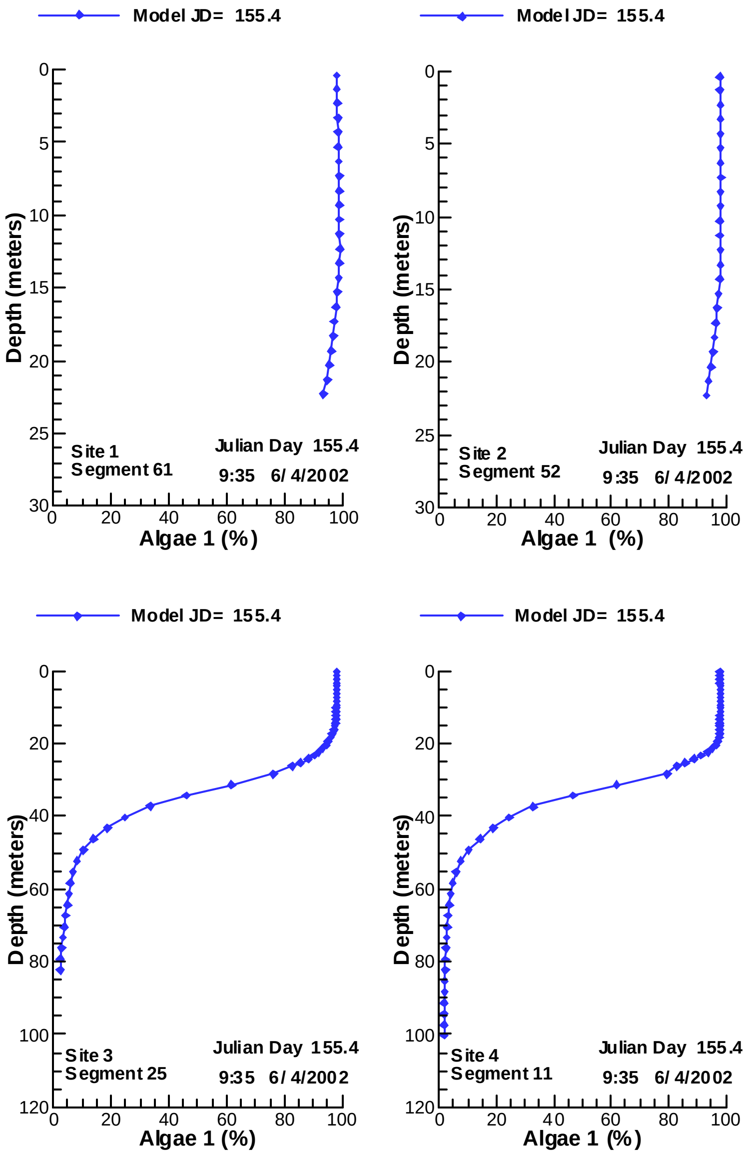

Figure 626. Vertical profiles of ALGAE 1 compared with data for 6/ 4/2002.

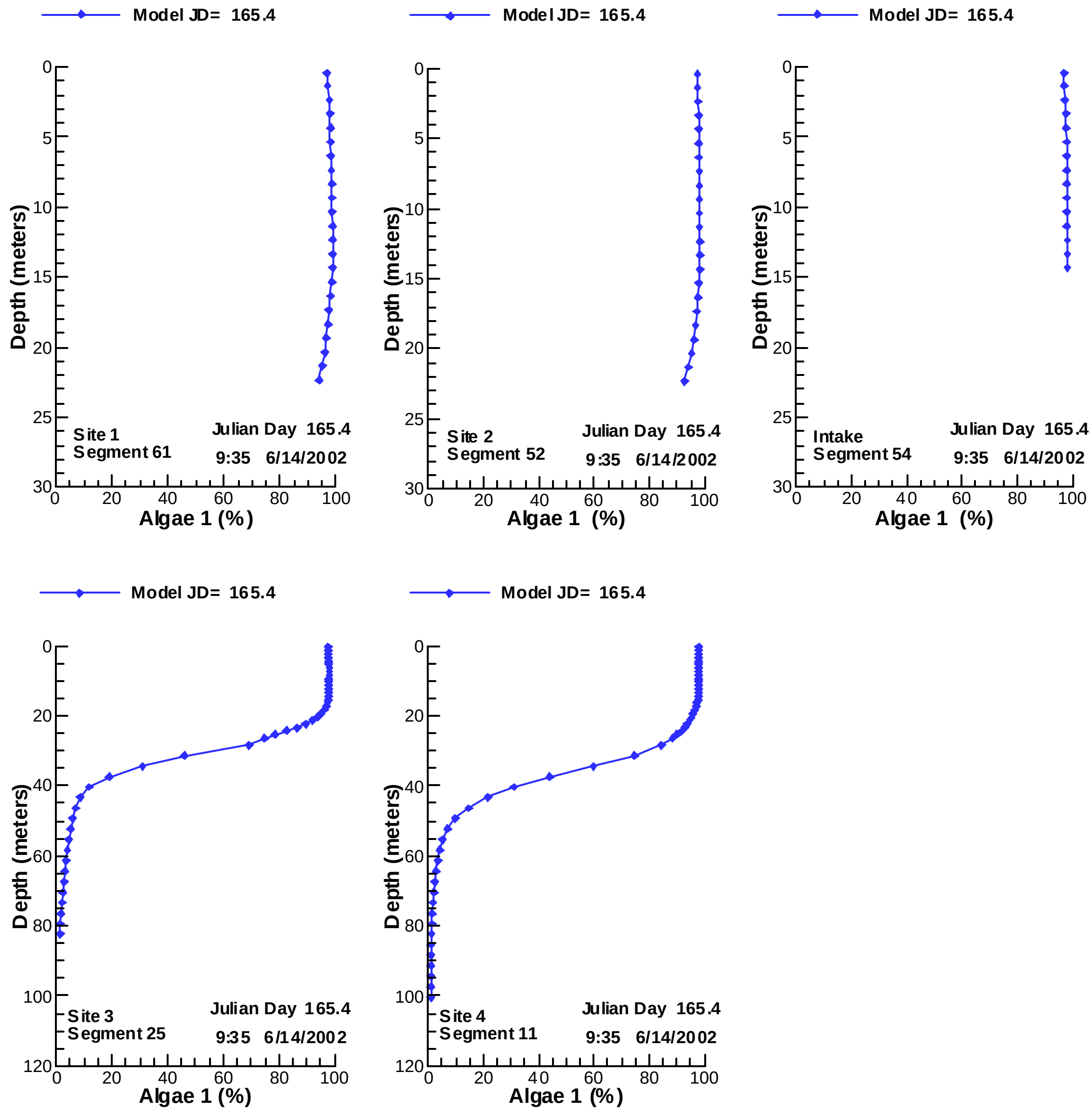

Figure 627. Vertical profiles of ALGAE 1 compared with data for 6/14/2002.

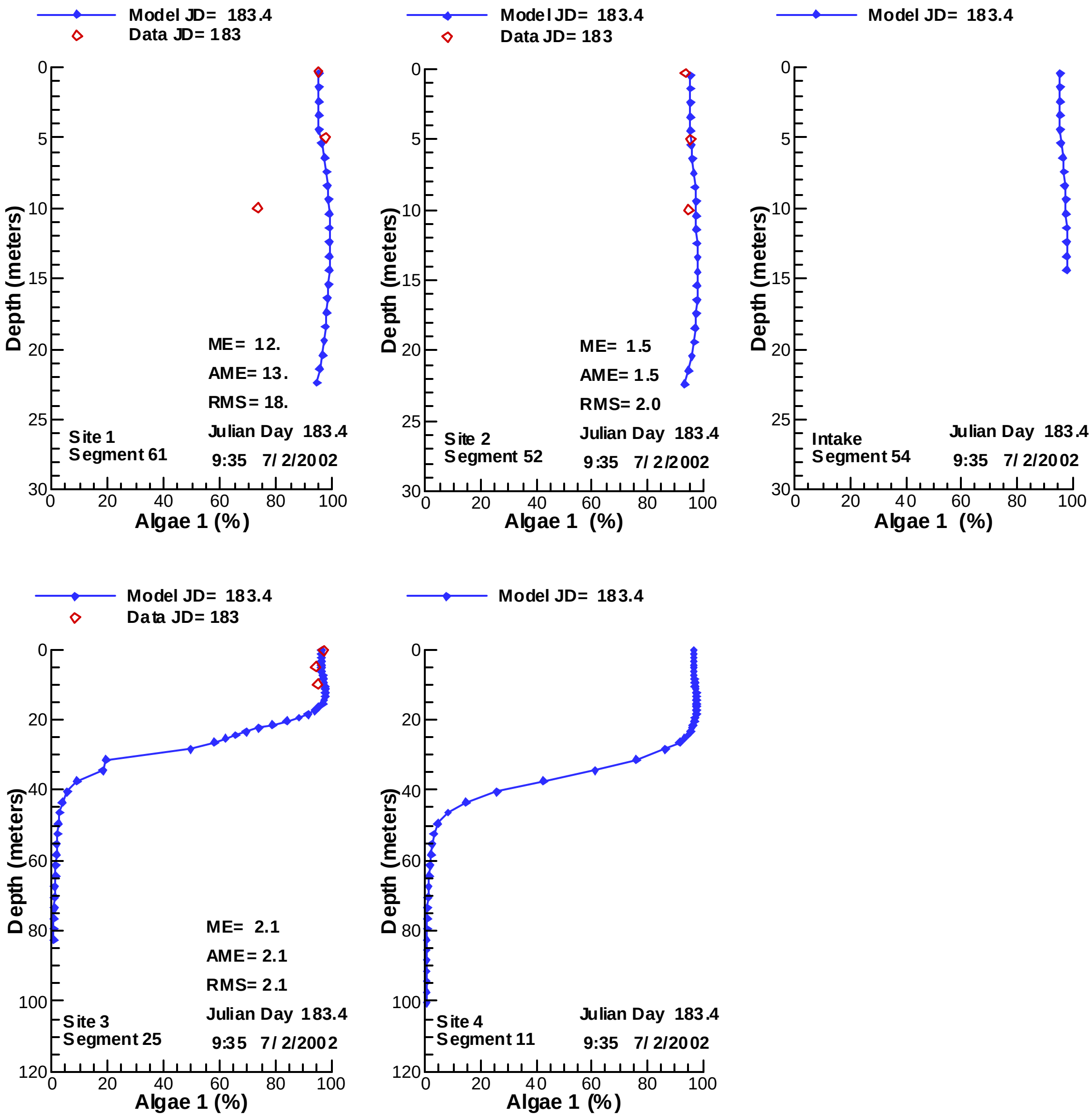

Figure 628. Vertical profiles of ALGAE 1 compared with data for 7/ 2/2002.

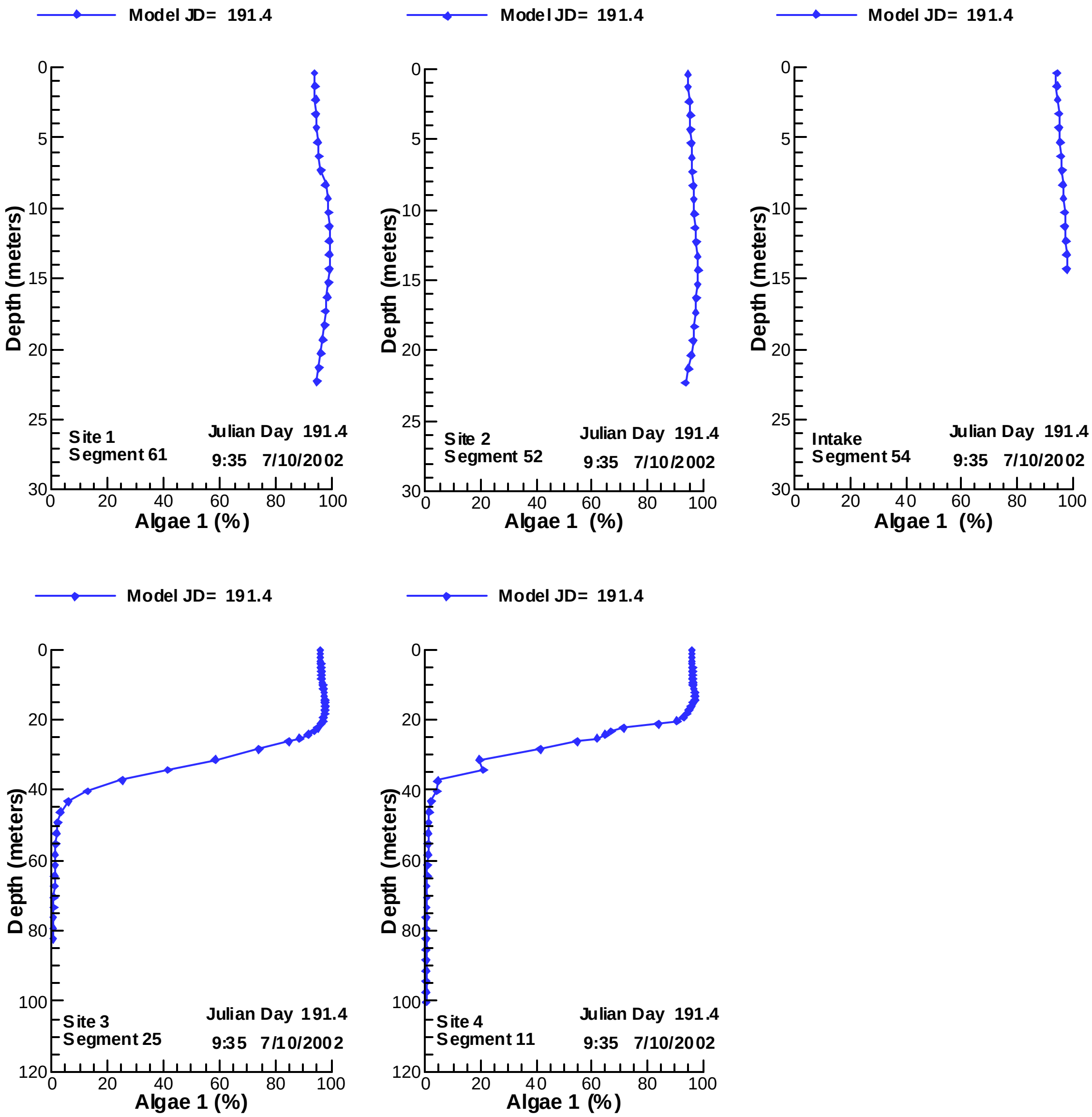

Figure 629. Vertical profiles of ALGAE 1 compared with data for 7/10/2002.

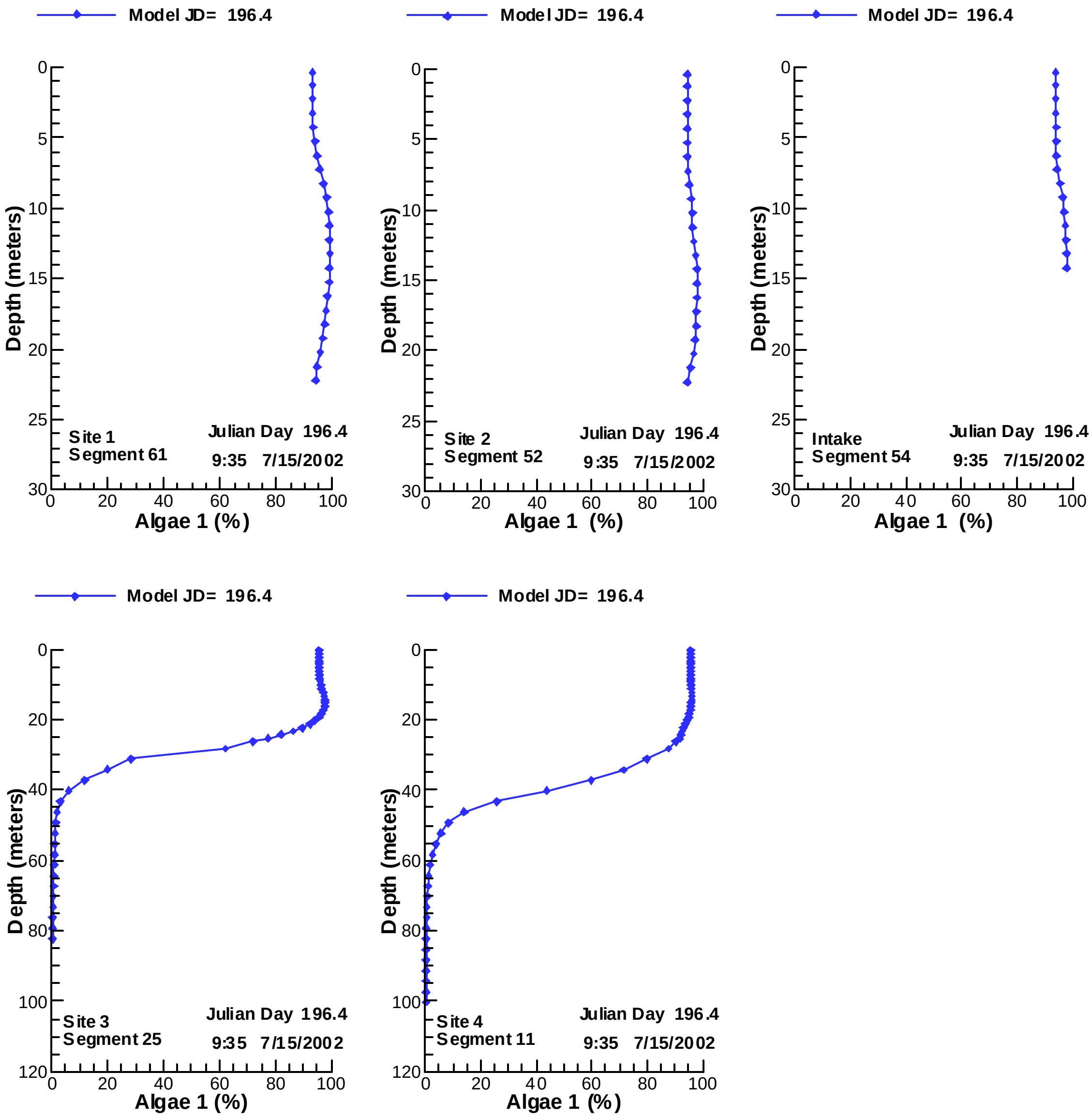

Figure 630. Vertical profiles of ALGAE 1 compared with data for 7/15/2002.

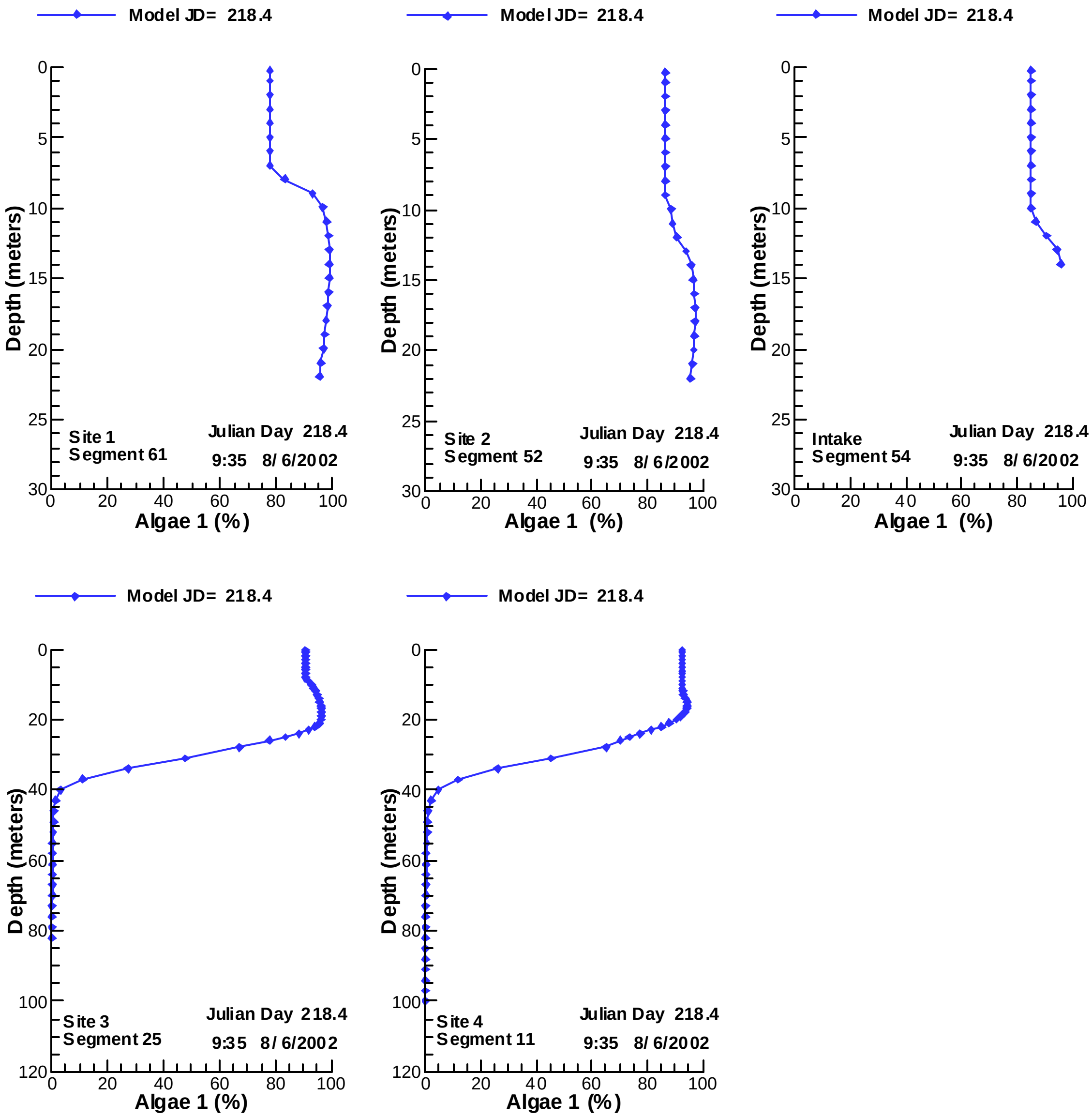

Figure 631. Vertical profiles of ALGAE 1 compared with data for 8/ 6/2002.

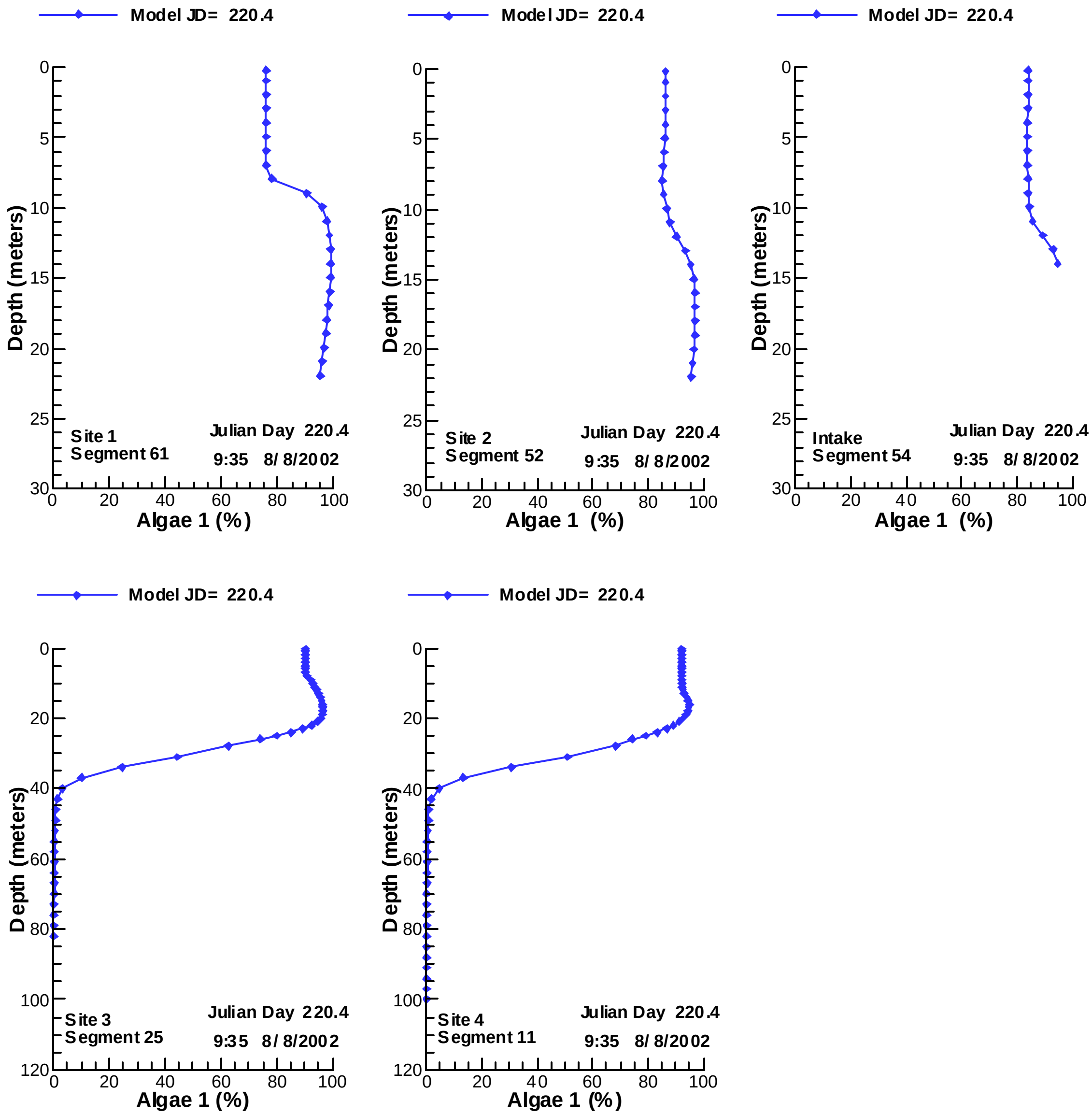

Figure 632. Vertical profiles of ALGAE 1 compared with data for 8/ 8/2002.

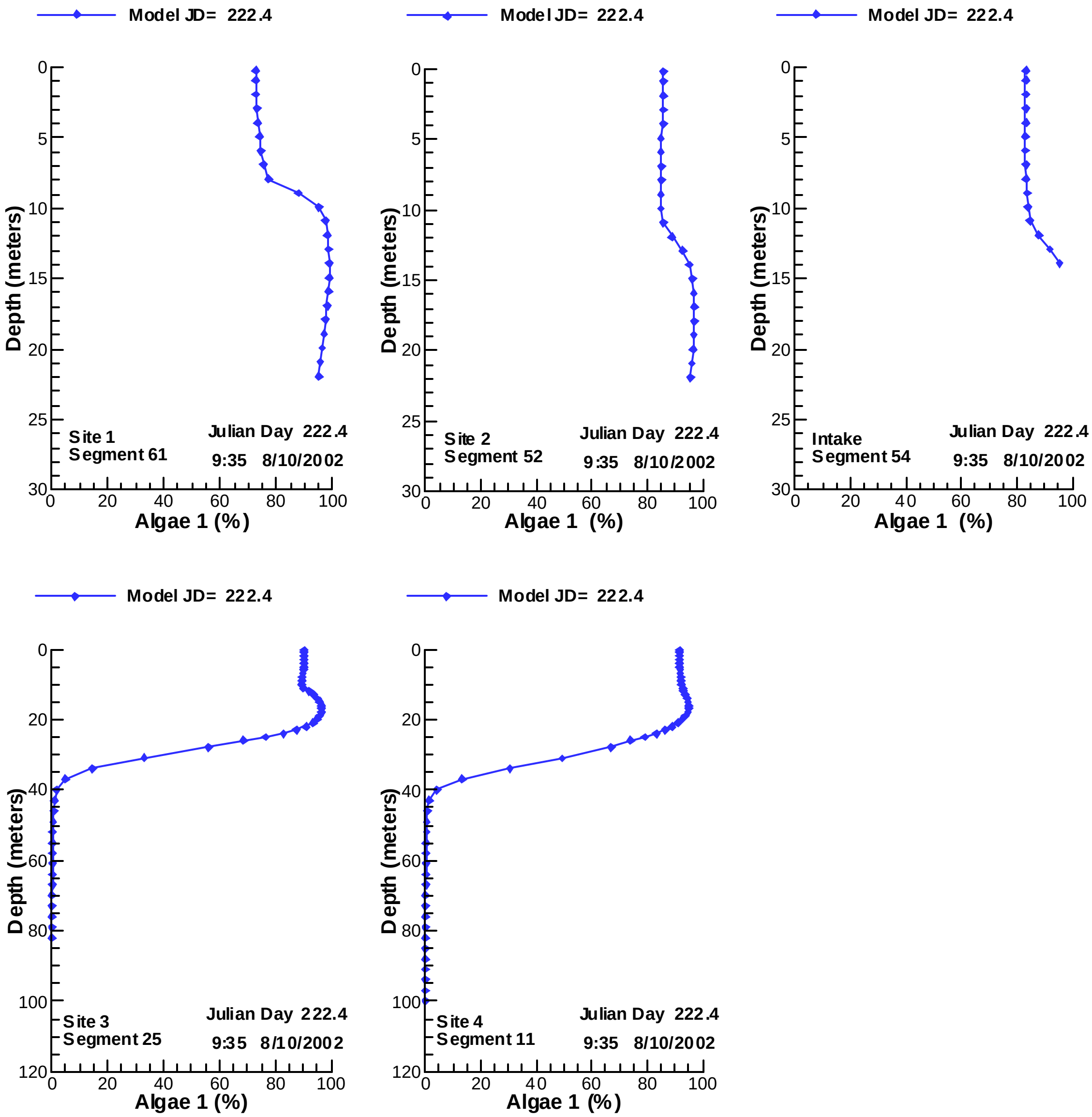

Figure 633. Vertical profiles of ALGAE 1 compared with data for 8/10/2002.

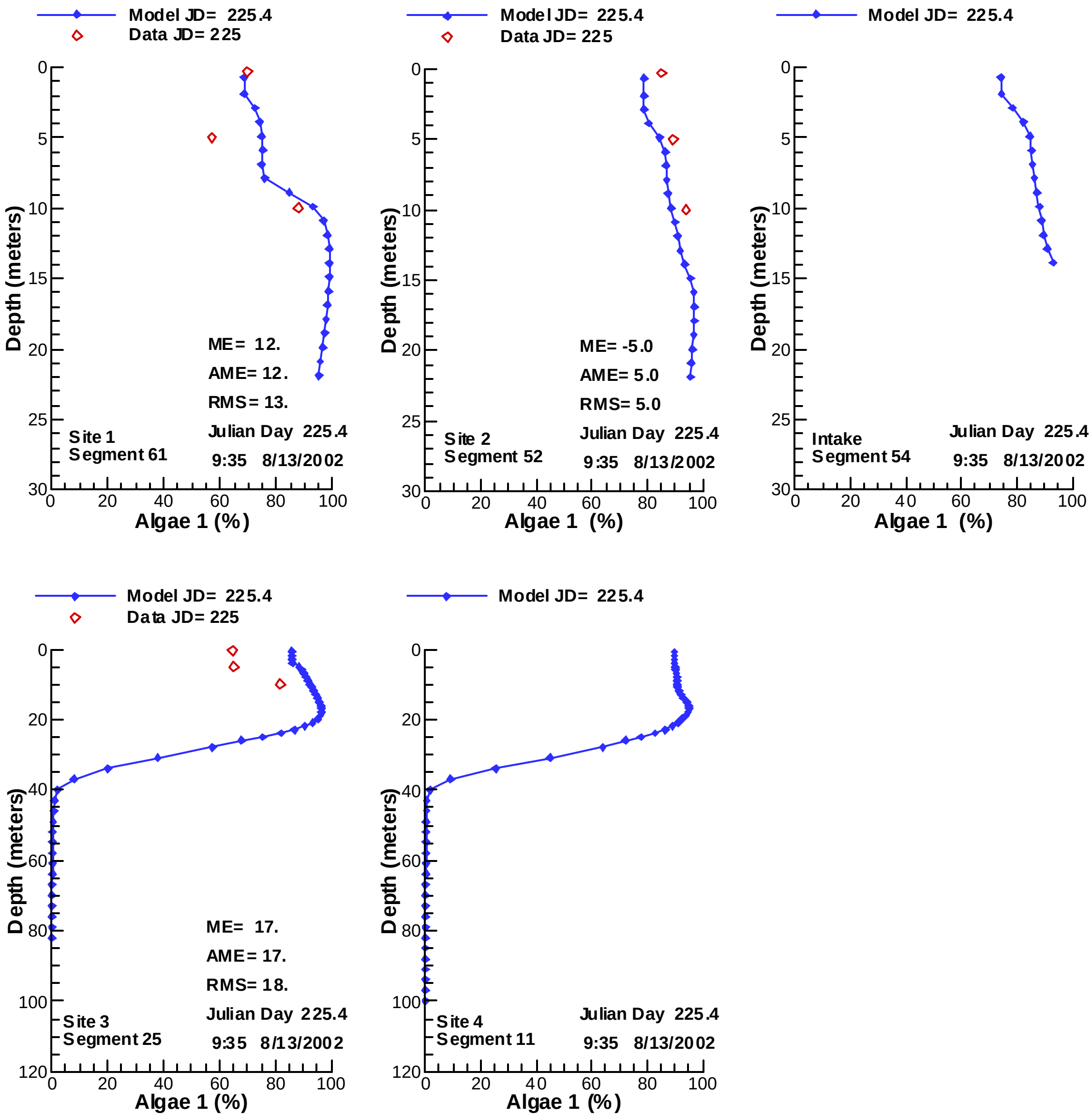

Figure 634. Vertical profiles of ALGAE 1 compared with data for 8/13/2002.

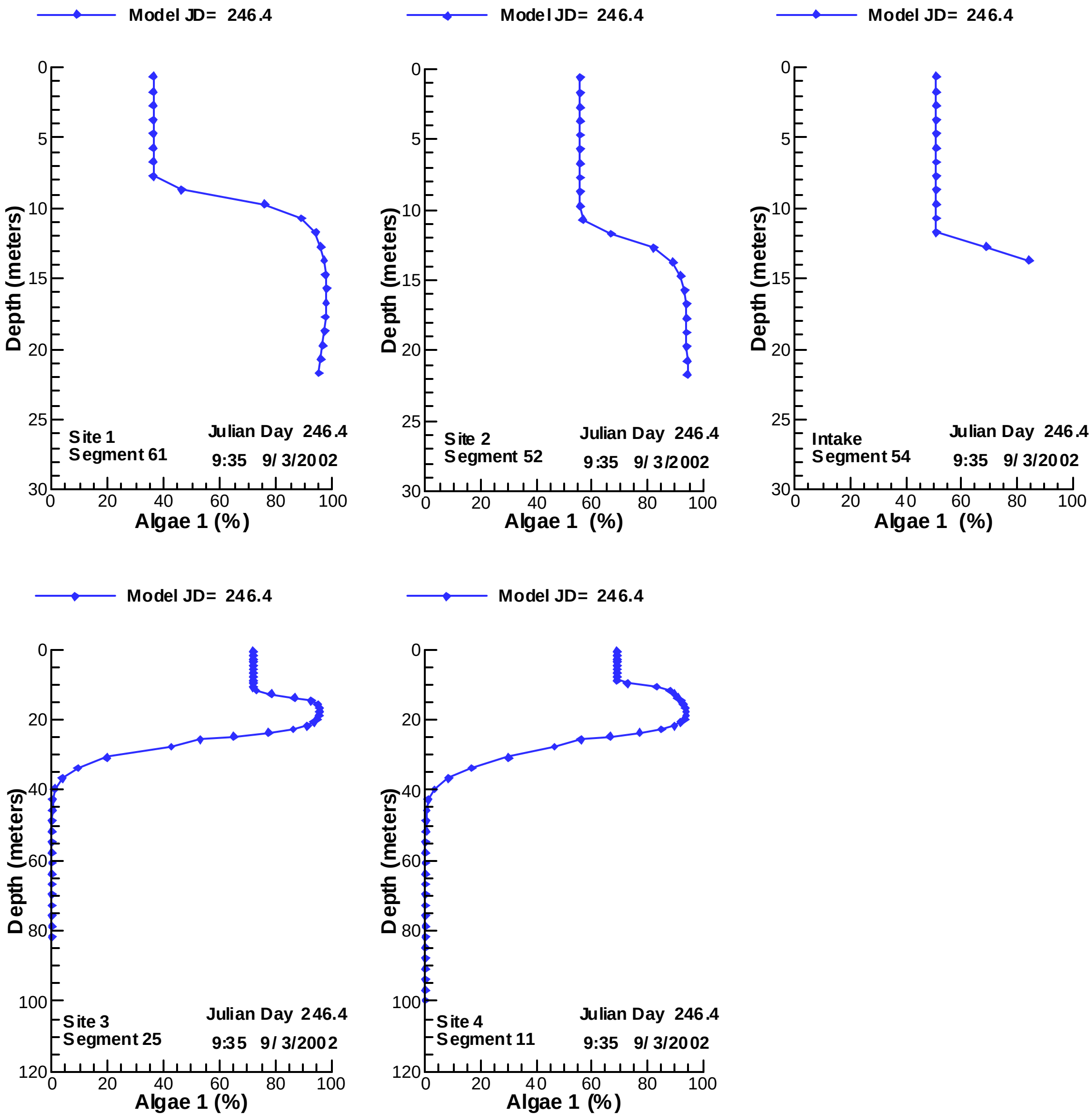

Figure 635. Vertical profiles of ALGAE 1 compared with data for 9/ 3/2002.

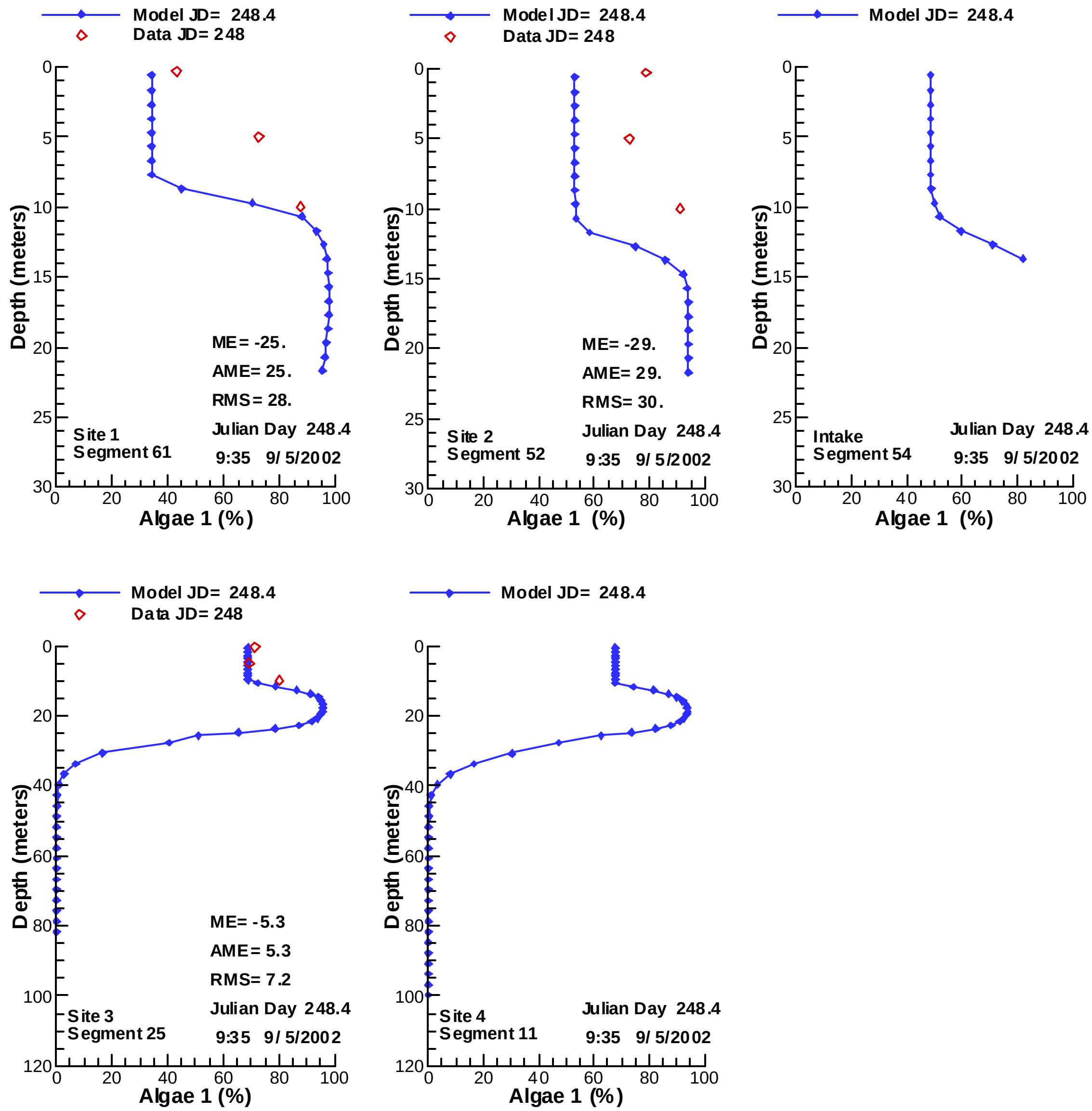

Figure 636. Vertical profiles of ALGAE 1 compared with data for 9/ 5/2002.

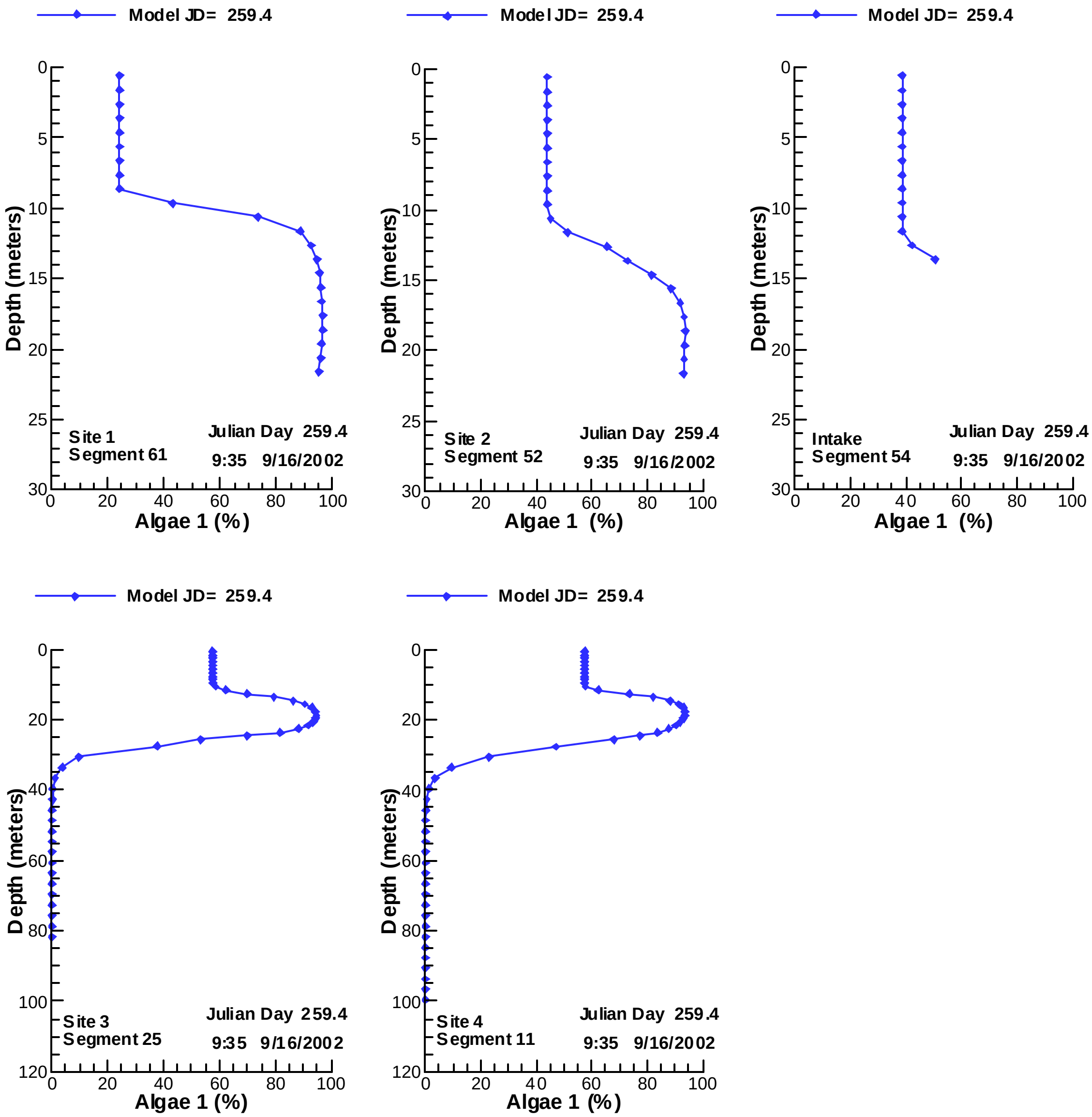

Figure 637. Vertical profiles of ALGAE 1 compared with data for 9/16/2002.

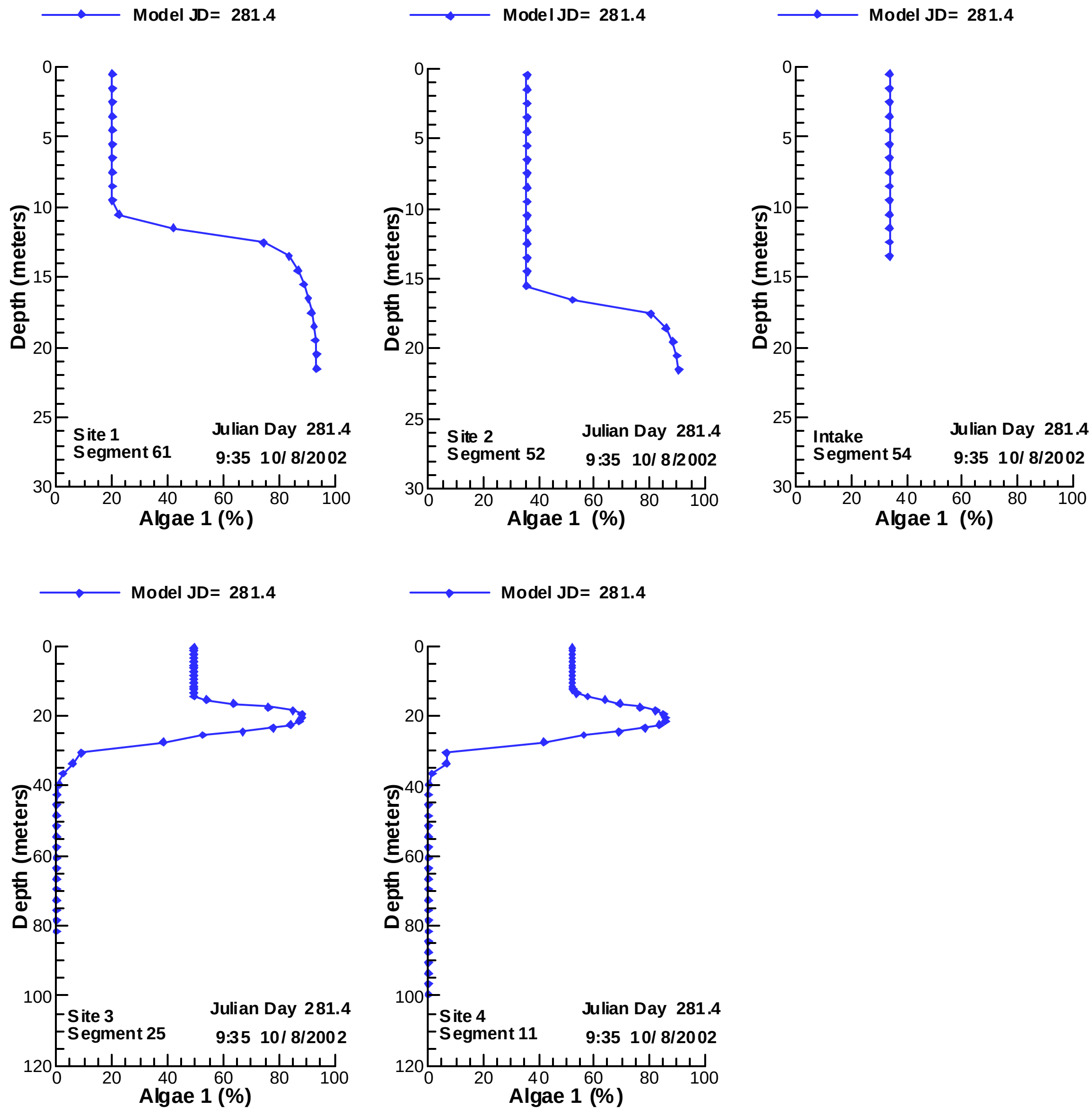

Figure 638. Vertical profiles of ALGAE 1 compared with data for 10/ 8/2002.

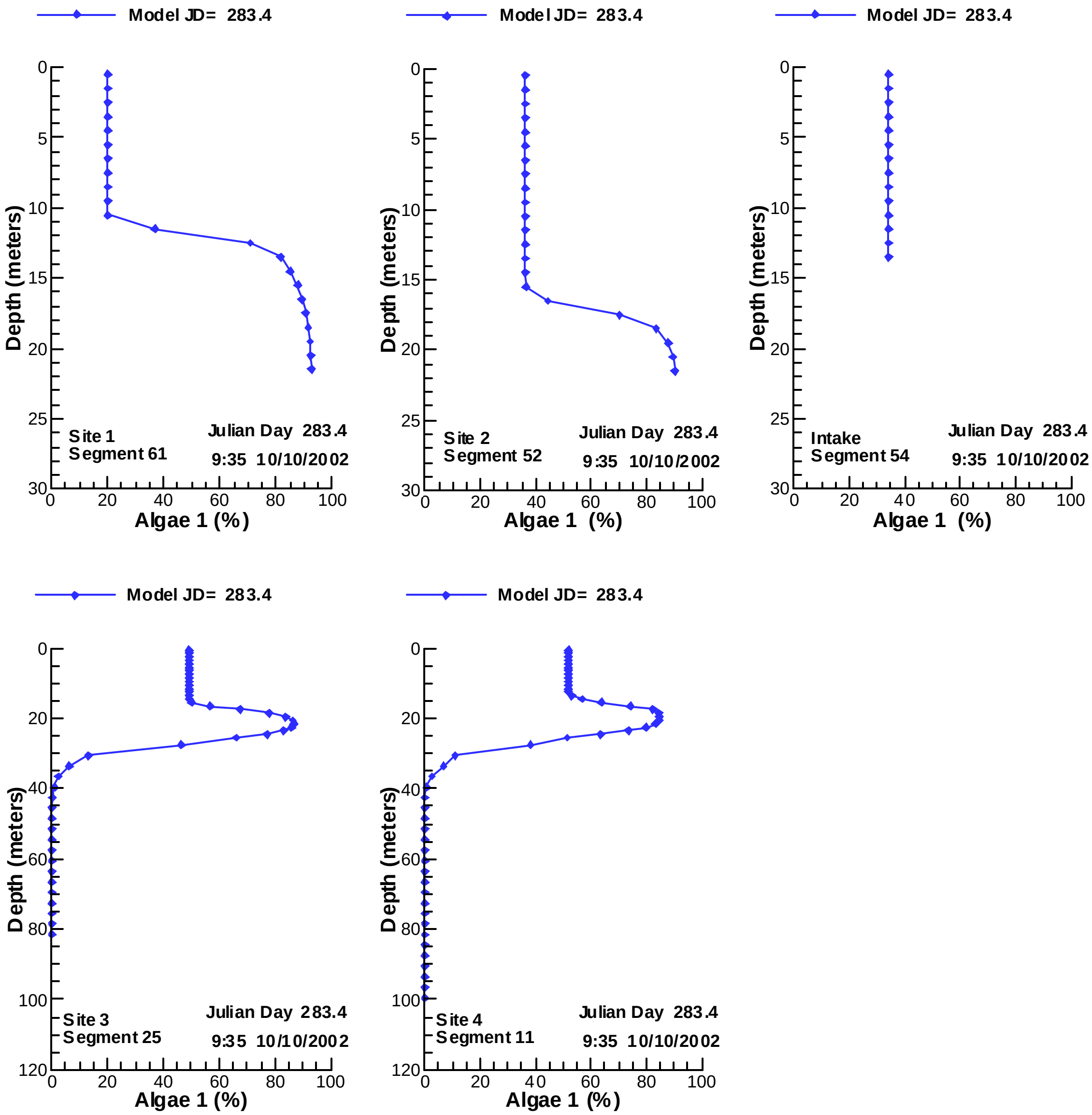

Figure 639. Vertical profiles of ALGAE 1 compared with data for 10/10/2002.

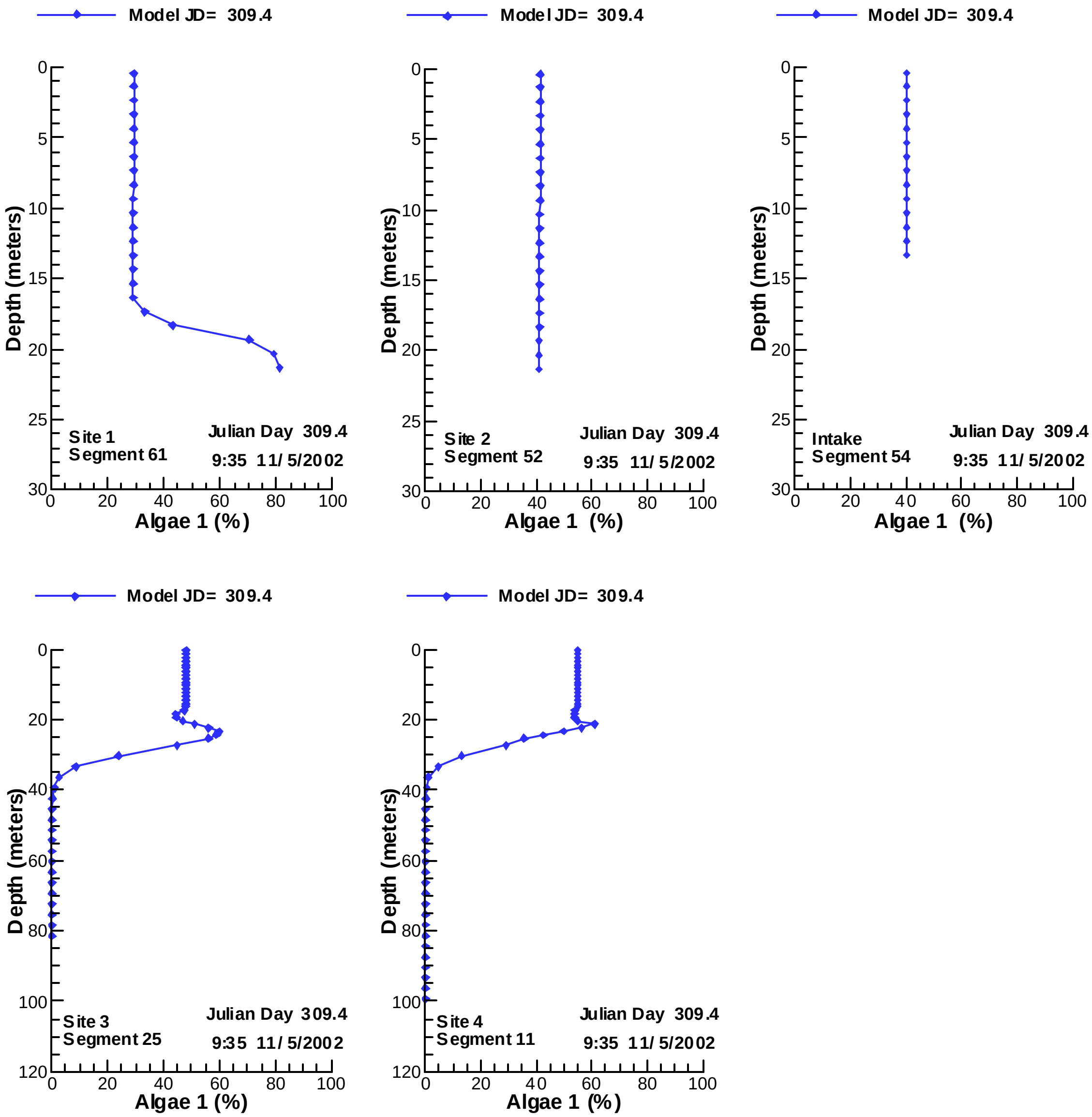

Figure 640. Vertical profiles of ALGAE 1 compared with data for 11/ 5/2002.

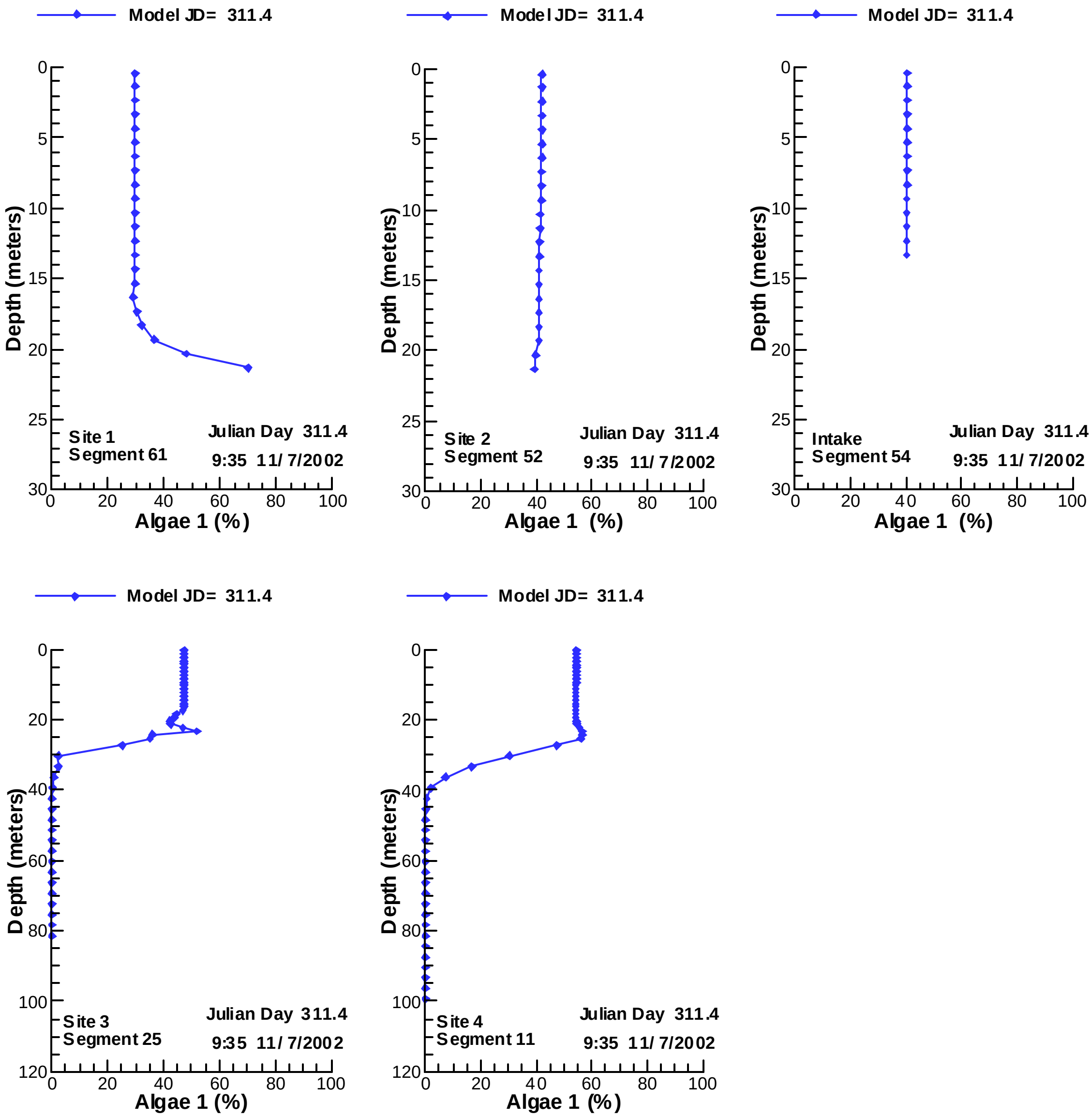

Figure 641. Vertical profiles of ALGAE 1 compared with data for 11/ 7/2002.

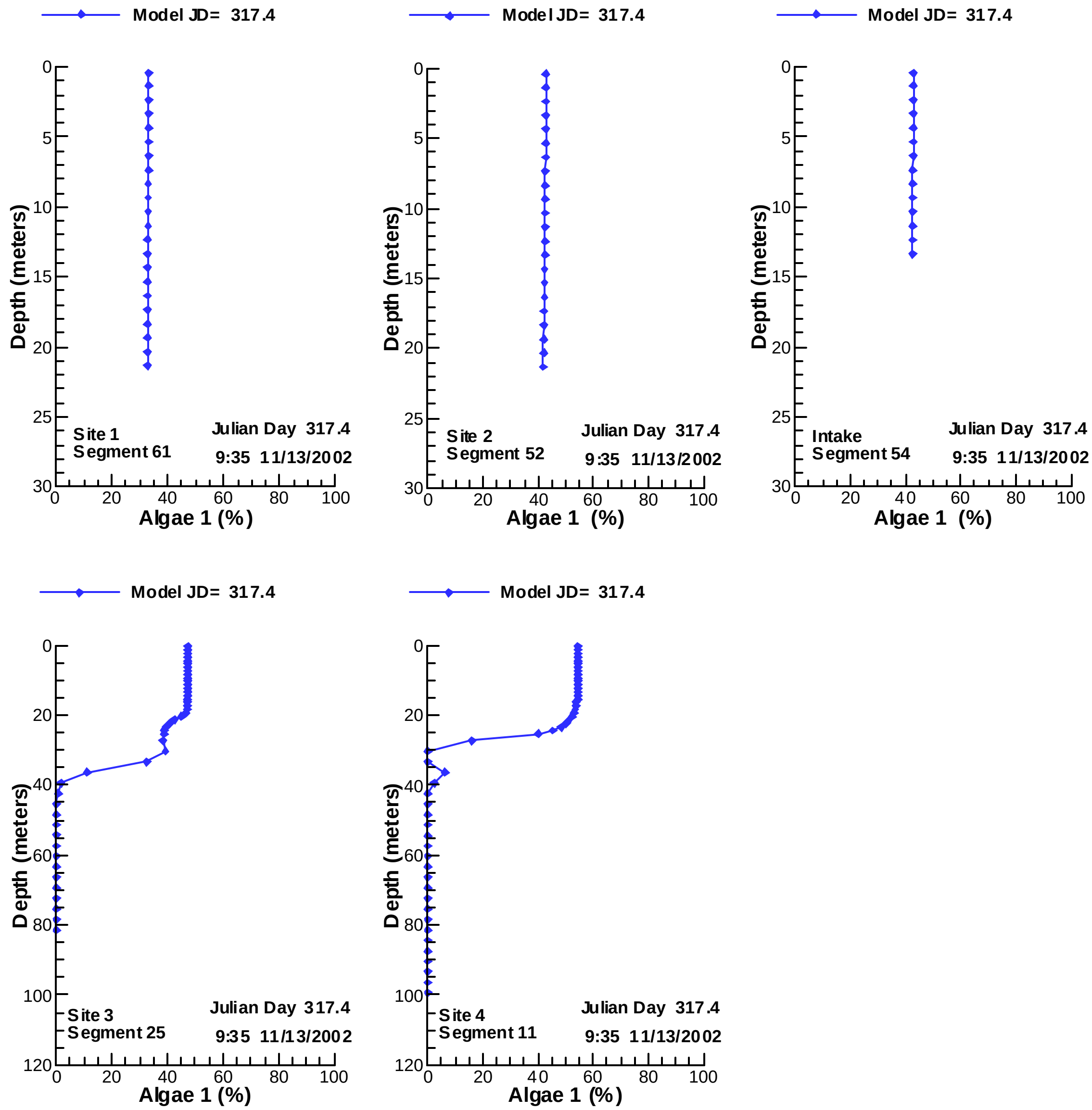

Figure 642. Vertical profiles of ALGAE 1 compared with data for 11/13/2002.

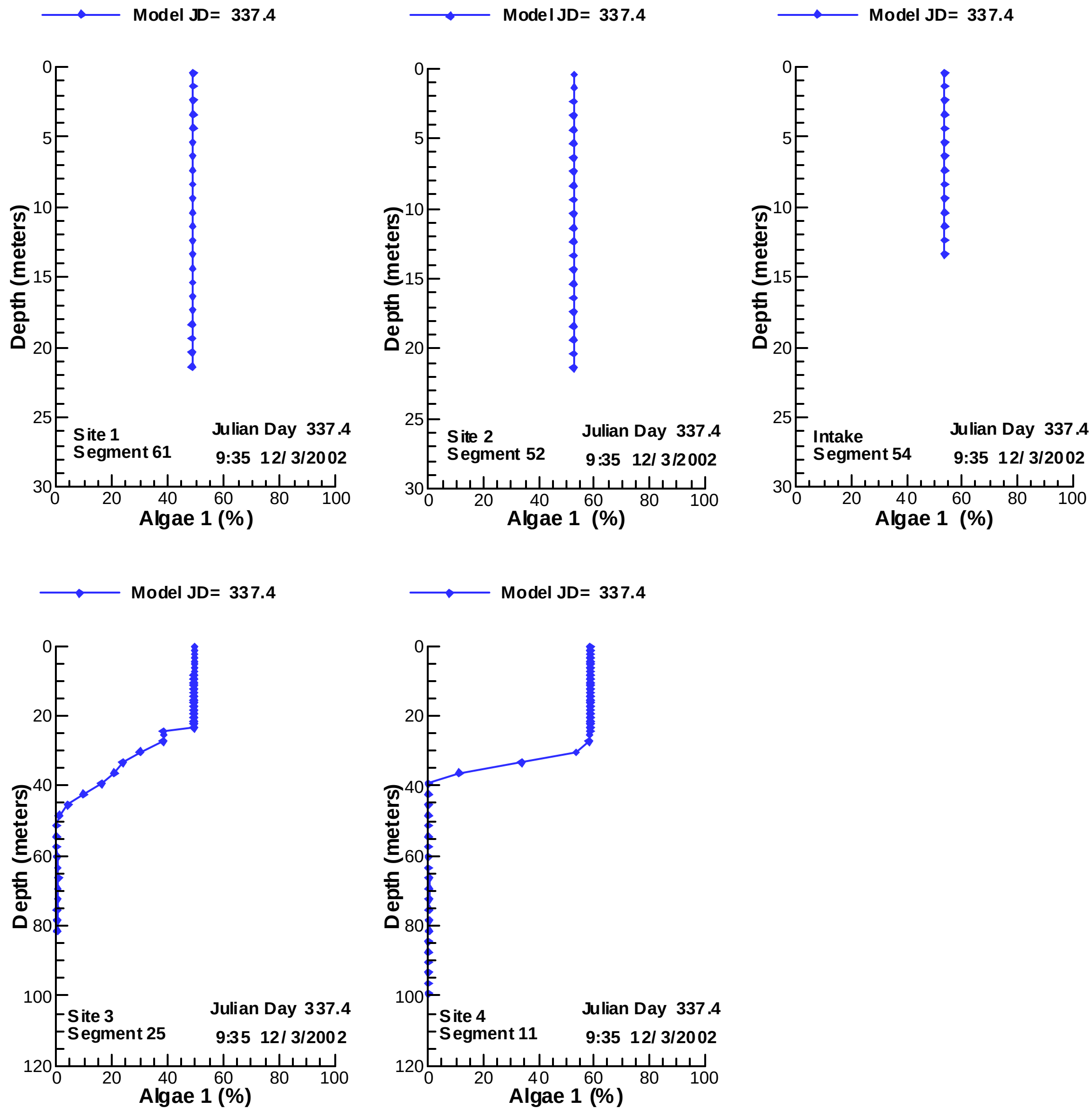

Figure 643. Vertical profiles of ALGAE 1 compared with data for 12/ 3/2002.

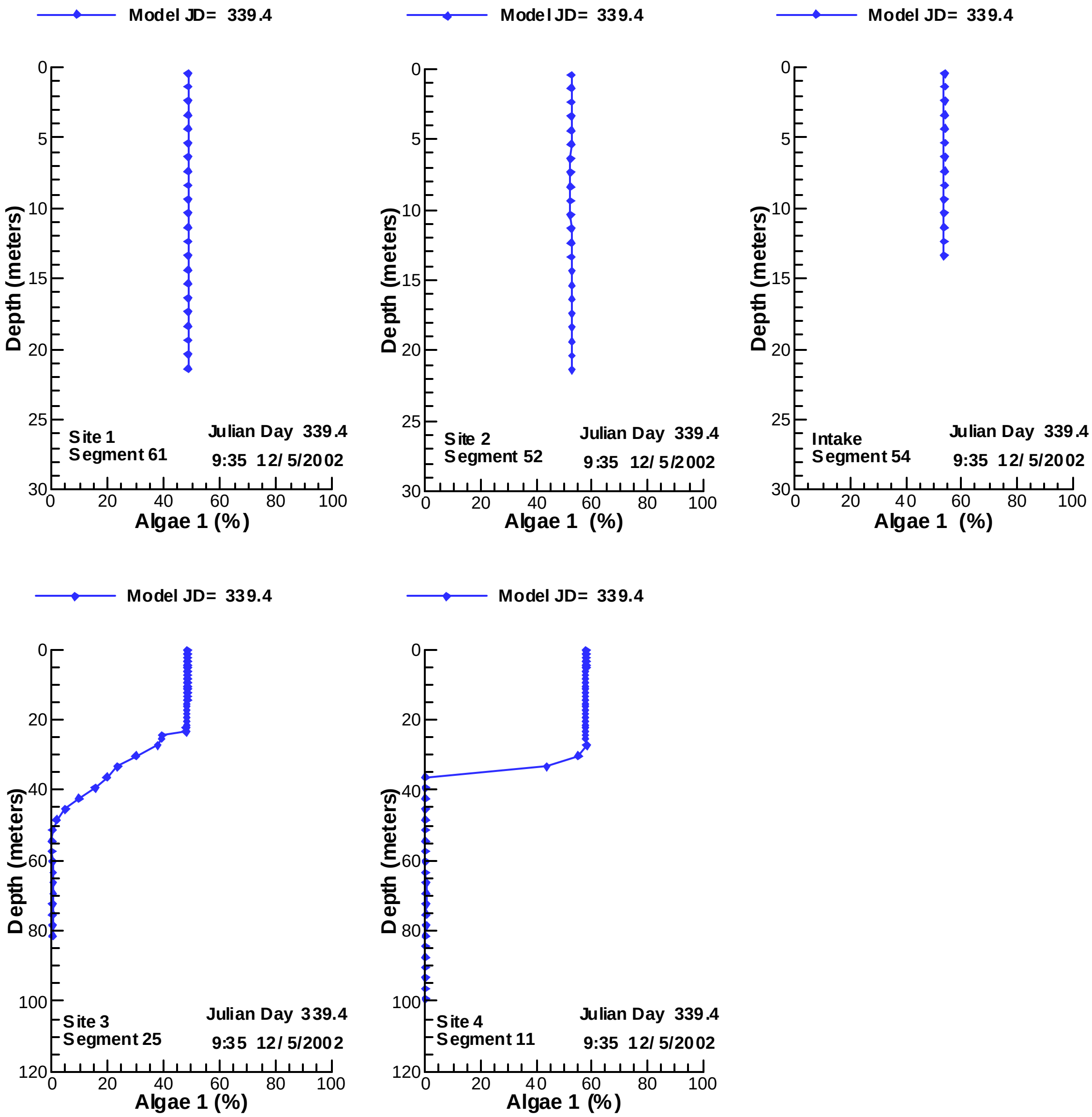

Figure 644. Vertical profiles of ALGAE 1 compared with data for 12/ 5/2002.

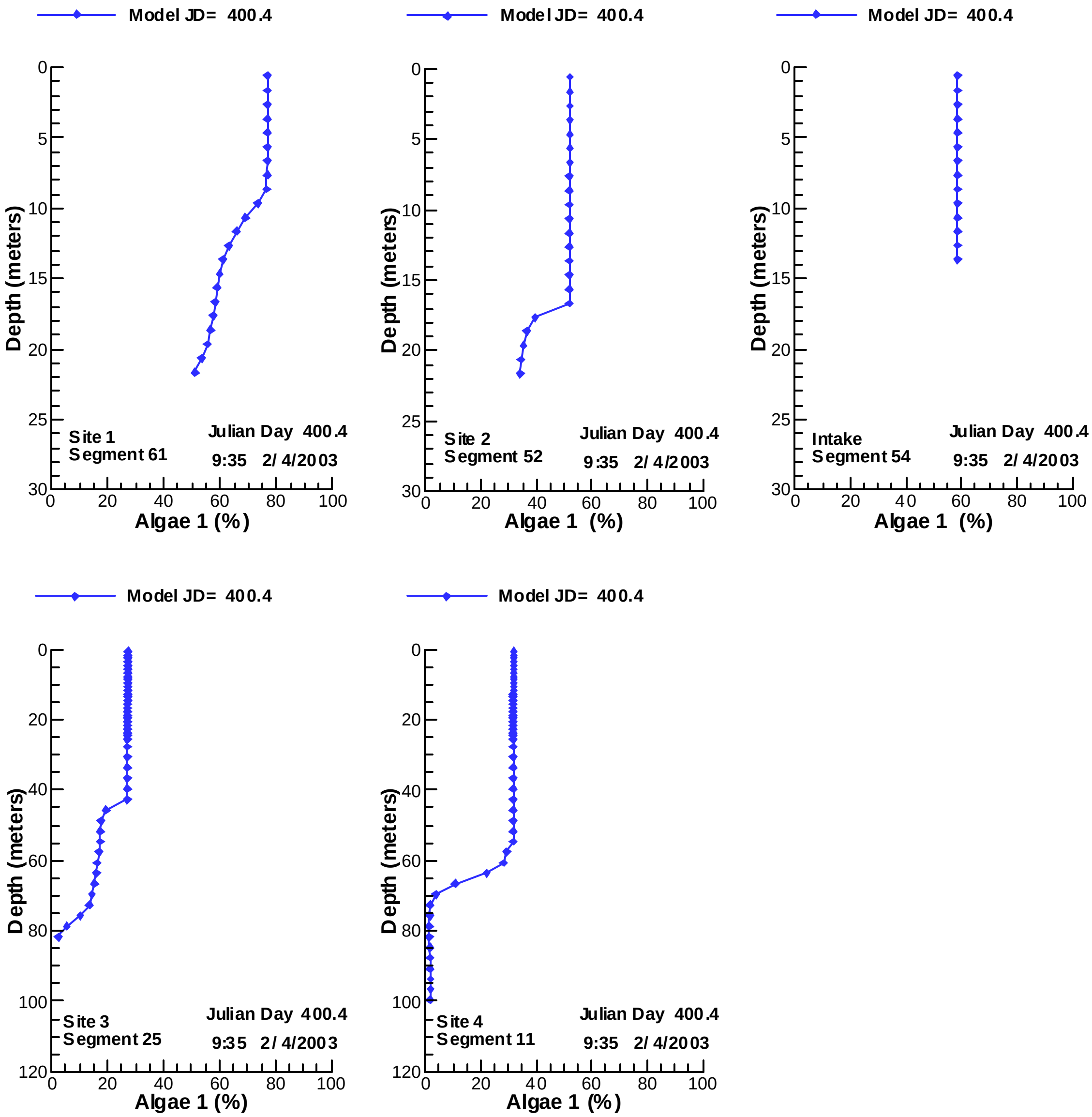

Figure 645. Vertical profiles of ALGAE 1 compared with data for 2/ 4/2003.

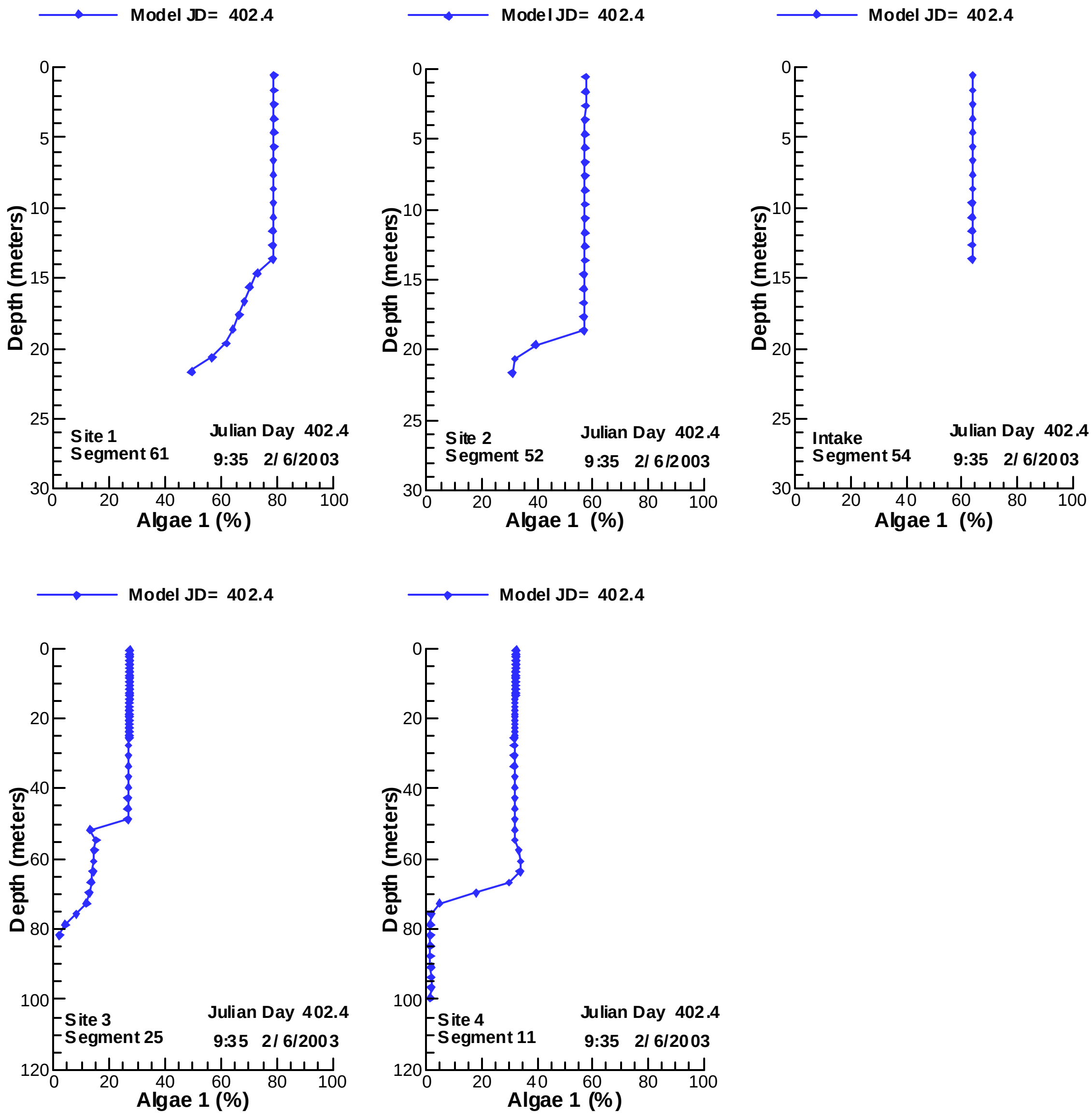

Figure 646. Vertical profiles of ALGAE 1 compared with data for 2/ 6/2003.

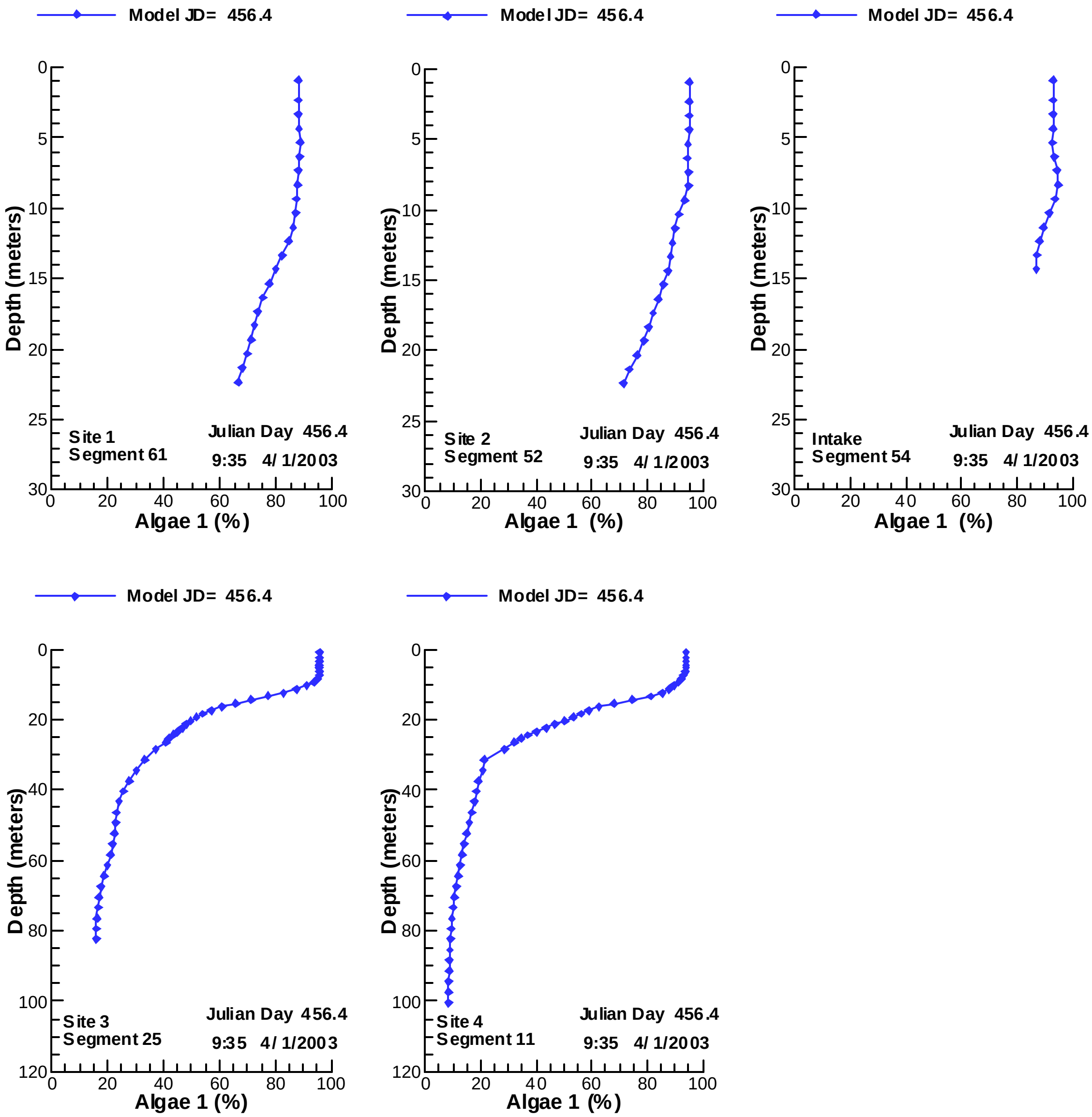

Figure 647. Vertical profiles of ALGAE 1 compared with data for 4/ 1/2003.

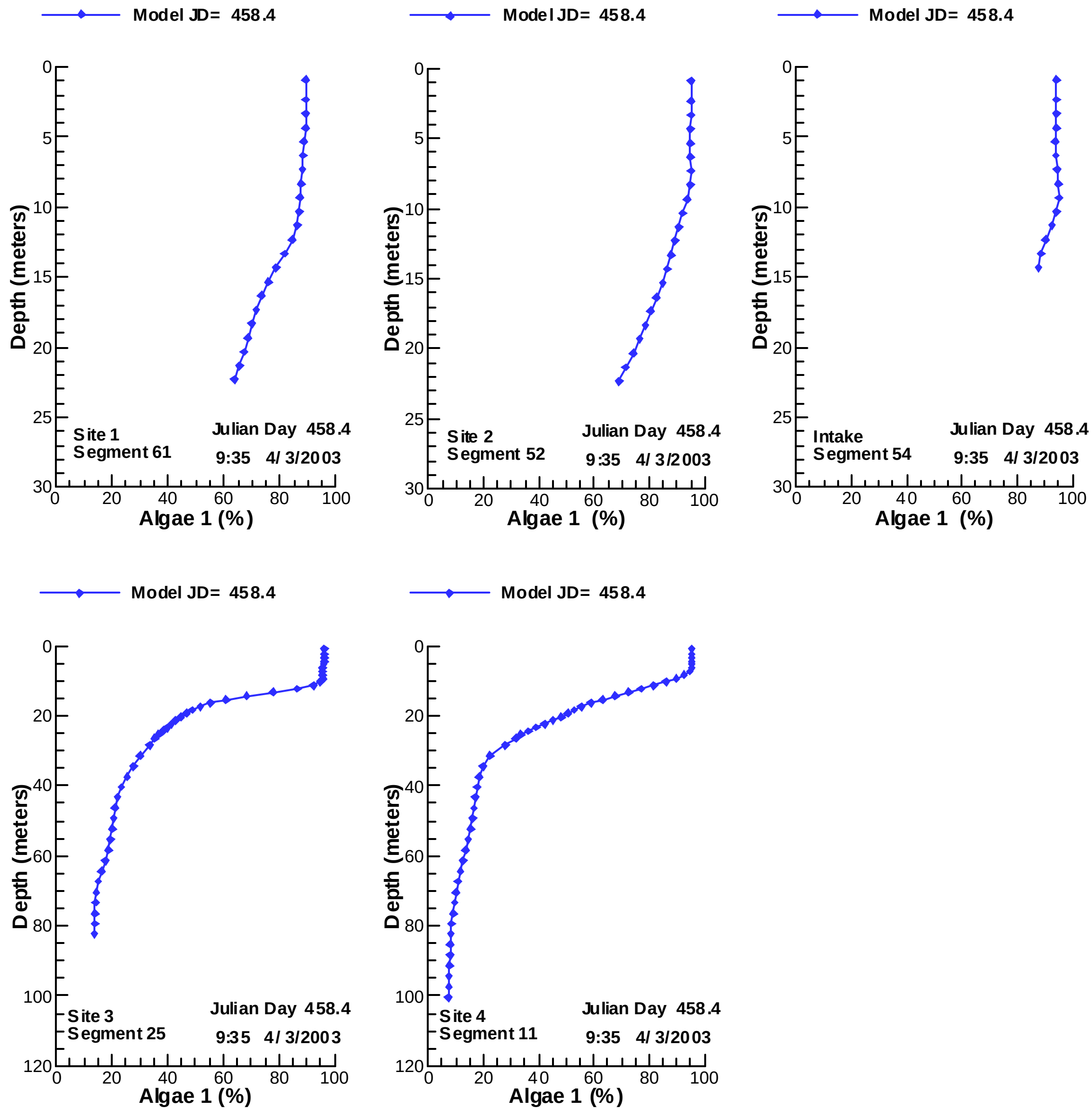

Figure 648. Vertical profiles of ALGAE 1 compared with data for 4/ 3/2003.

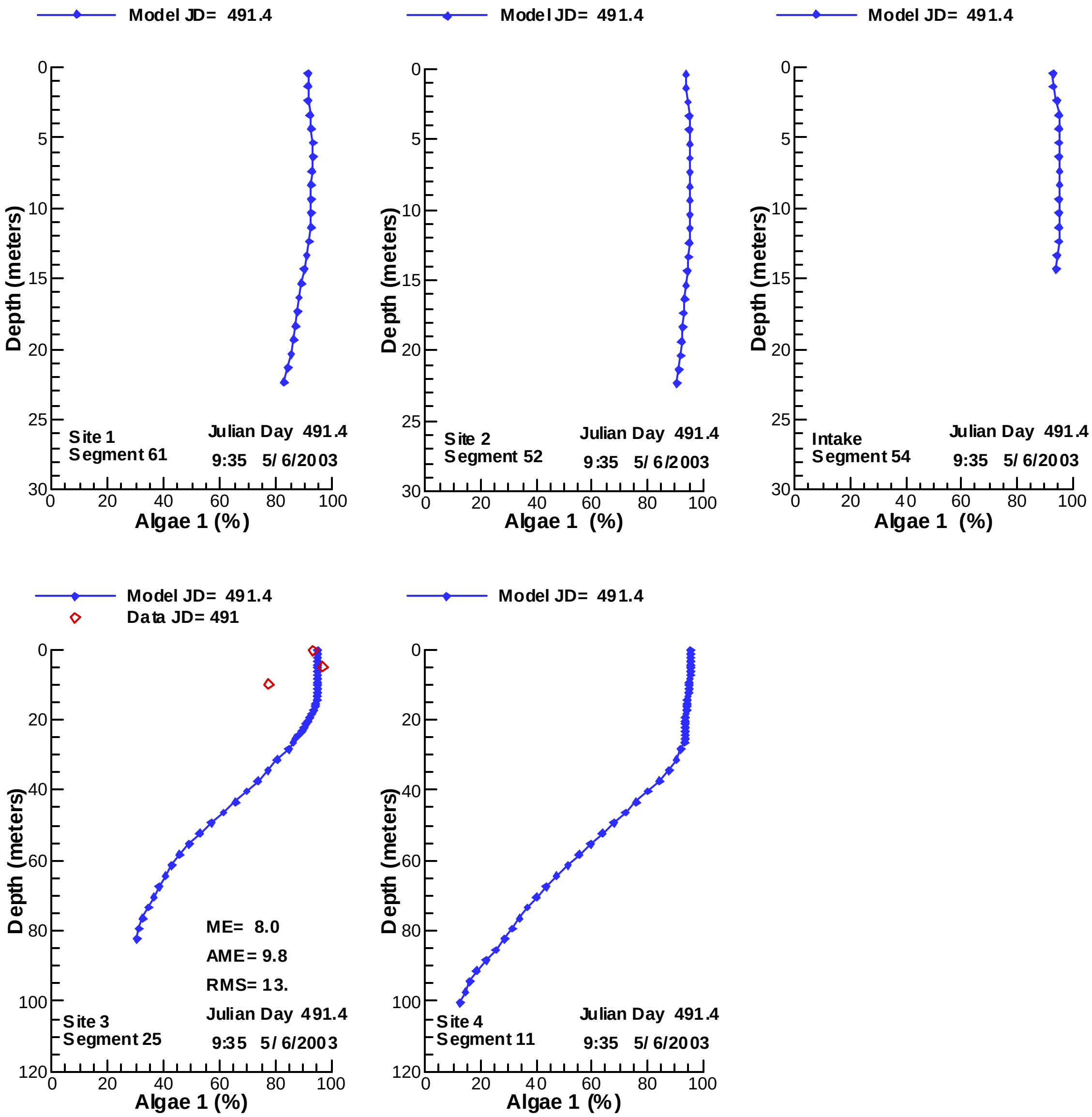

Figure 649. Vertical profiles of ALGAE 1 compared with data for 5/ 6/2003.

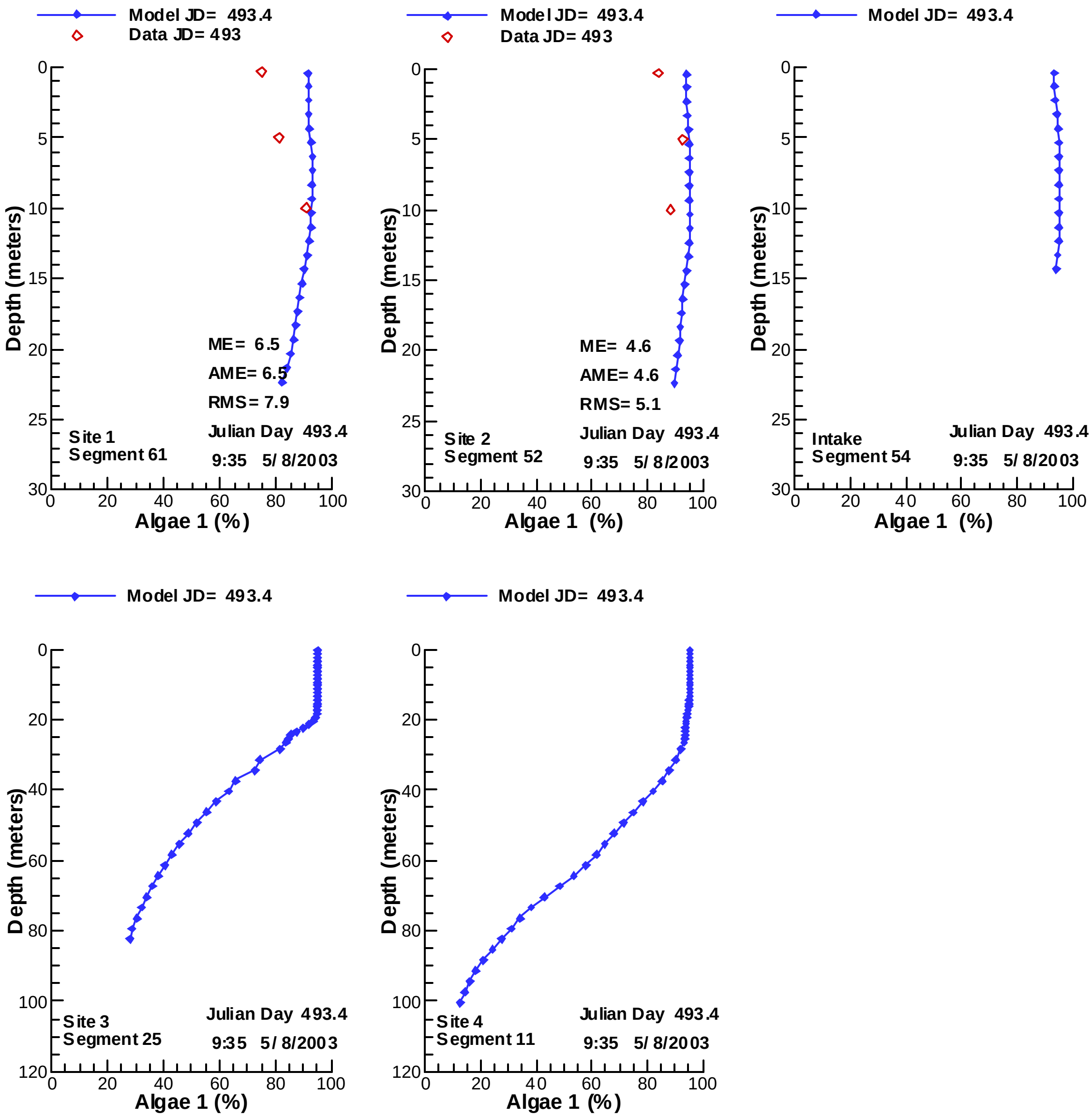

Figure 650. Vertical profiles of ALGAE 1 compared with data for 5/ 8/2003.

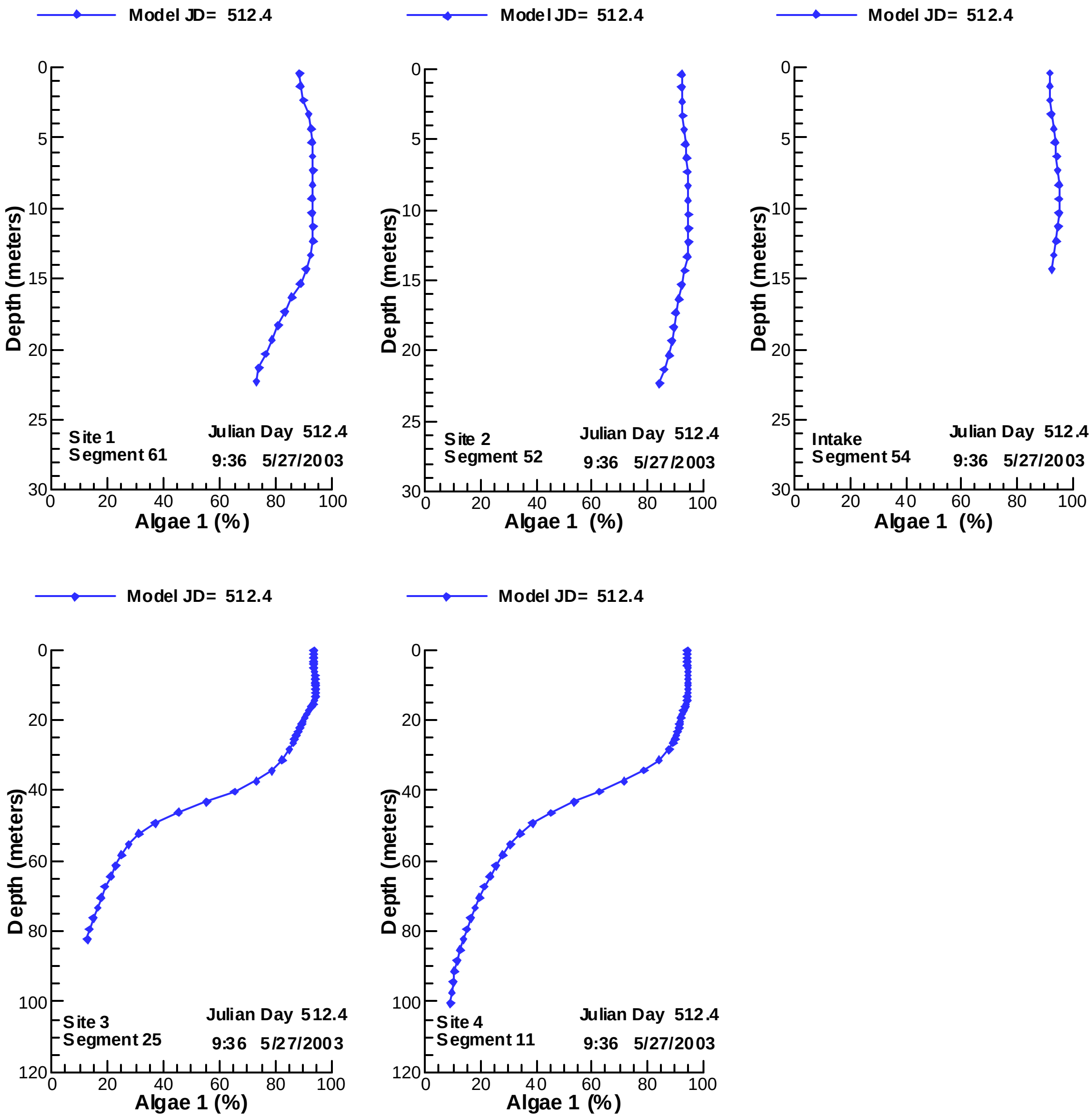

Figure 651. Vertical profiles of ALGAE 1 compared with data for 5/27/2003.

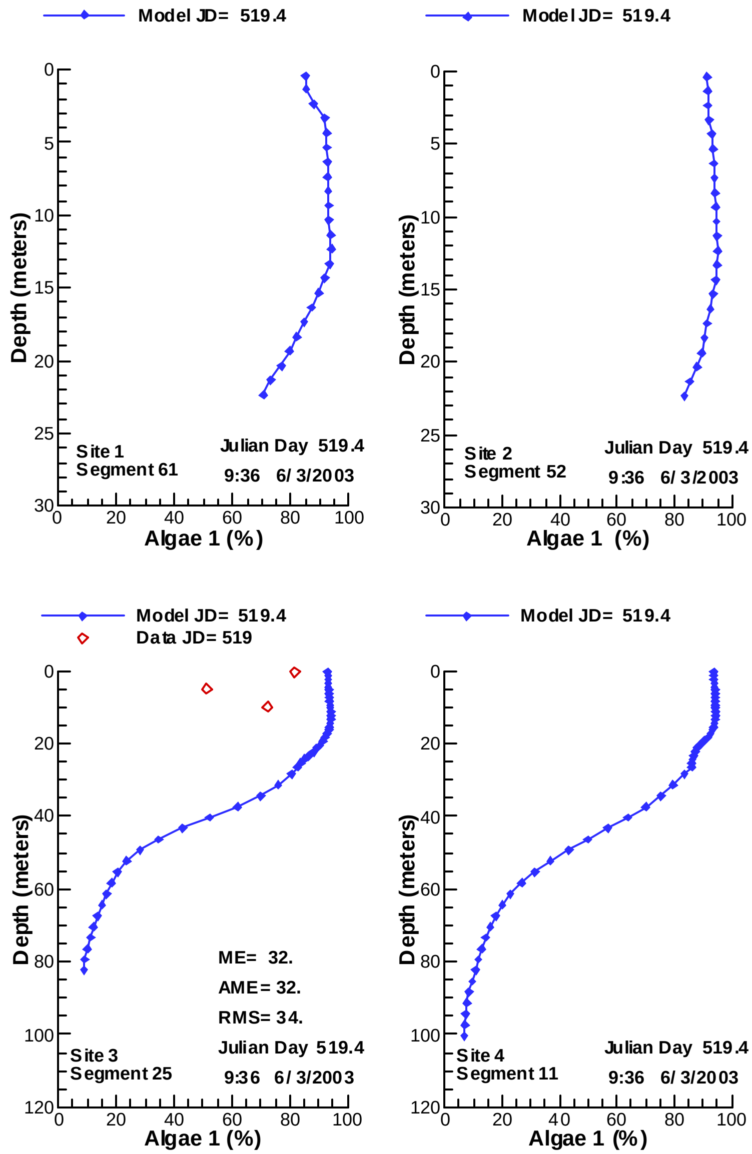

Figure 652. Vertical profiles of ALGAE 1 compared with data for 6/ 3/2003.

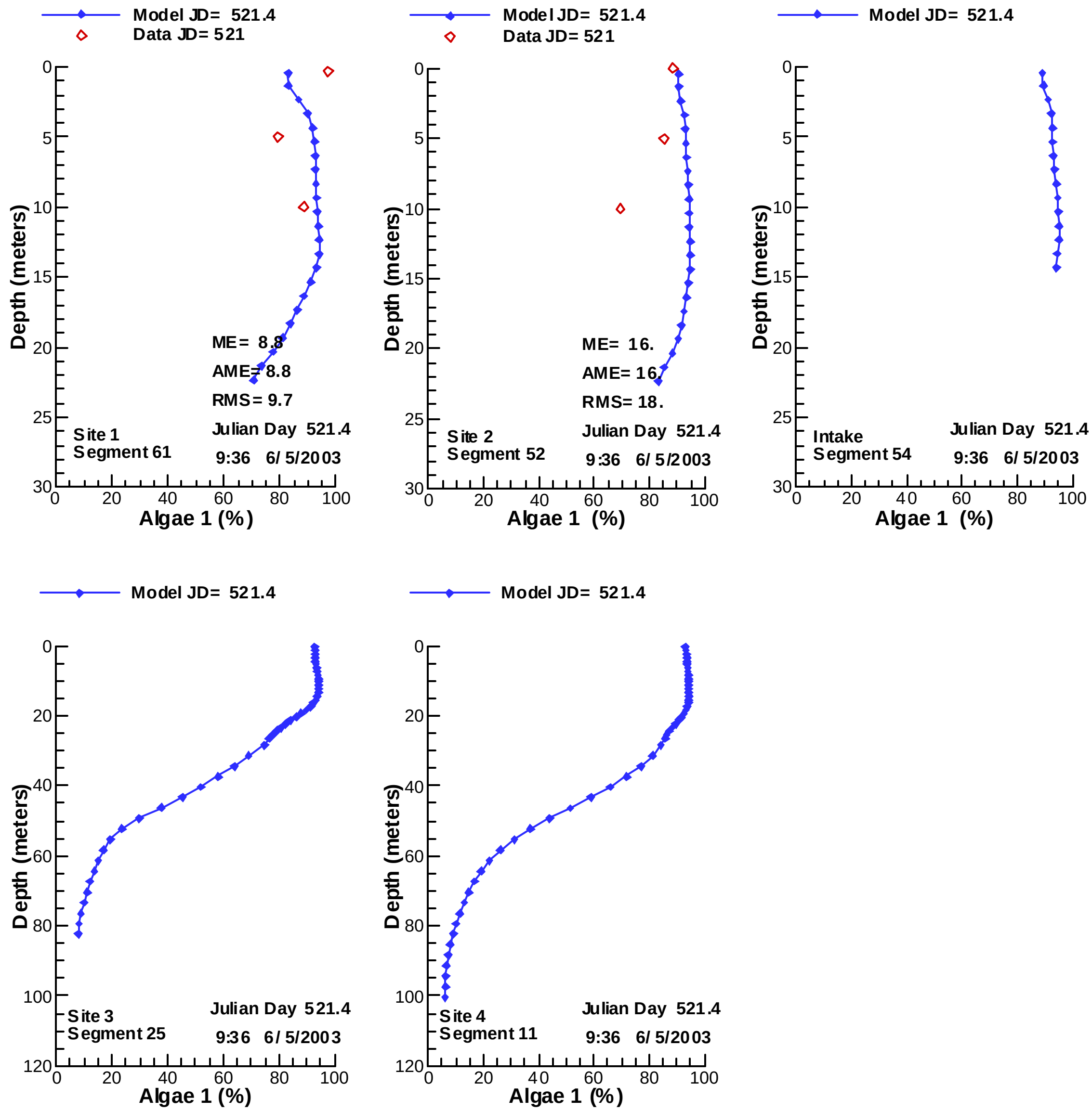

Figure 653. Vertical profiles of ALGAE 1 compared with data for 6/ 5/2003.

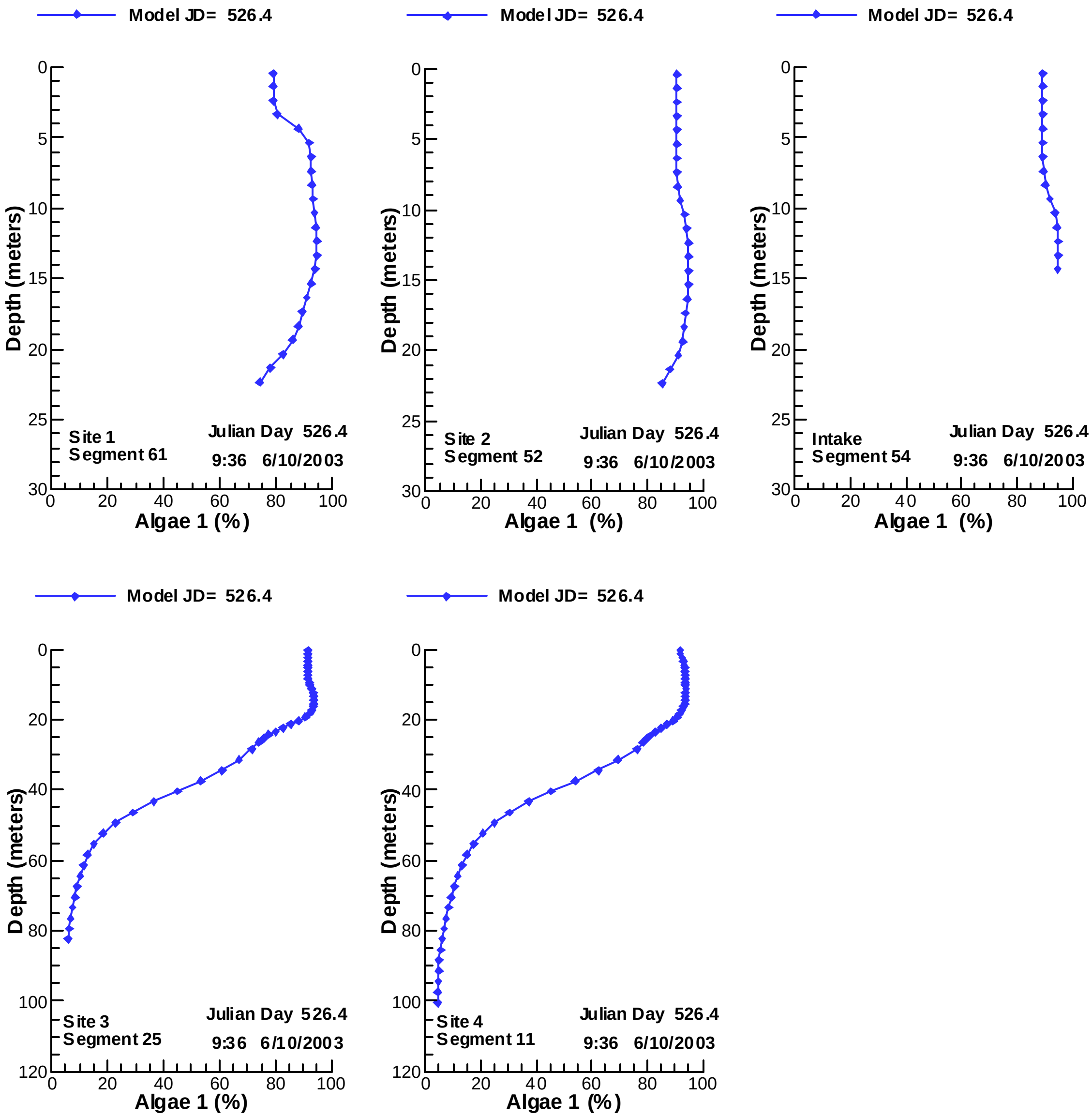

Figure 654. Vertical profiles of ALGAE 1 compared with data for 6/10/2003.

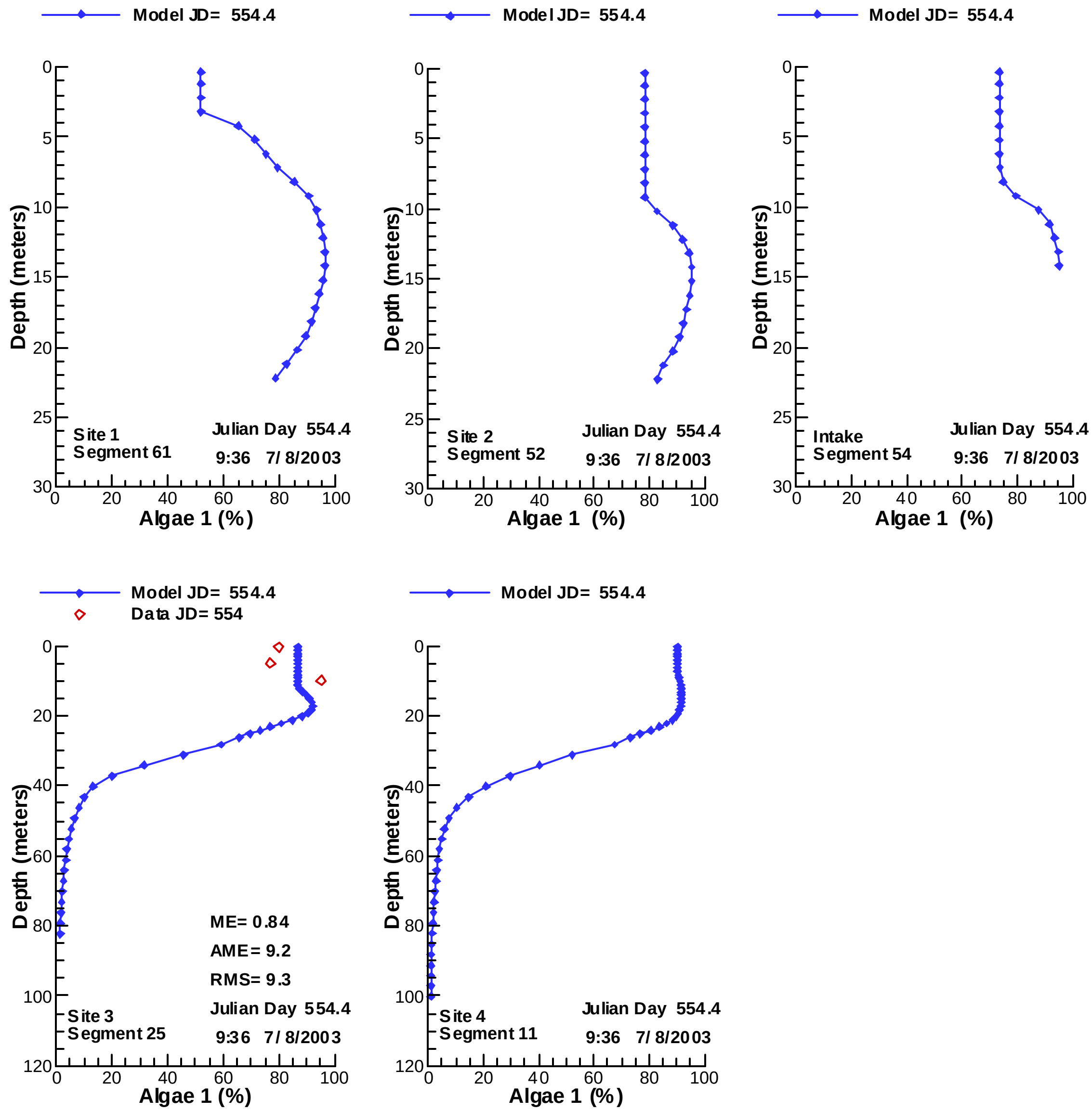

Figure 655. Vertical profiles of ALGAE 1 compared with data for 7/ 8/2003.

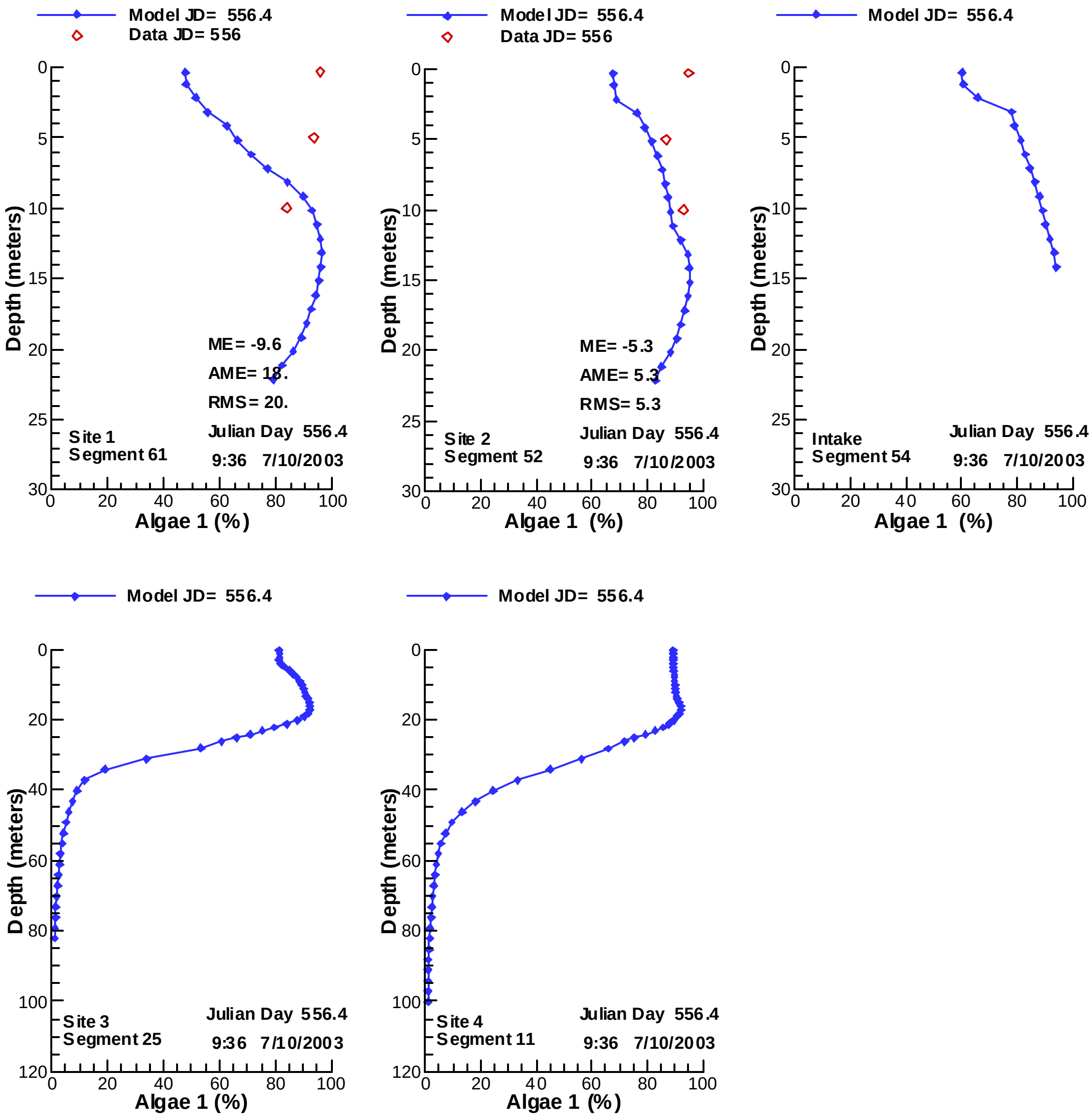

Figure 656. Vertical profiles of ALGAE 1 compared with data for 7/10/2003.

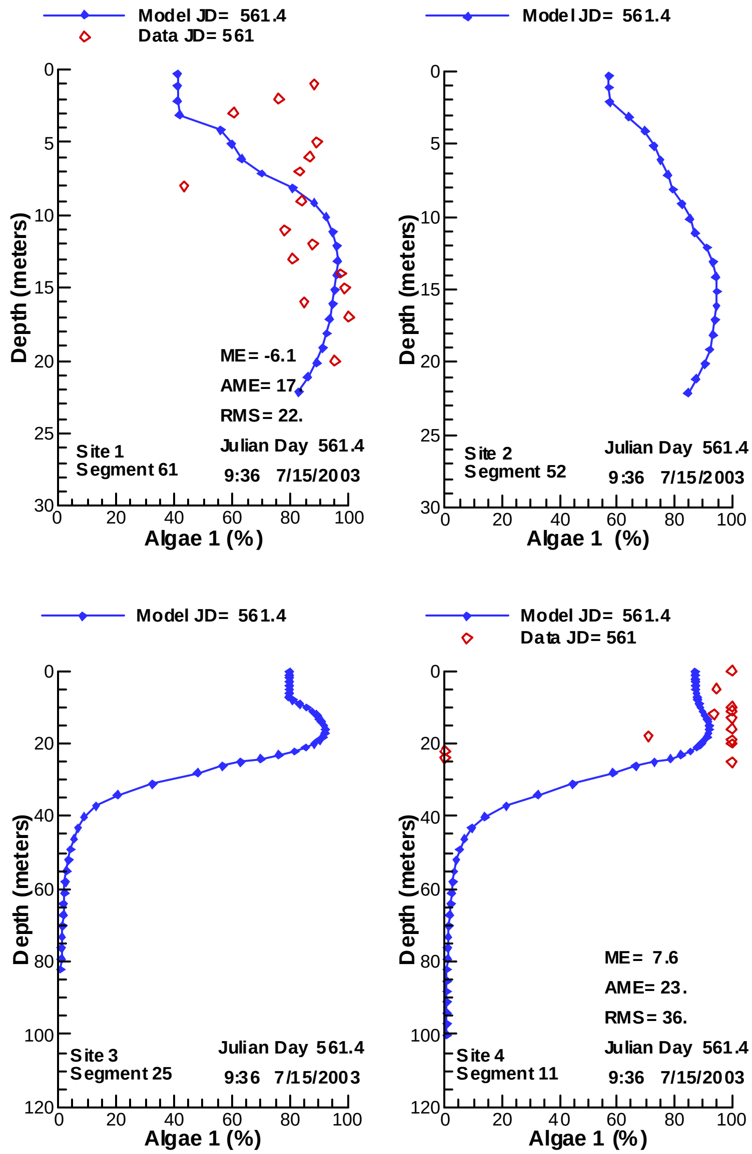

Figure 657. Vertical profiles of ALGAE 1 compared with data for 7/15/2003.

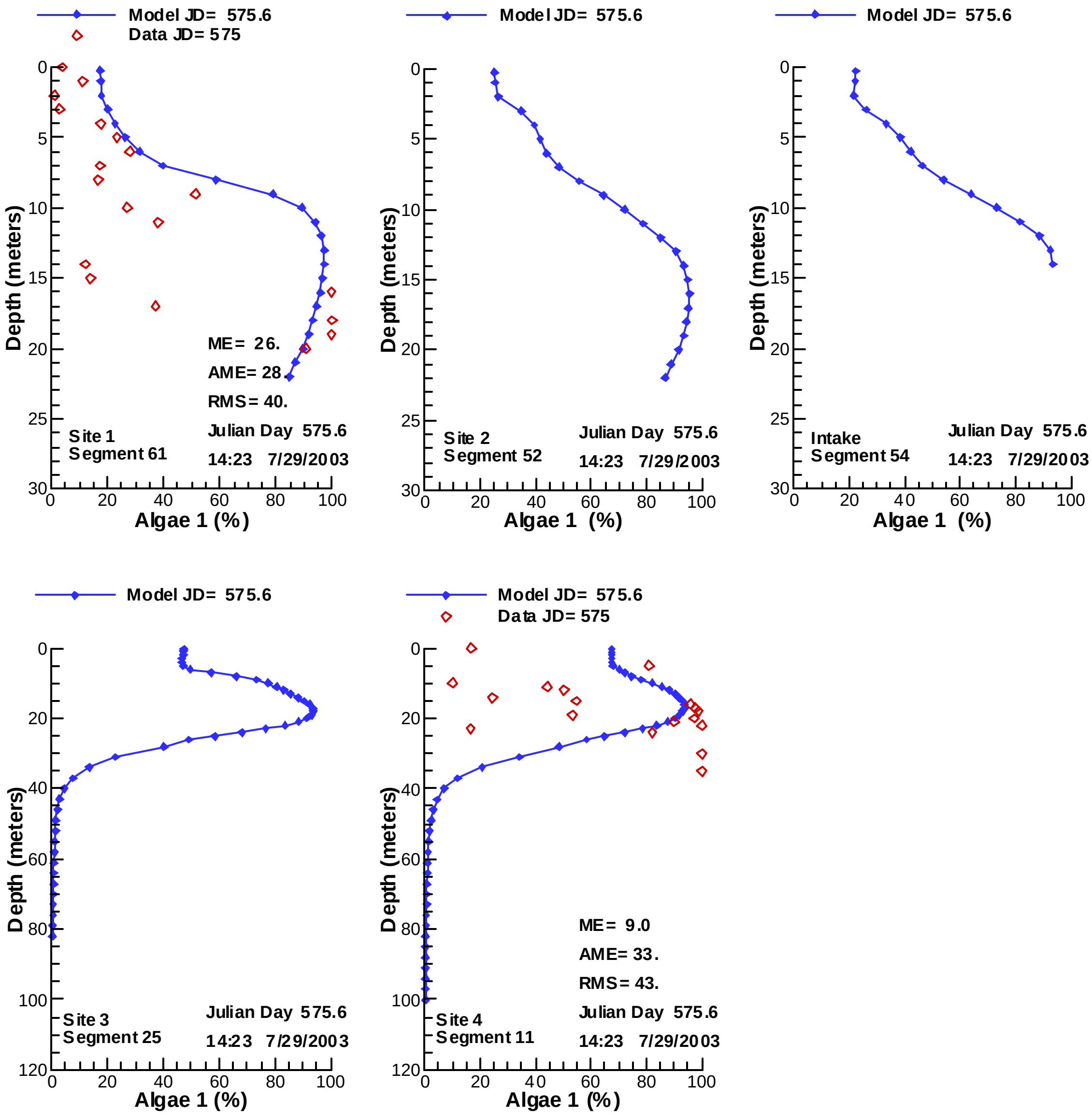

Figure 658. Vertical profiles of ALGAE 1 compared with data for 7/29/2003.

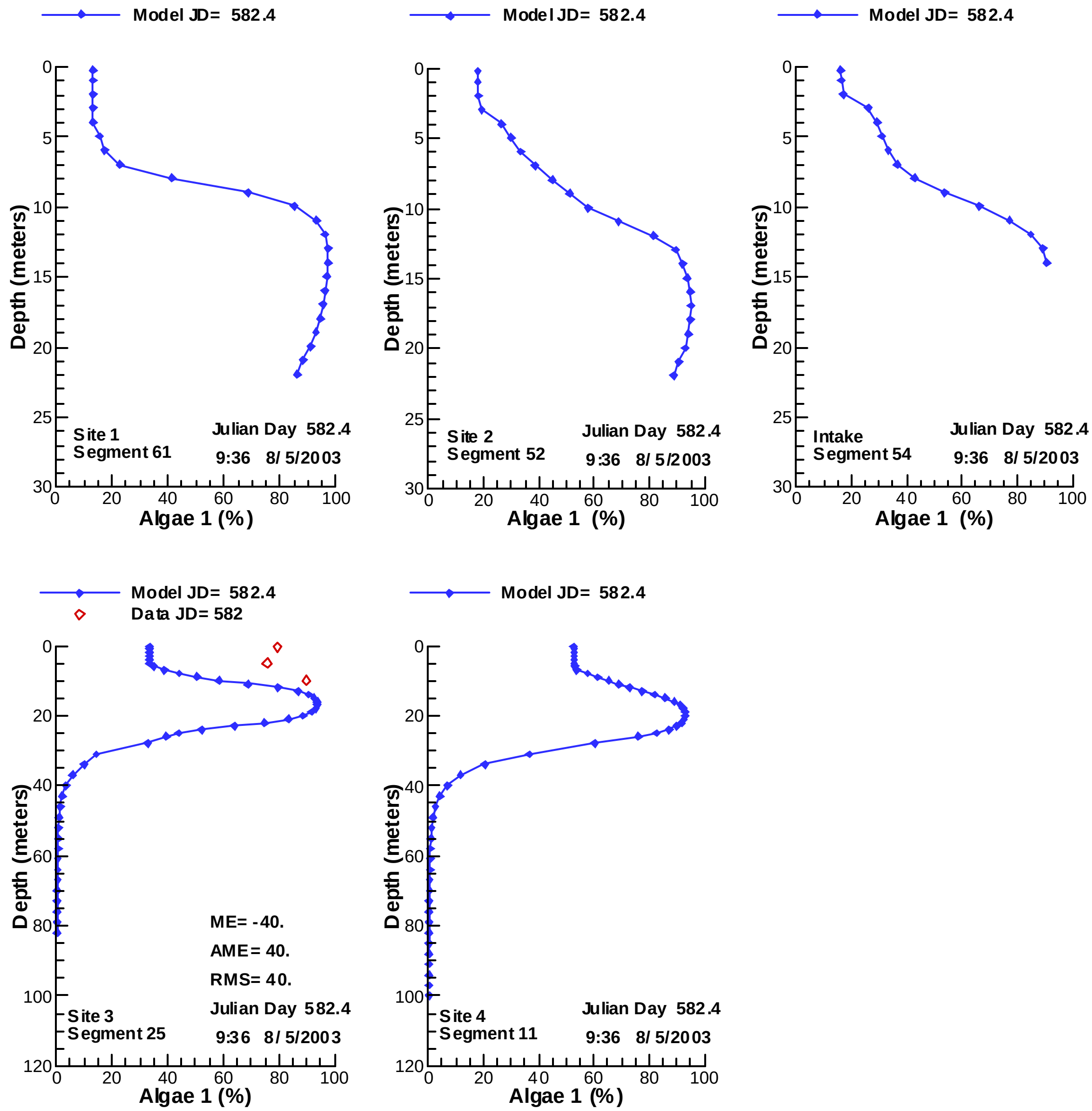

Figure 659. Vertical profiles of ALGAE 1 compared with data for 8/ 5/2003.

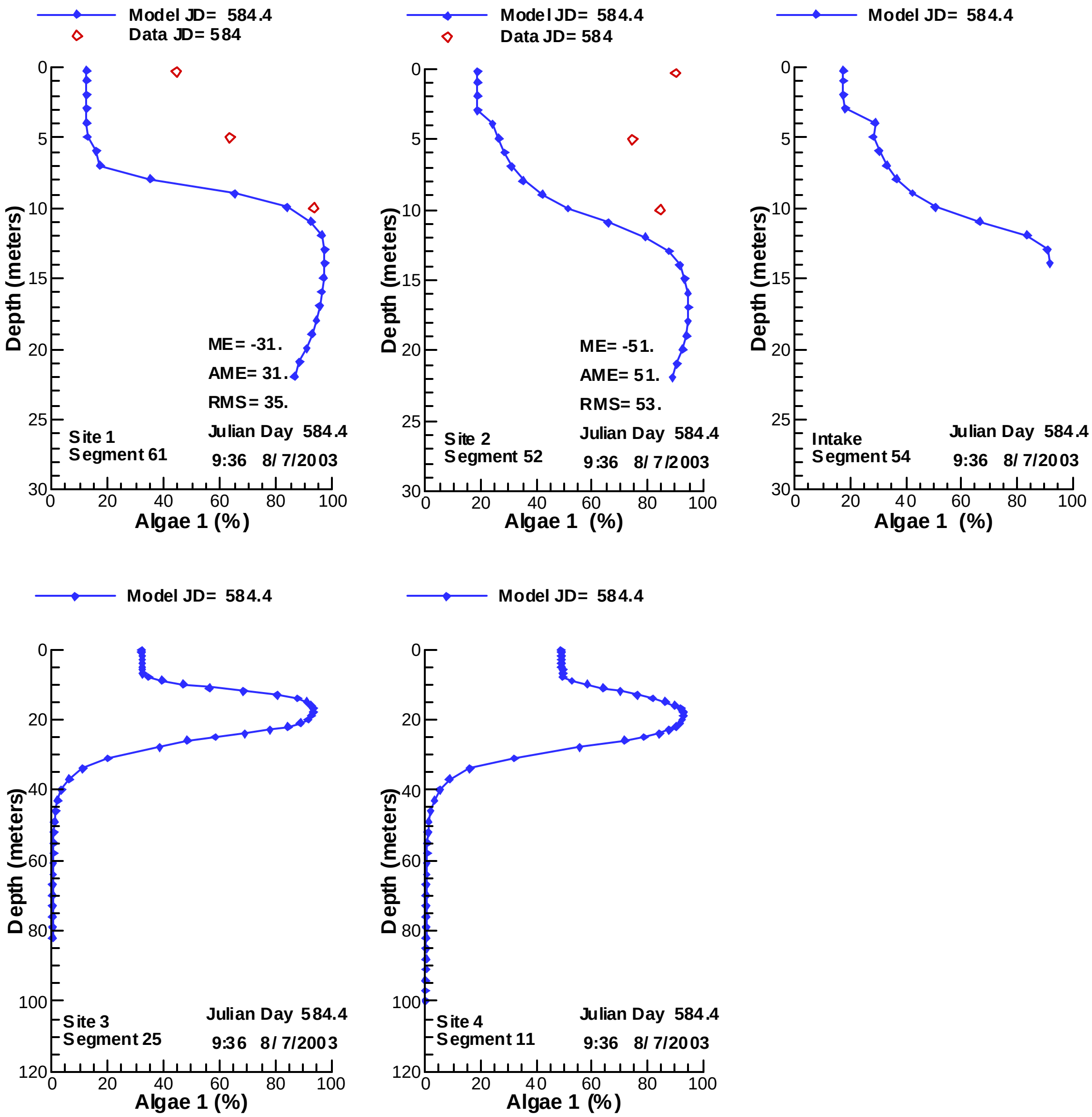

Figure 660. Vertical profiles of ALGAE 1 compared with data for 8/ 7/2003.

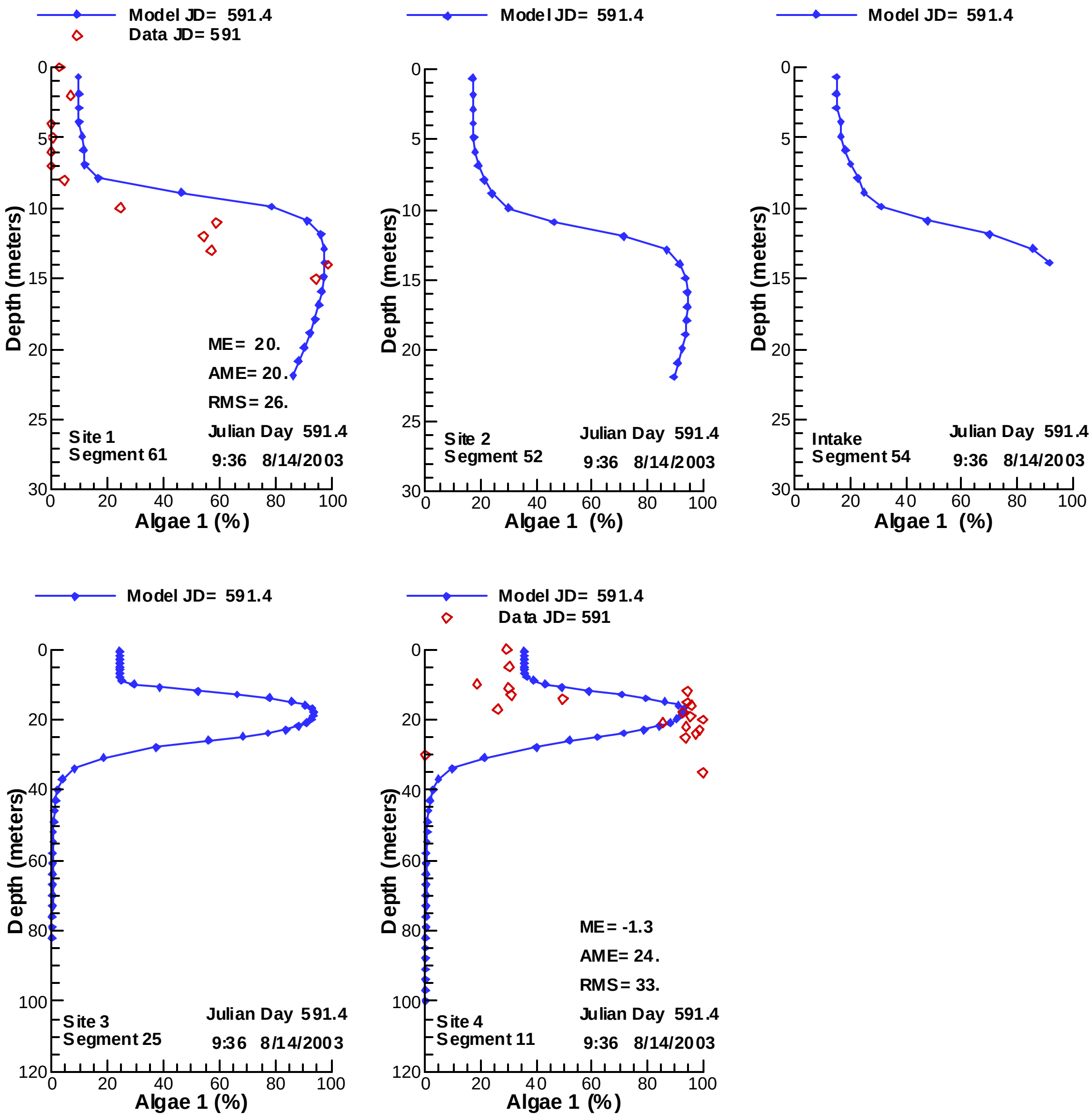

Figure 661. Vertical profiles of ALGAE 1 compared with data for 8/14/2003.

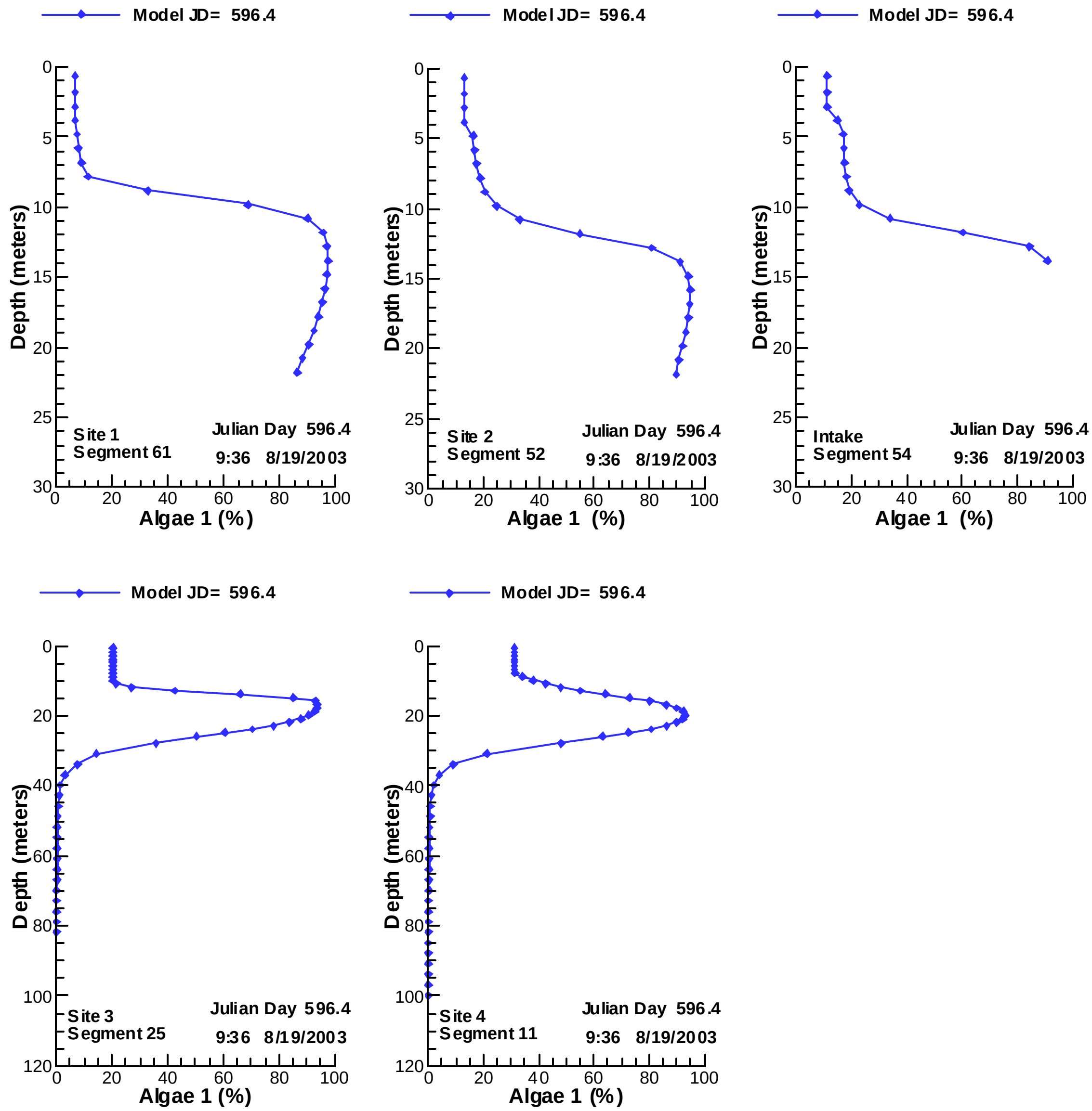

Figure 662. Vertical profiles of ALGAE 1 compared with data for 8/19/2003.

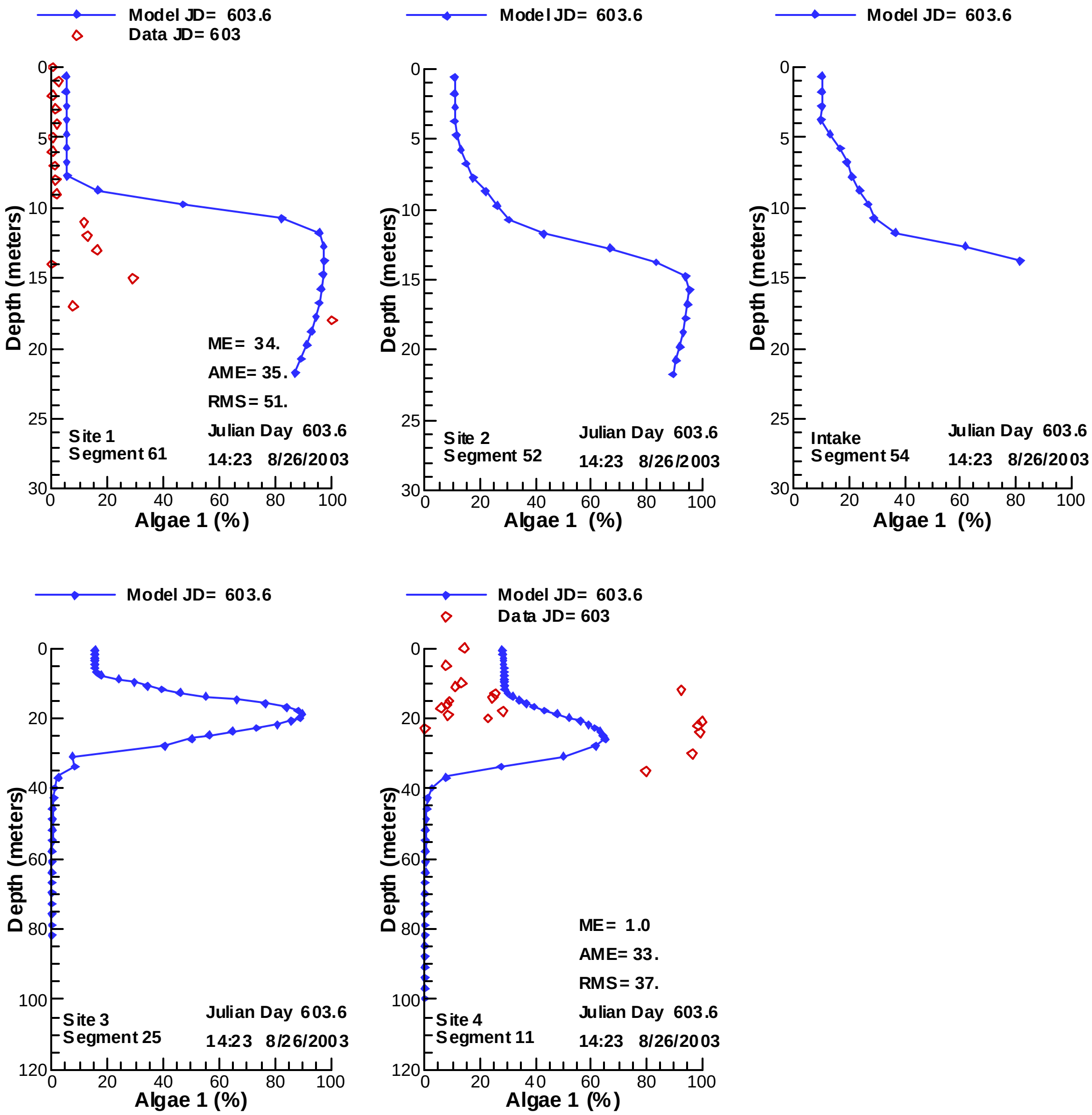

Figure 663. Vertical profiles of ALGAE 1 compared with data for 8/26/2003.

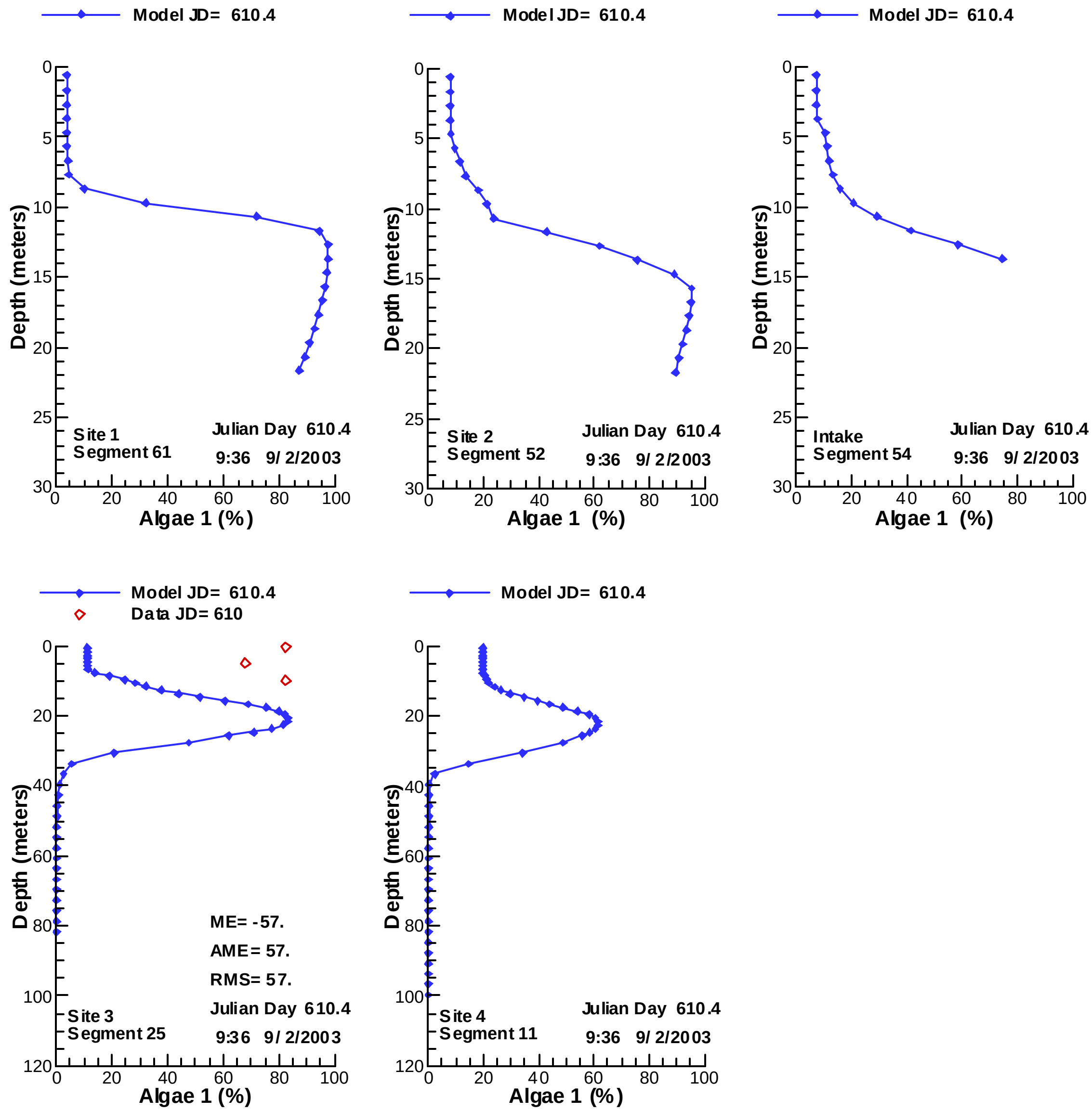

Figure 664. Vertical profiles of ALGAE 1 compared with data for 9/ 2/2003.

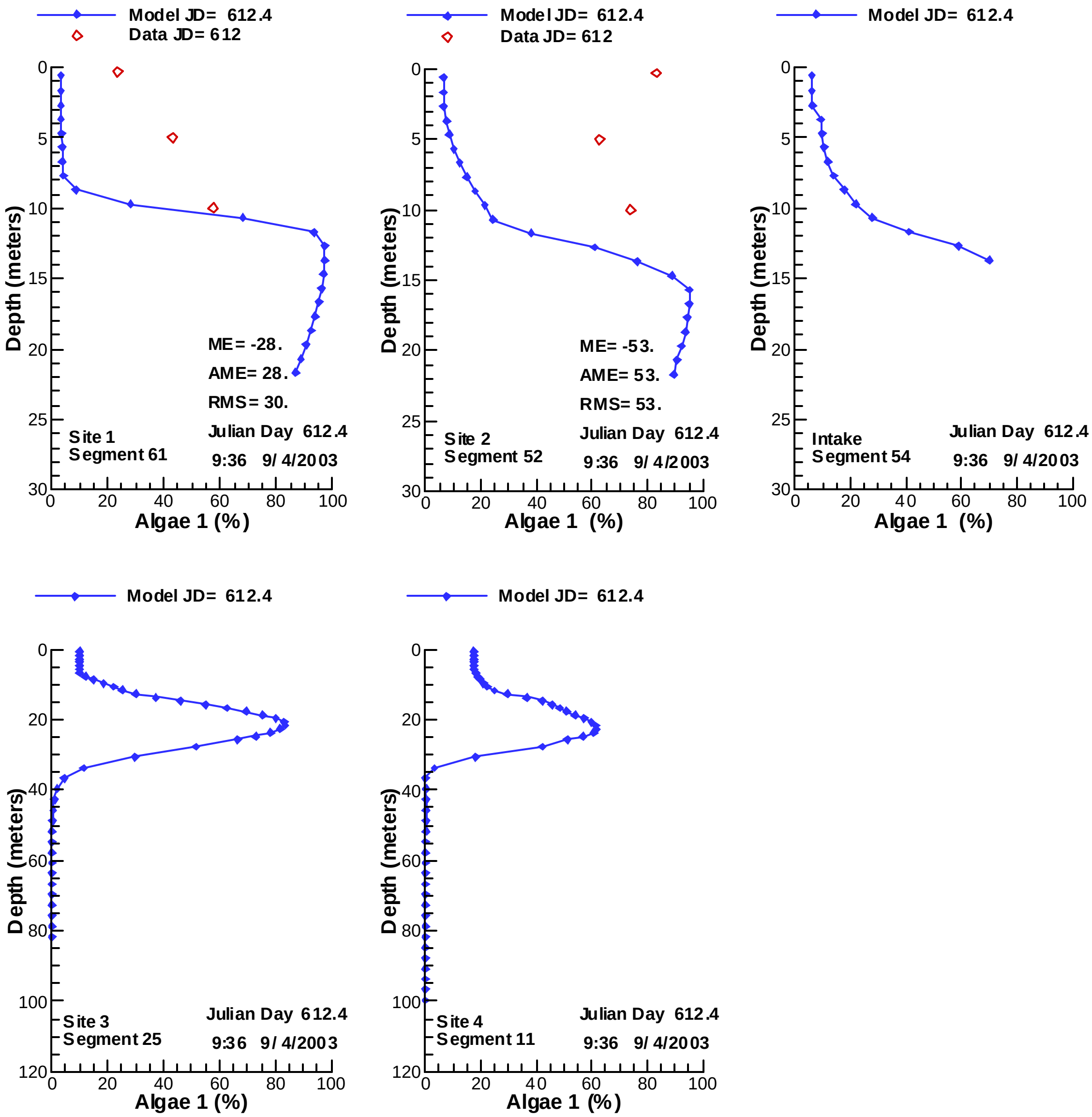

Figure 665. Vertical profiles of ALGAE 1 compared with data for 9/ 4/2003.

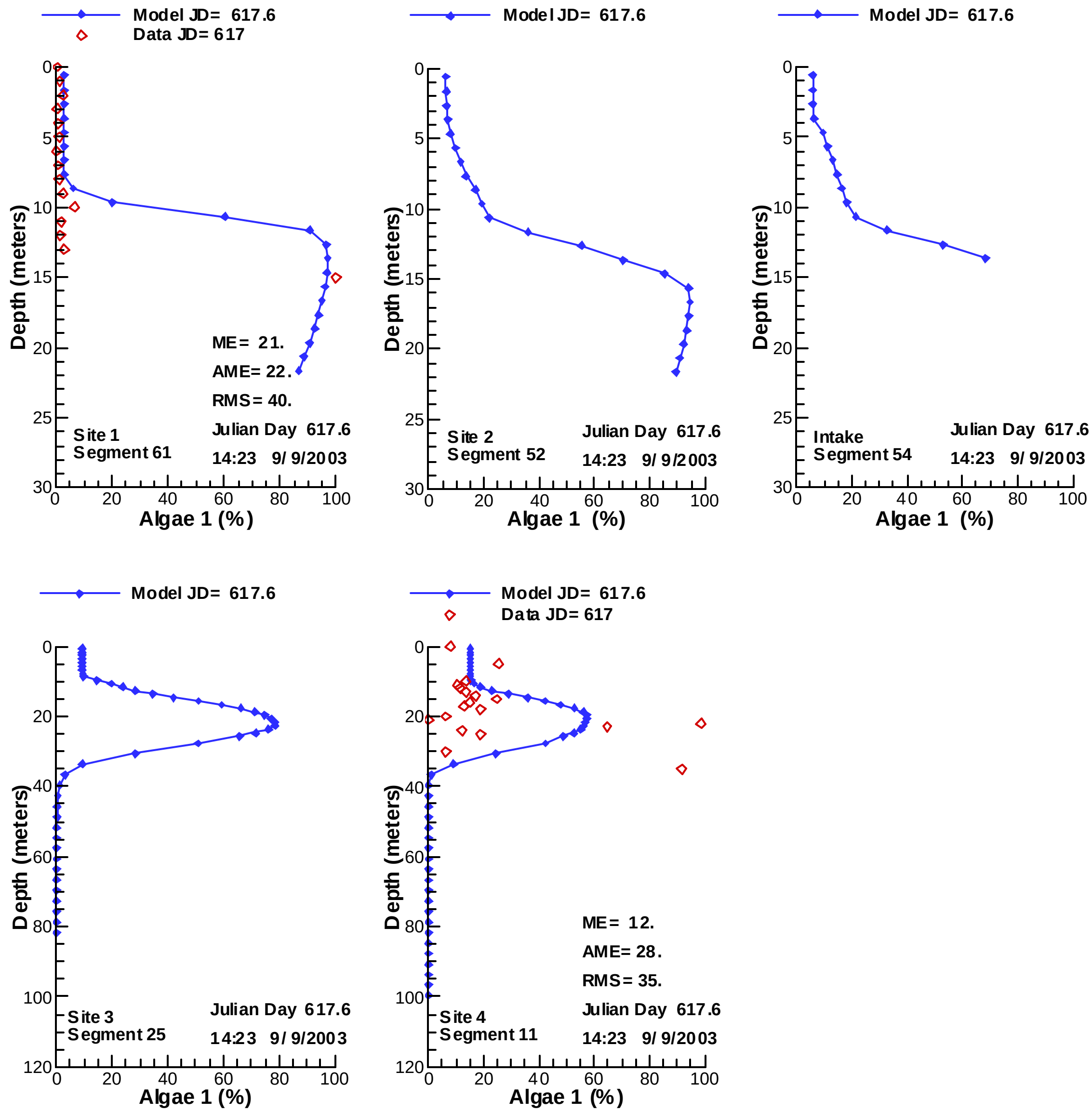

Figure 666. Vertical profiles of ALGAE 1 compared with data for 9/ 9/2003.

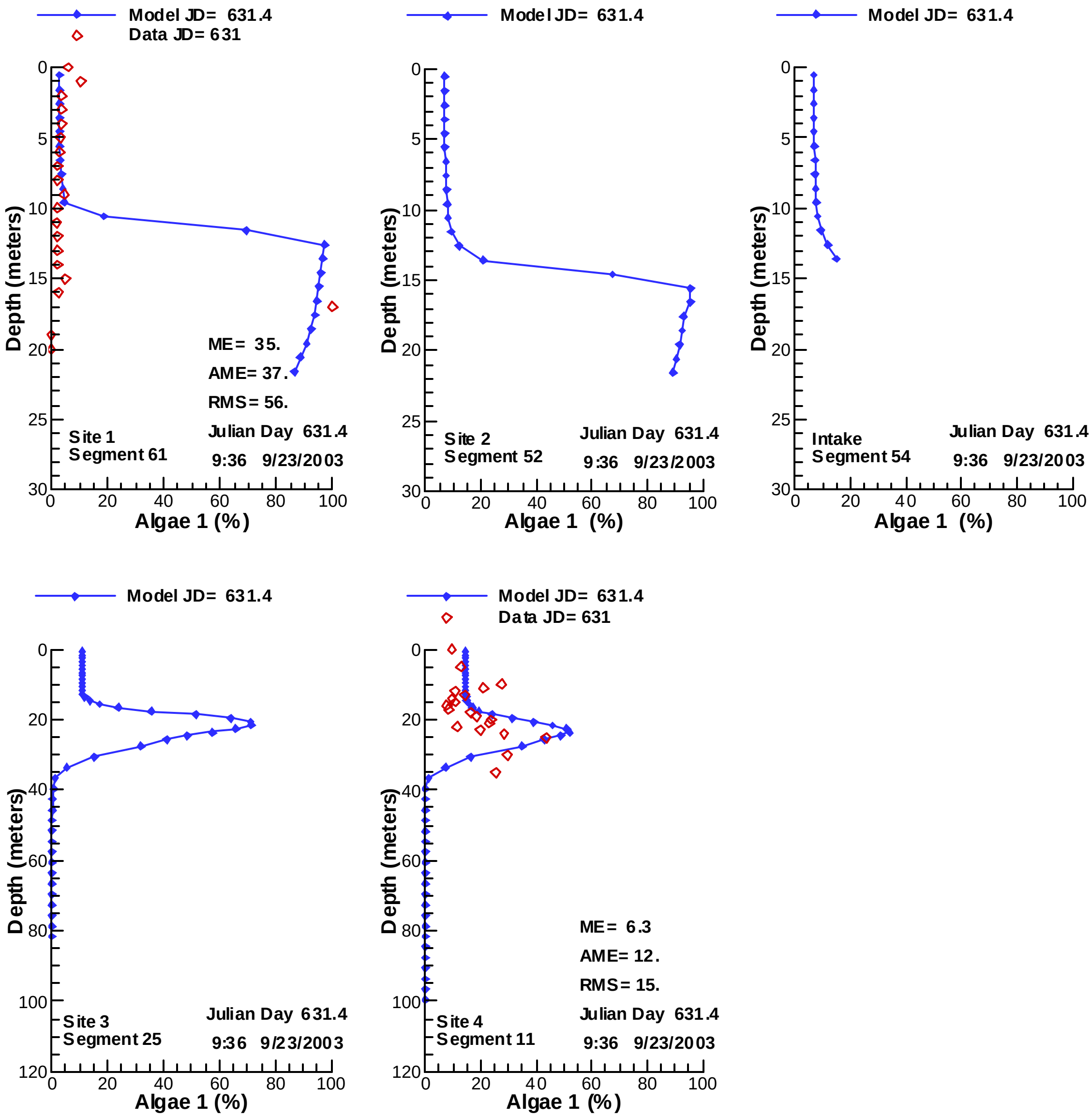

Figure 667. Vertical profiles of ALGAE 1 compared with data for 9/23/2003.

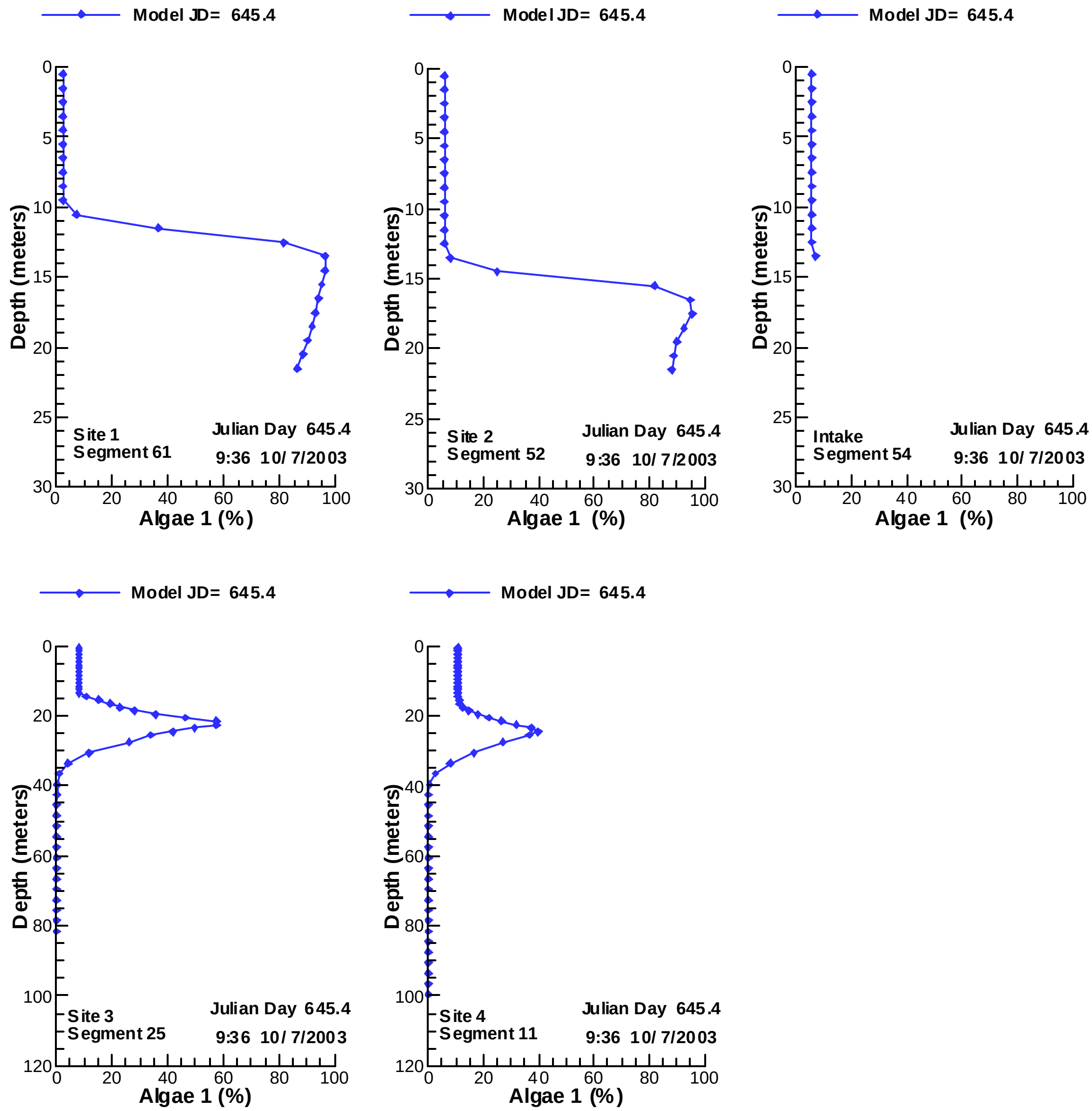

Figure 668. Vertical profiles of ALGAE 1 compared with data for 10/ 7/2003.

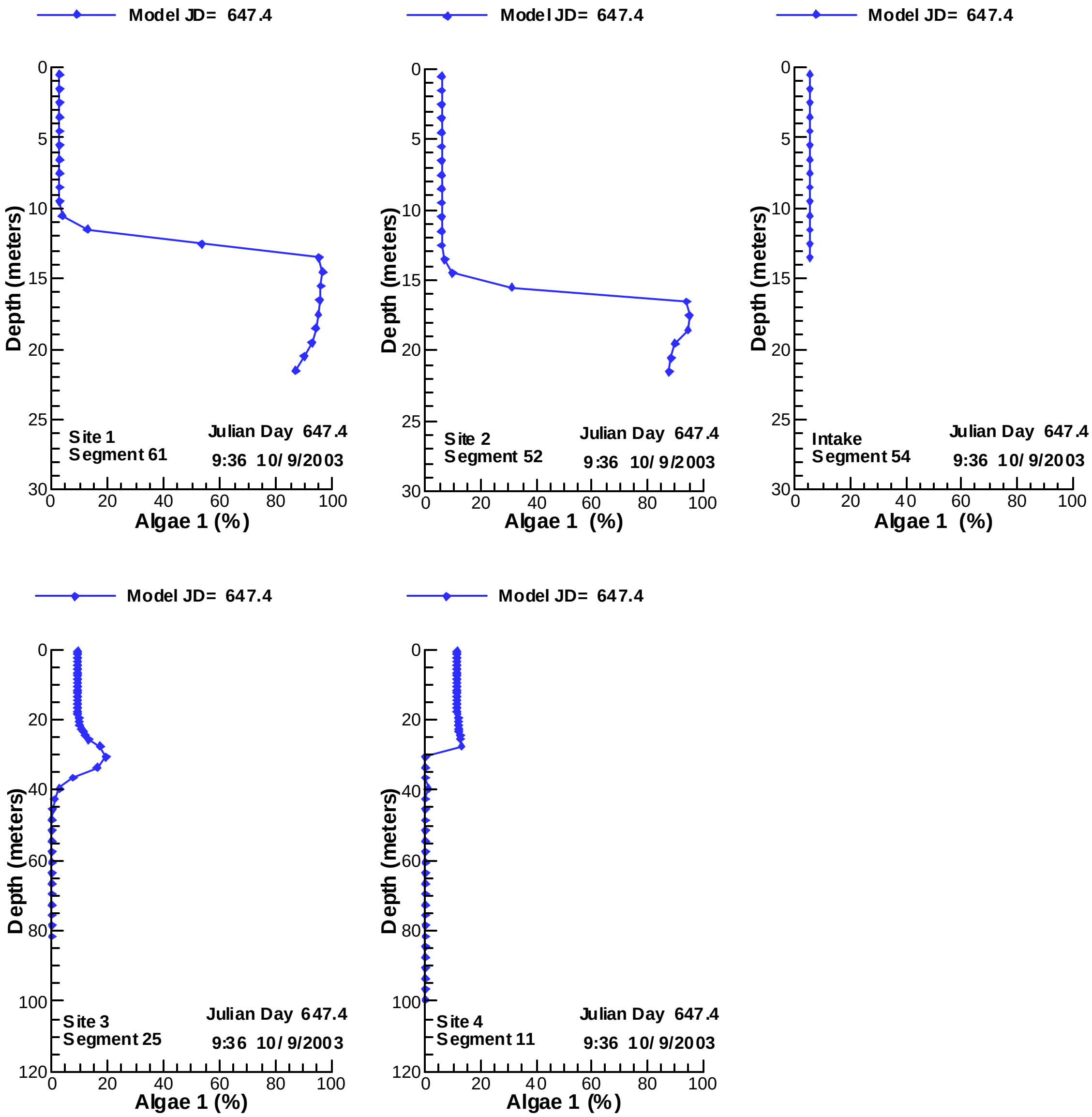

Figure 669. Vertical profiles of ALGAE 1 compared with data for 10/ 9/2003.

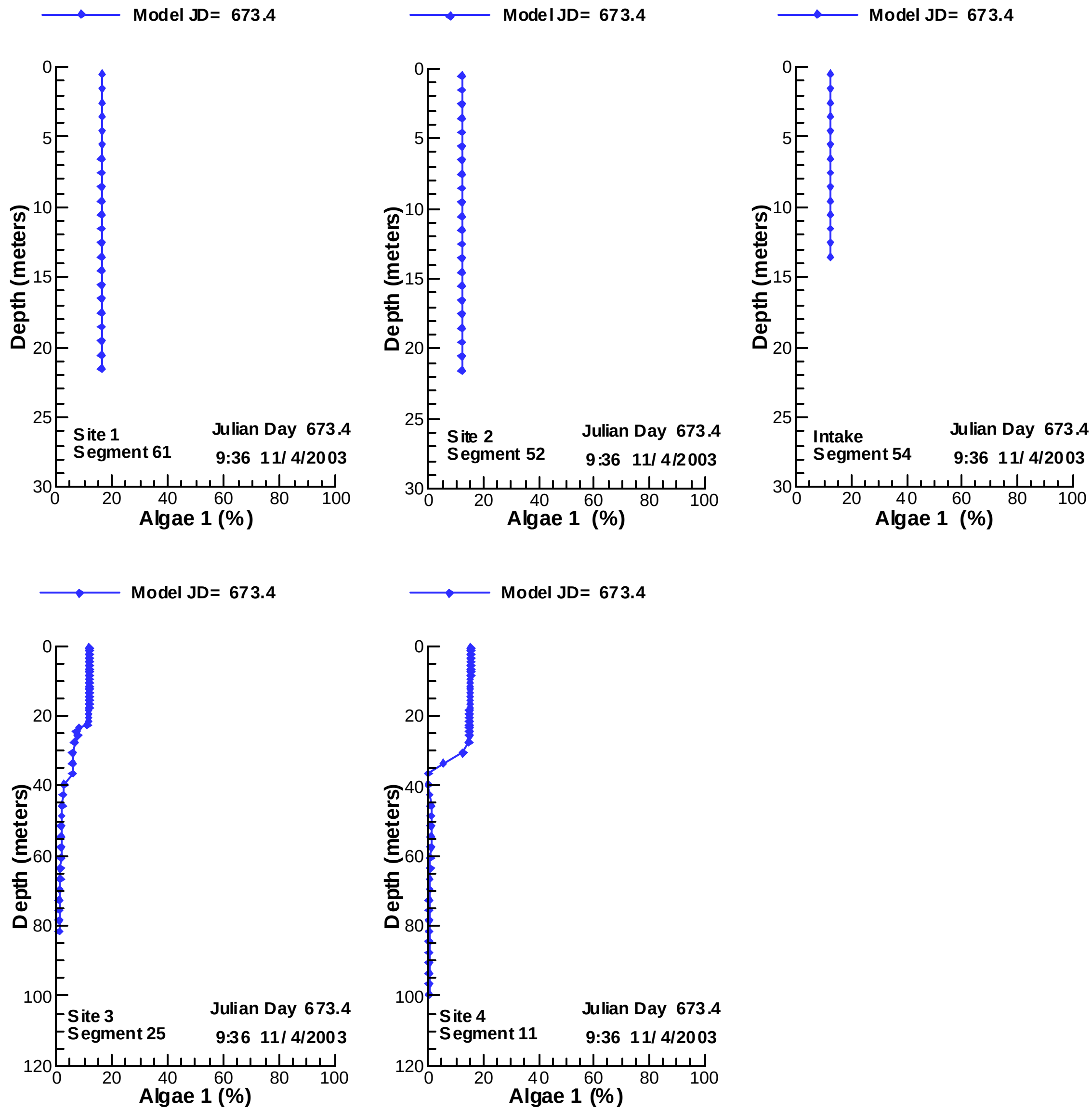

Figure 670. Vertical profiles of ALGAE 1 compared with data for 11/ 4/2003.

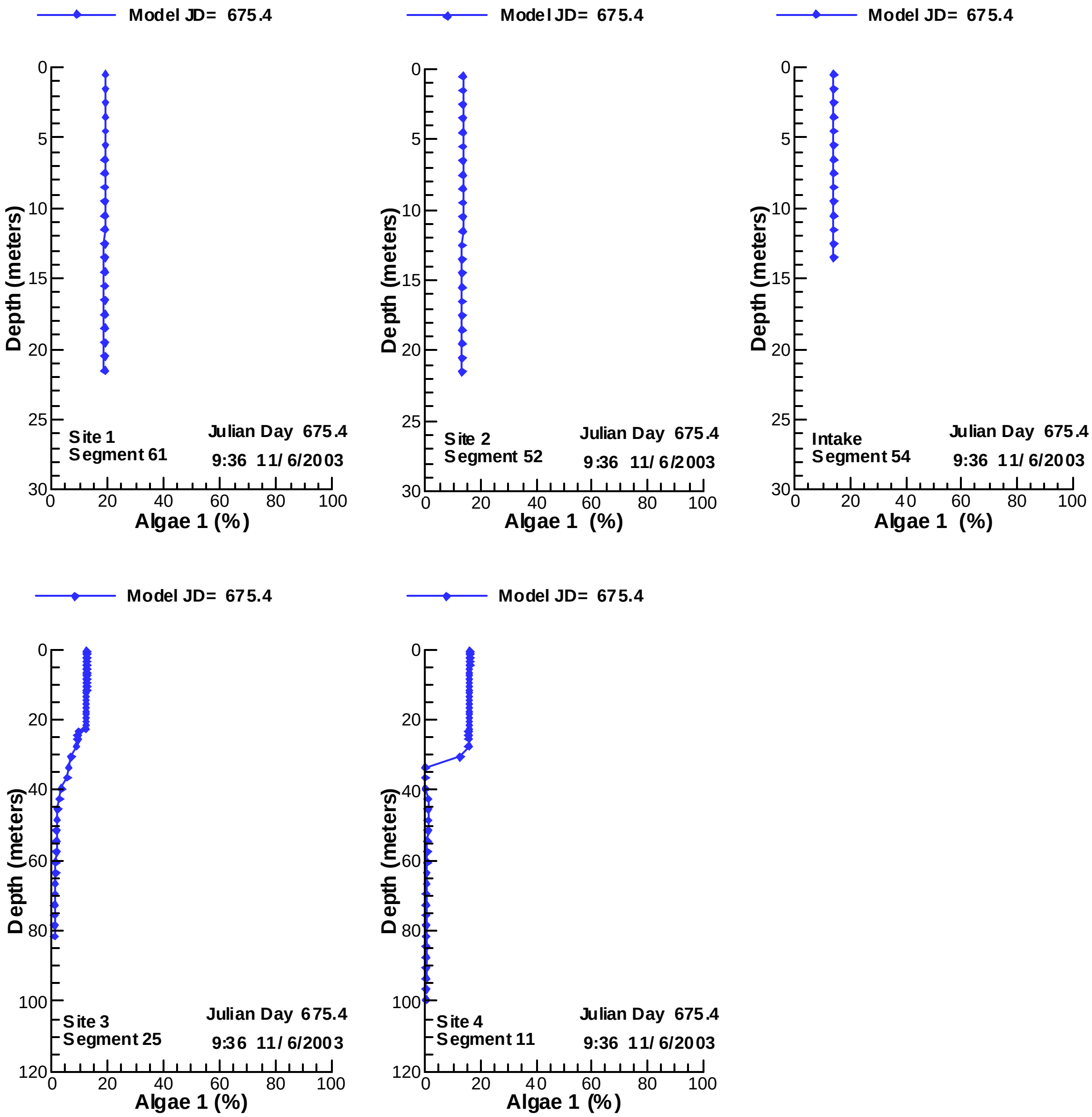

Figure 671. Vertical profiles of ALGAE 1 compared with data for 11/ 6/2003.

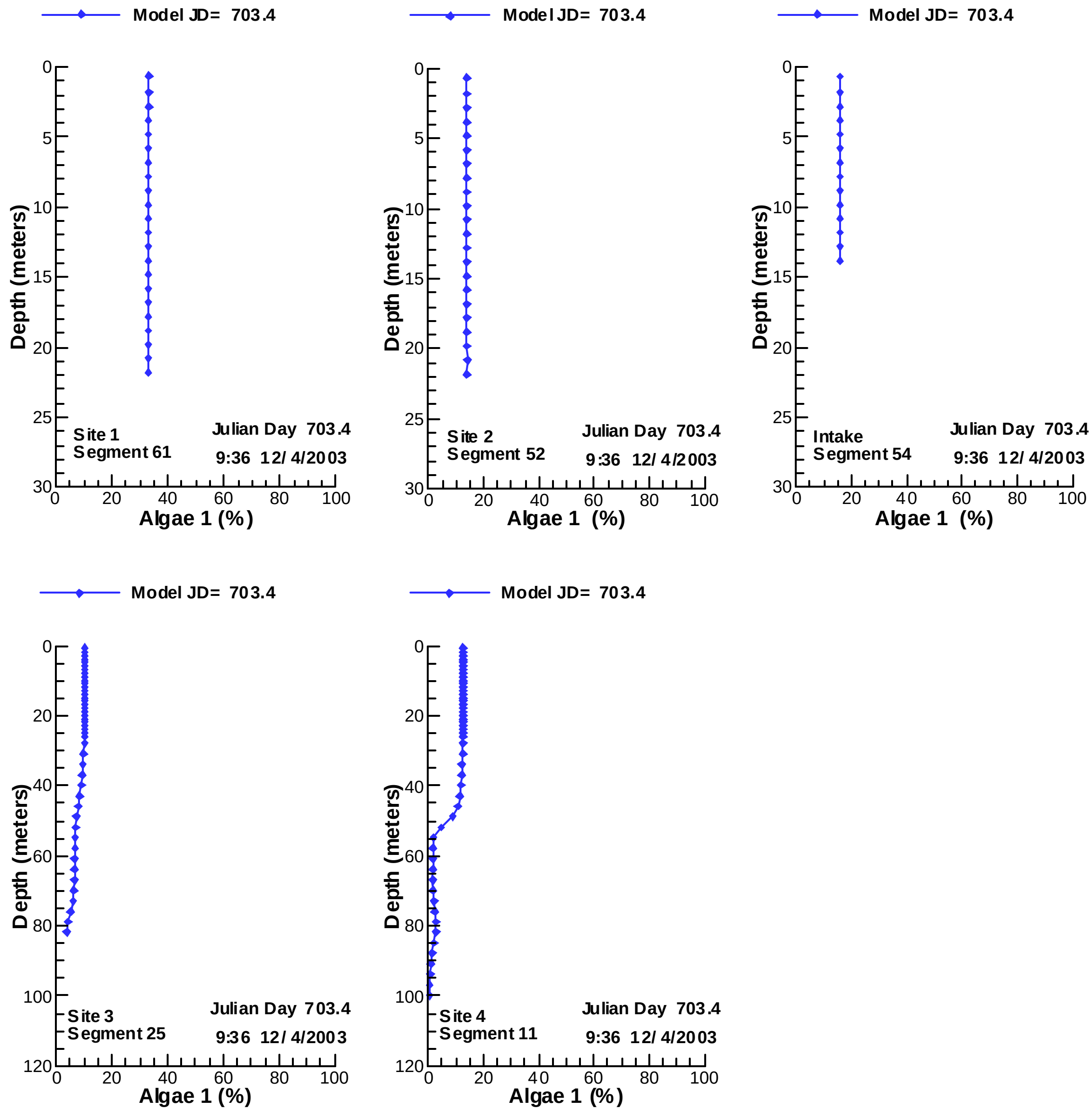

Figure 672. Vertical profiles of ALGAE 1 compared with data for 12/ 4/2003.

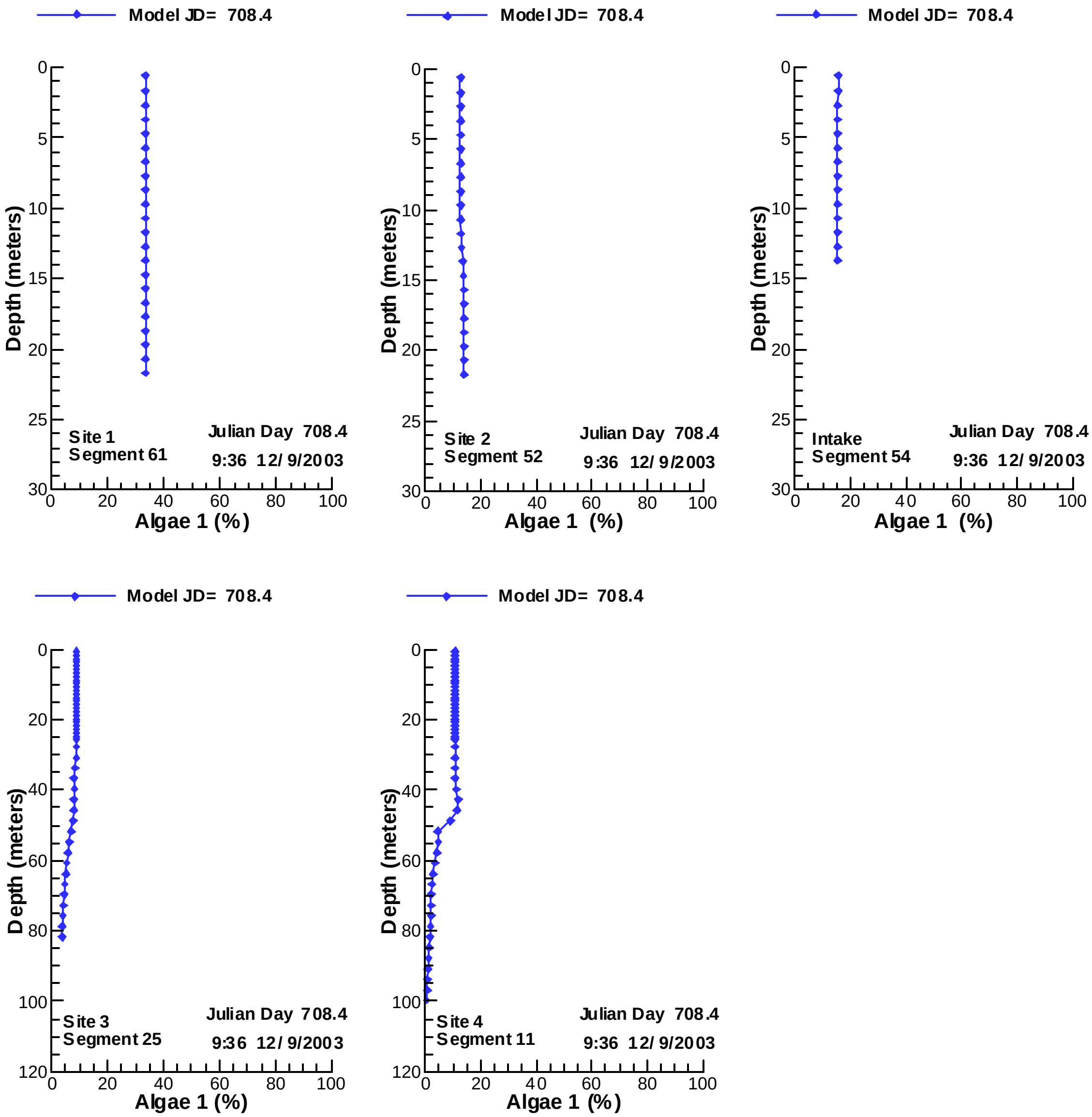

Figure 673. Vertical profiles of ALGAE 1 compared with data for 12/ 9/2003.

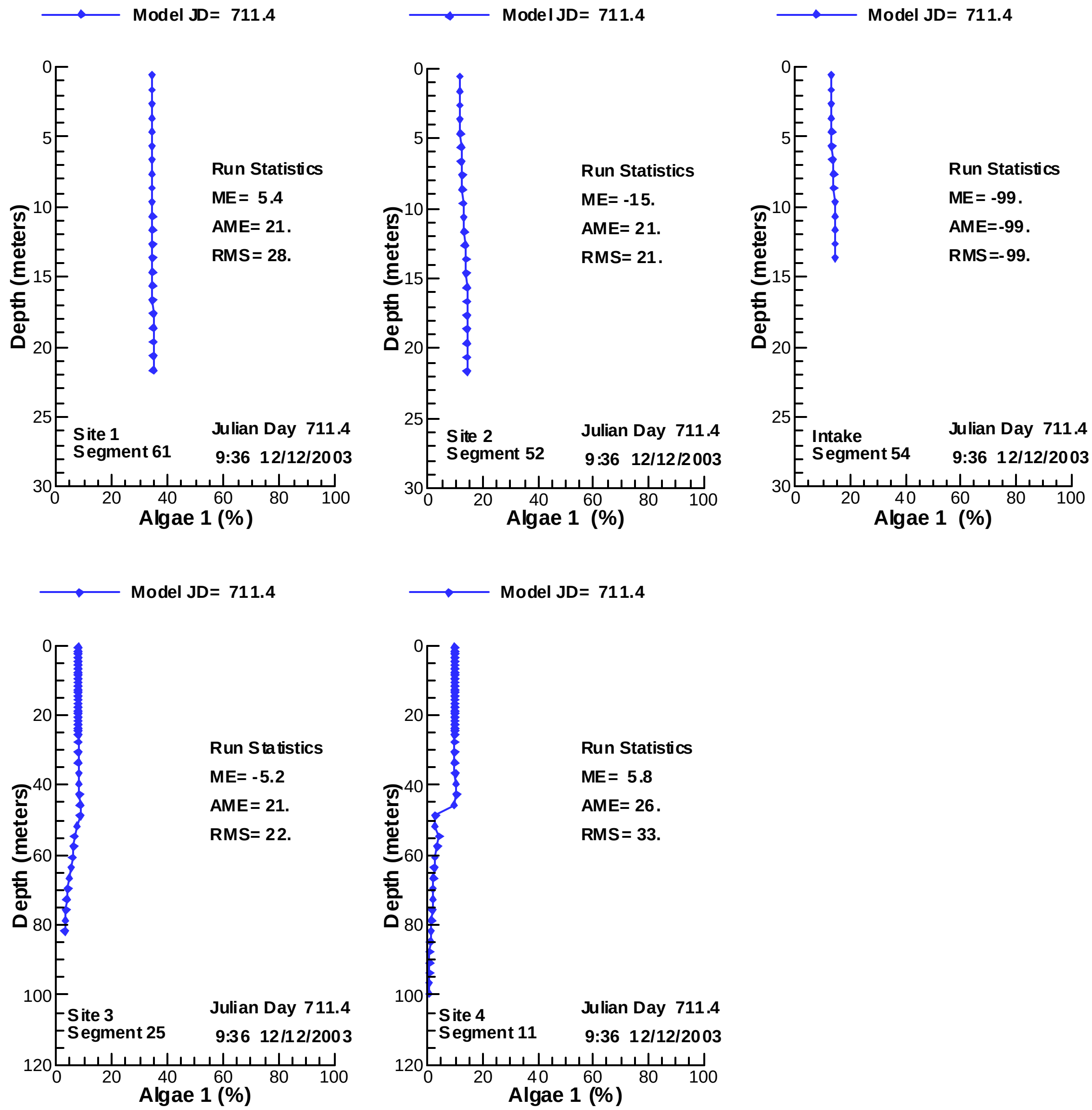

Figure 674. Vertical profiles of ALGAE 1 compared with data for 12/12/2003.

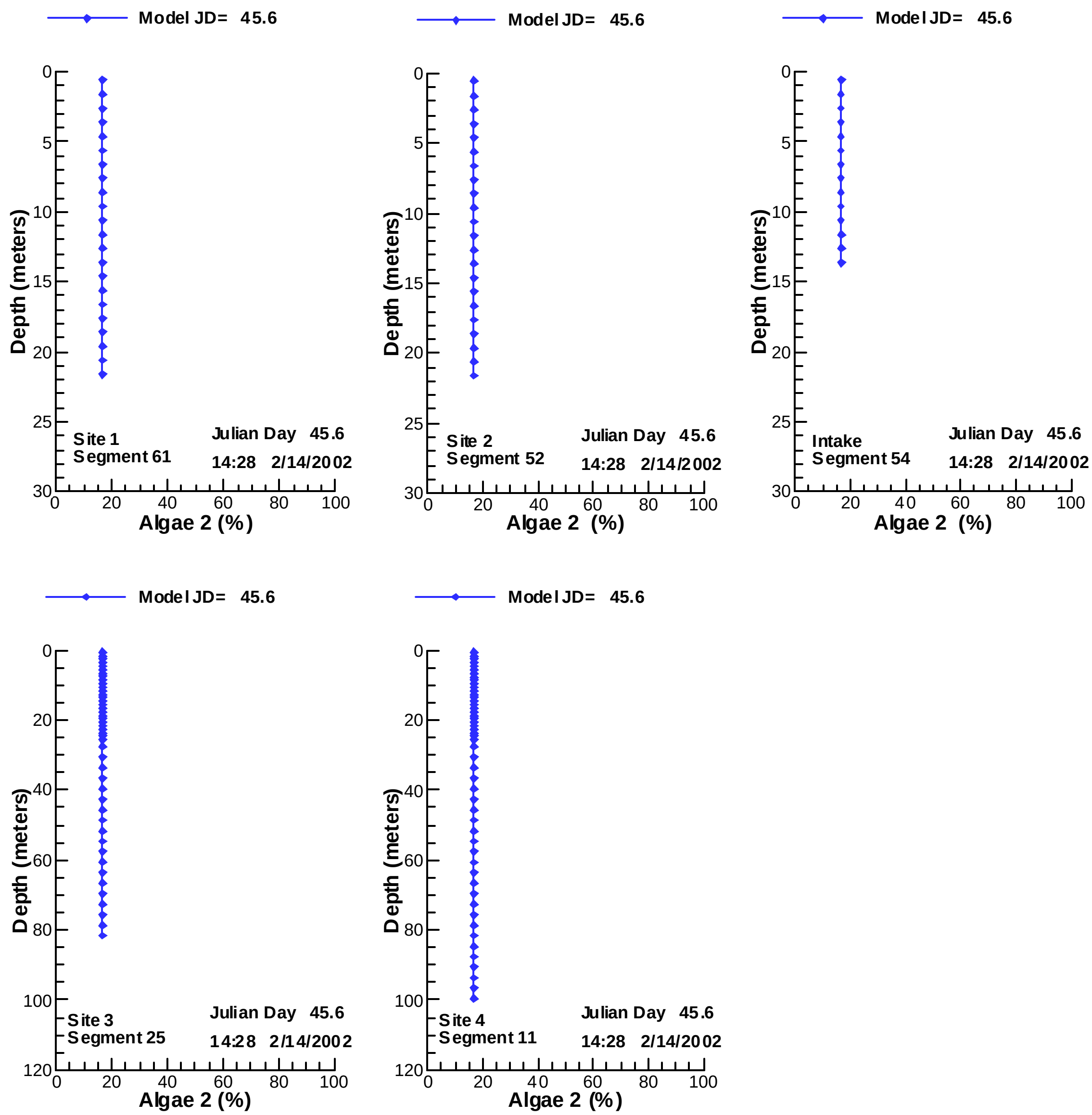

Figure 675. Vertical profiles of ALGAE 2 compared with data for 2/14/2002.

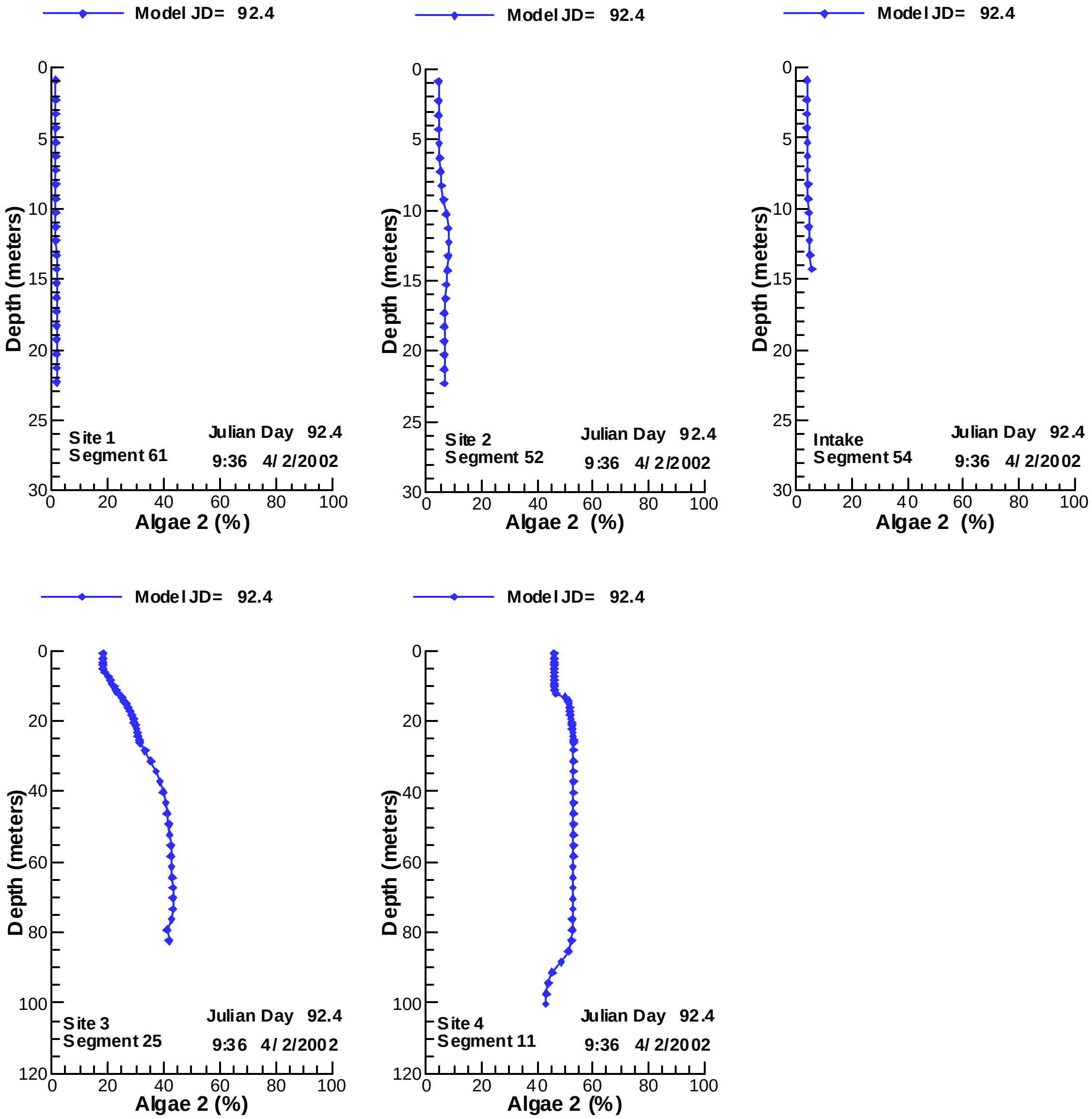

Figure 676. Vertical profiles of ALGAE 2 compared with data for 4/ 2/2002.

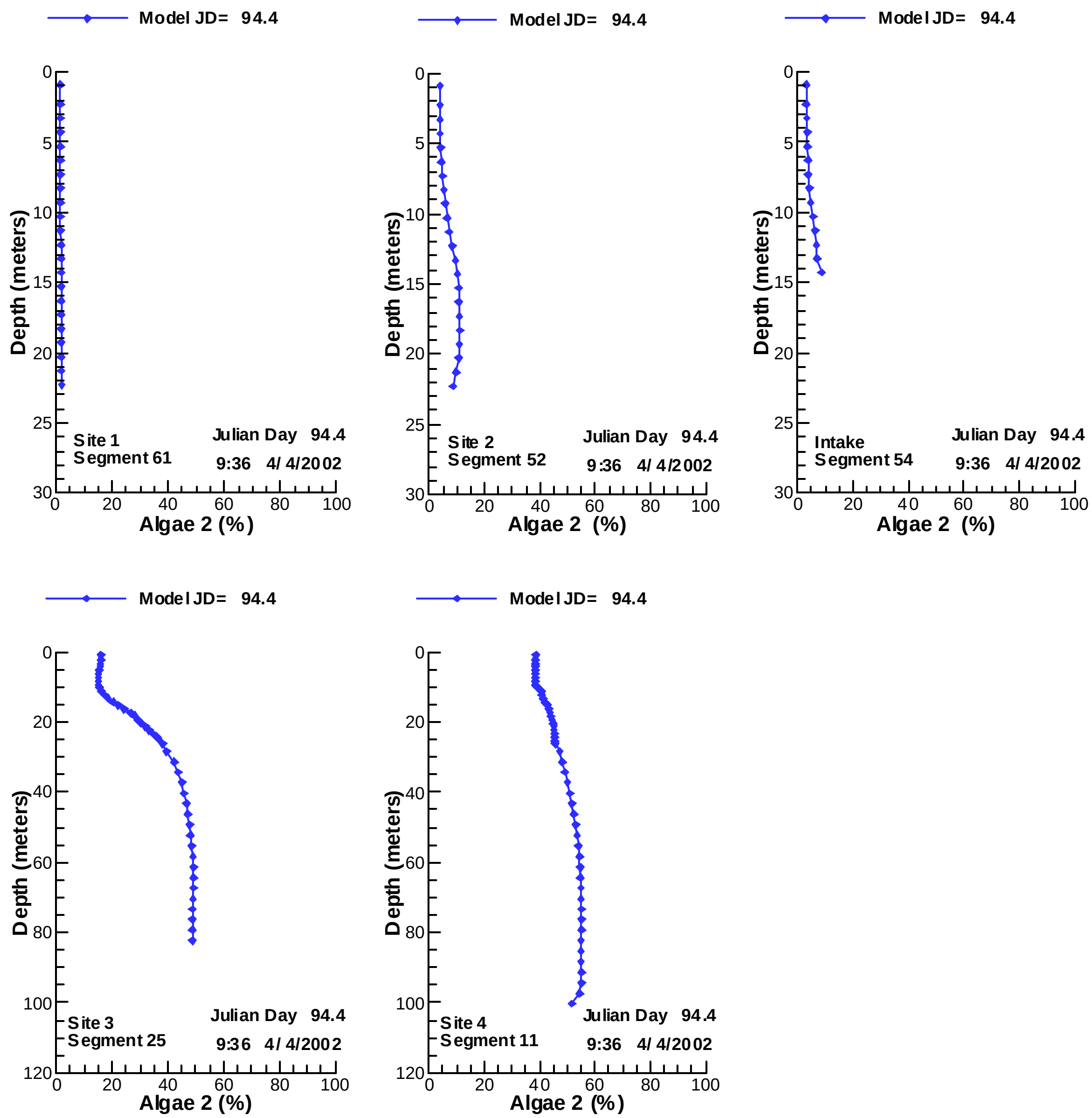

Figure 677. Vertical profiles of ALGAE 2 compared with data for 4/ 4/2002.

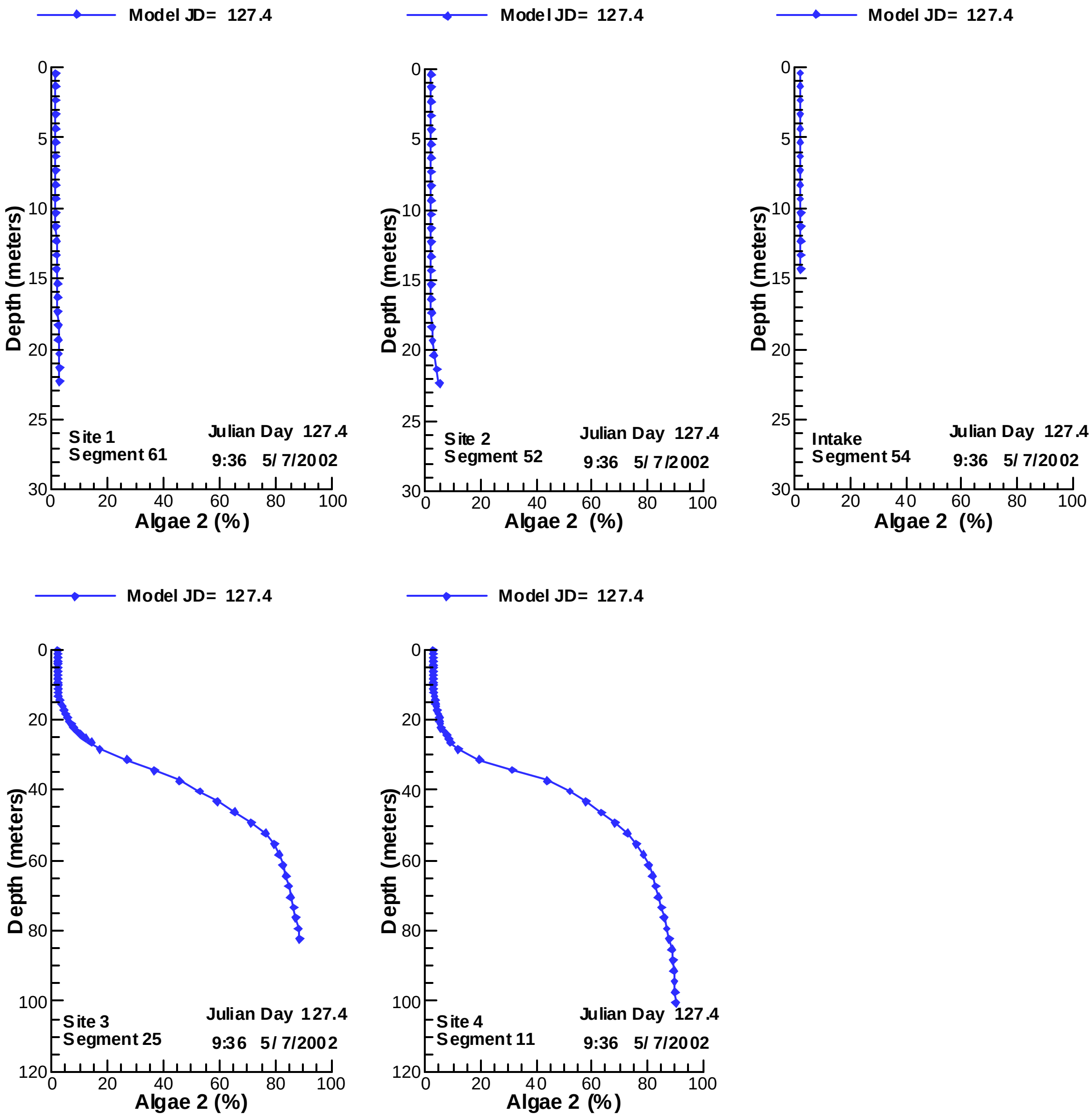

Figure 678. Vertical profiles of ALGAE 2 compared with data for 5/ 7/2002.

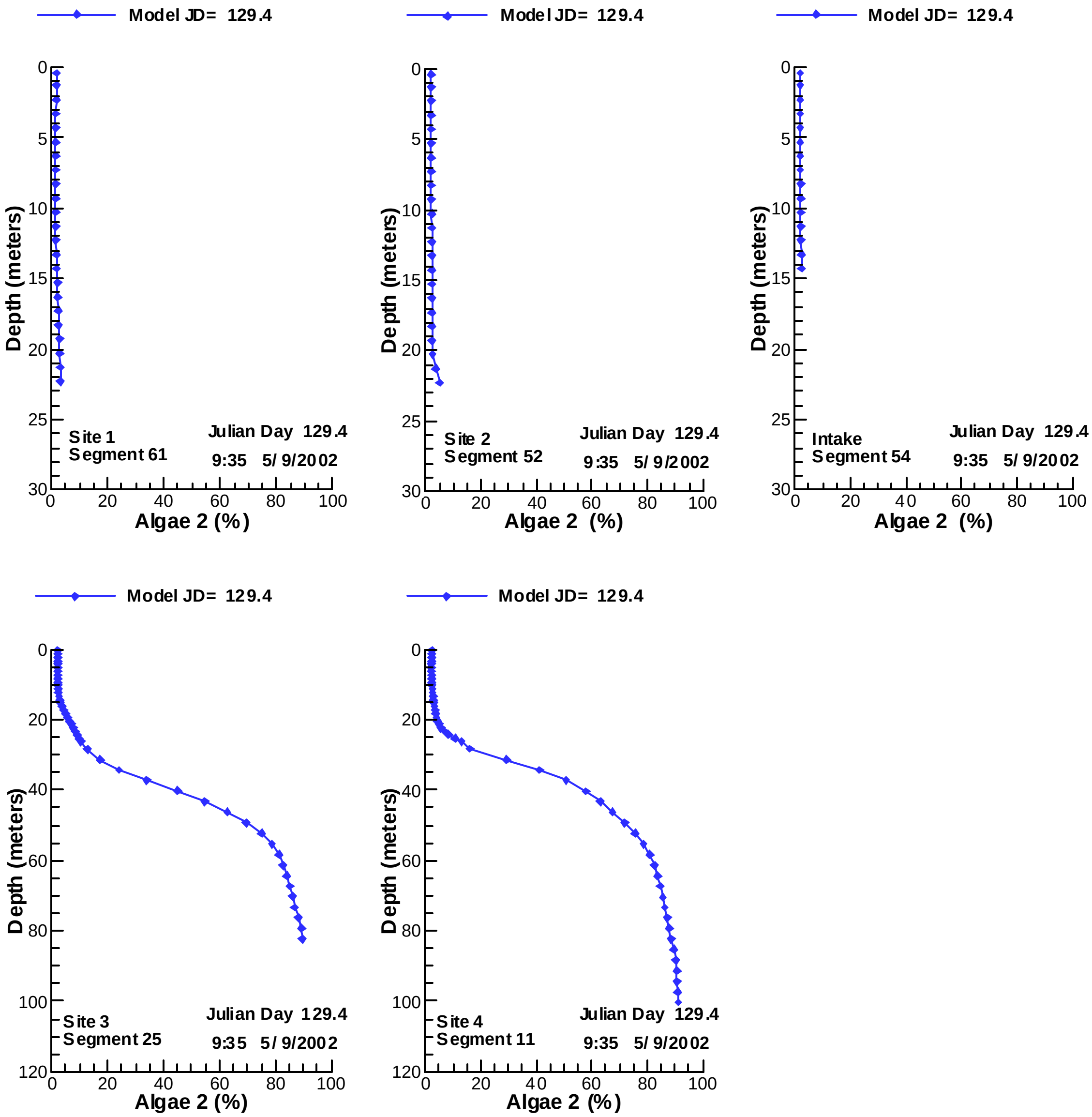

Figure 679. Vertical profiles of ALGAE 2 compared with data for 5/ 9/2002.

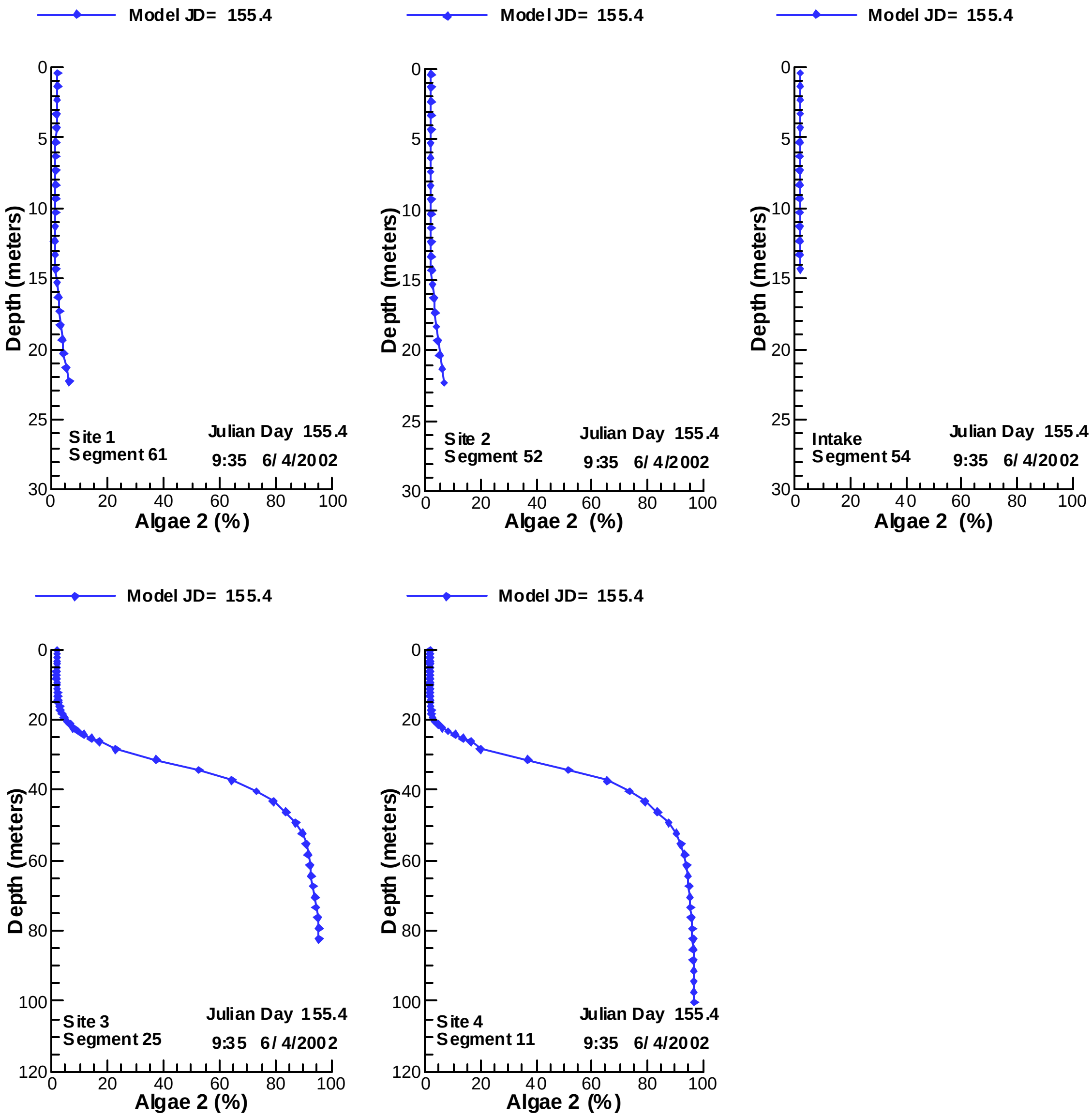

Figure 680. Vertical profiles of ALGAE 2 compared with data for 6/ 4/2002.

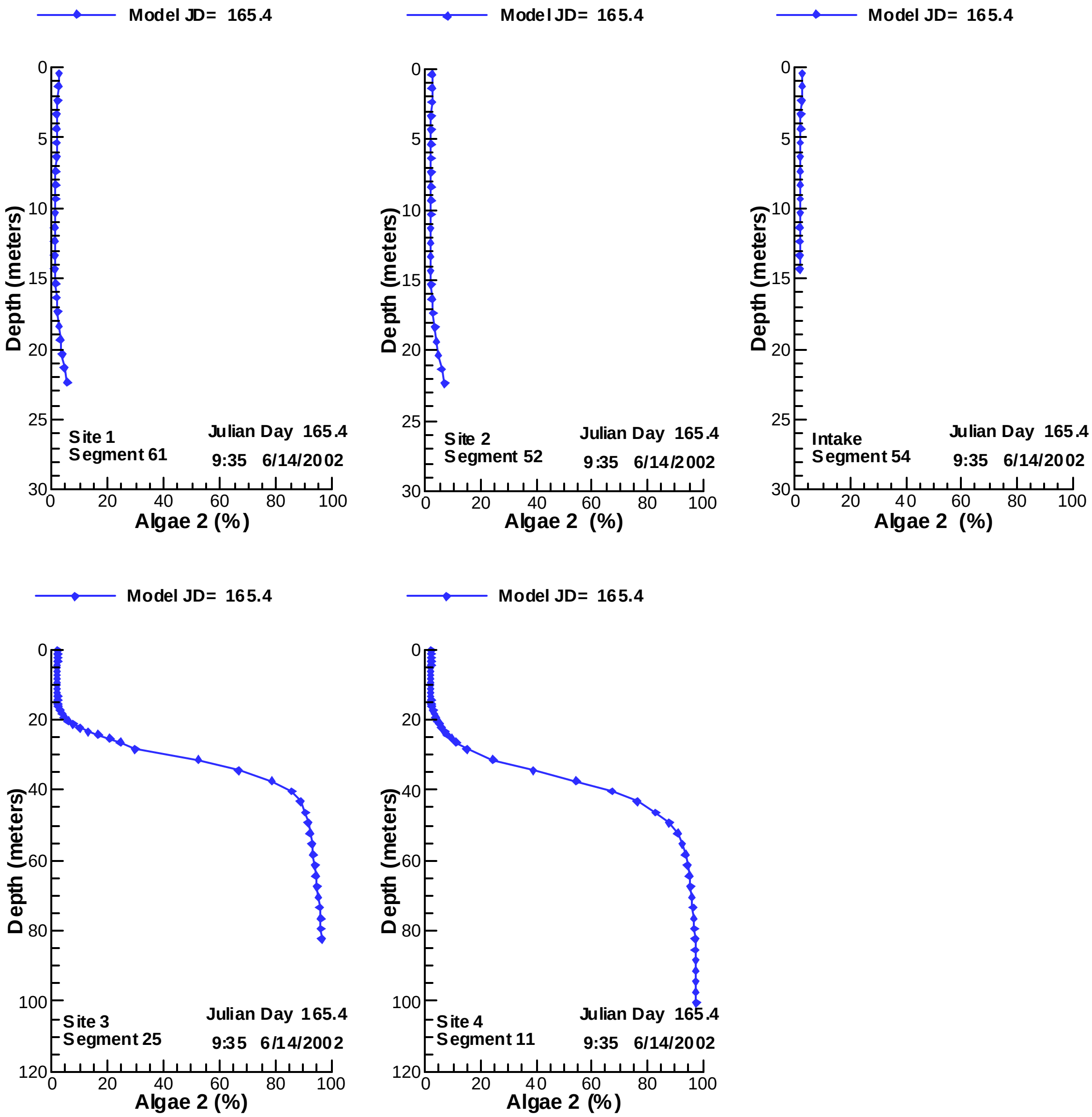

Figure 681. Vertical profiles of ALGAE 2 compared with data for 6/14/2002.

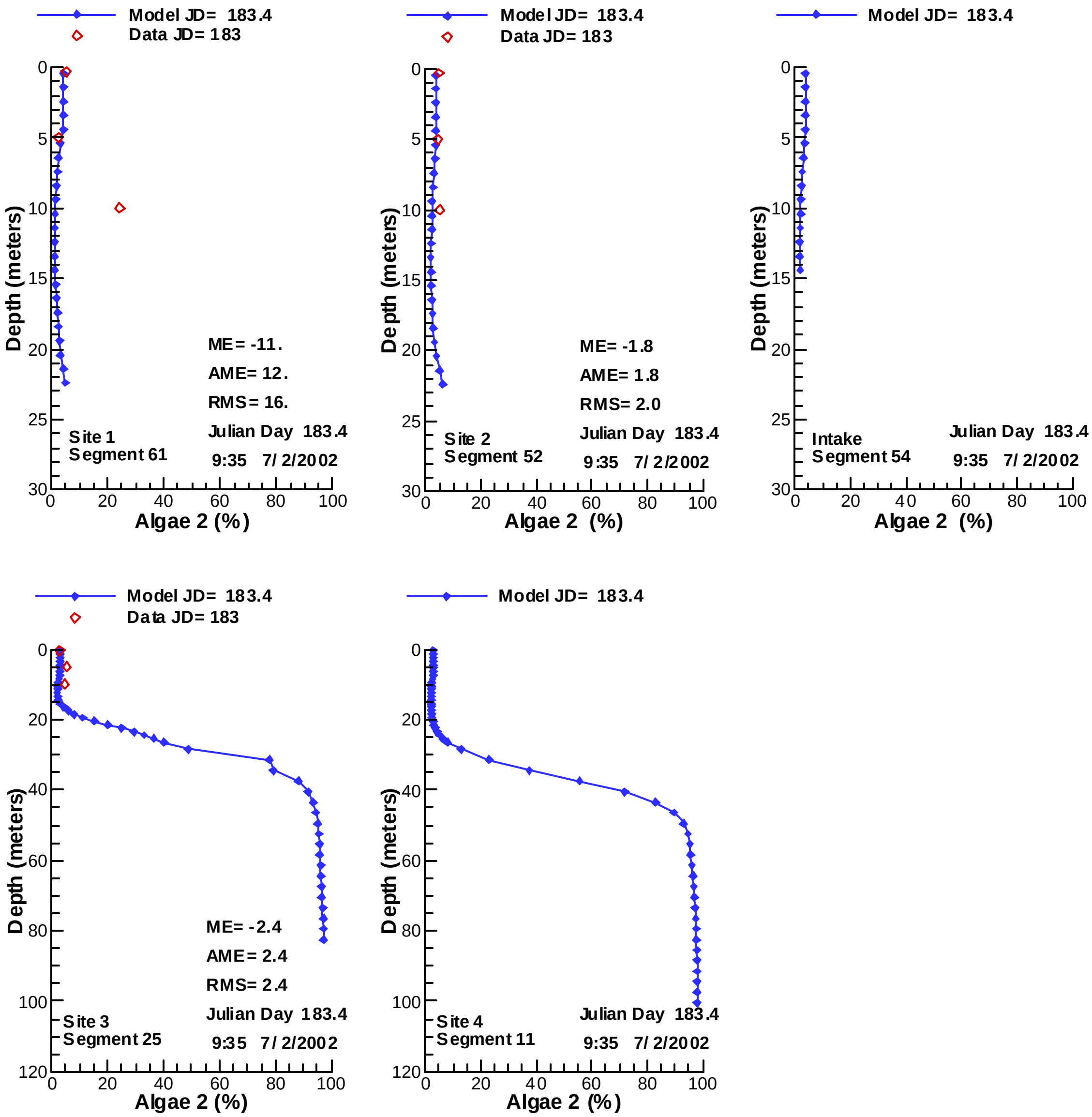

Figure 682. Vertical profiles of ALGAE 2 compared with data for 7/ 2/2002.

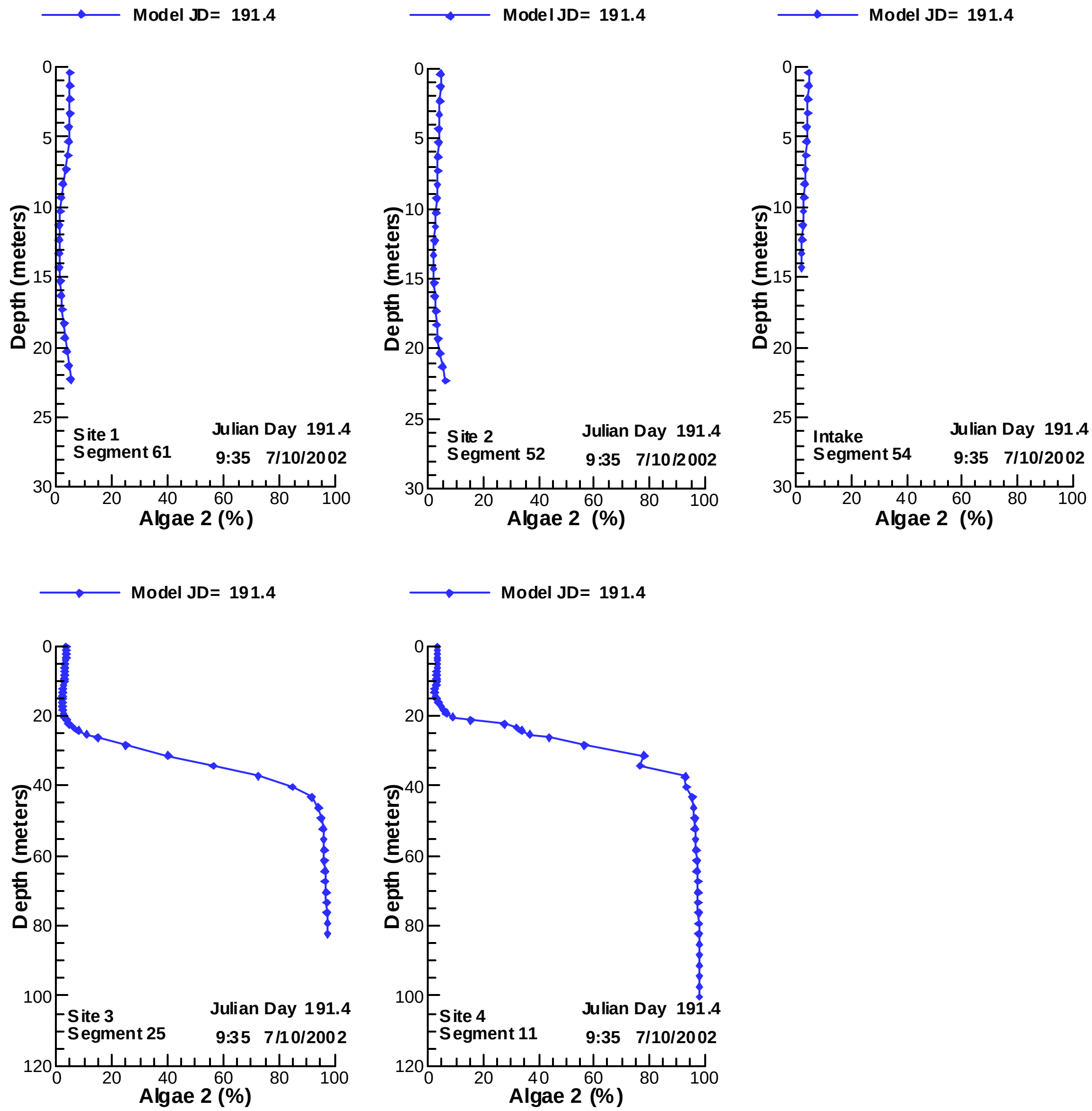

Figure 683. Vertical profiles of ALGAE 2 compared with data for 7/10/2002.

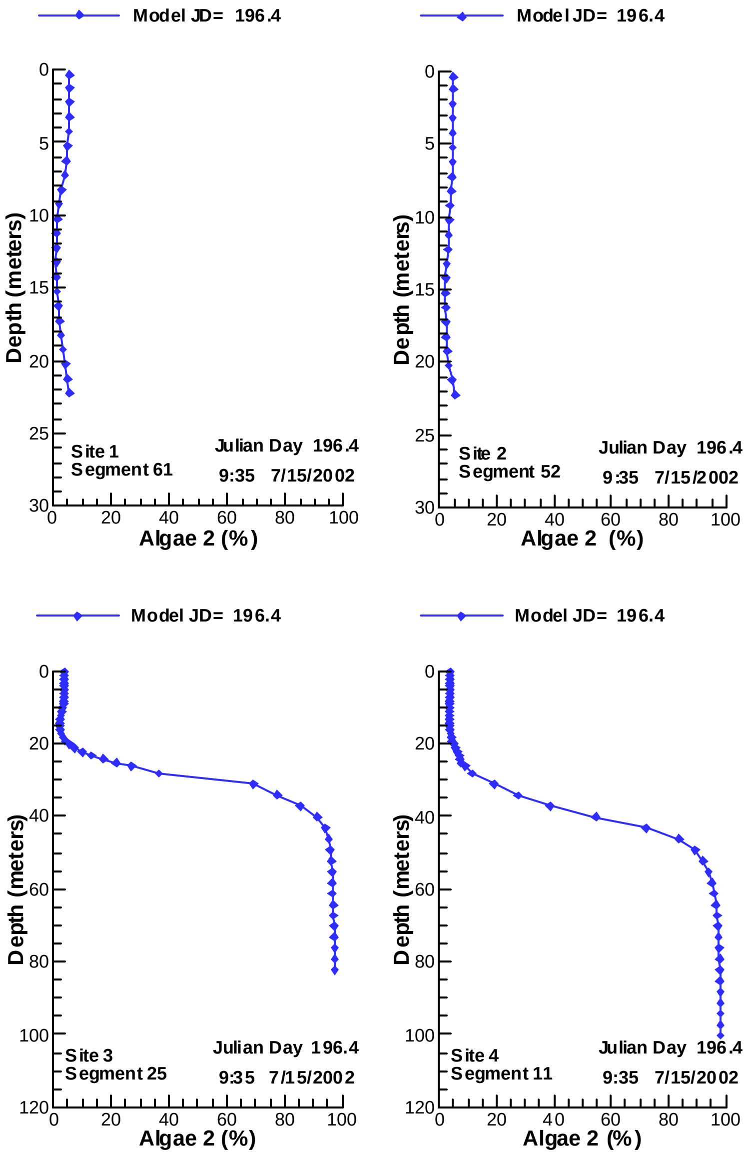

Figure 684. Vertical profiles of ALGAE 2 compared with data for 7/15/2002.

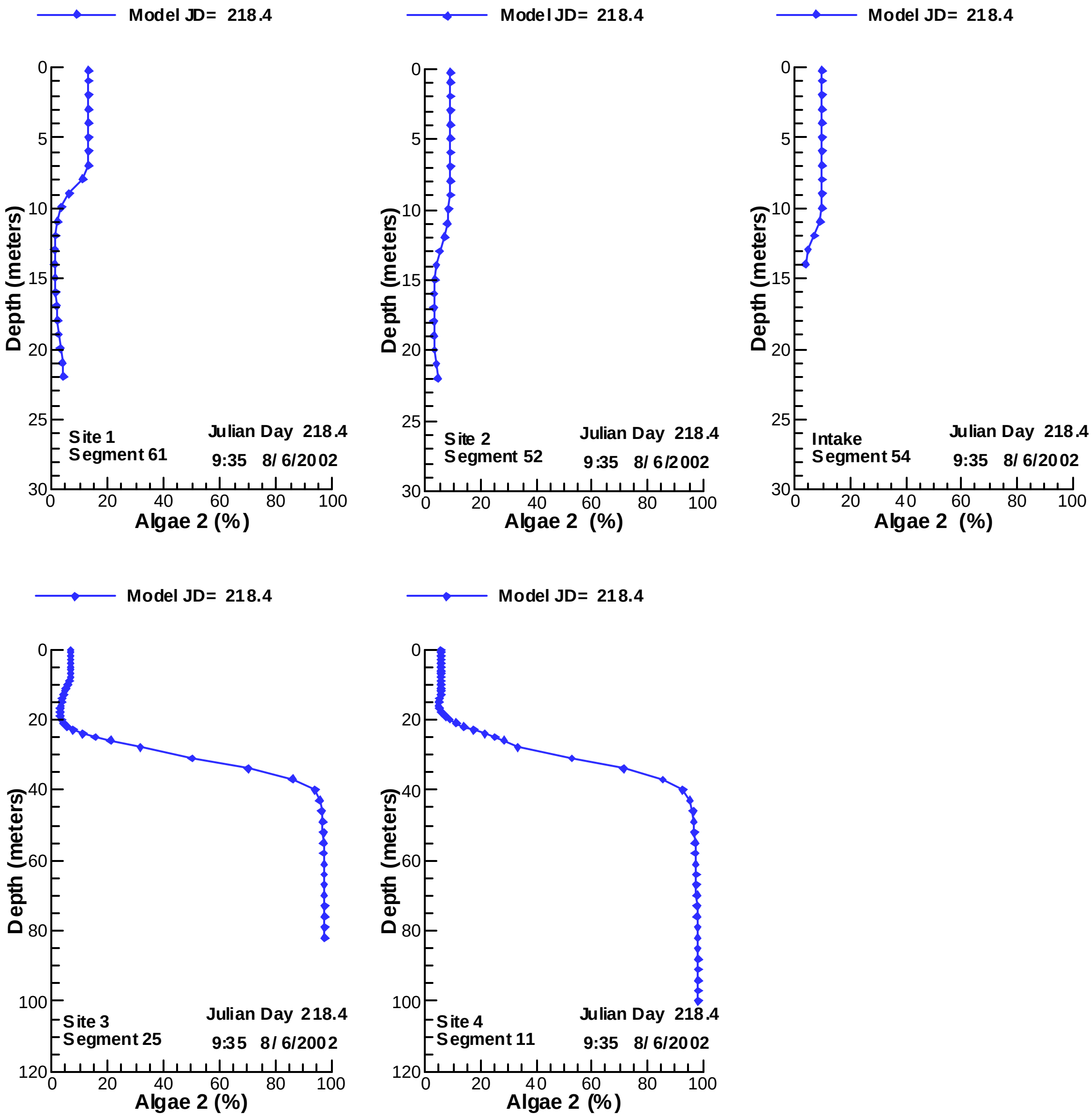

Figure 685. Vertical profiles of ALGAE 2 compared with data for 8/ 6/2002.

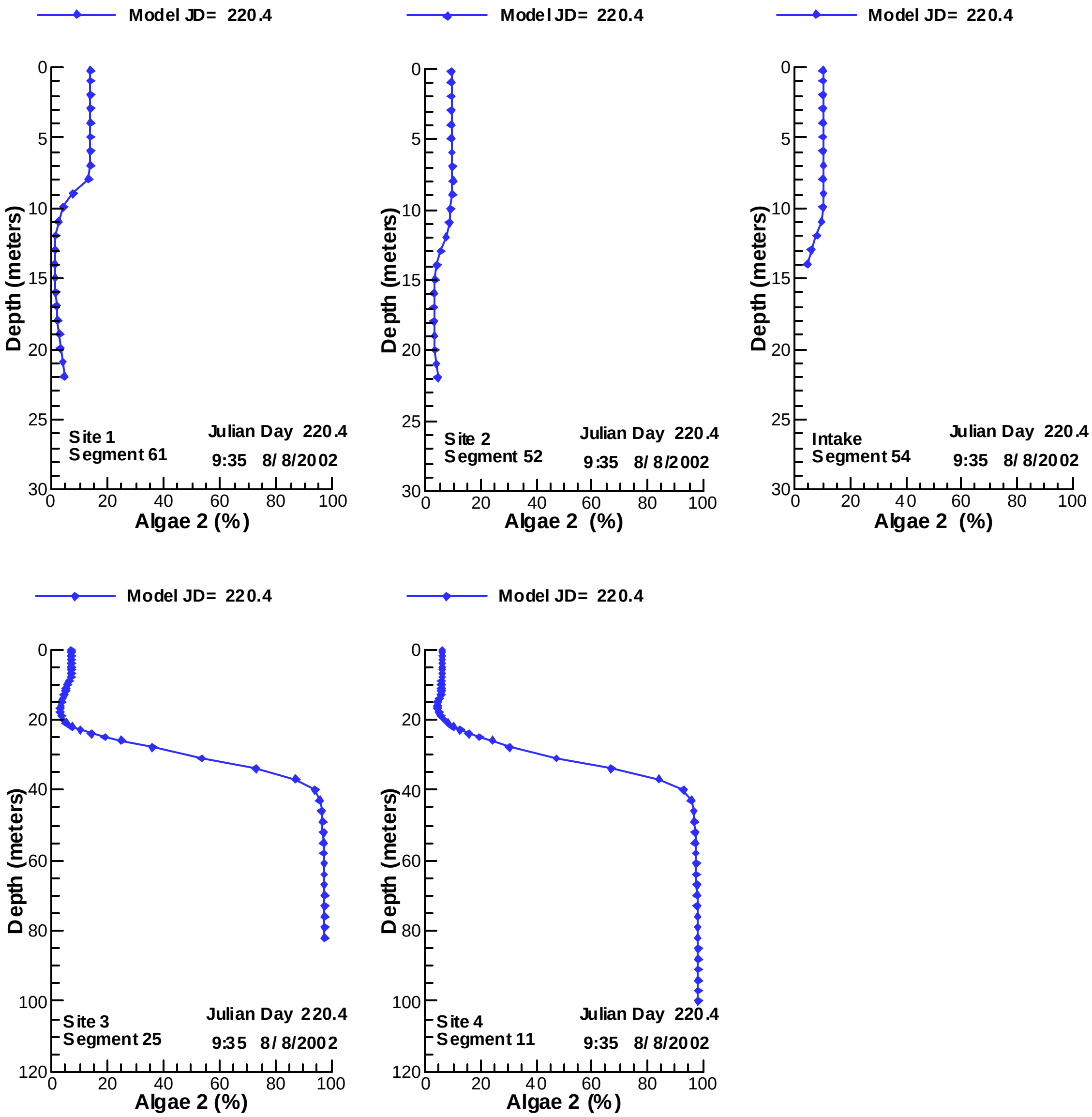

Figure 686. Vertical profiles of ALGAE 2 compared with data for 8/ 8/2002.

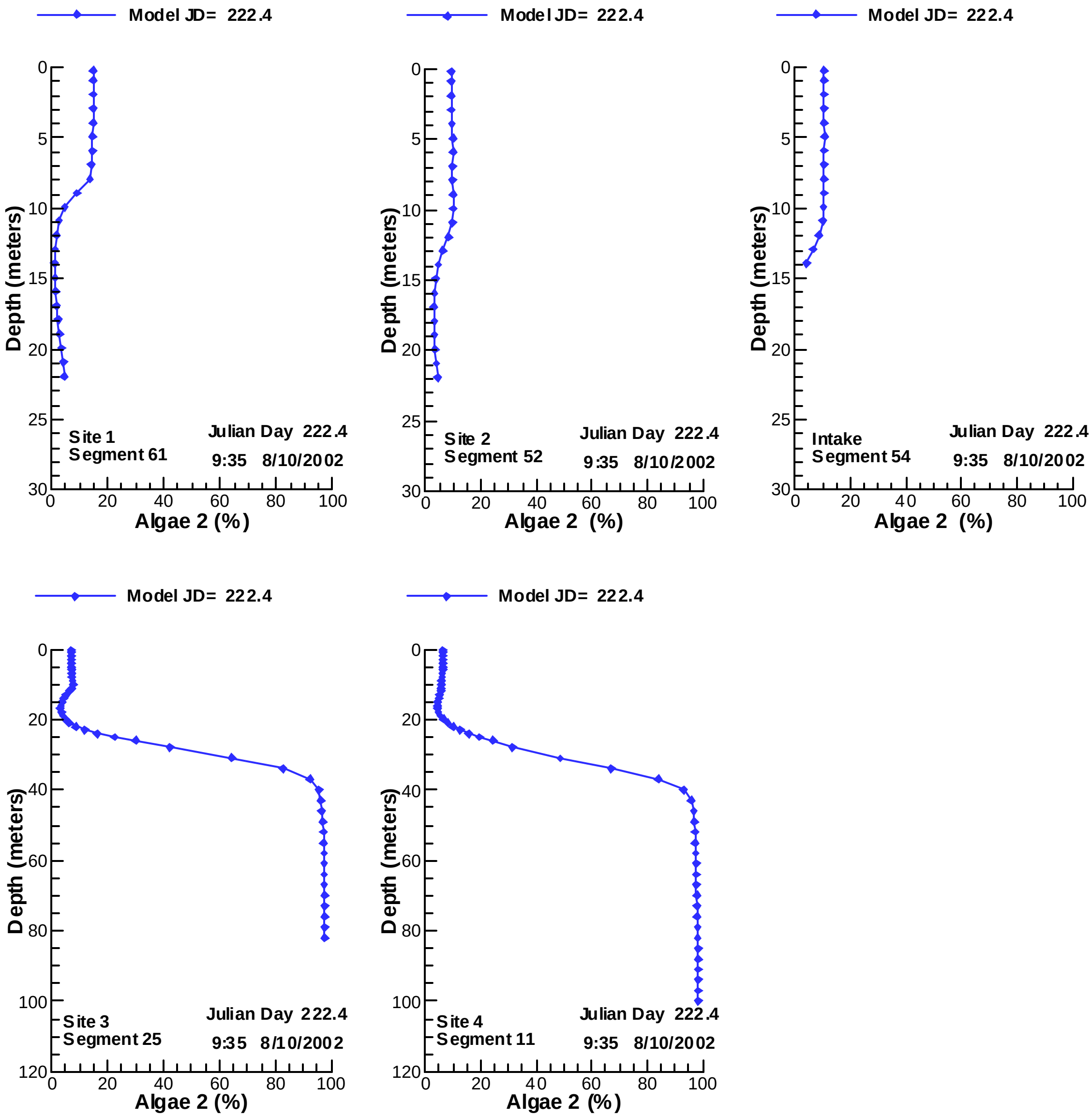

Figure 687. Vertical profiles of ALGAE 2 compared with data for 8/10/2002.

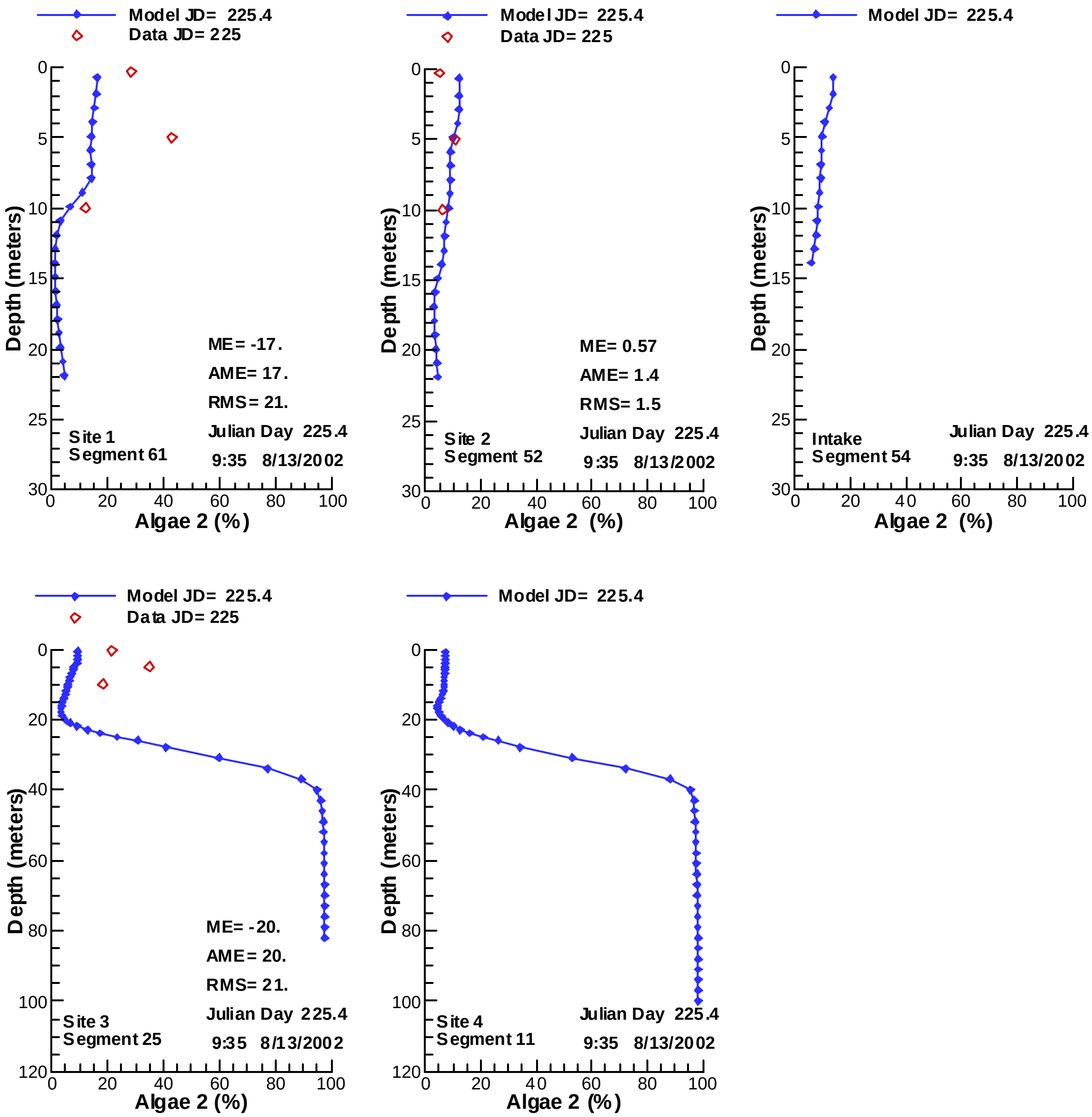

Figure 688. Vertical profiles of ALGAE 2 compared with data for 8/13/2002.

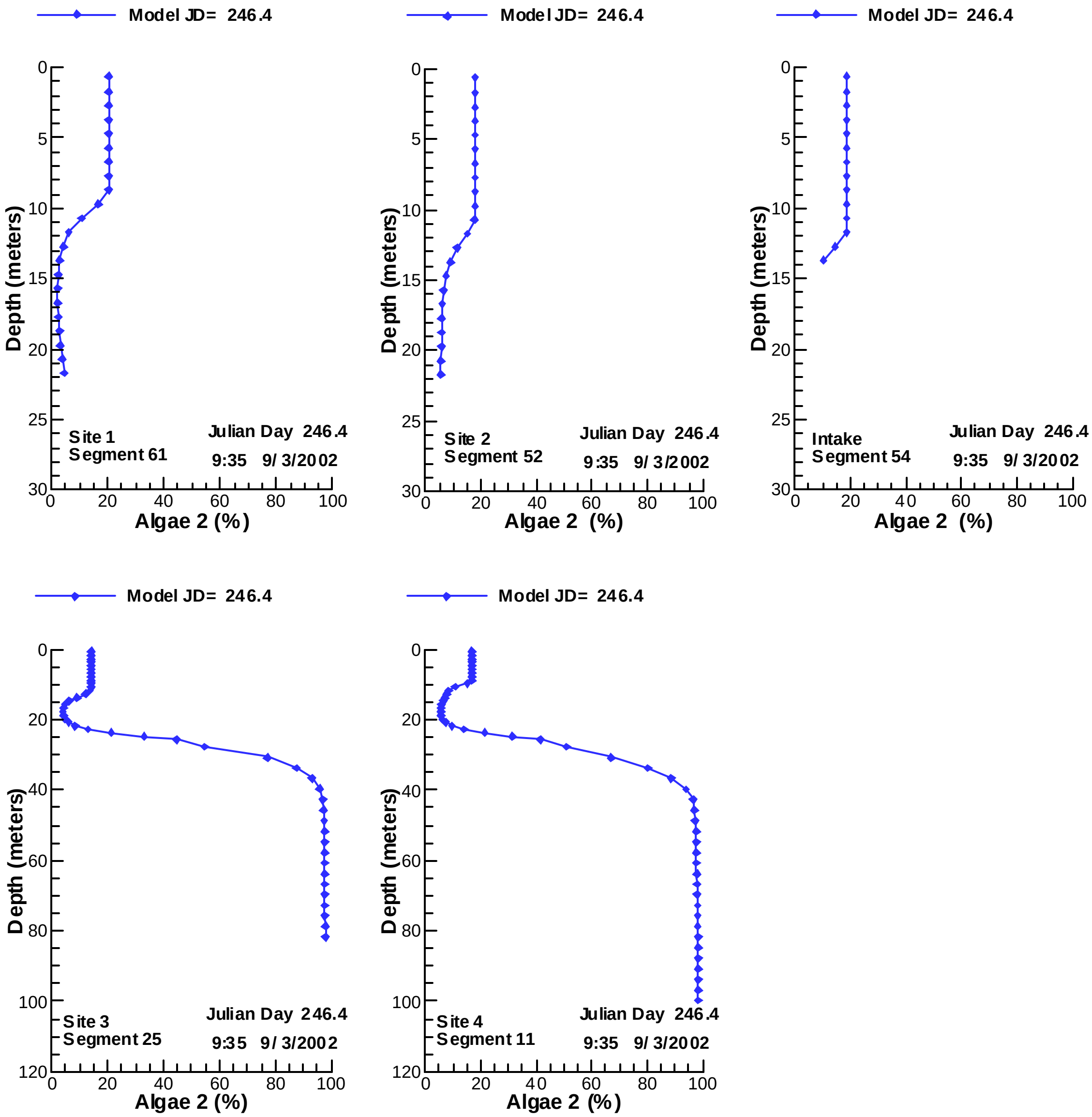

Figure 689. Vertical profiles of ALGAE 2 compared with data for 9/ 3/2002.

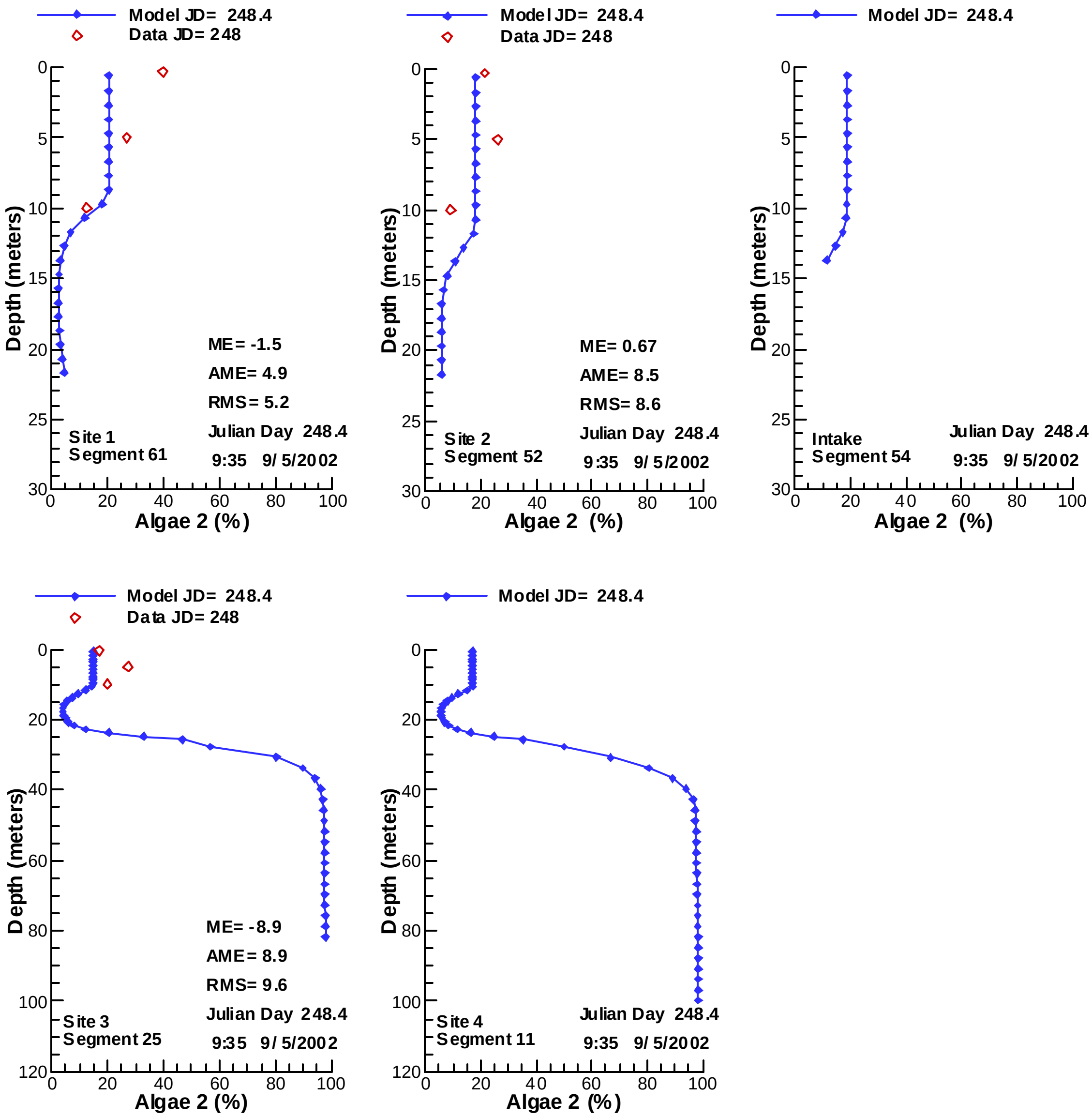

Figure 690. Vertical profiles of ALGAE 2 compared with data for 9/ 5/2002.

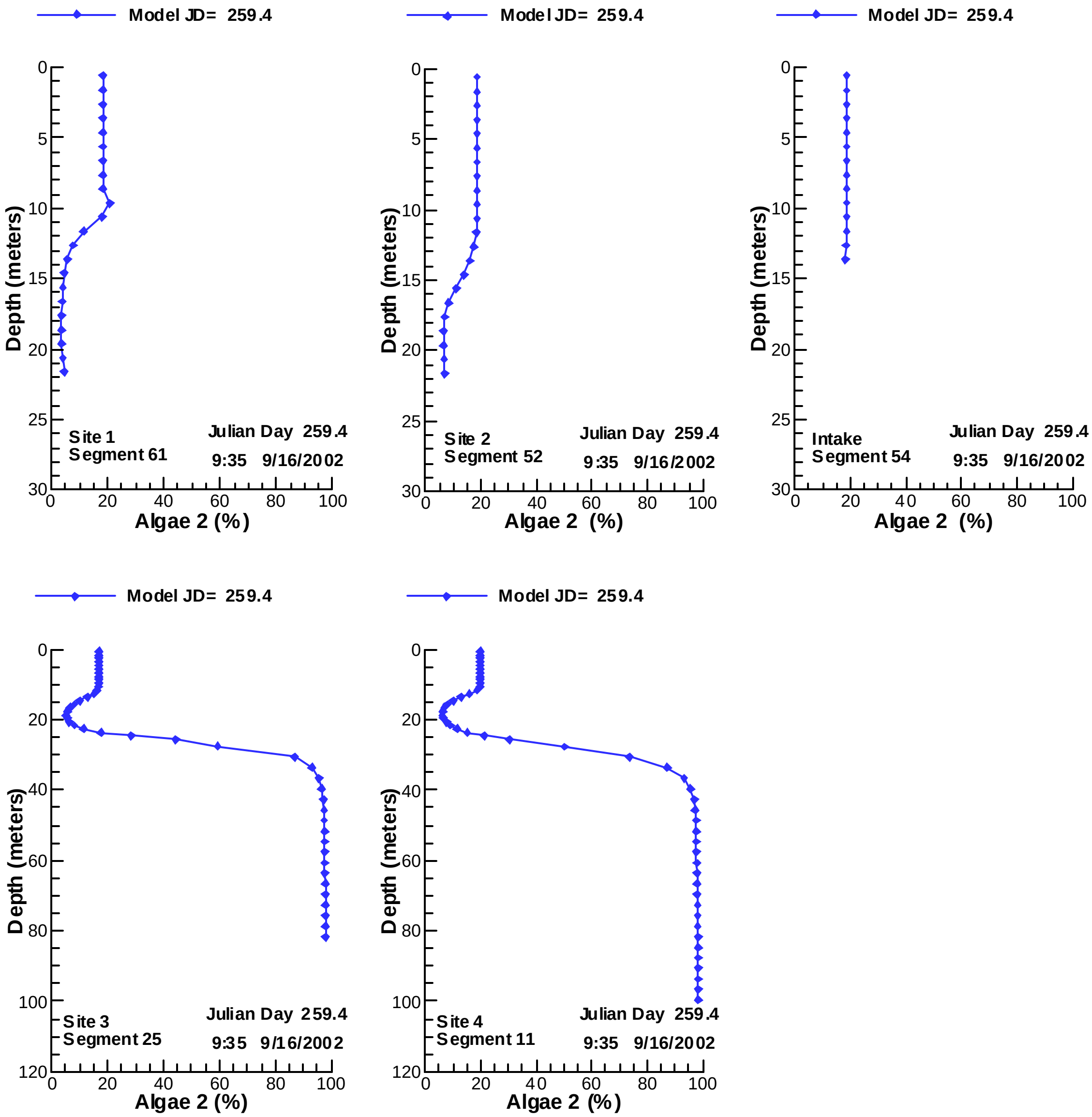

Figure 691. Vertical profiles of ALGAE 2 compared with data for 9/16/2002.

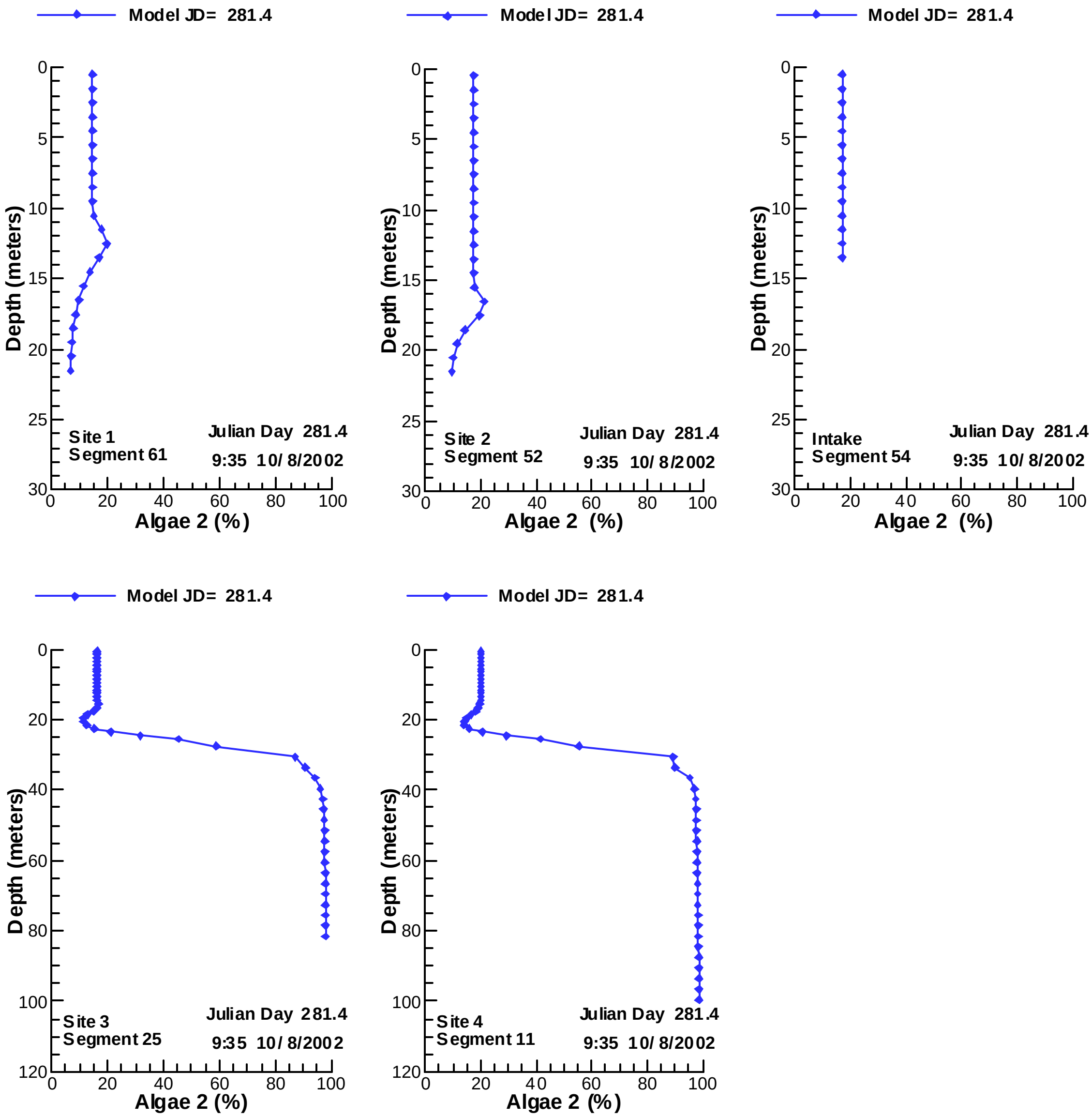

Figure 692. Vertical profiles of ALGAE 2 compared with data for 10/ 8/2002.

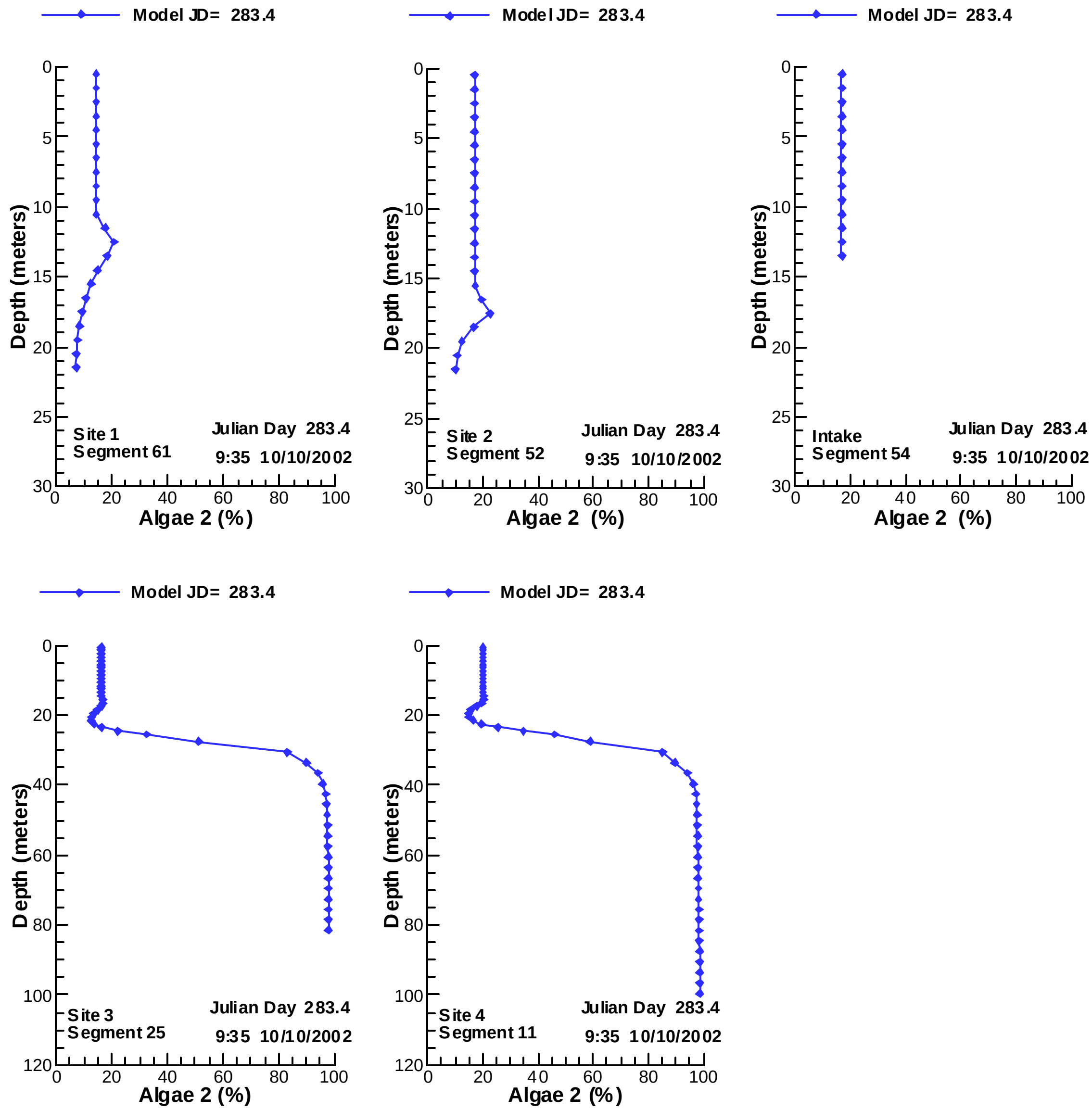

Figure 693. Vertical profiles of ALGAE 2 compared with data for 10/10/2002.

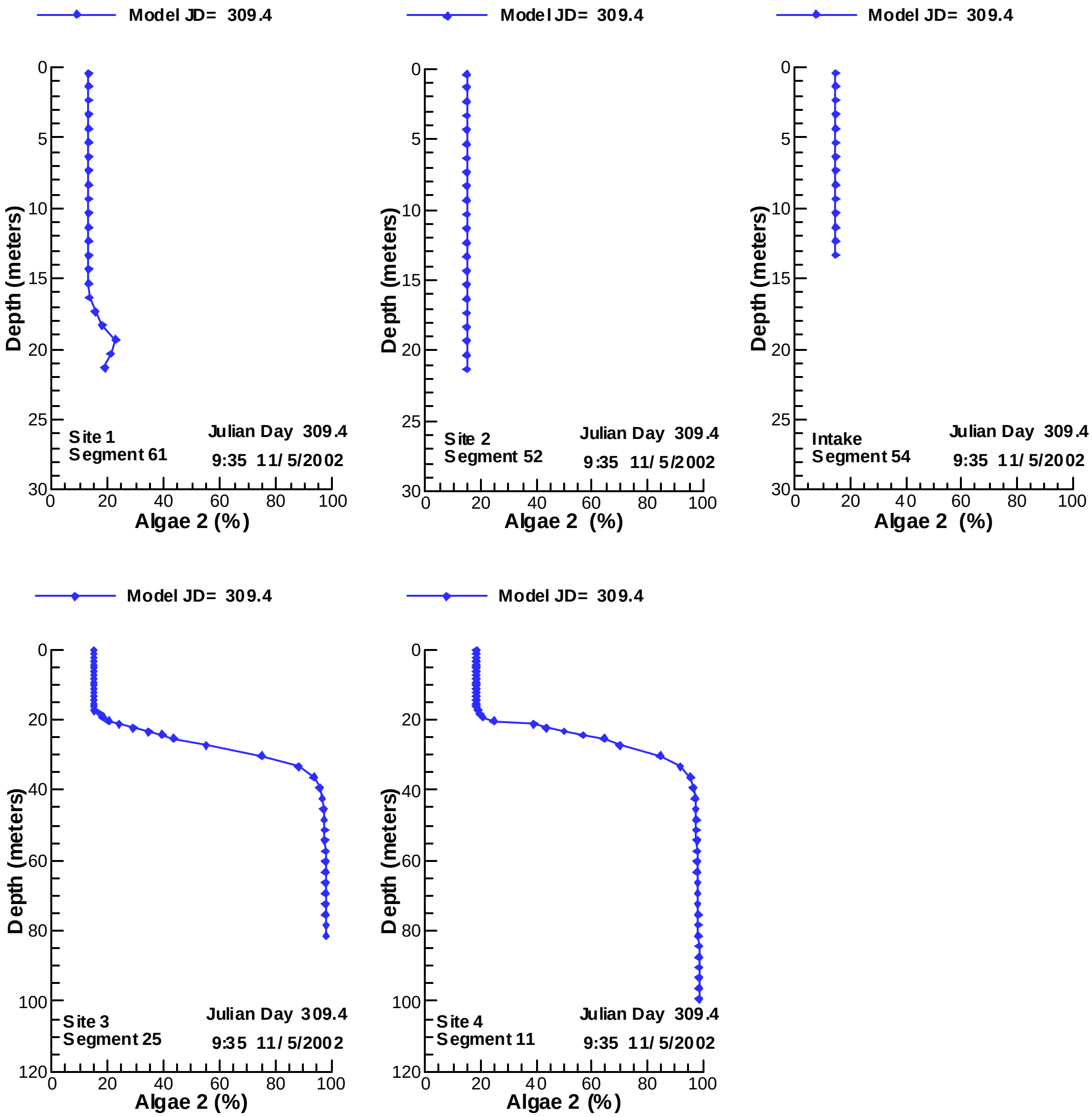

Figure 694. Vertical profiles of ALGAE 2 compared with data for 11/ 5/2002.

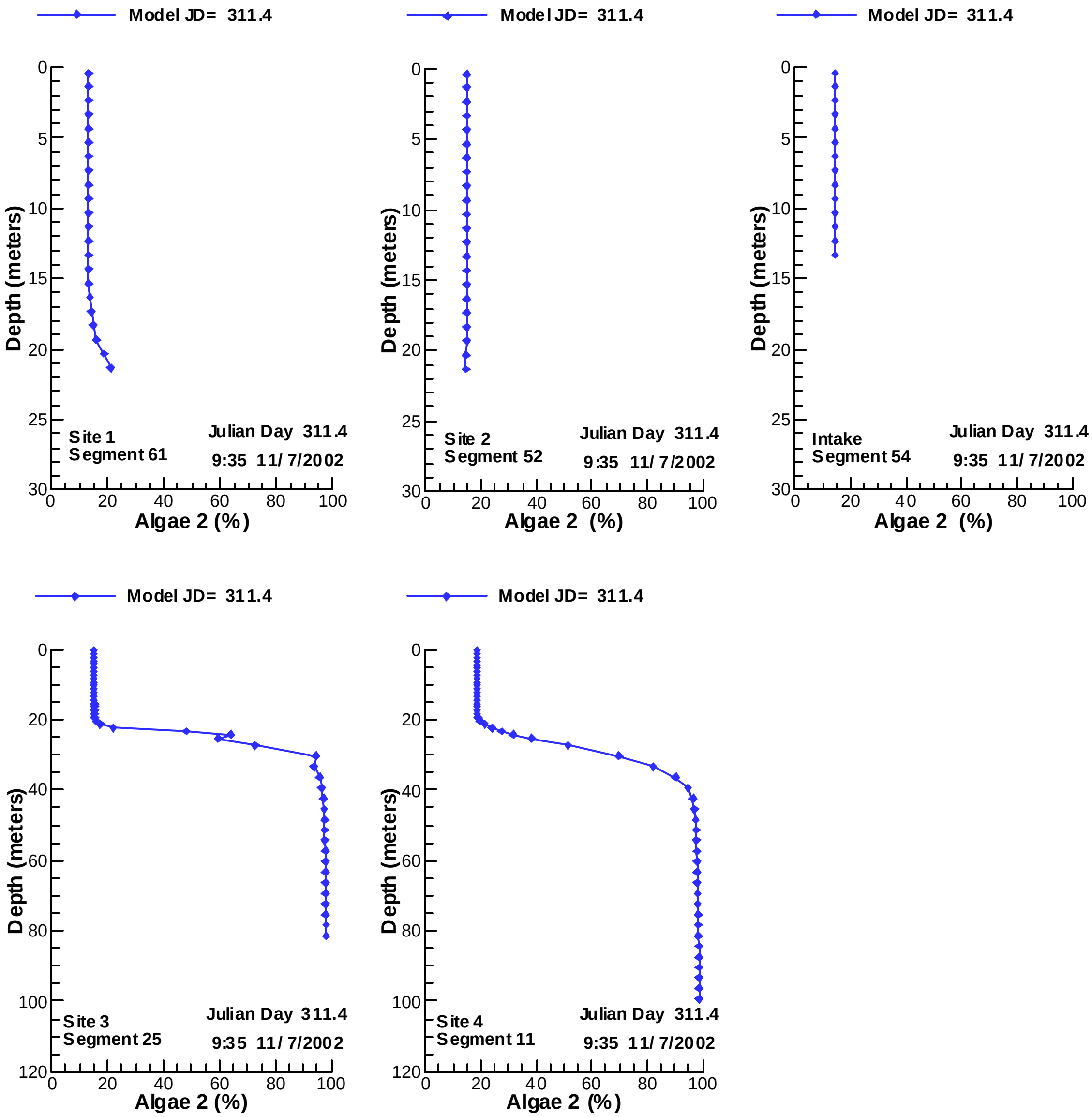

Figure 695. Vertical profiles of ALGAE 2 compared with data for 11/ 7/2002.

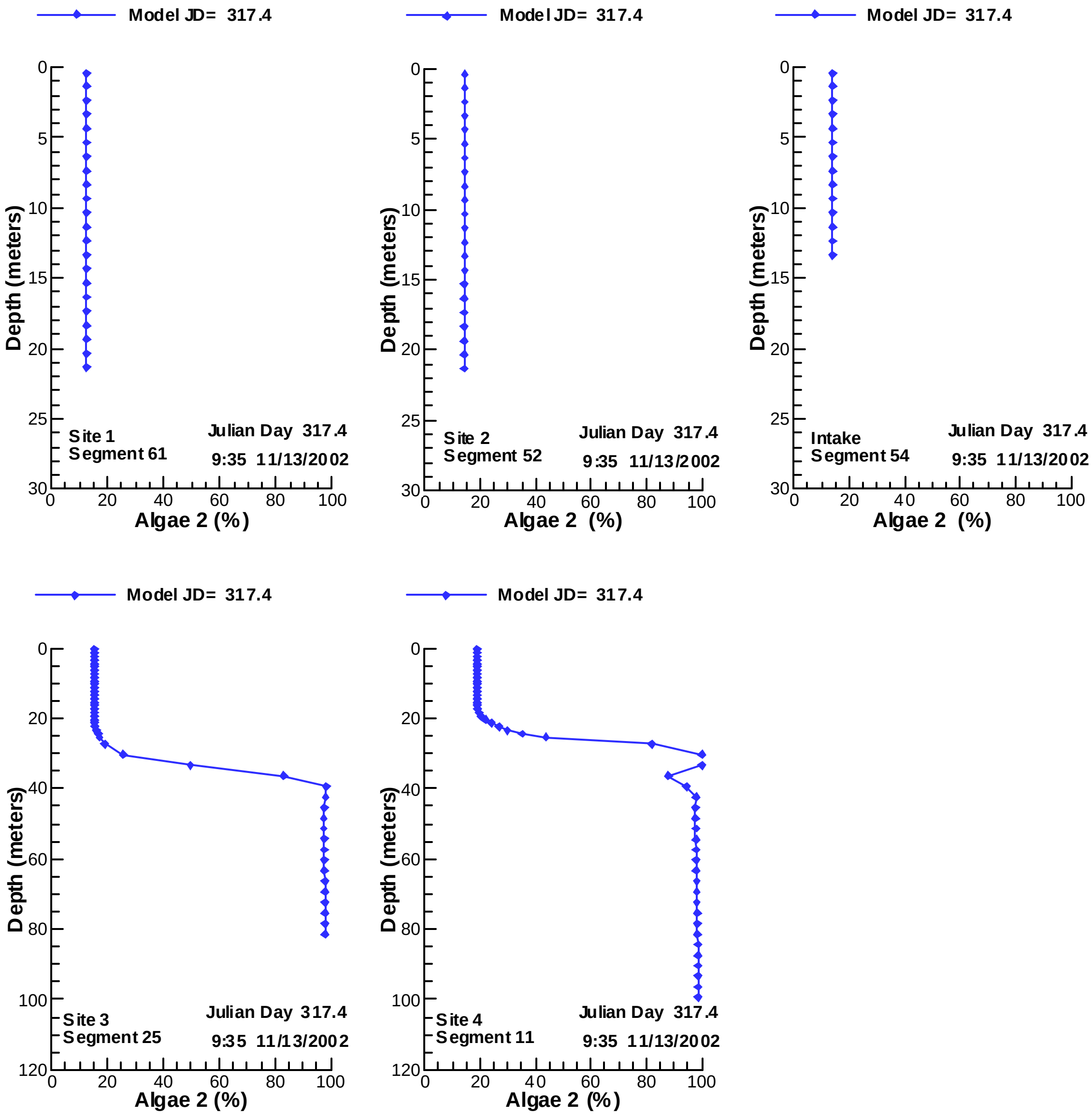

Figure 696. Vertical profiles of ALGAE 2 compared with data for 11/13/2002.

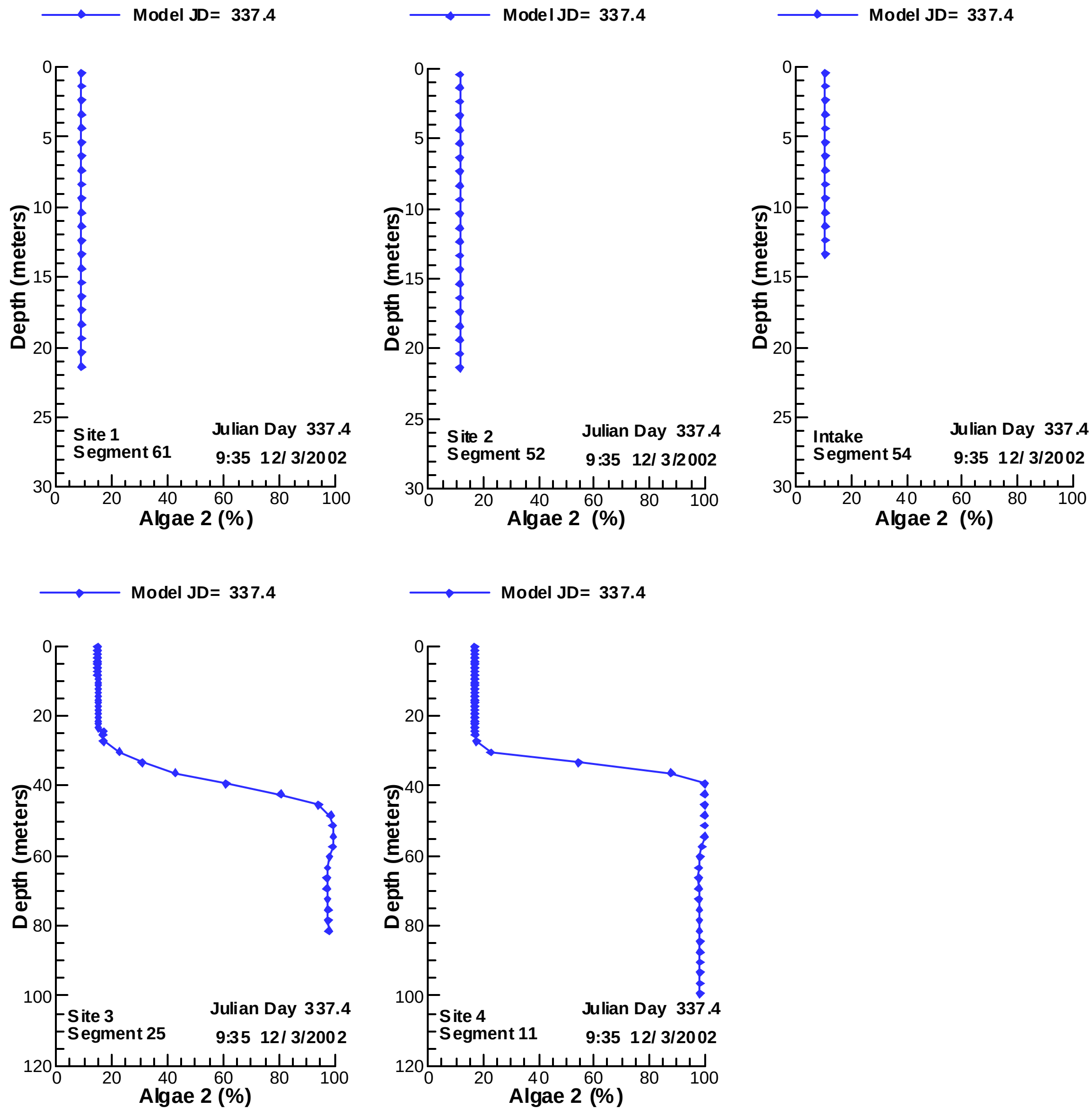

Figure 697. Vertical profiles of ALGAE 2 compared with data for 12/ 3/2002.

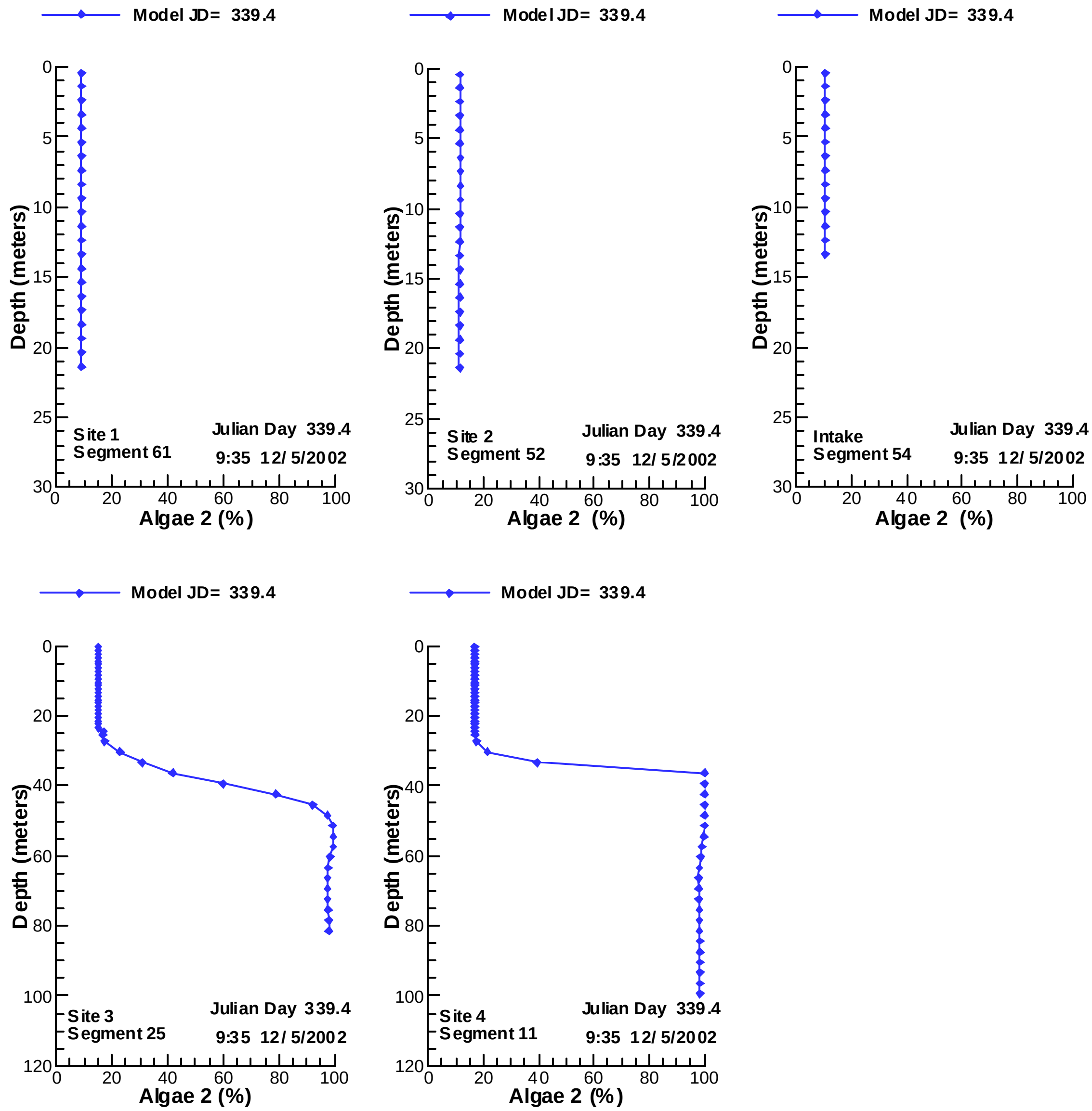

Figure 698. Vertical profiles of ALGAE 2 compared with data for 12/ 5/2002.

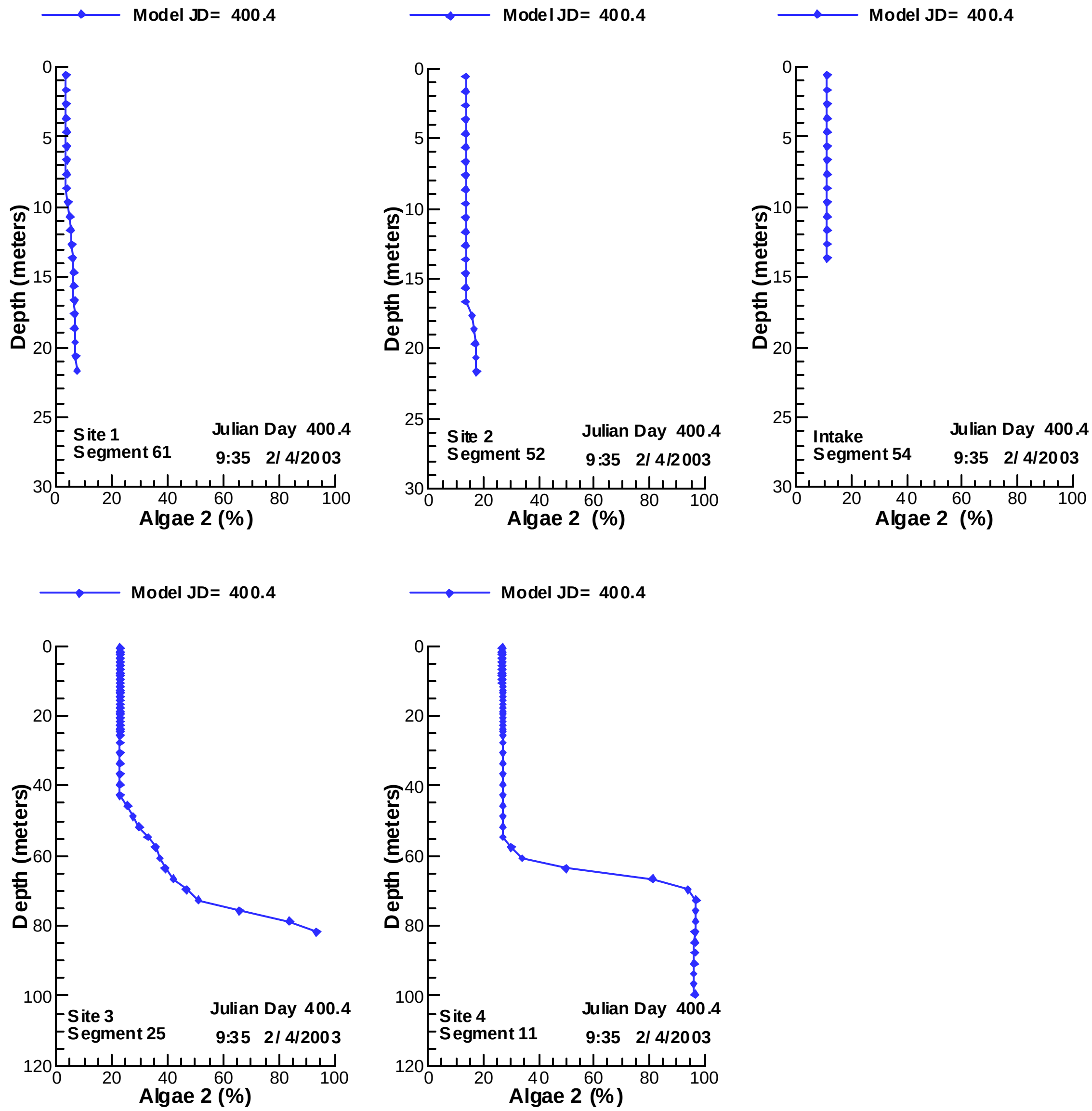

Figure 699. Vertical profiles of ALGAE 2 compared with data for 2/ 4/2003.

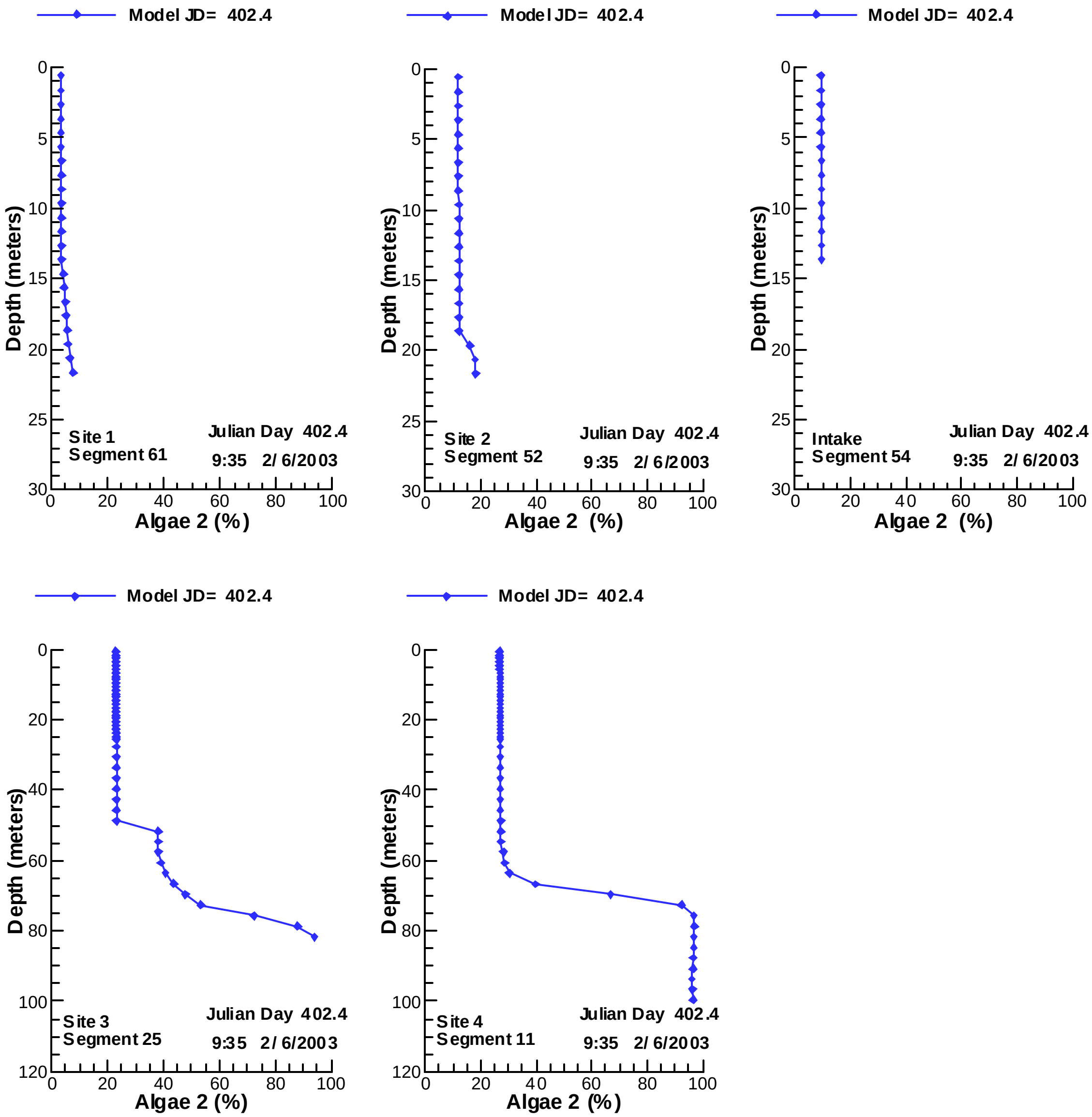

Figure 700. Vertical profiles of ALGAE 2 compared with data for 2/ 6/2003.

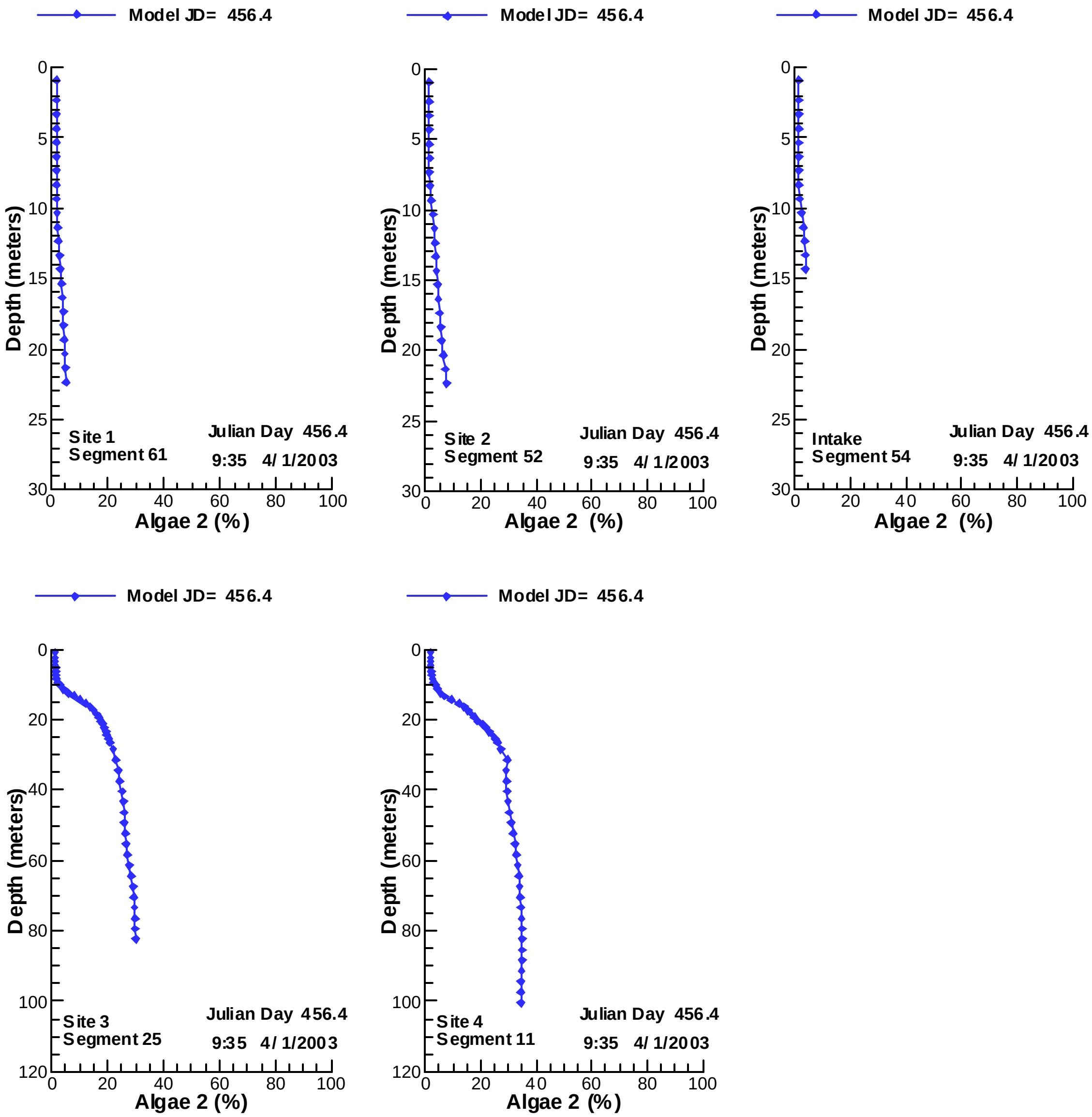

Figure 701. Vertical profiles of ALGAE 2 compared with data for 4/ 1/2003.

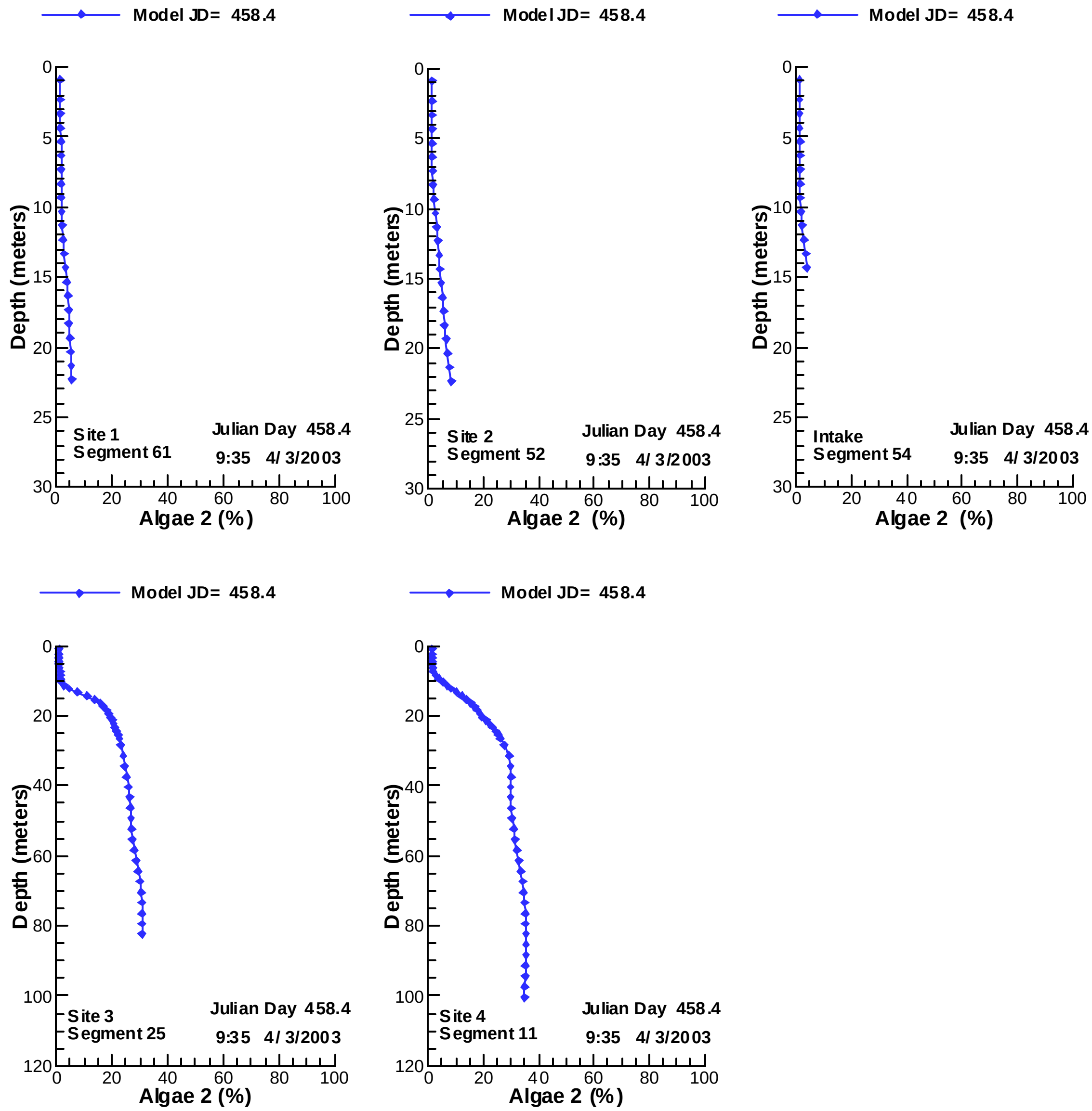

Figure 702. Vertical profiles of ALGAE 2 compared with data for 4/ 3/2003.

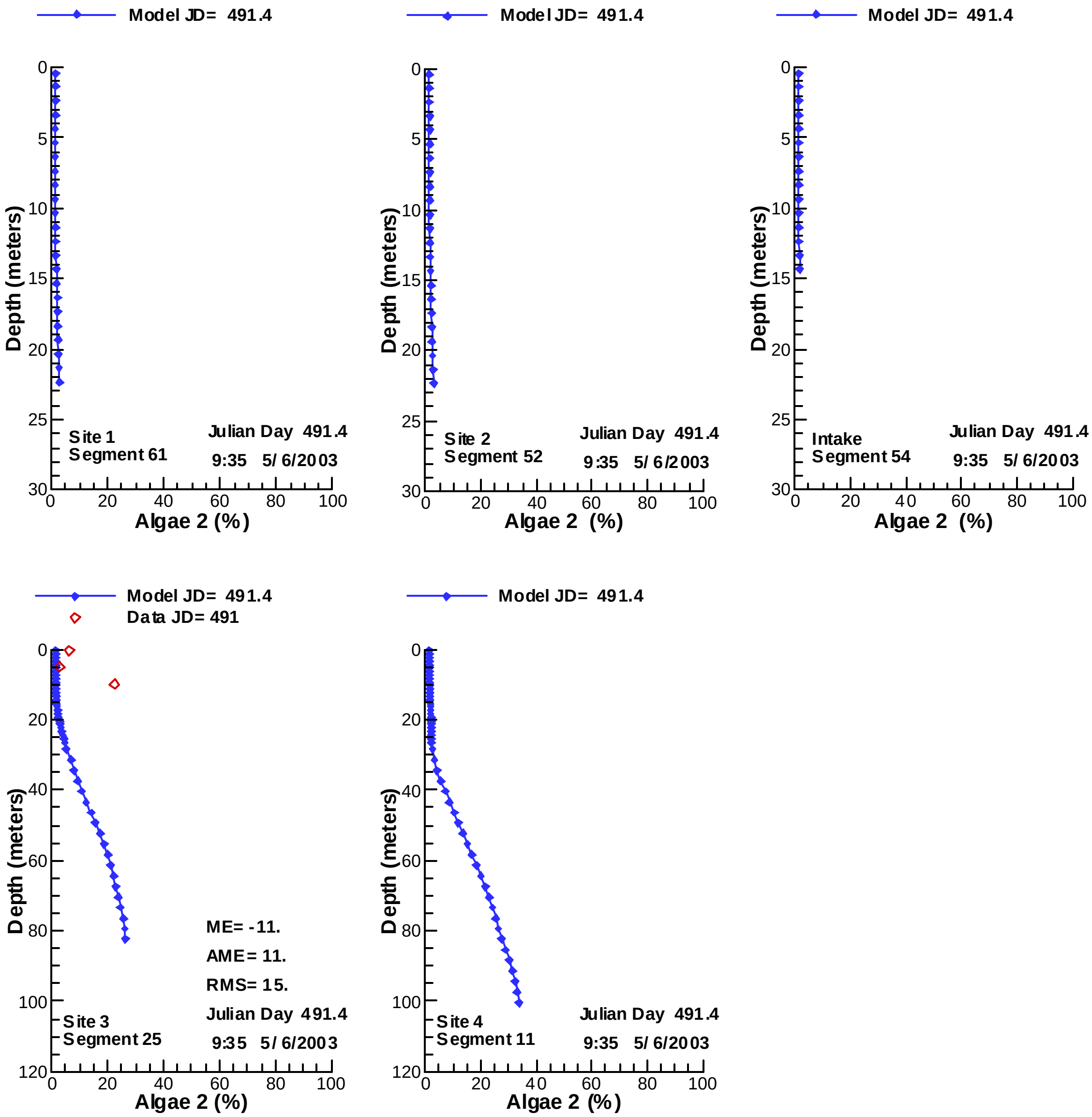

Figure 703. Vertical profiles of ALGAE 2 compared with data for 5/ 6/2003.

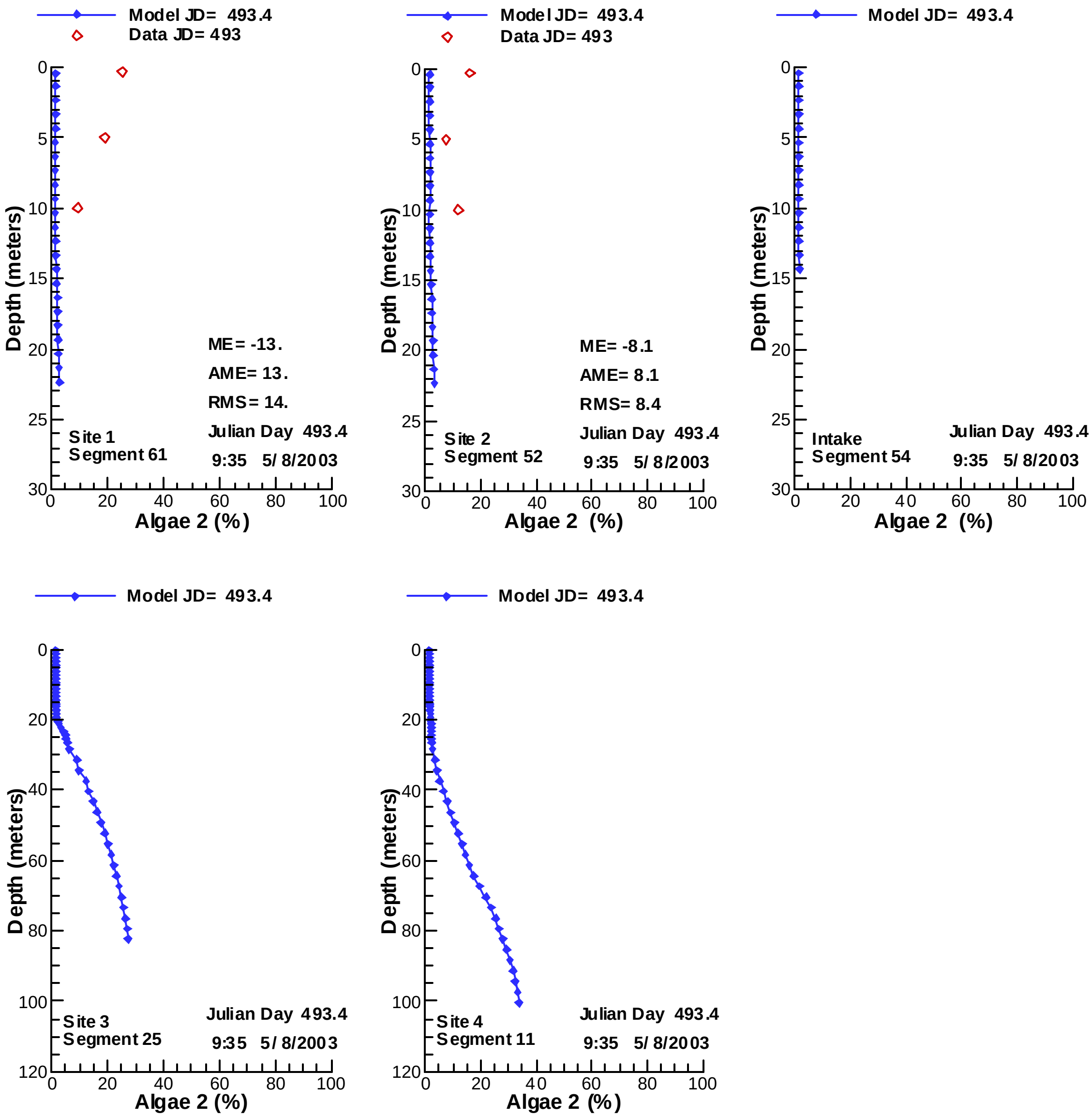

Figure 704. Vertical profiles of ALGAE 2 compared with data for 5/ 8/2003.

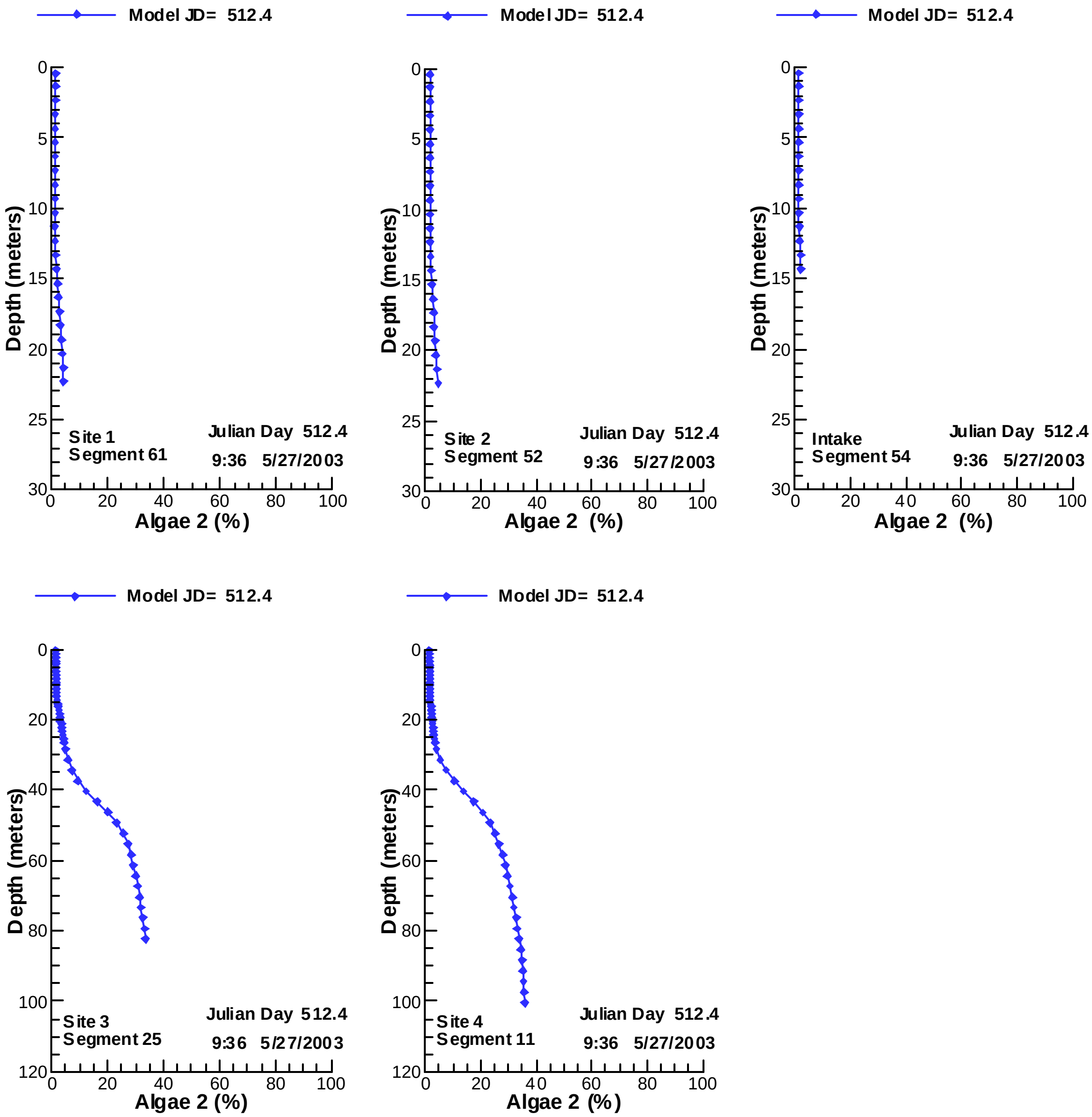

Figure 705. Vertical profiles of ALGAE 2 compared with data for 5/27/2003.

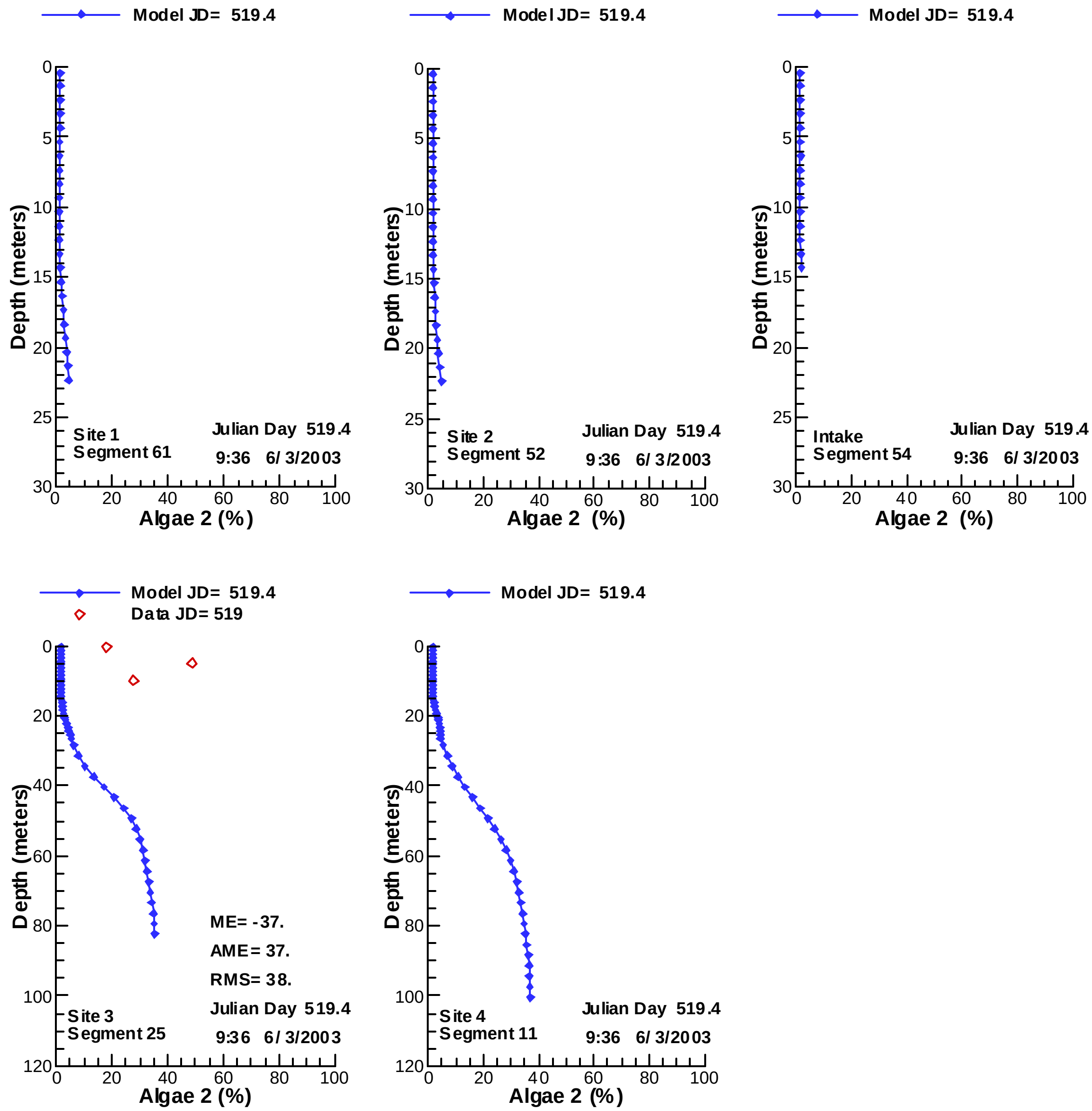

Figure 706. Vertical profiles of ALGAE 2 compared with data for 6/ 3/2003.

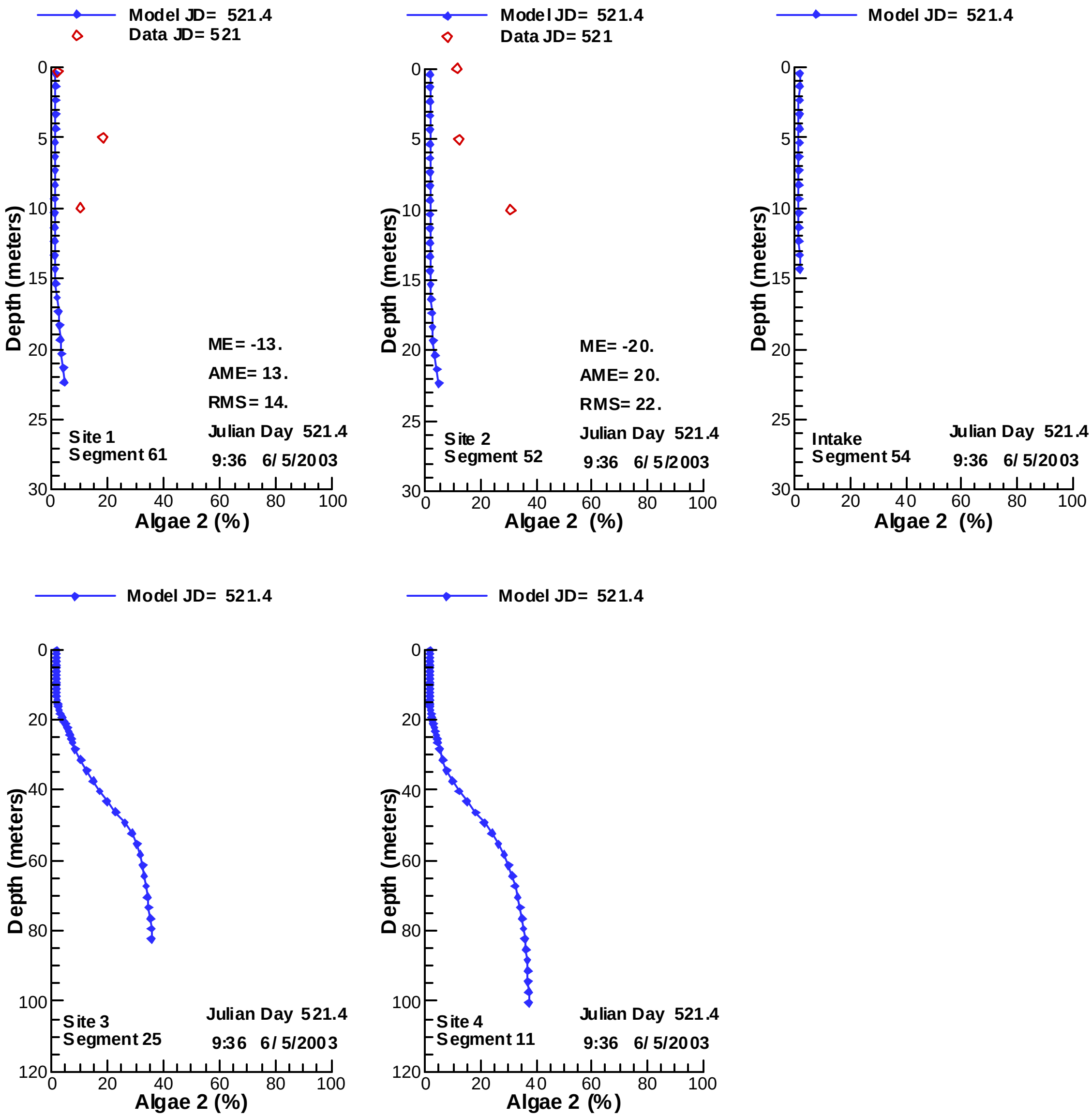

Figure 707. Vertical profiles of ALGAE 2 compared with data for 6/ 5/2003.

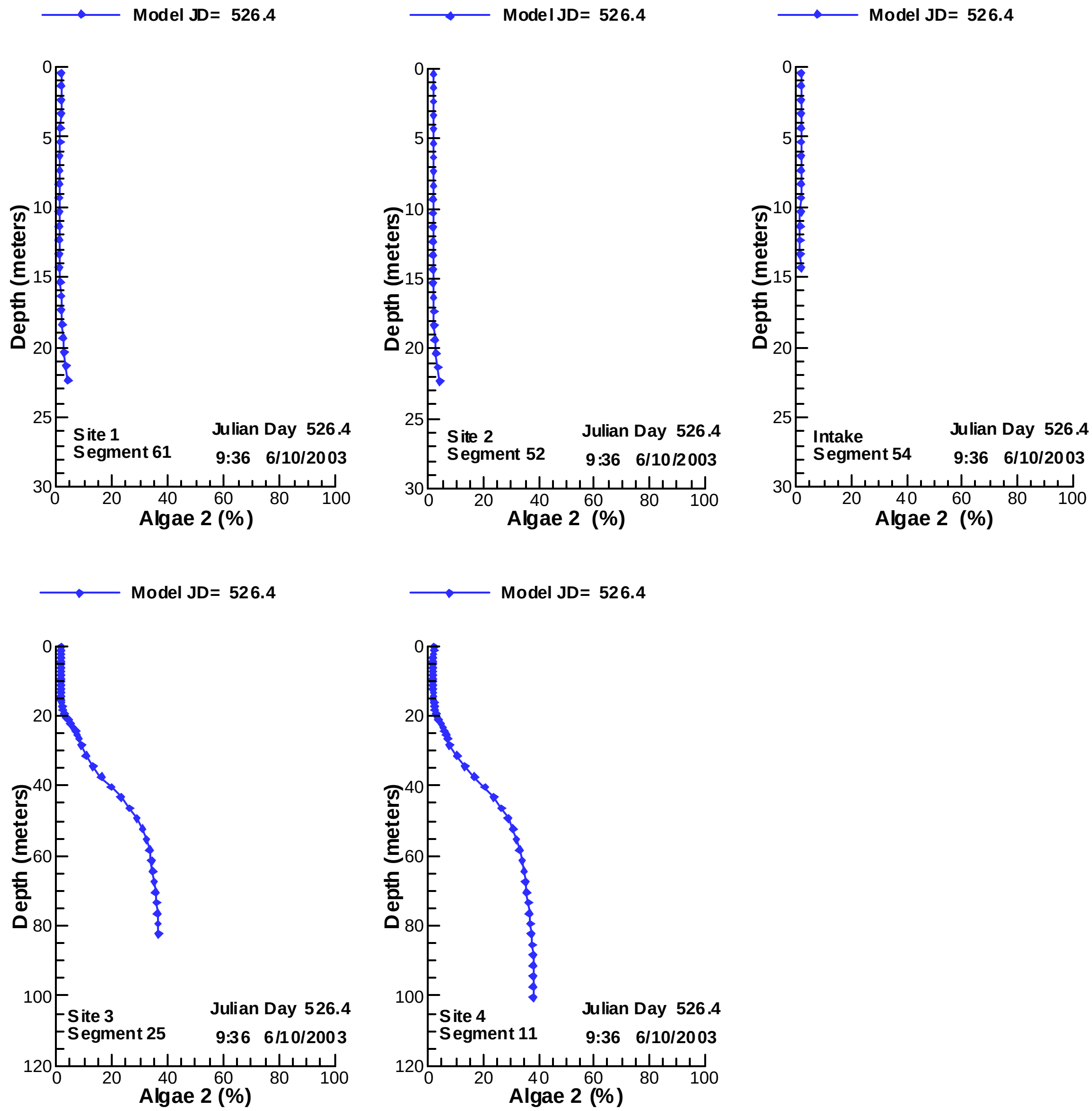

Figure 708. Vertical profiles of ALGAE 2 compared with data for 6/10/2003.

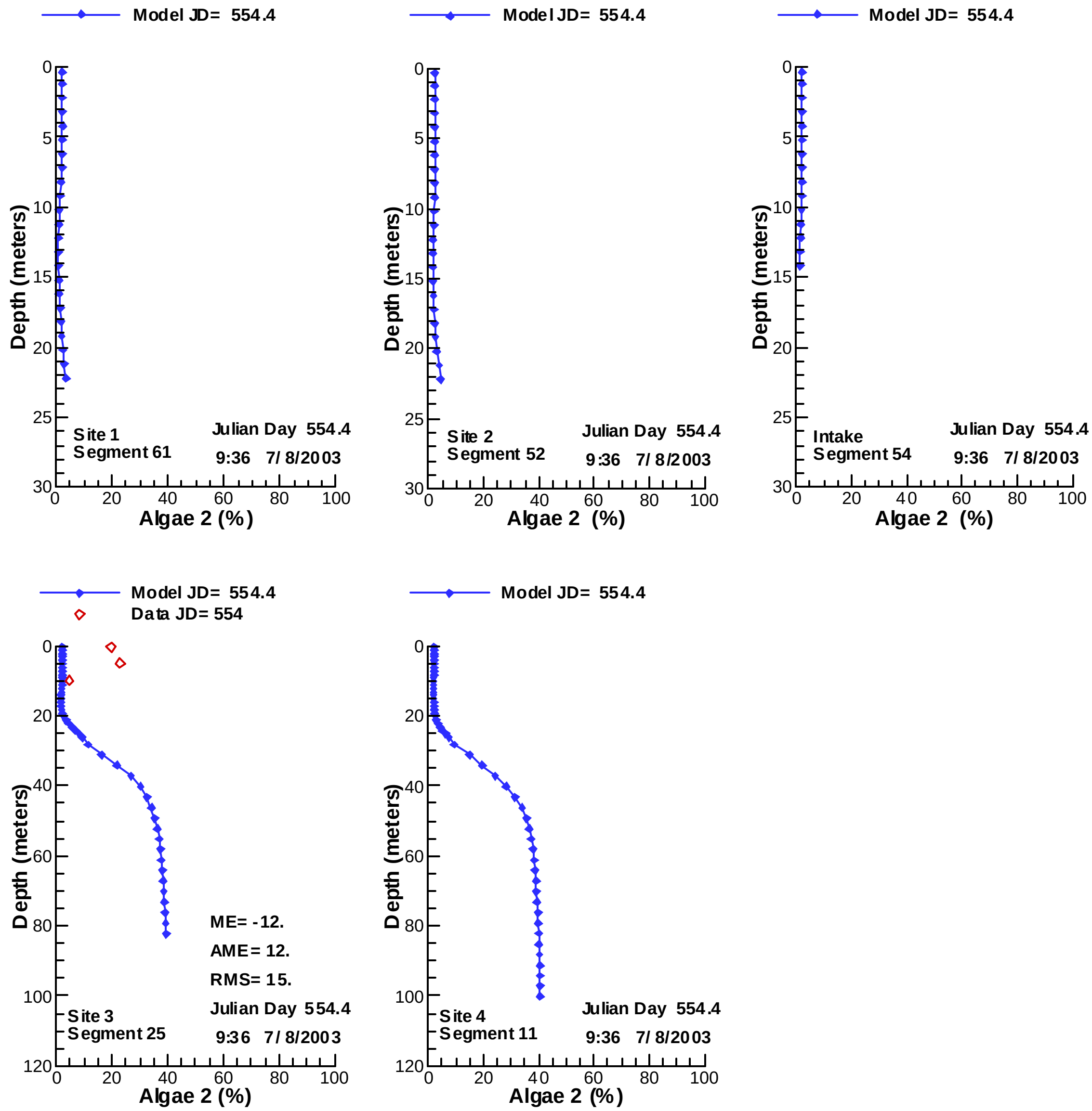

Figure 709. Vertical profiles of ALGAE 2 compared with data for 7/ 8/2003.

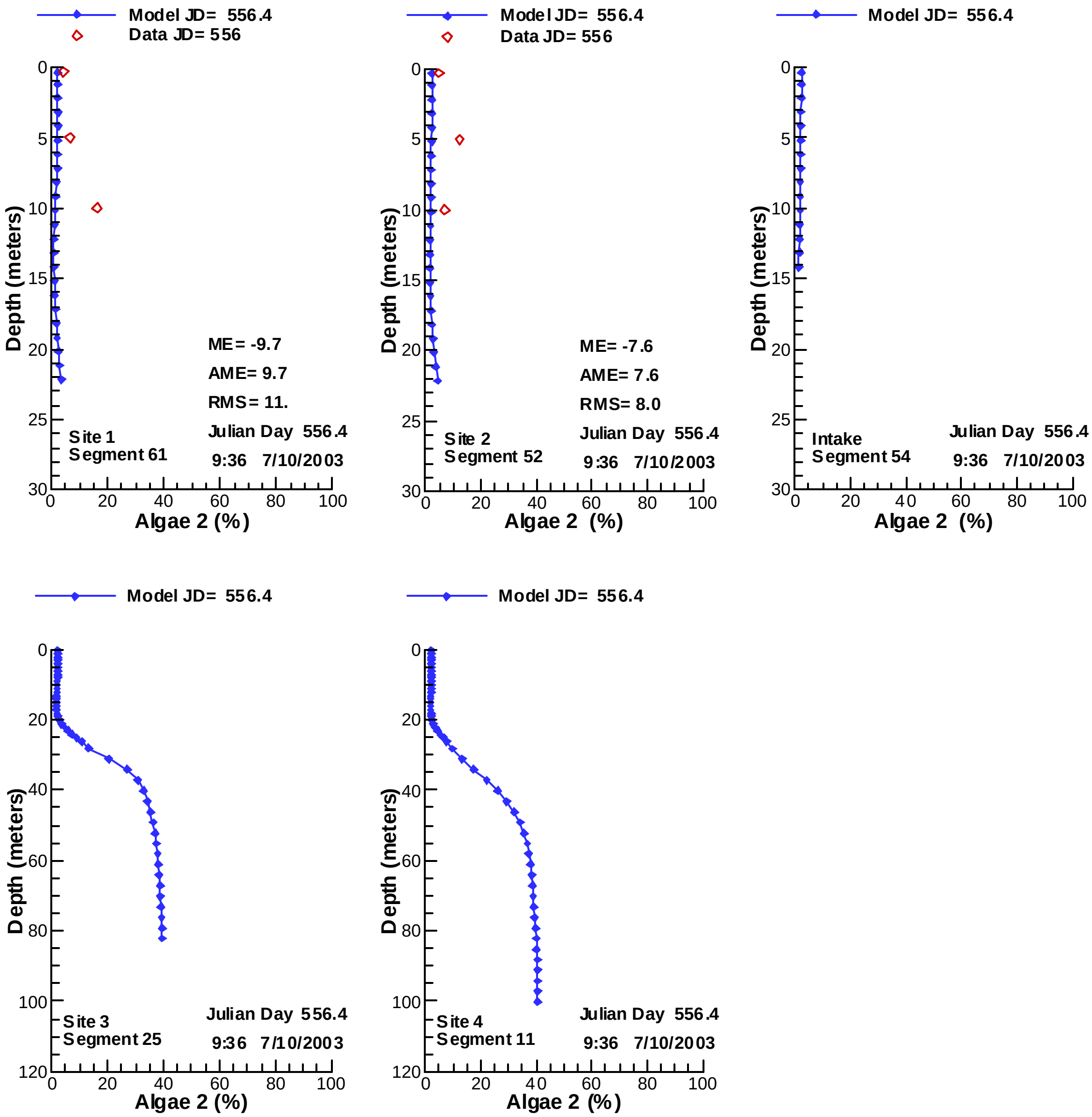

Figure 710. Vertical profiles of ALGAE 2 compared with data for 7/10/2003.

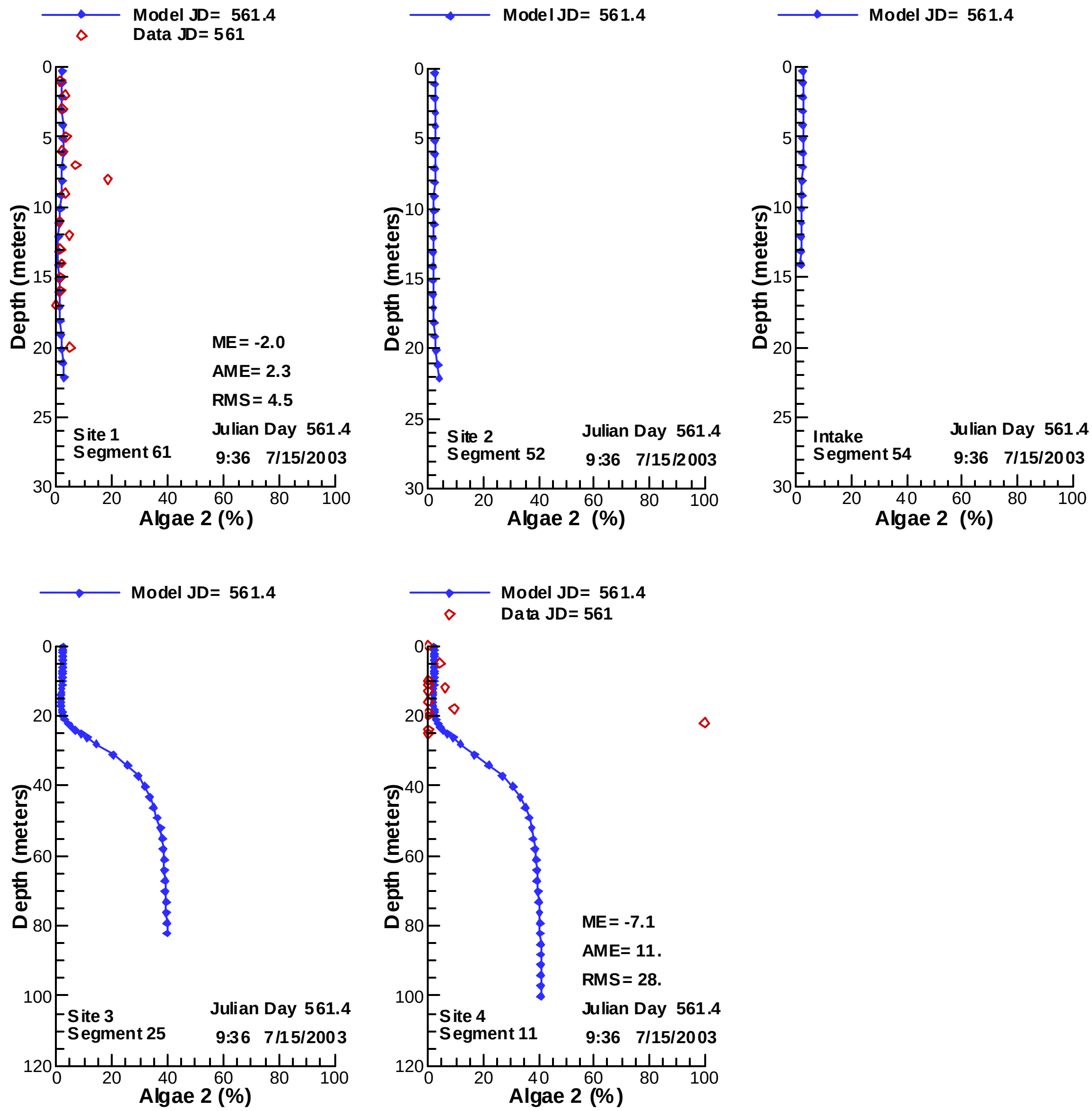

Figure 711. Vertical profiles of ALGAE 2 compared with data for 7/15/2003.

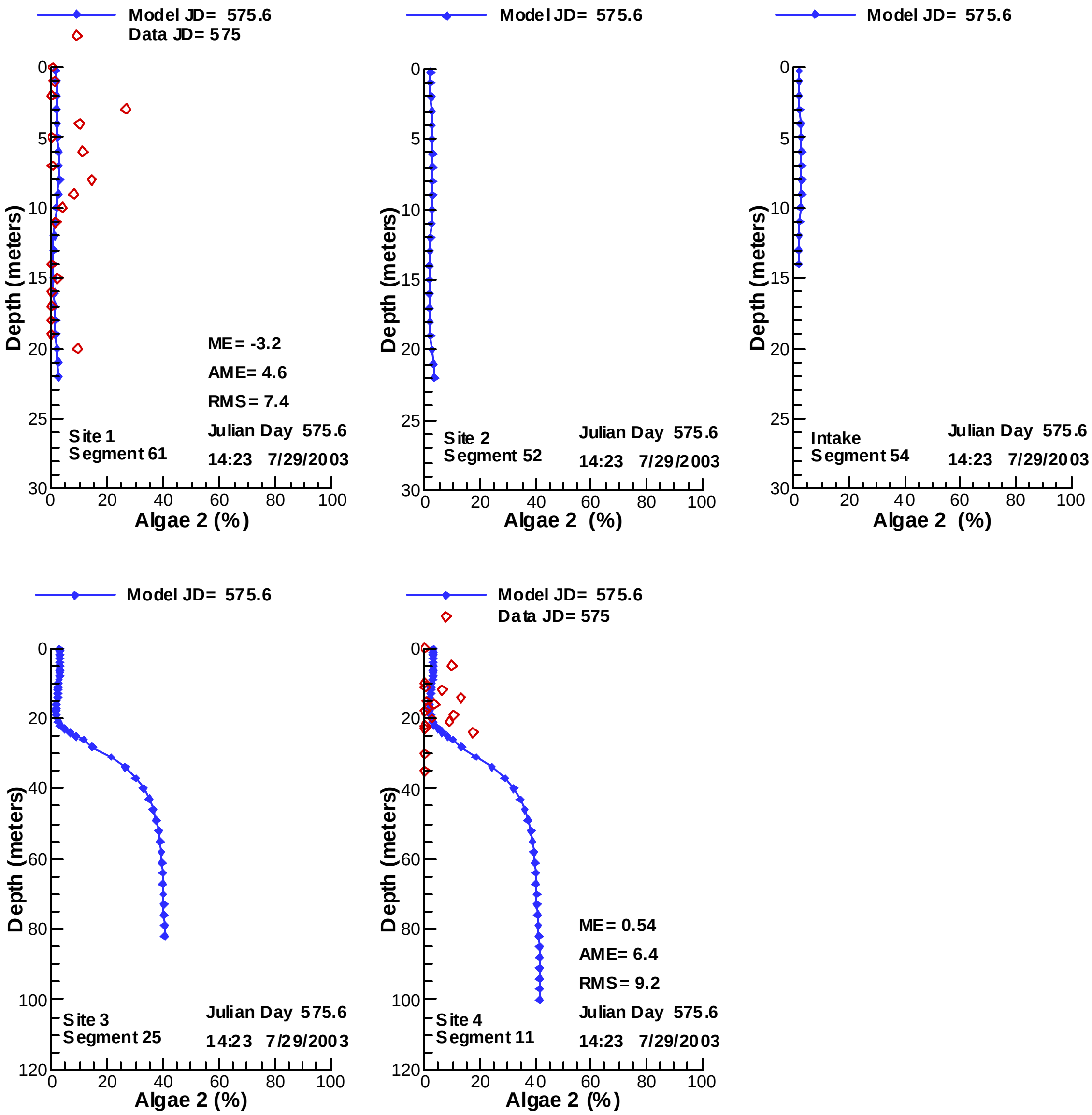

Figure 712. Vertical profiles of ALGAE 2 compared with data for 7/29/2003.

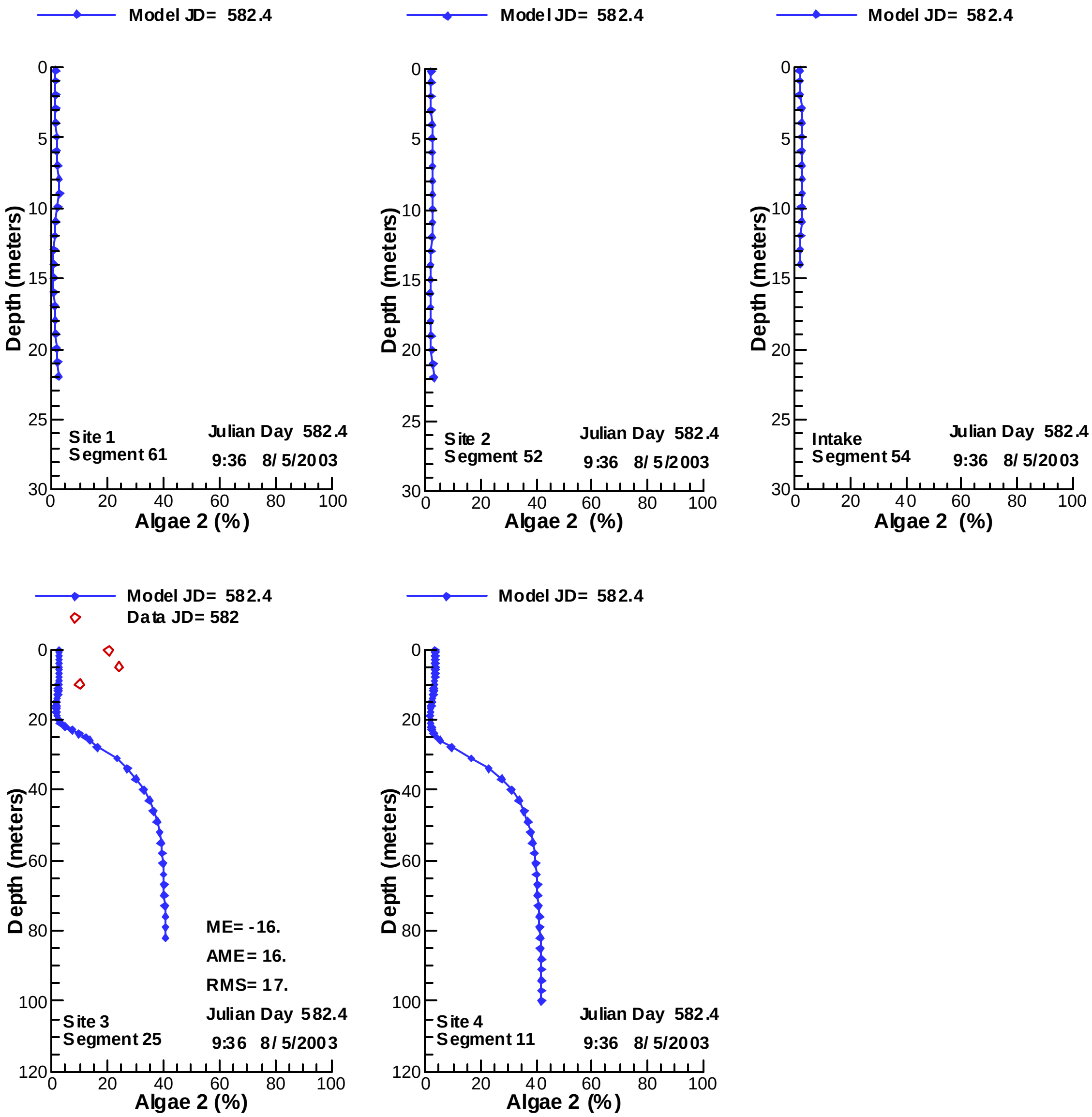

Figure 713. Vertical profiles of ALGAE 2 compared with data for 8/ 5/2003.

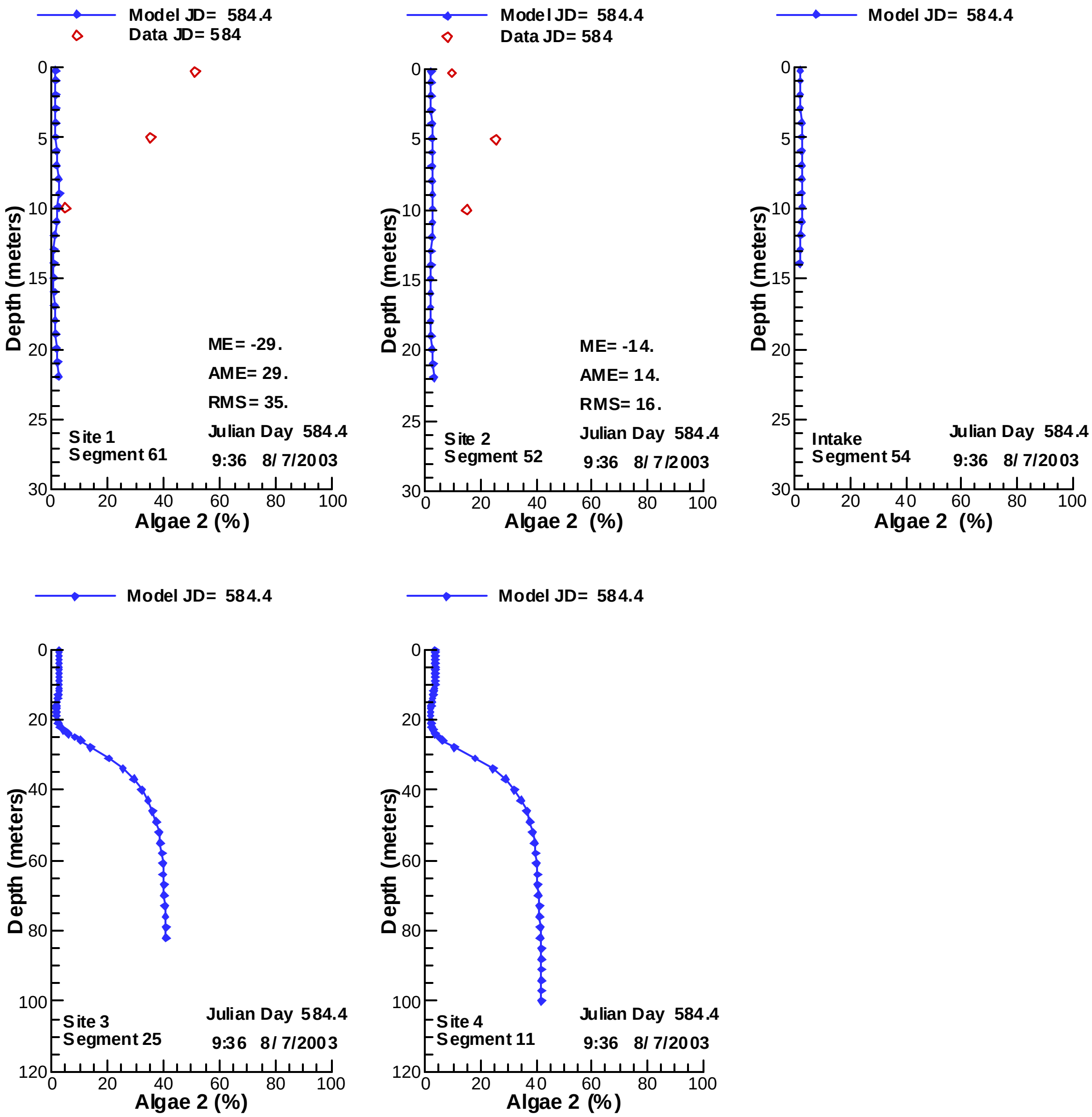

Figure 714. Vertical profiles of ALGAE 2 compared with data for 8/ 7/2003.

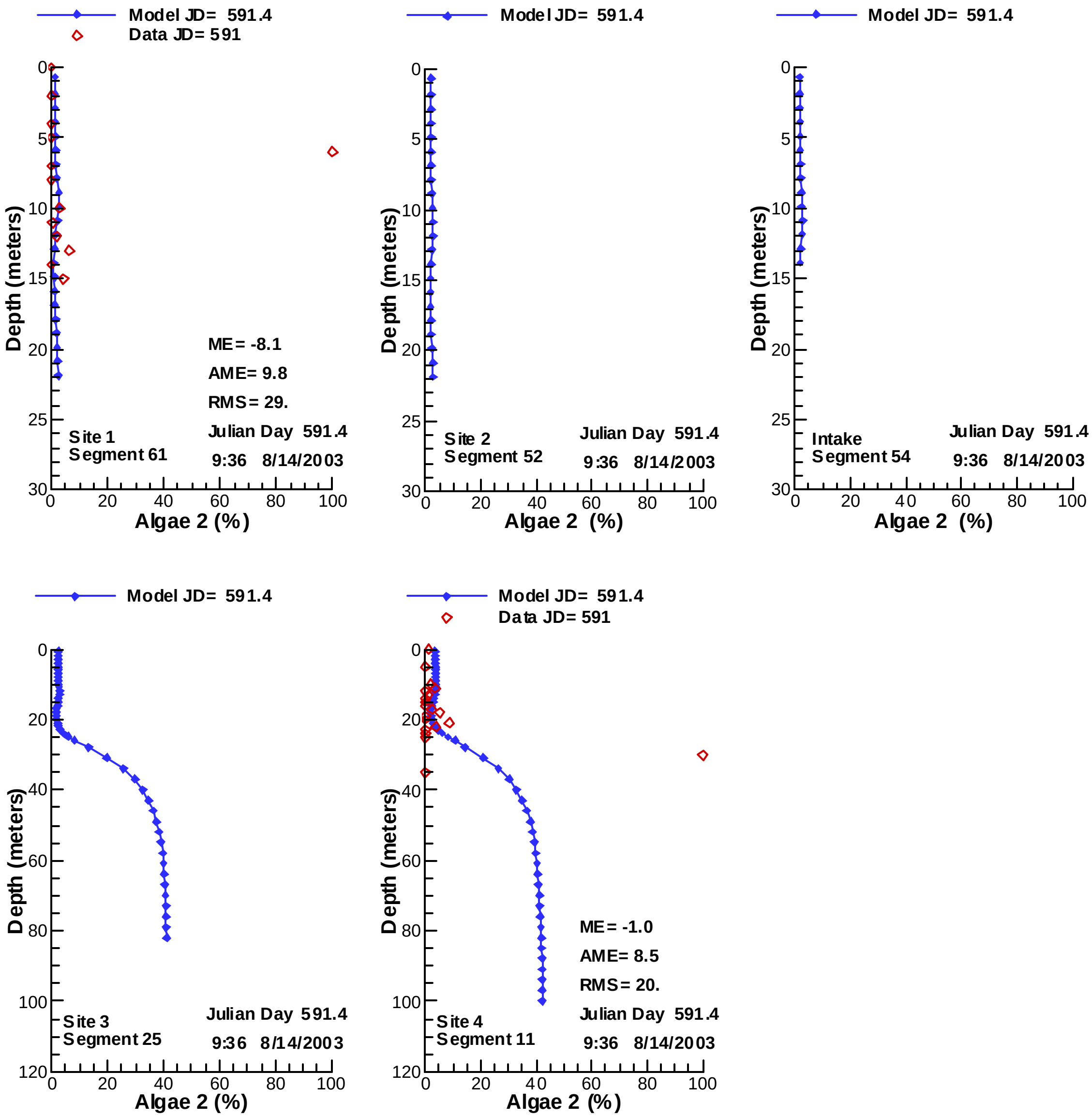

Figure 715. Vertical profiles of ALGAE 2 compared with data for 8/14/2003.

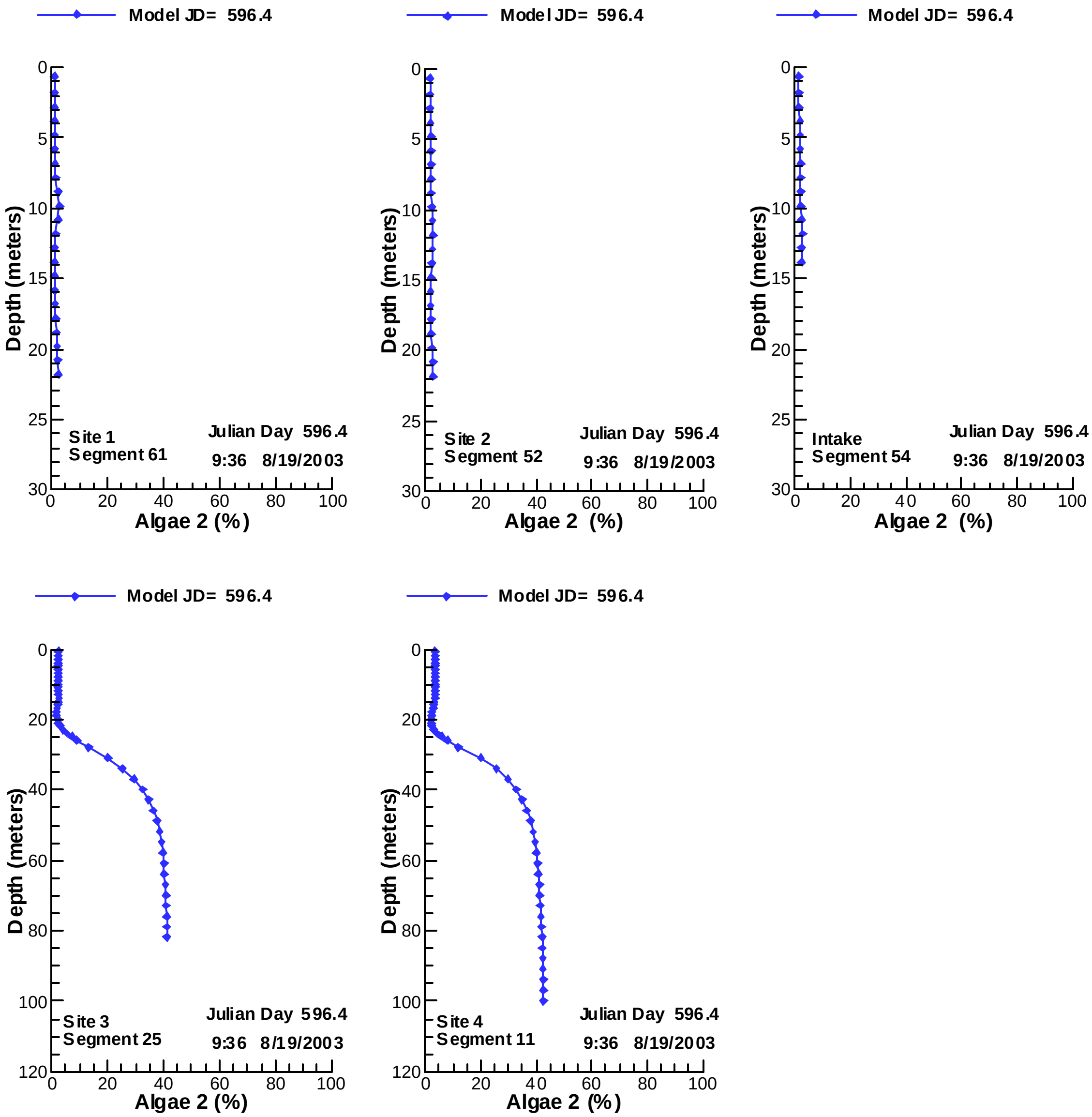

Figure 716. Vertical profiles of ALGAE 2 compared with data for 8/19/2003.

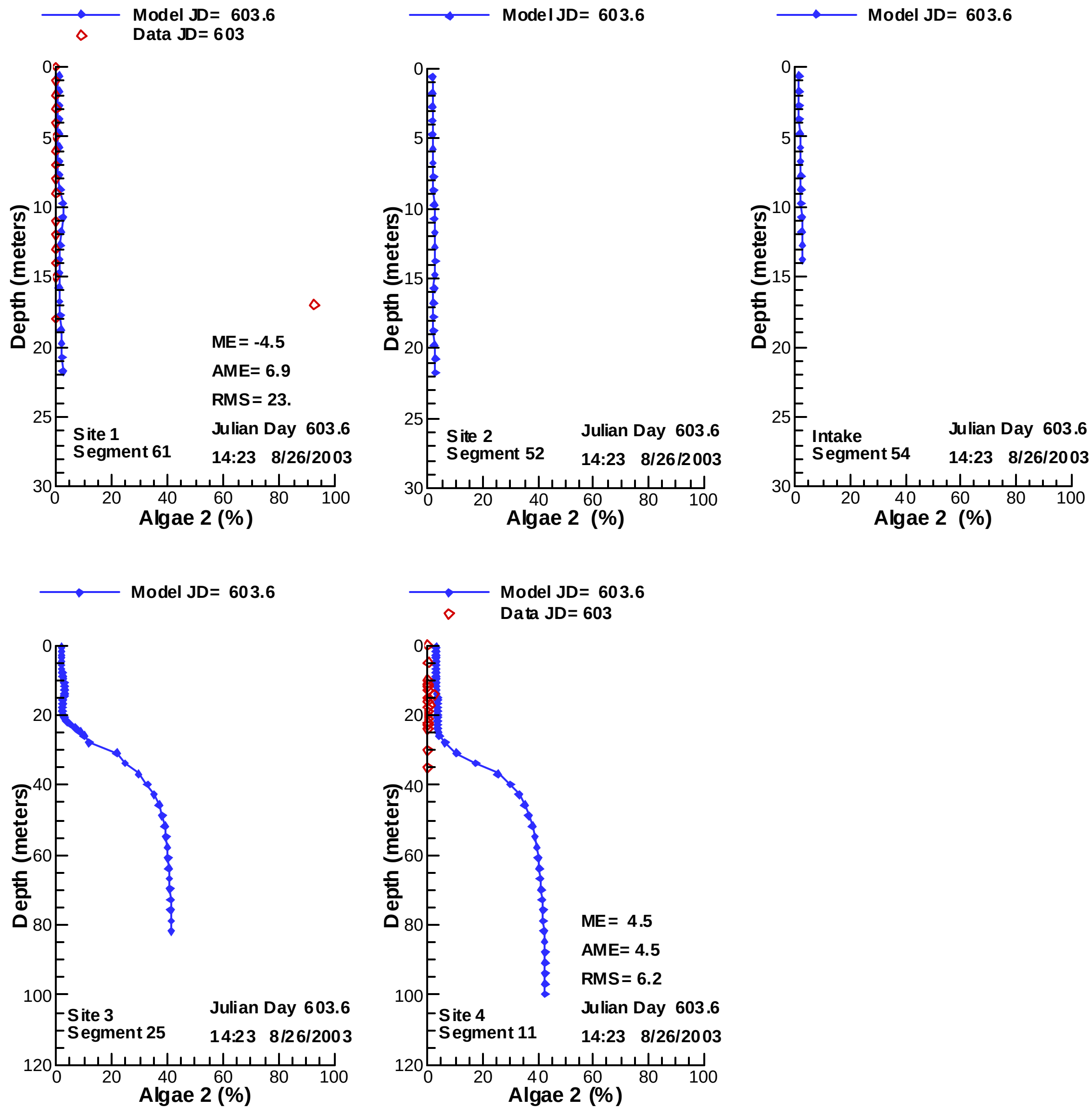

Figure 717. Vertical profiles of ALGAE 2 compared with data for 8/26/2003.

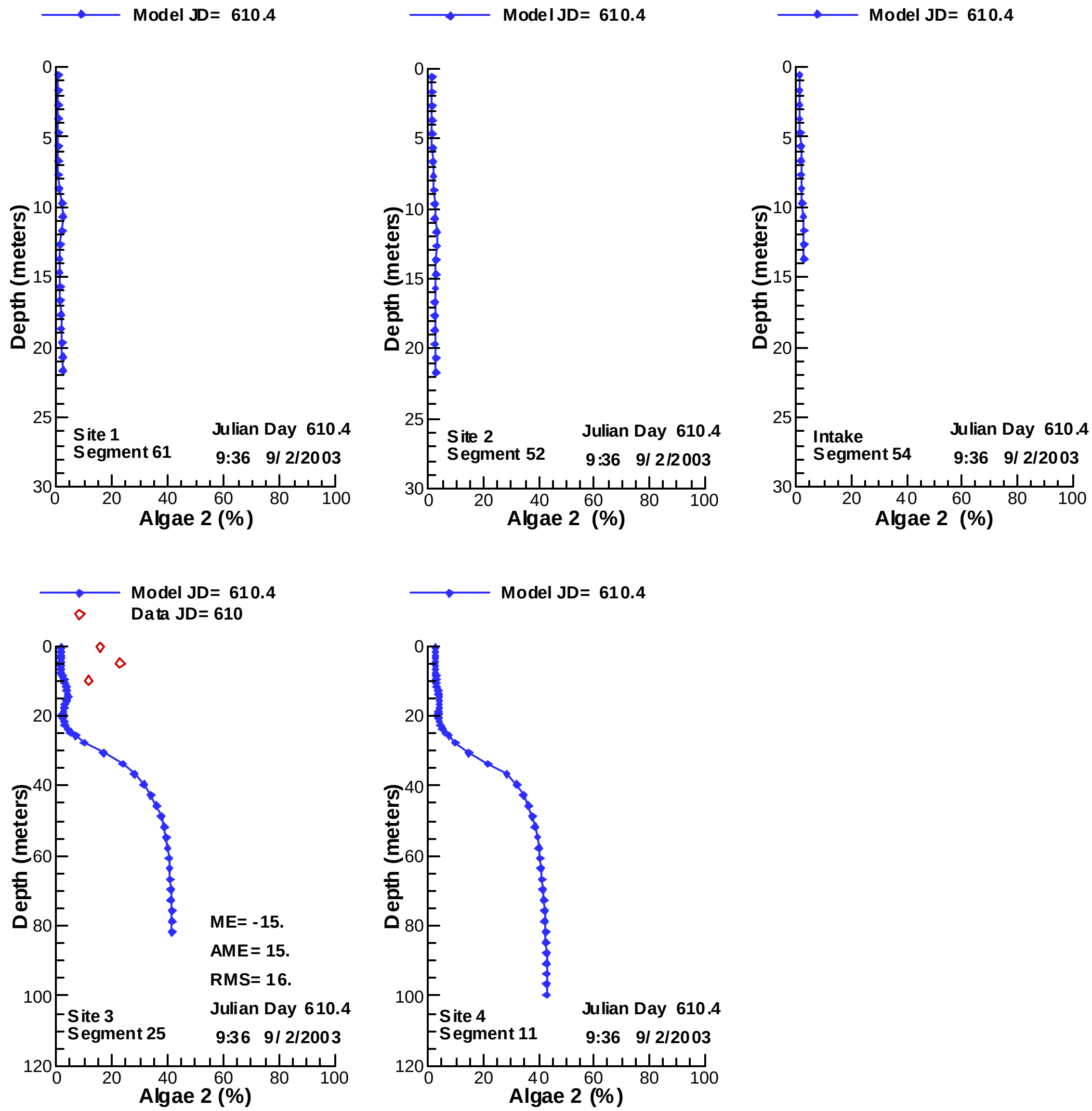

Figure 718. Vertical profiles of ALGAE 2 compared with data for 9/ 2/2003.

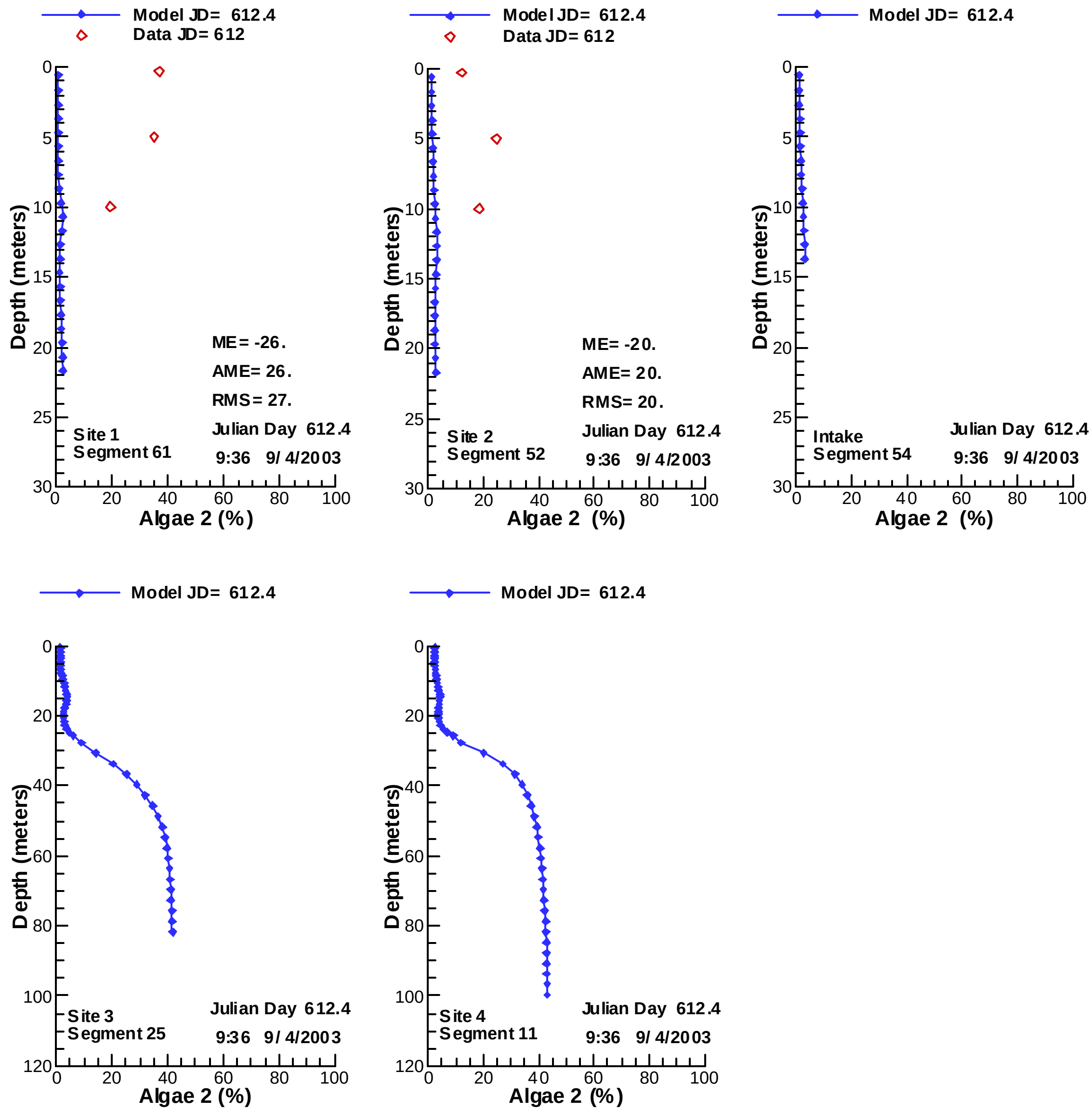

Figure 719. Vertical profiles of ALGAE 2 compared with data for 9/ 4/2003.

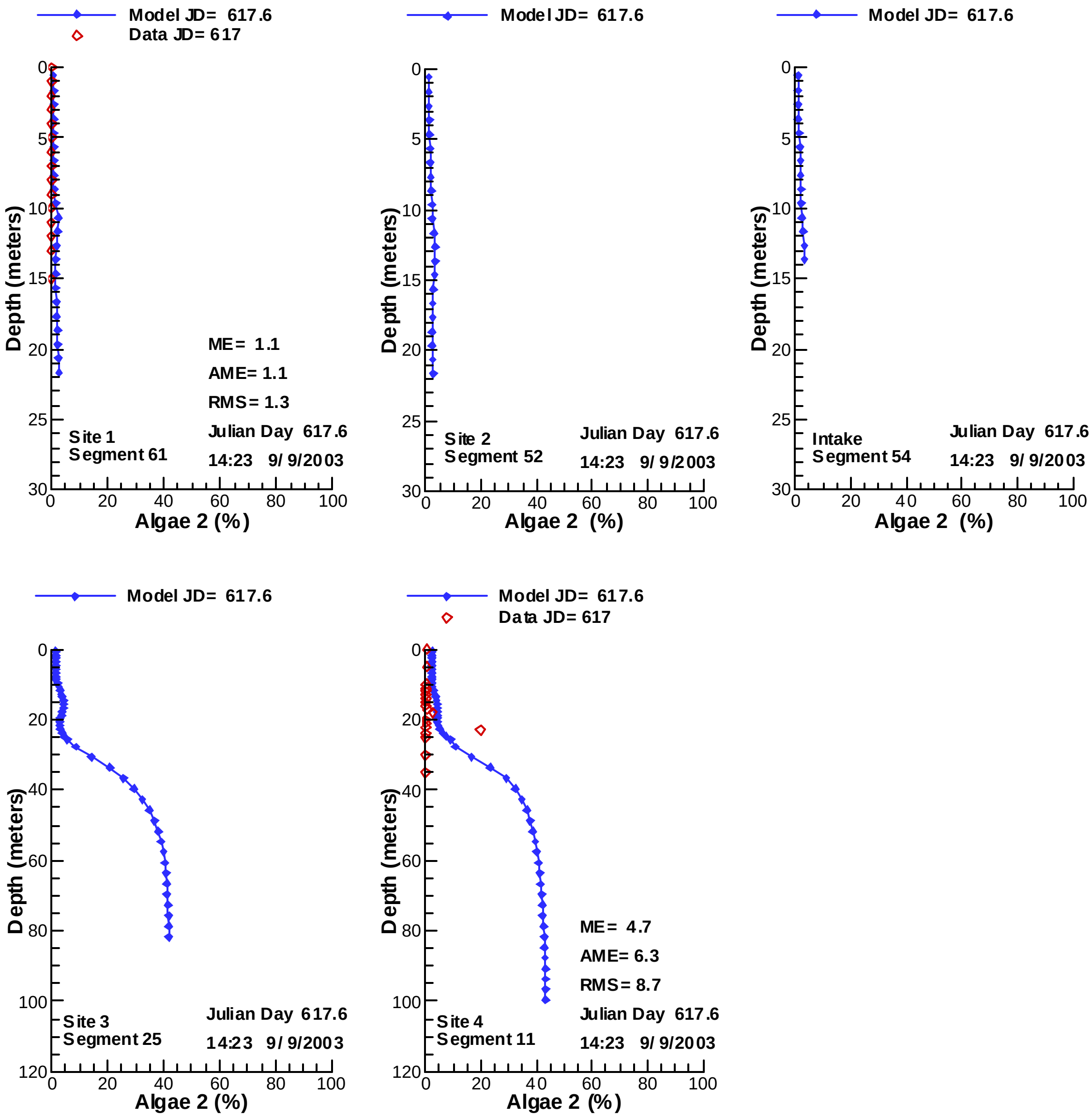

Figure 720. Vertical profiles of ALGAE 2 compared with data for 9/ 9/2003.

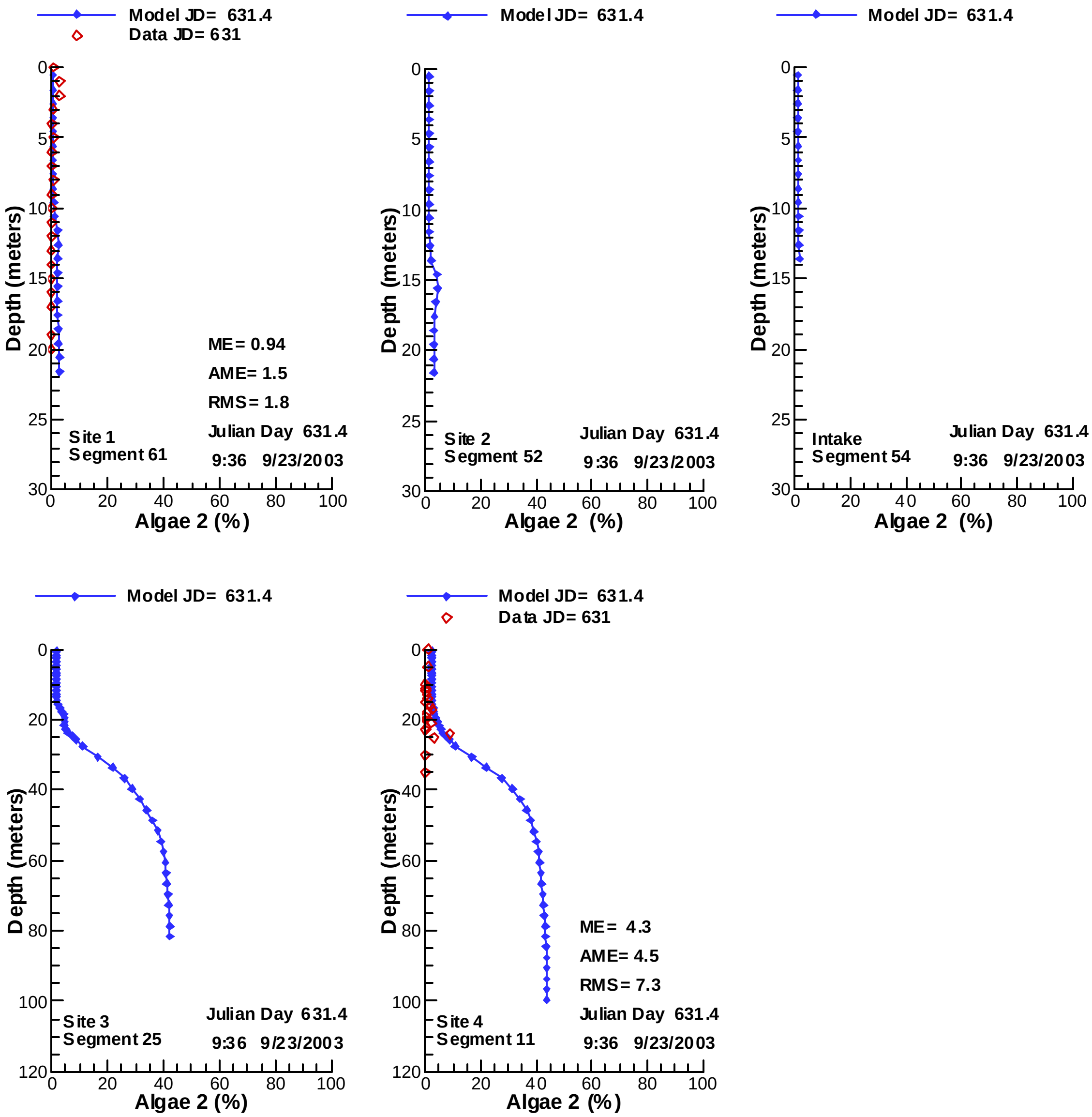

Figure 721. Vertical profiles of ALGAE 2 compared with data for 9/23/2003.

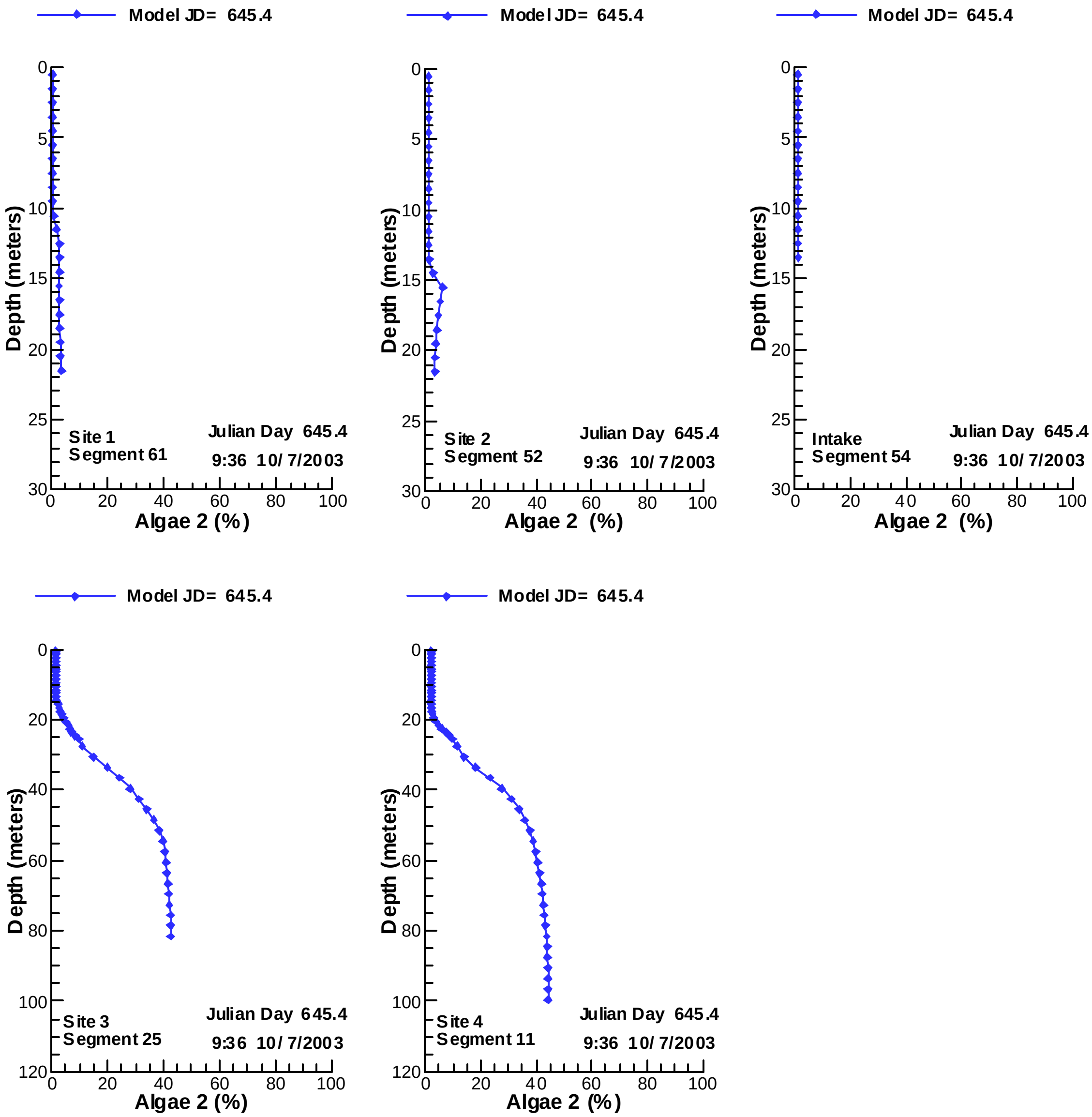

Figure 722. Vertical profiles of ALGAE 2 compared with data for 10/ 7/2003.

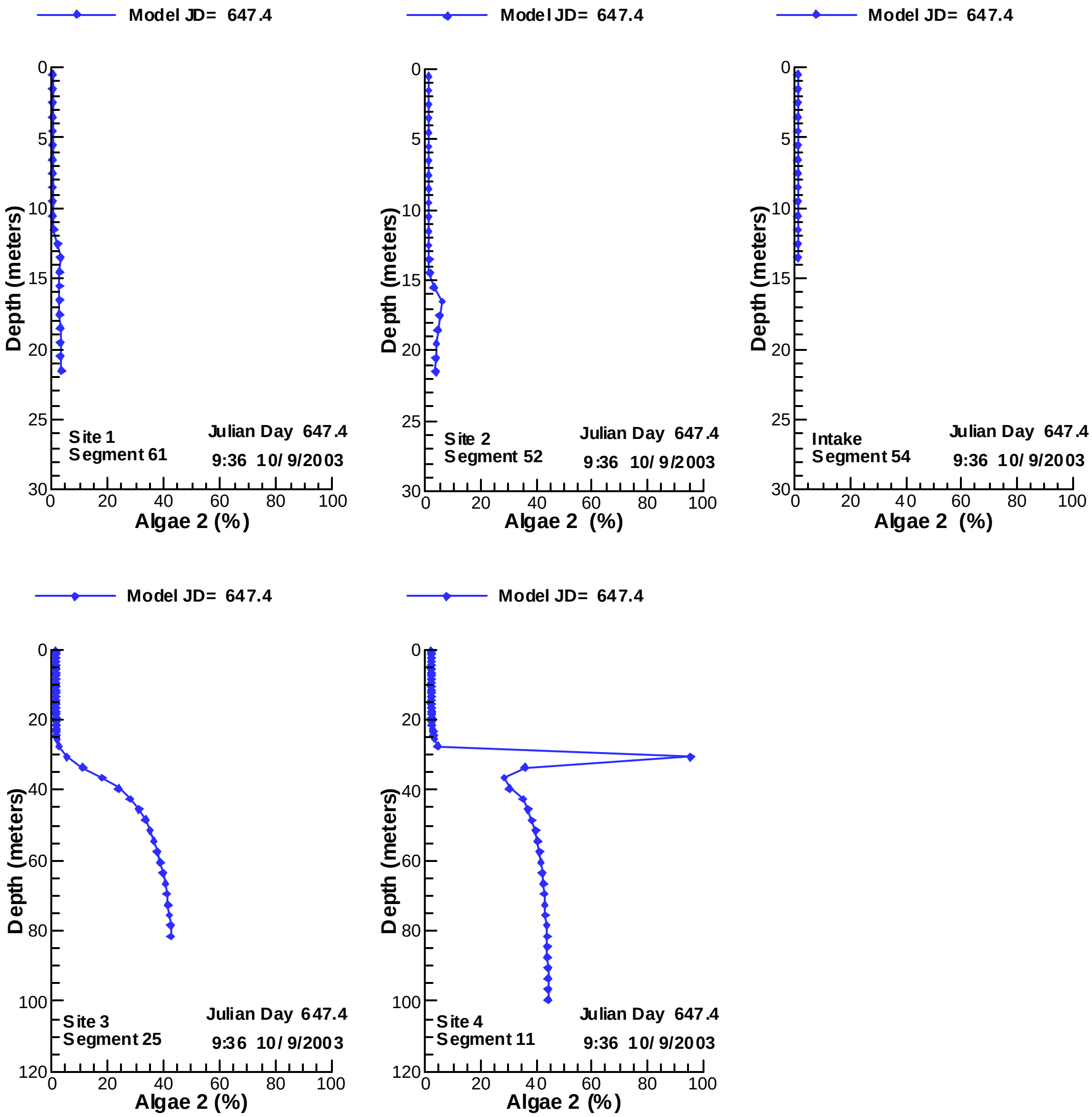

Figure 723. Vertical profiles of ALGAE 2 compared with data for 10/ 9/2003.

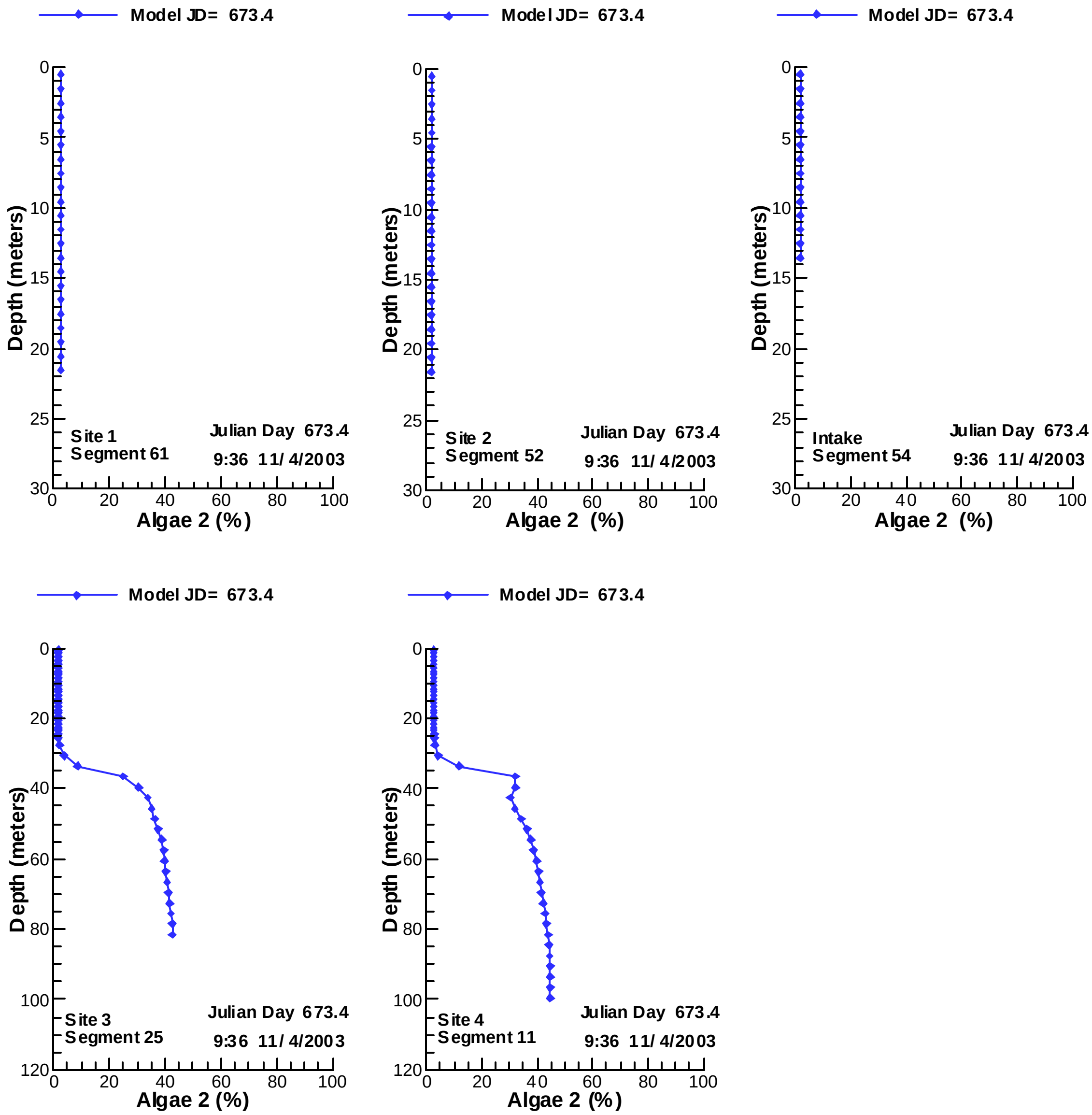

Figure 724. Vertical profiles of ALGAE 2 compared with data for 11/ 4/2003.

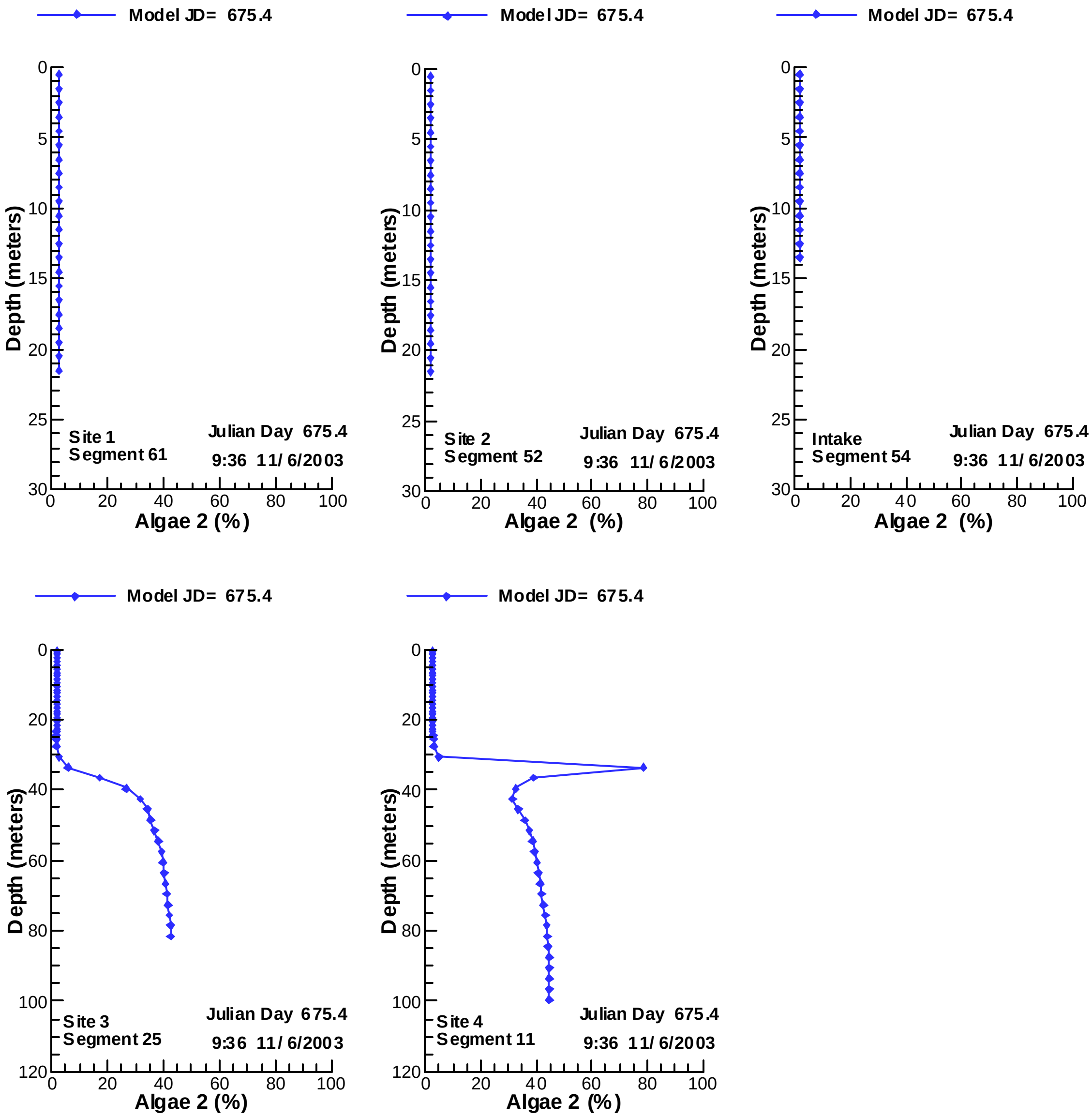

Figure 725. Vertical profiles of ALGAE 2 compared with data for 11/ 6/2003.

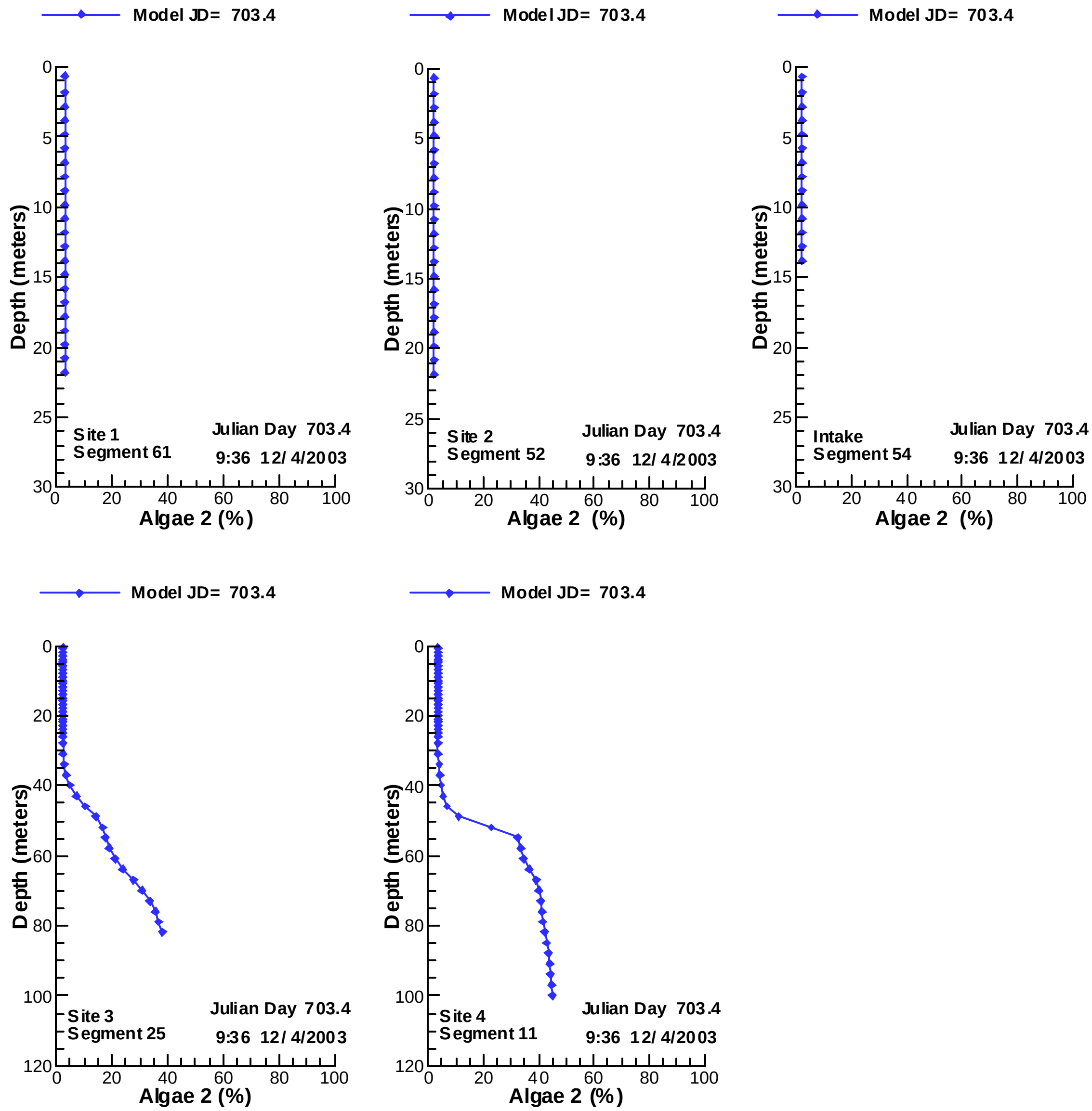

Figure 726. Vertical profiles of ALGAE 2 compared with data for 12/ 4/2003.

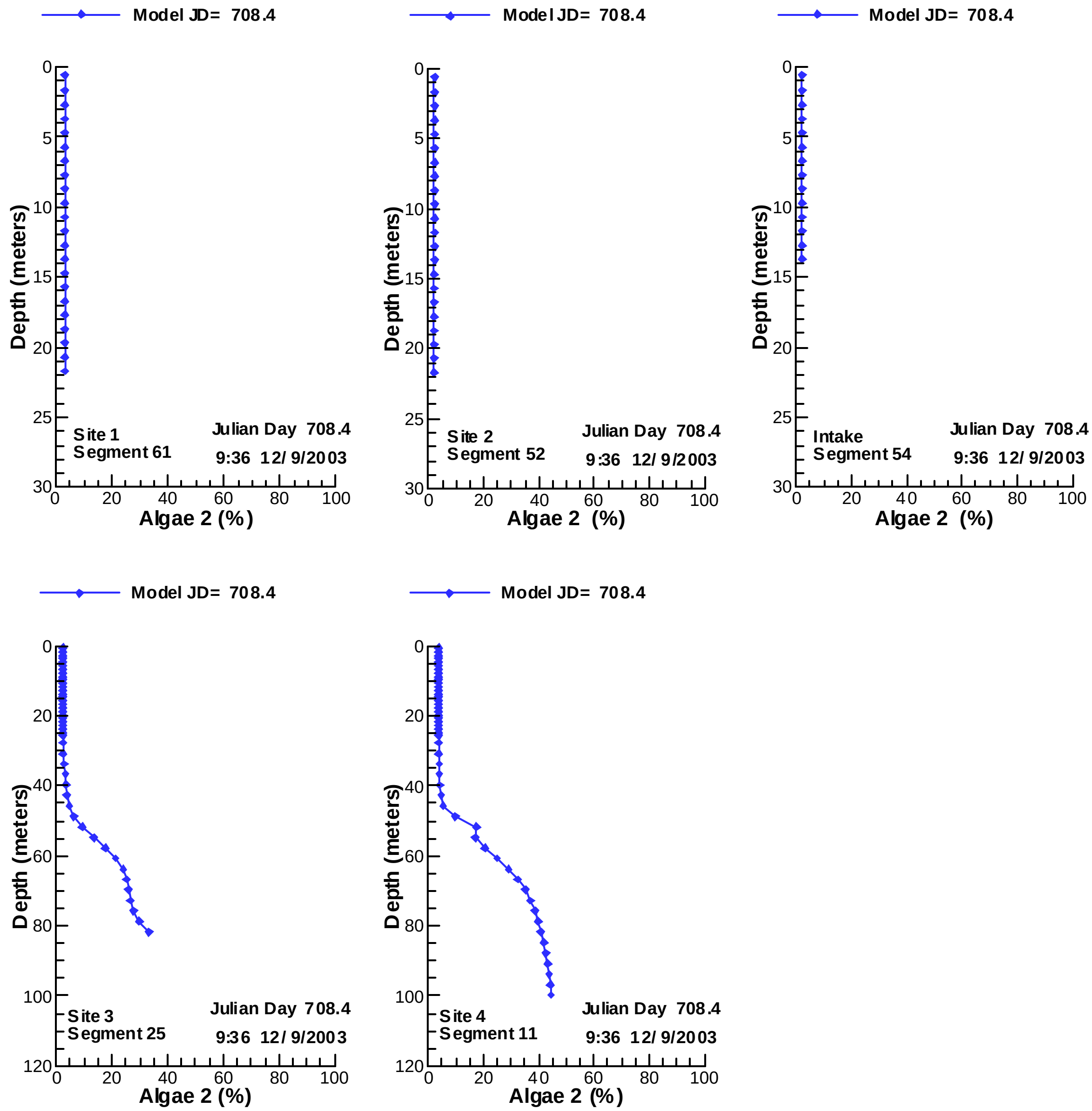

Figure 727. Vertical profiles of ALGAE 2 compared with data for 12/ 9/2003.

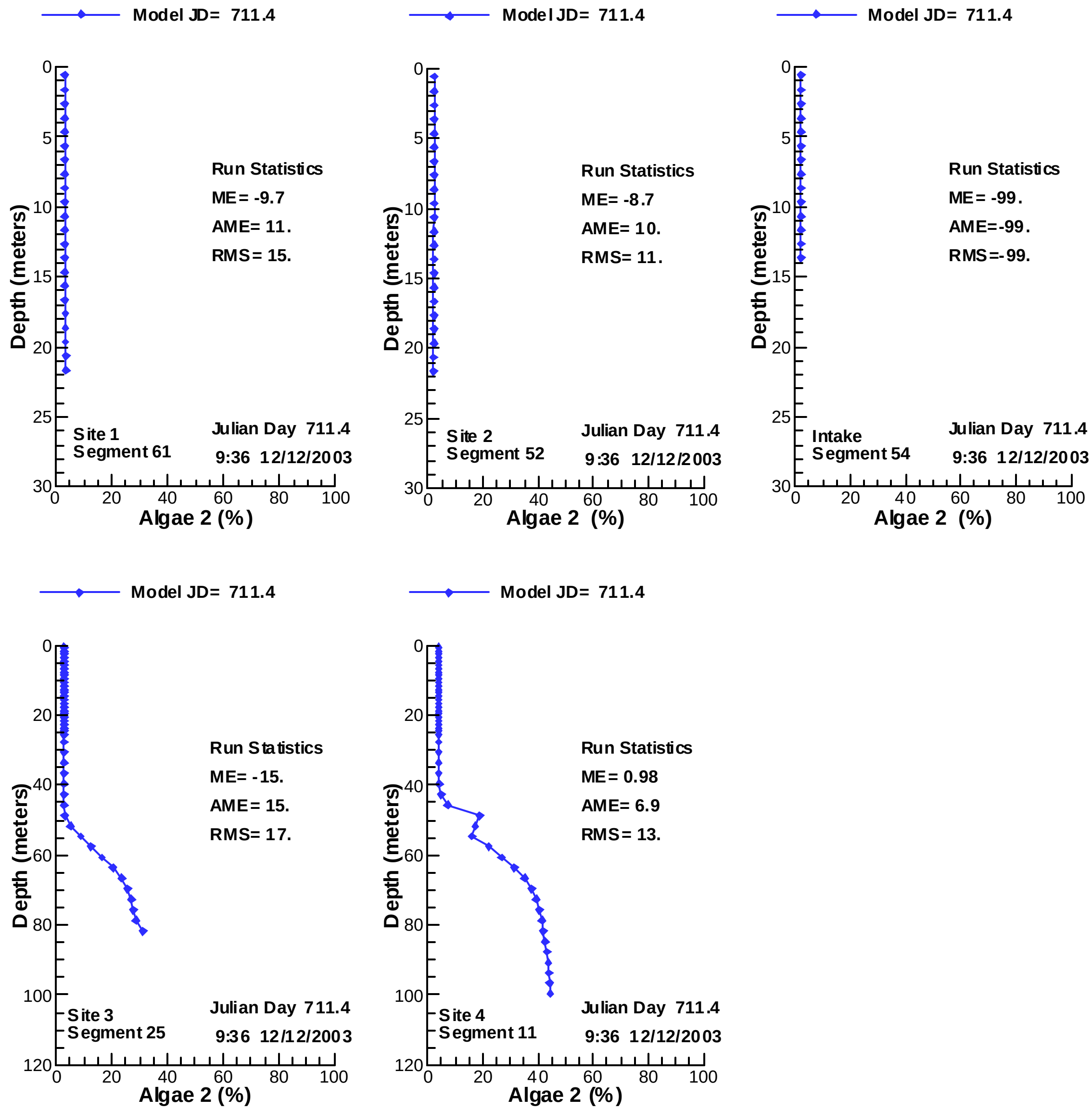

Figure 728. Vertical profiles of ALGAE 2 compared with data for 12/12/2003.

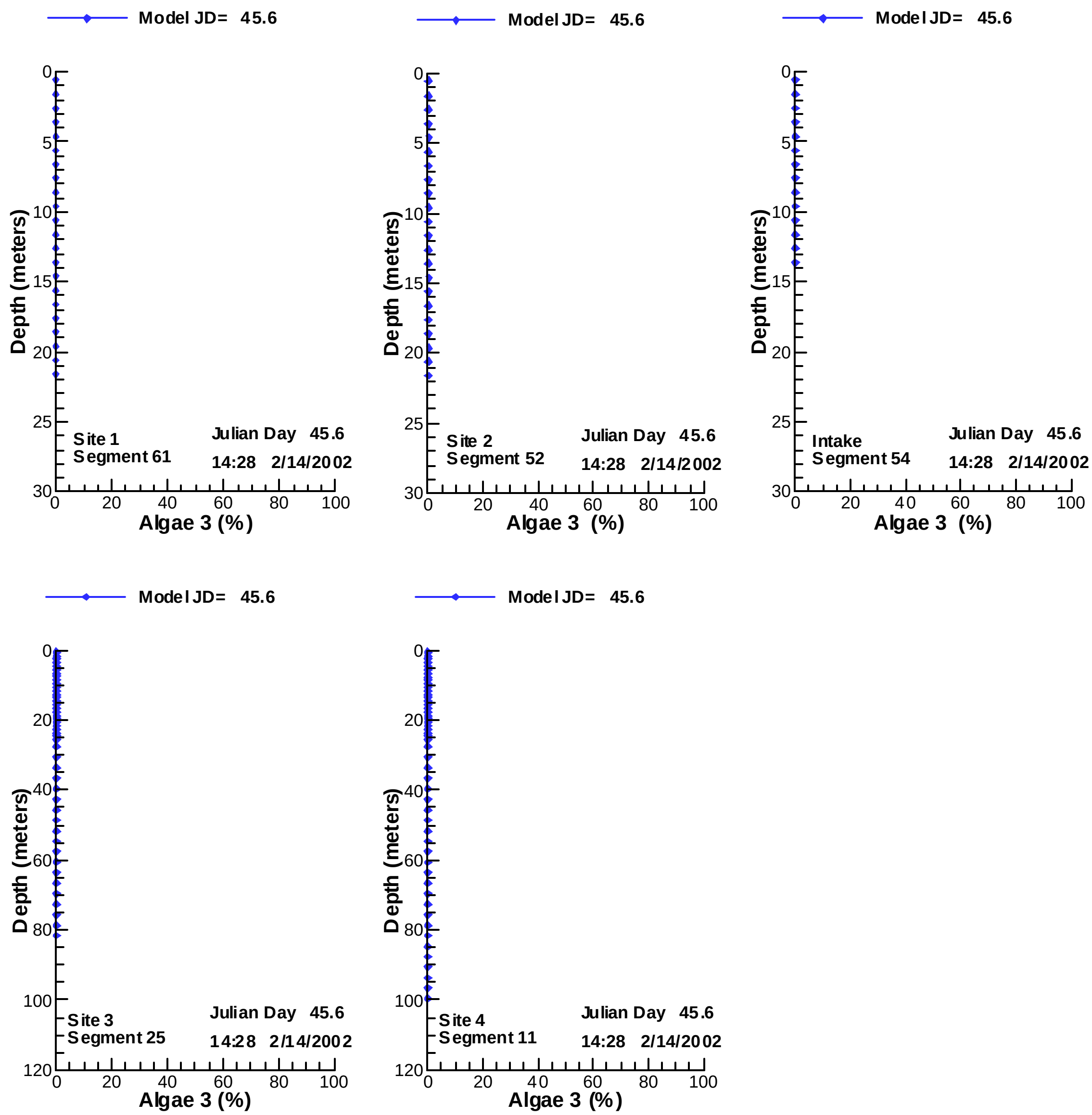

Figure 729. Vertical profiles of ALGAE 3 compared with data for 2/14/2002.

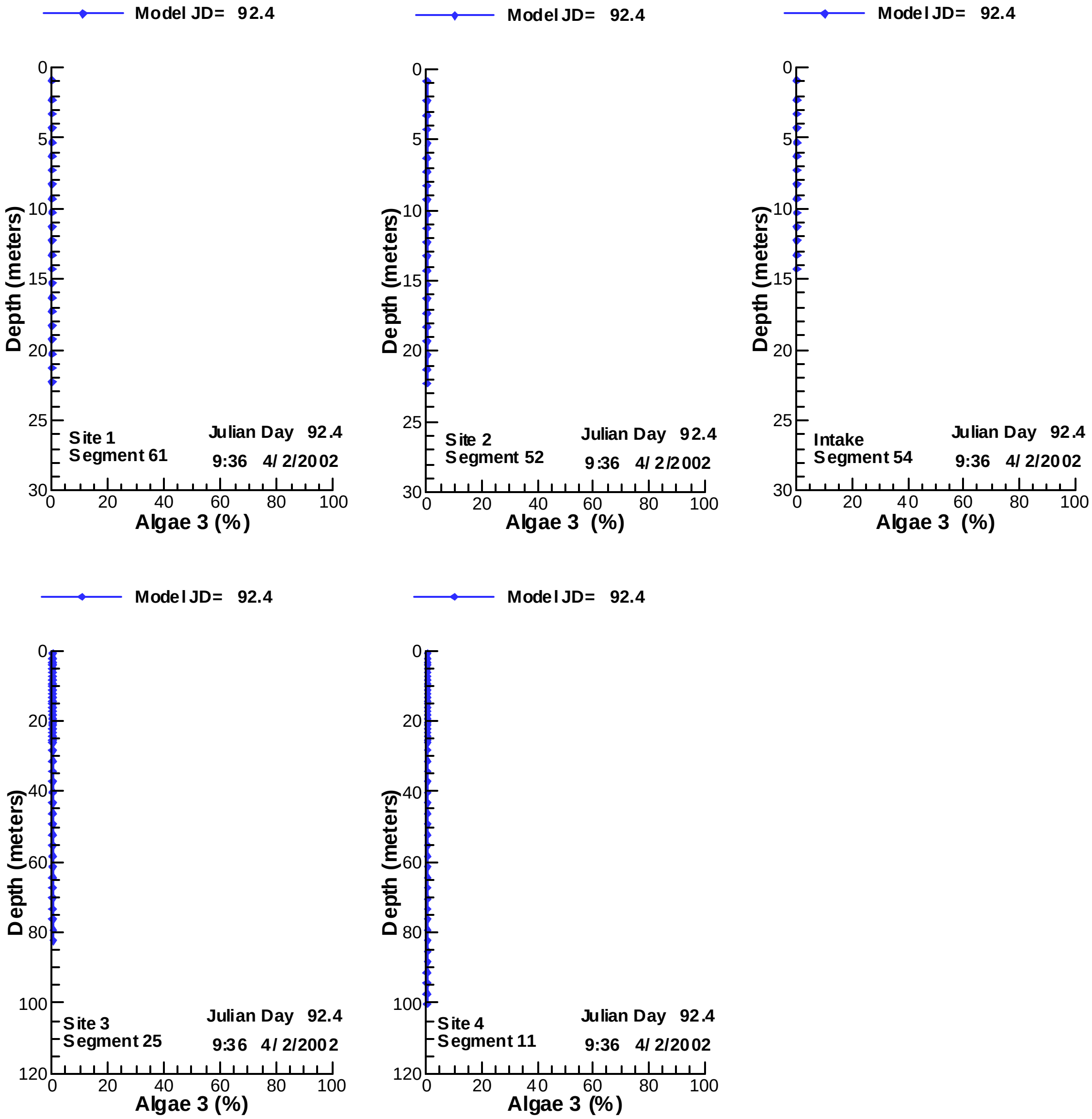

Figure 730. Vertical profiles of ALGAE 3 compared with data for 4/ 2/2002.

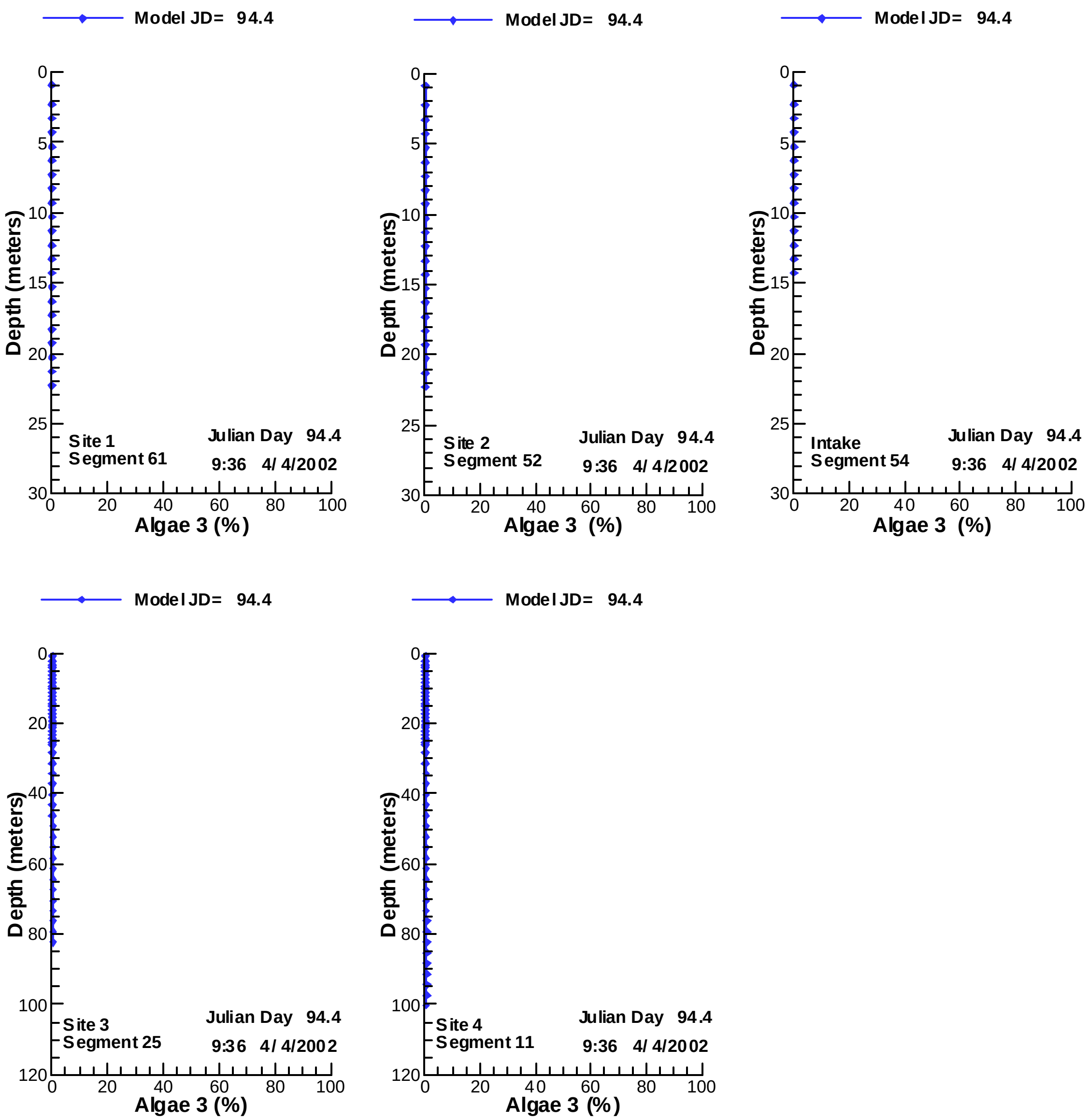

Figure 731. Vertical profiles of ALGAE 3 compared with data for 4/ 4/2002.

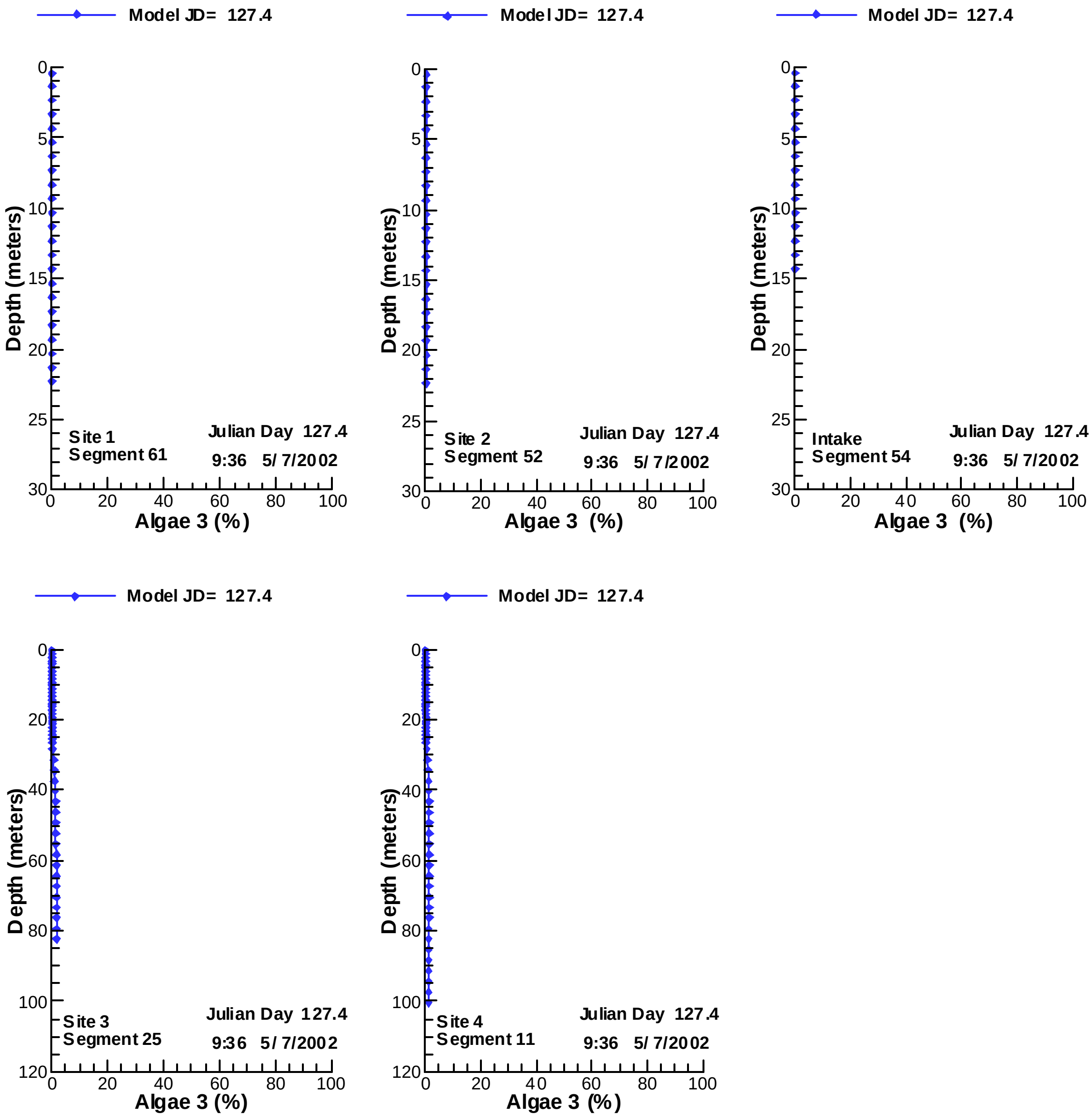

Figure 732. Vertical profiles of ALGAE 3 compared with data for 5/ 7/2002.

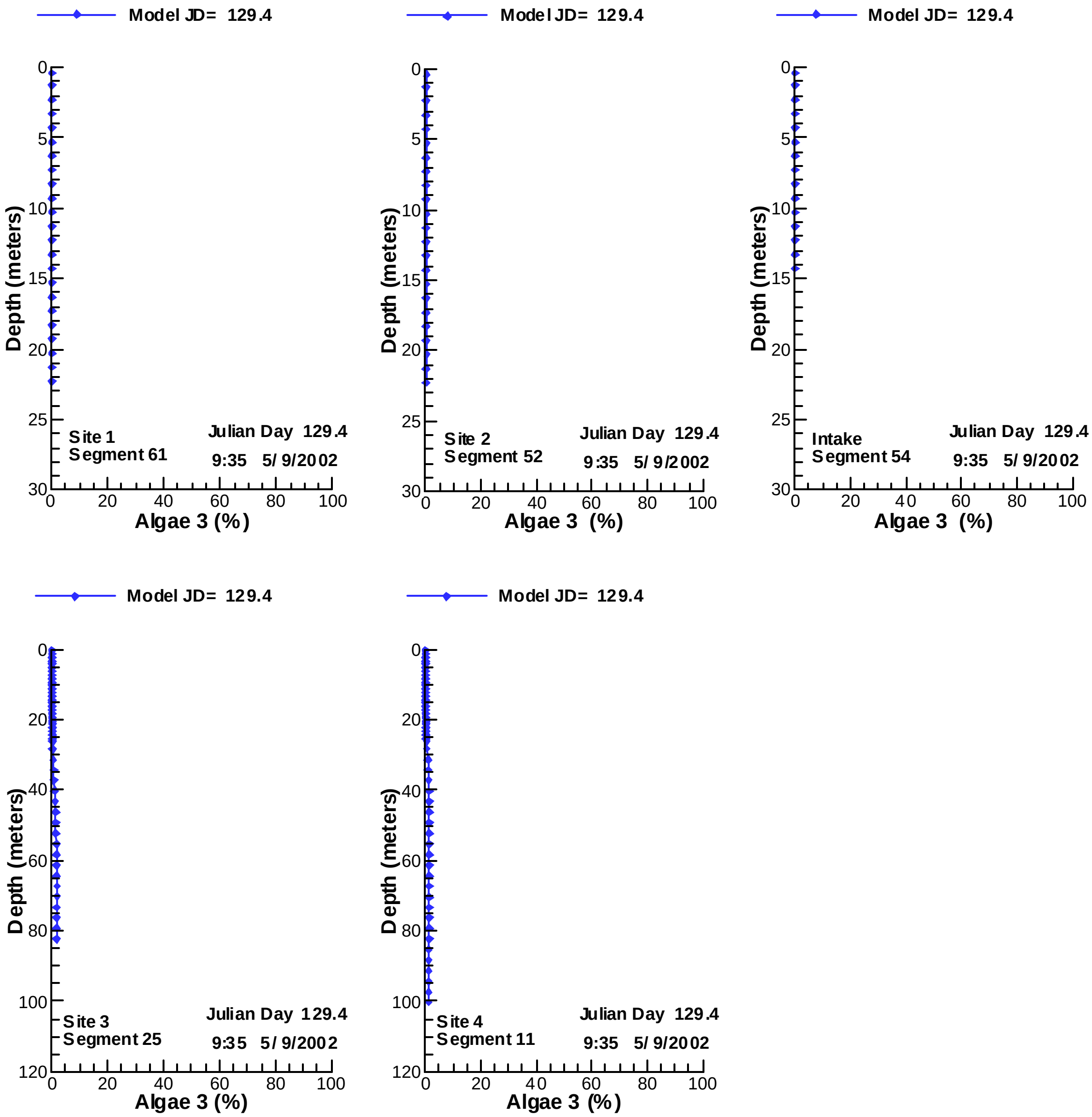

Figure 733. Vertical profiles of ALGAE 3 compared with data for 5/ 9/2002.

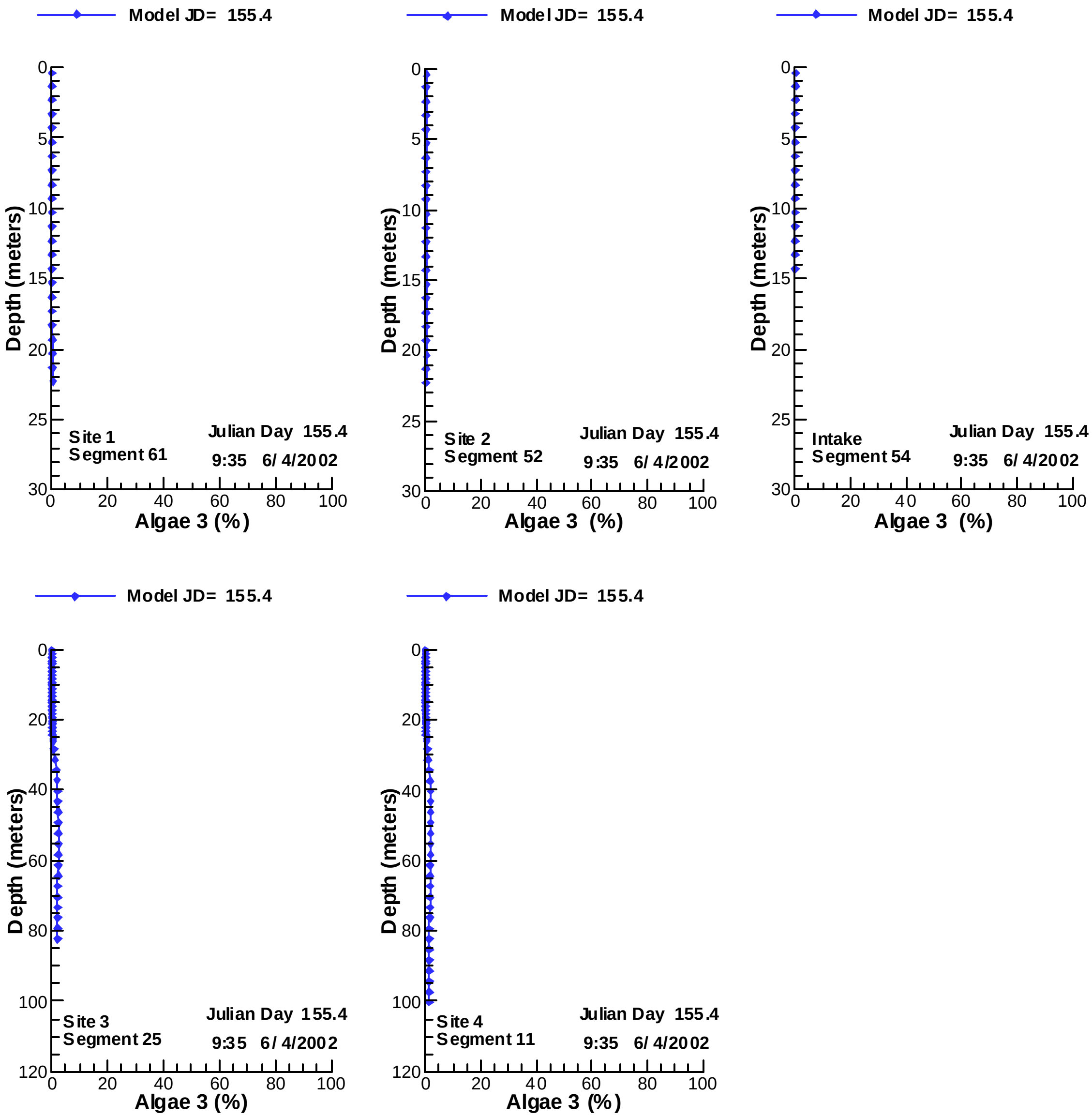

Figure 734. Vertical profiles of ALGAE 3 compared with data for 6/ 4/2002.

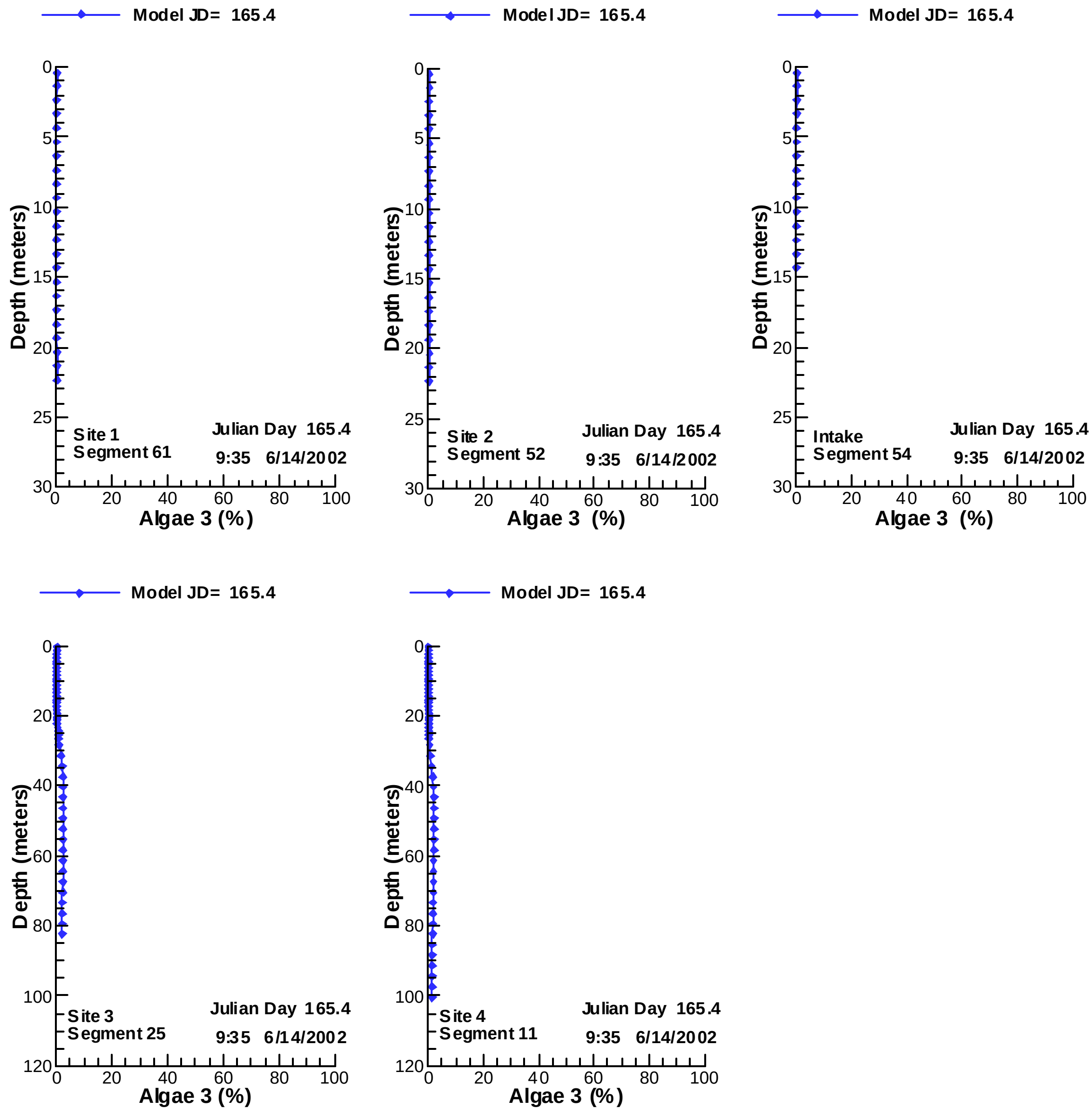

Figure 735. Vertical profiles of ALGAE 3 compared with data for 6/14/2002.

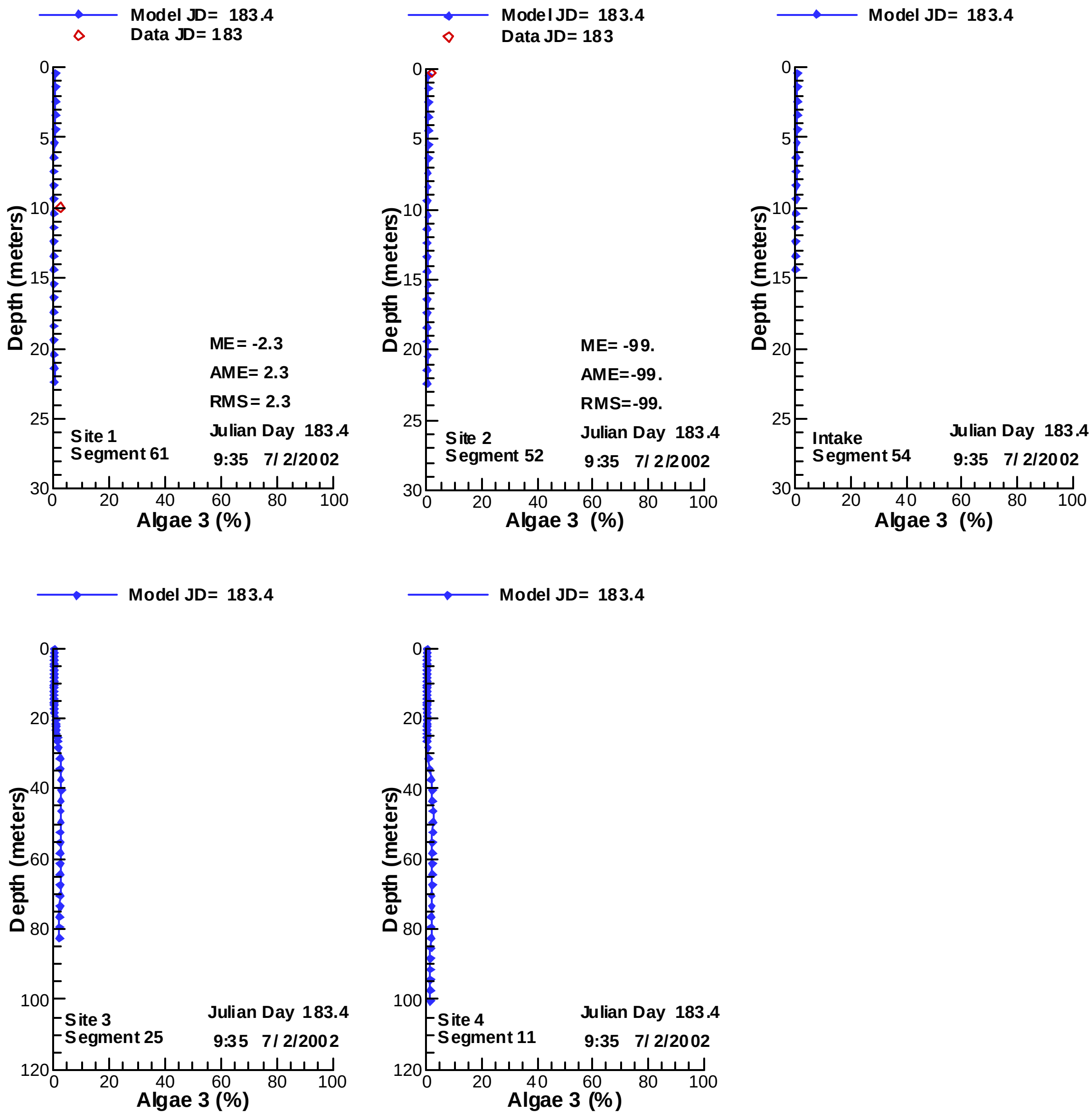

Figure 736. Vertical profiles of ALGAE 3 compared with data for 7/ 2/2002.

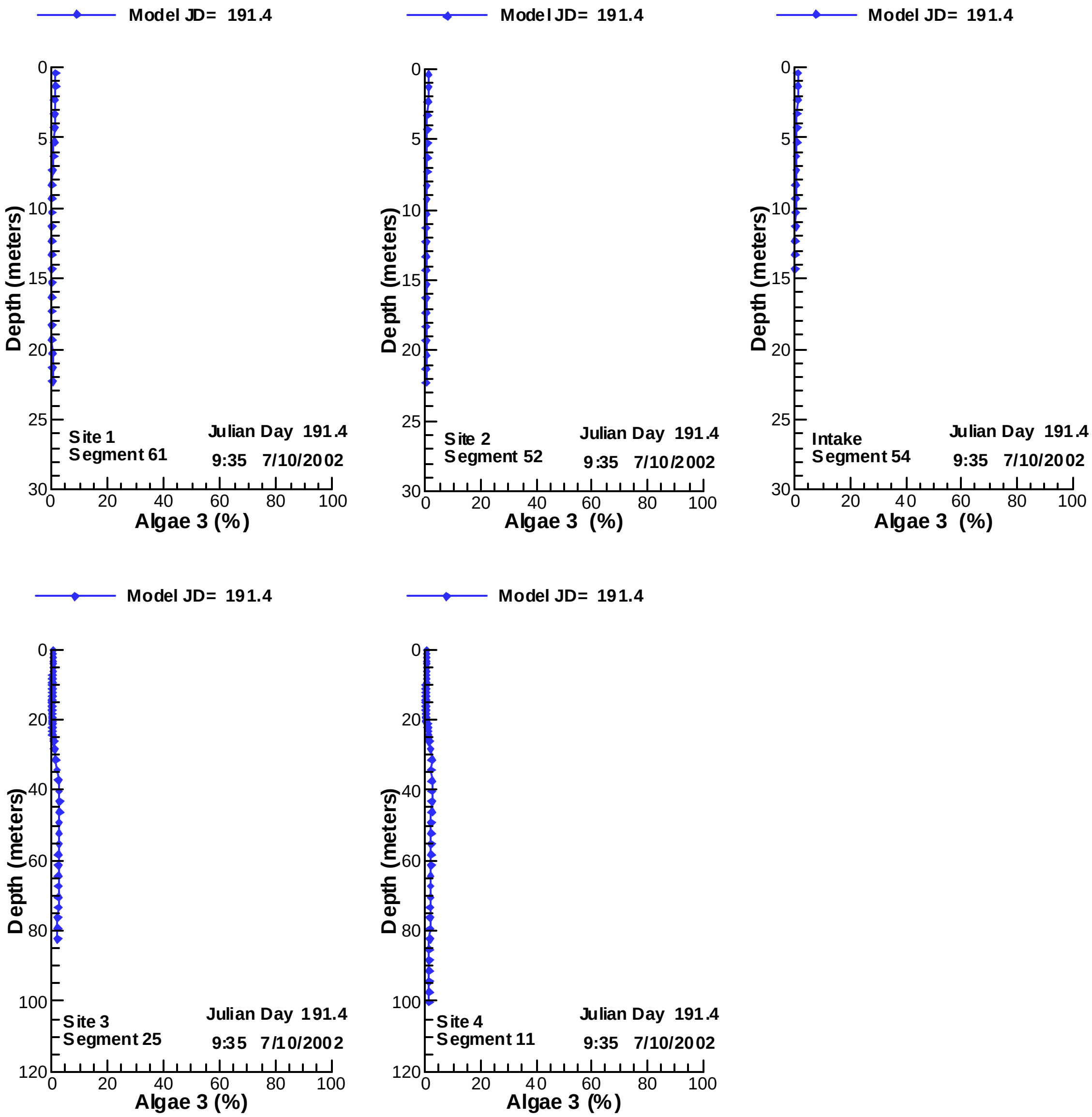

Figure 737. Vertical profiles of ALGAE 3 compared with data for 7/10/2002.

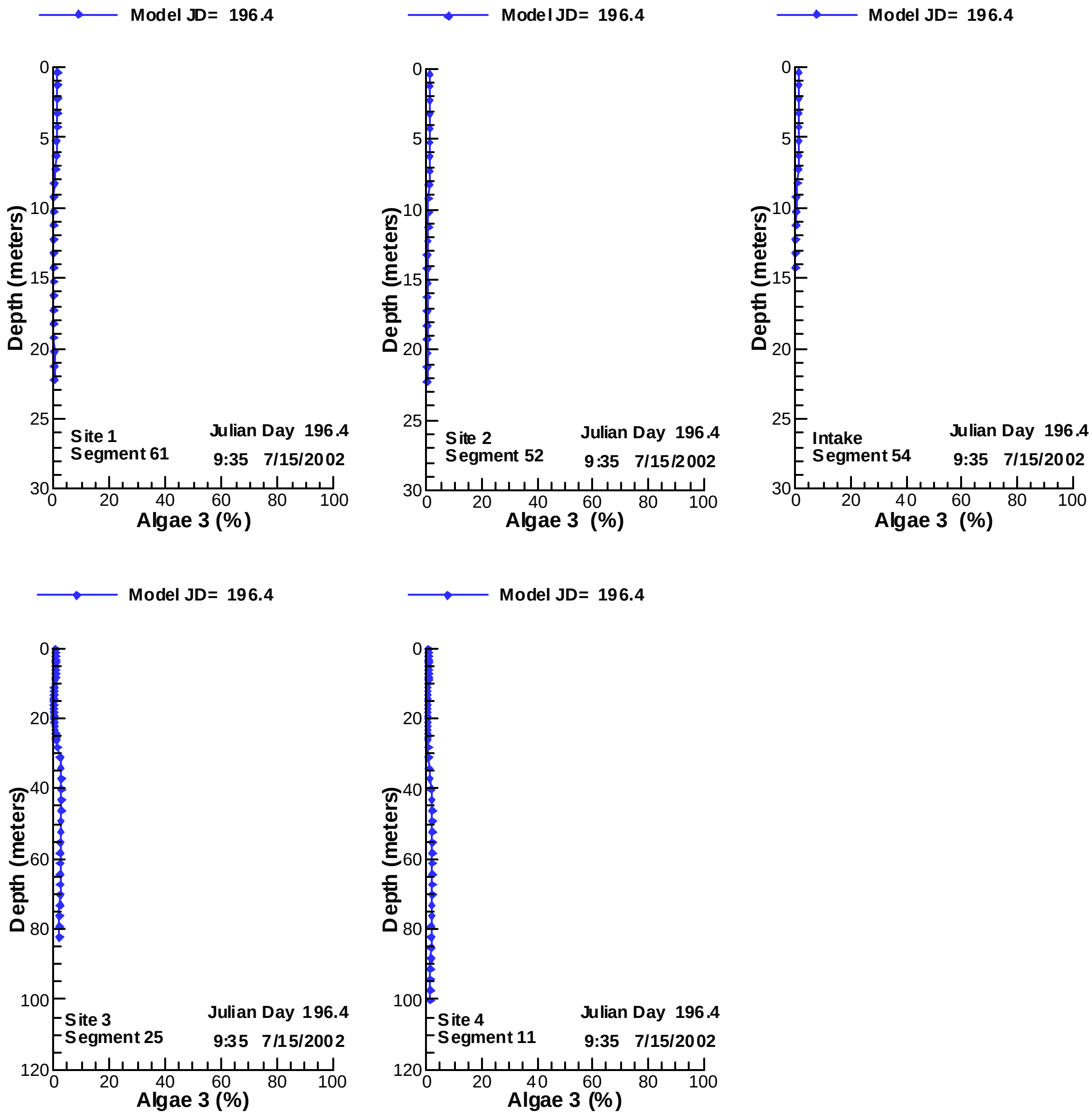

Figure 738. Vertical profiles of ALGAE 3 compared with data for 7/15/2002.

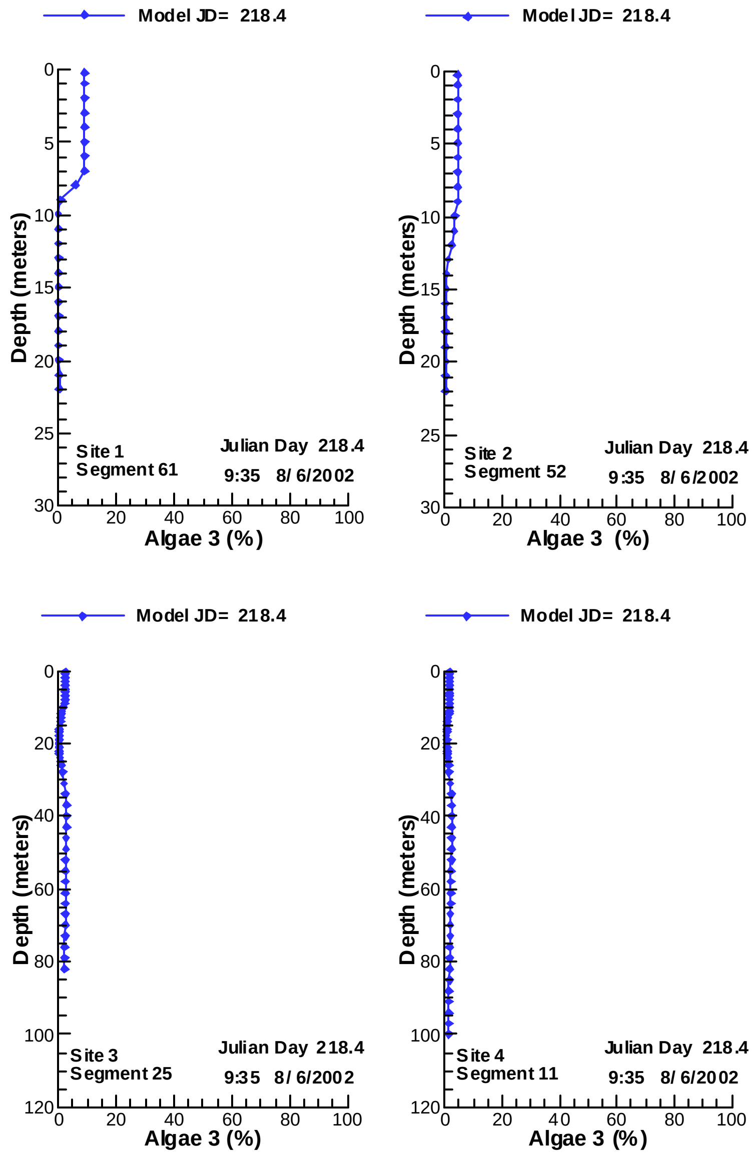

Figure 739. Vertical profiles of ALGAE 3 compared with data for 8/ 6/2002.

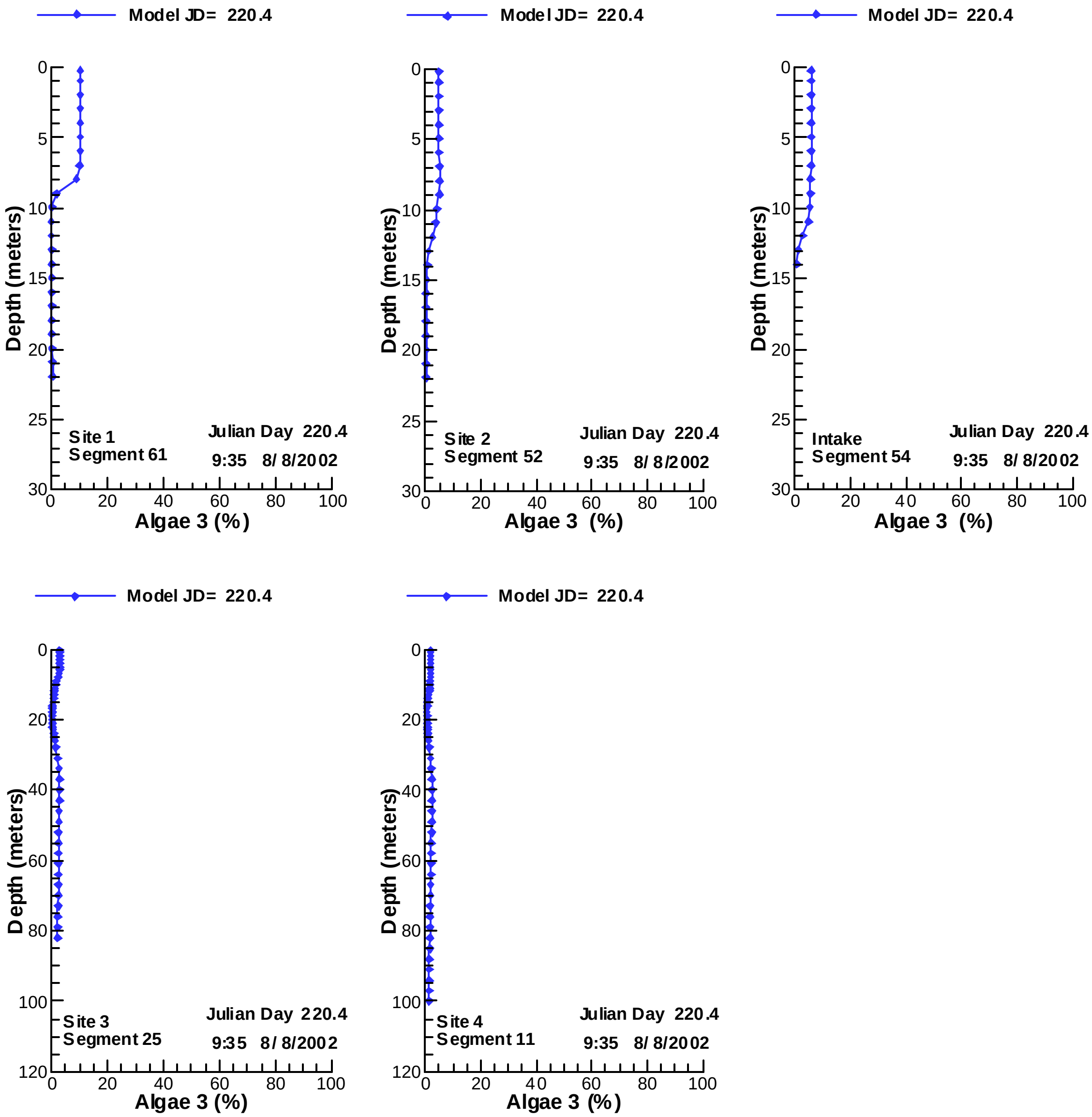

Figure 740. Vertical profiles of ALGAE 3 compared with data for 8/ 8/2002.

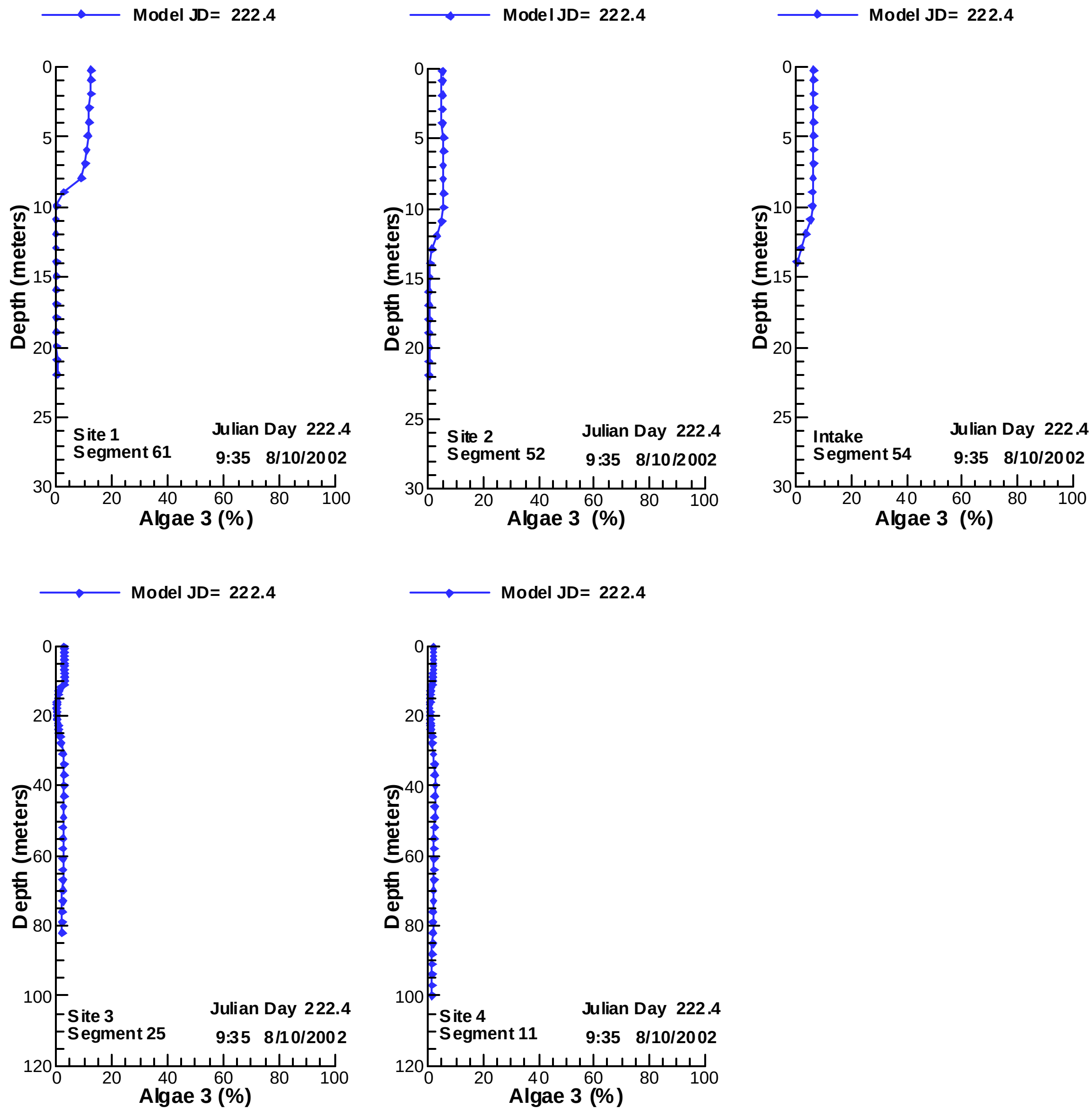

Figure 741. Vertical profiles of ALGAE 3 compared with data for 8/10/2002.

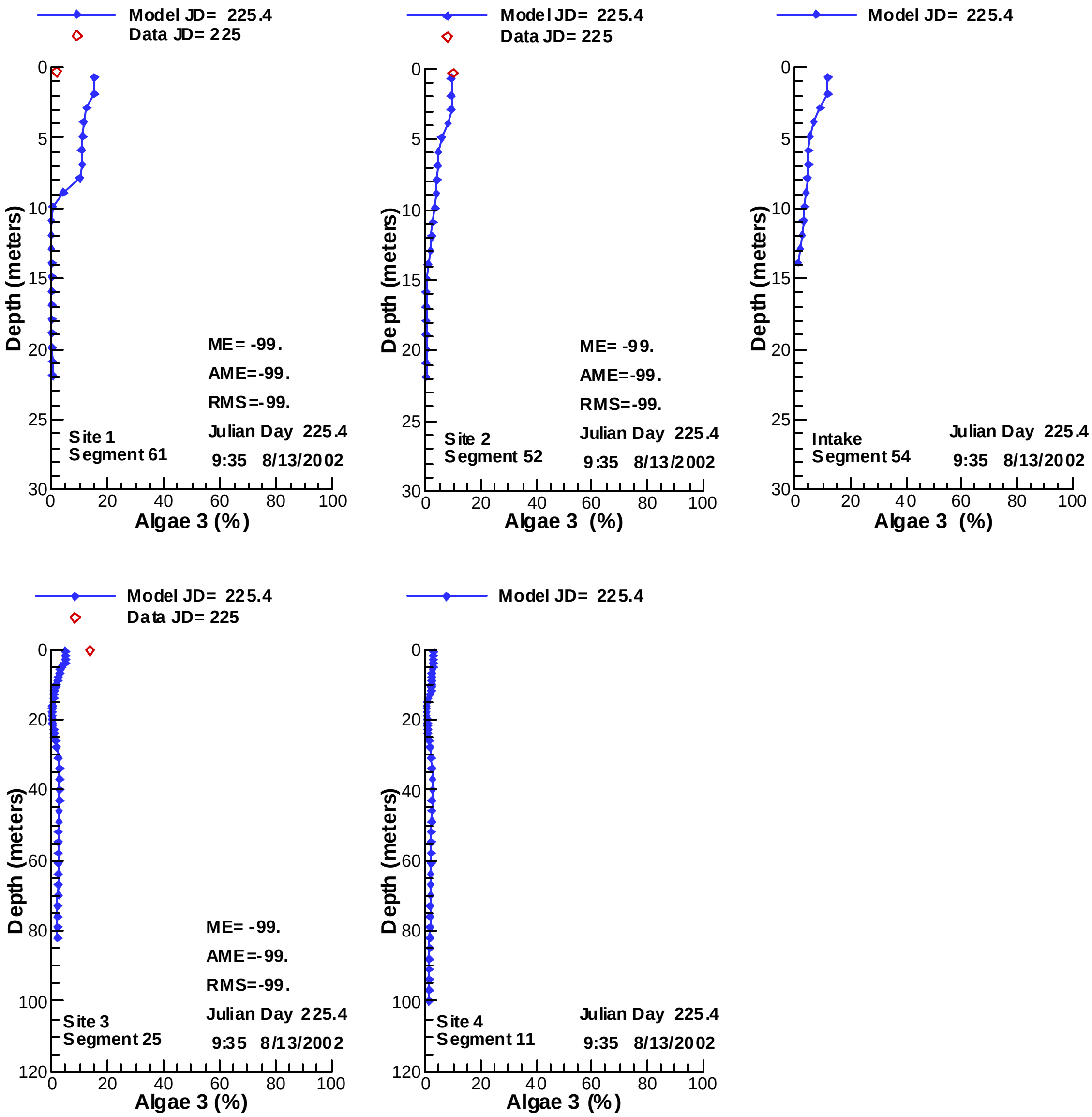

Figure 742. Vertical profiles of ALGAE 3 compared with data for 8/13/2002.

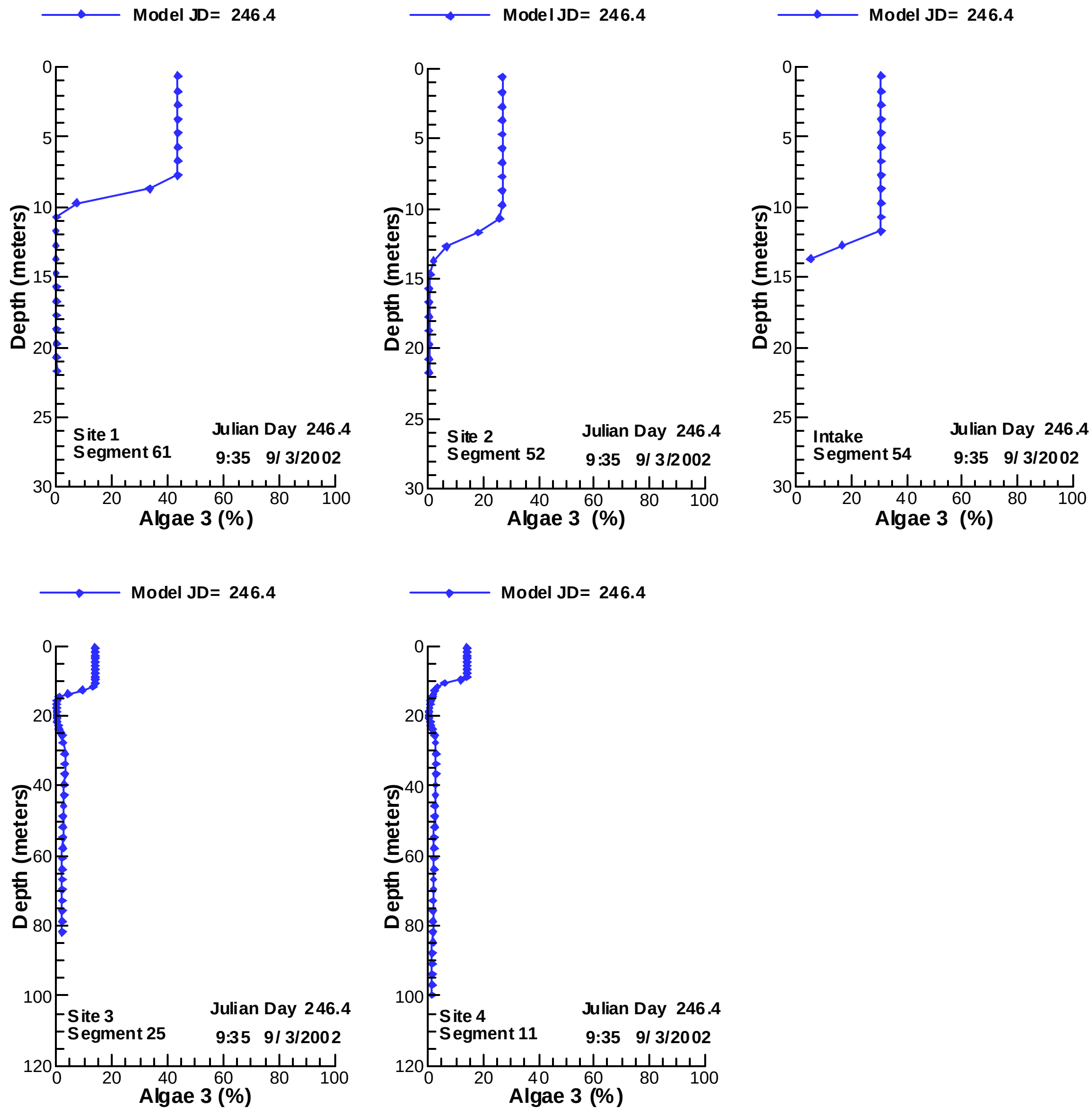

Figure 743. Vertical profiles of ALGAE 3 compared with data for 9/ 3/2002.

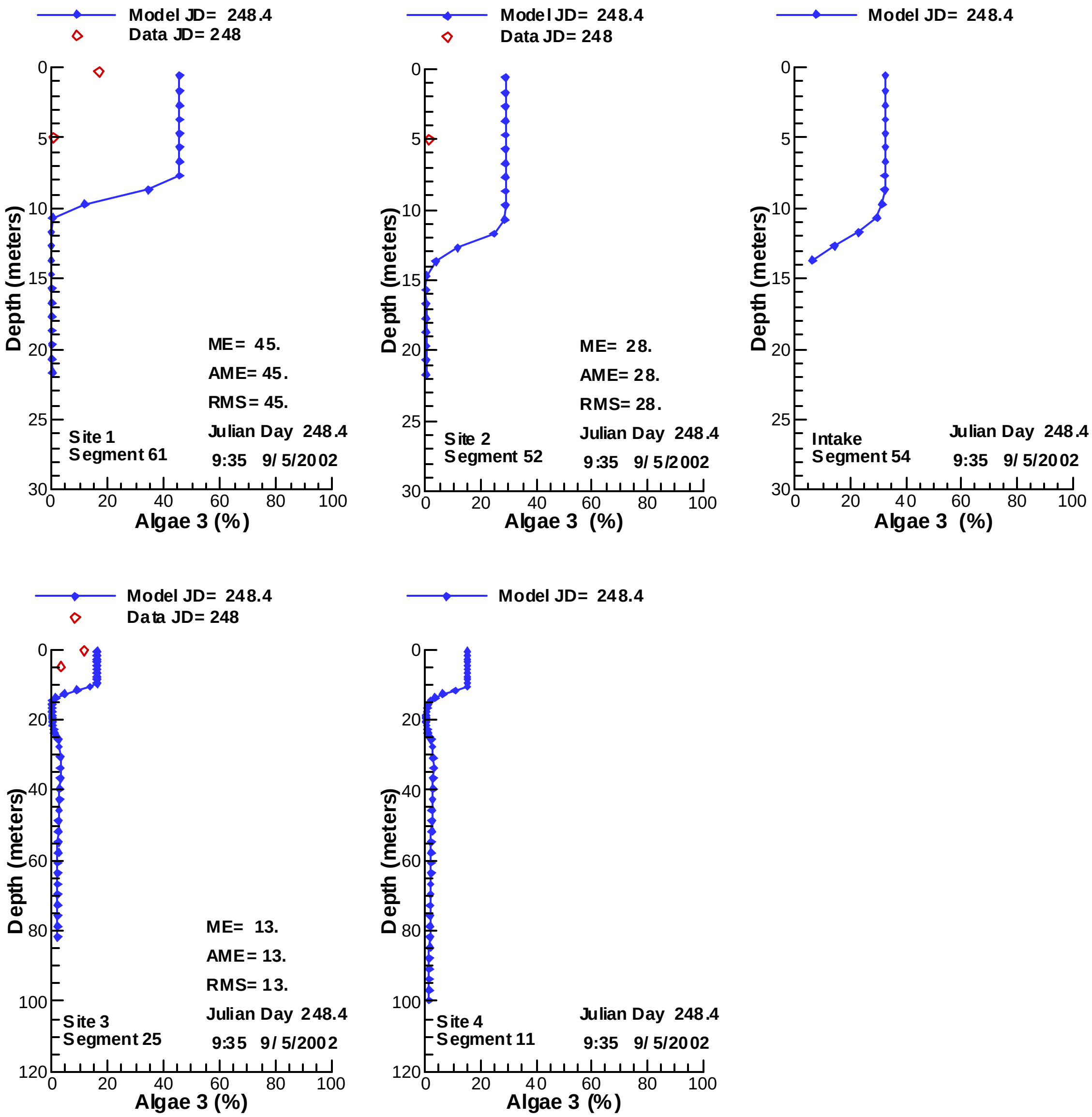

Figure 744. Vertical profiles of ALGAE 3 compared with data for 9/ 5/2002.

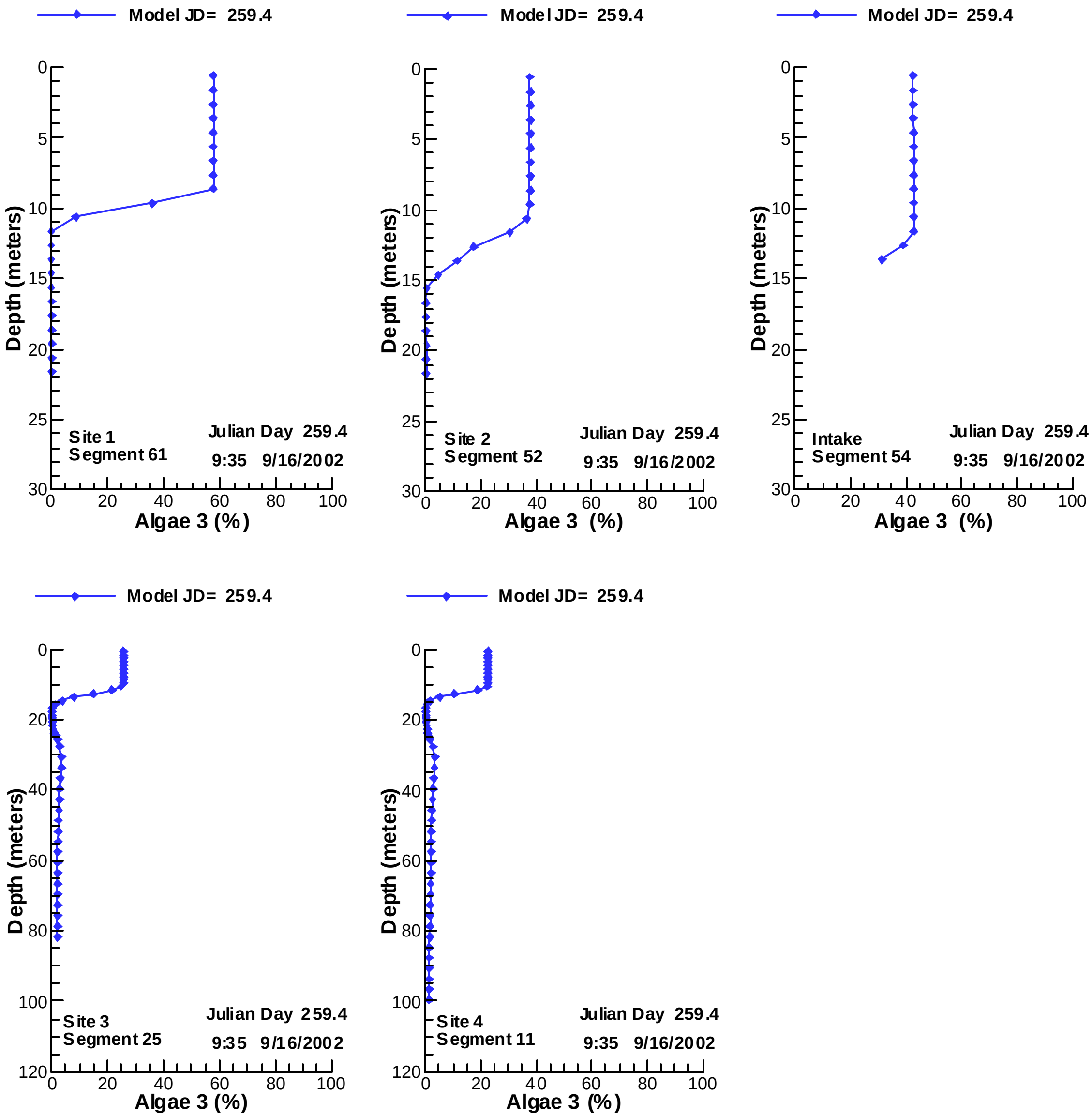

Figure 745. Vertical profiles of ALGAE 3 compared with data for 9/16/2002.

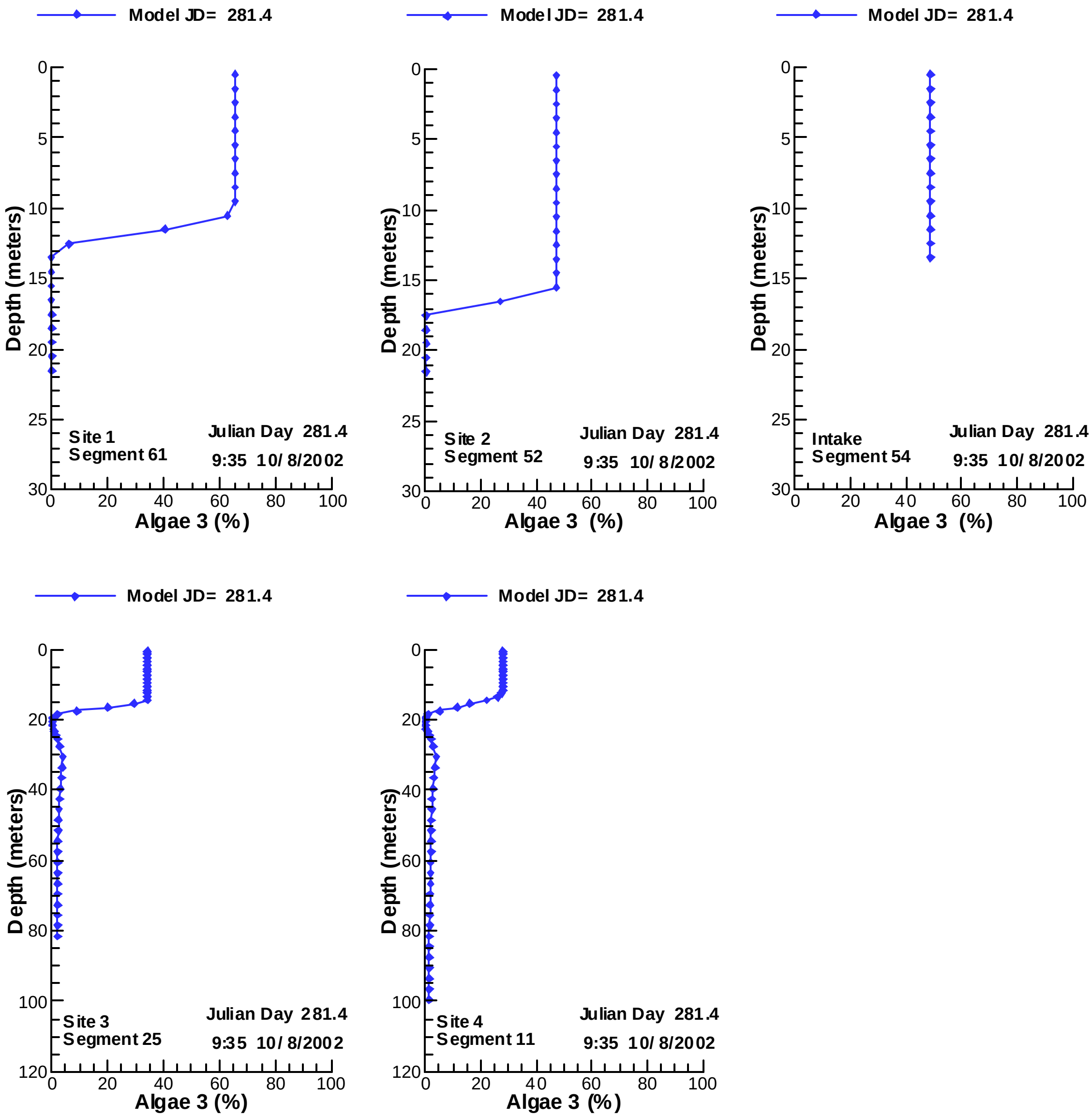

Figure 746. Vertical profiles of ALGAE 3 compared with data for 10/ 8/2002.

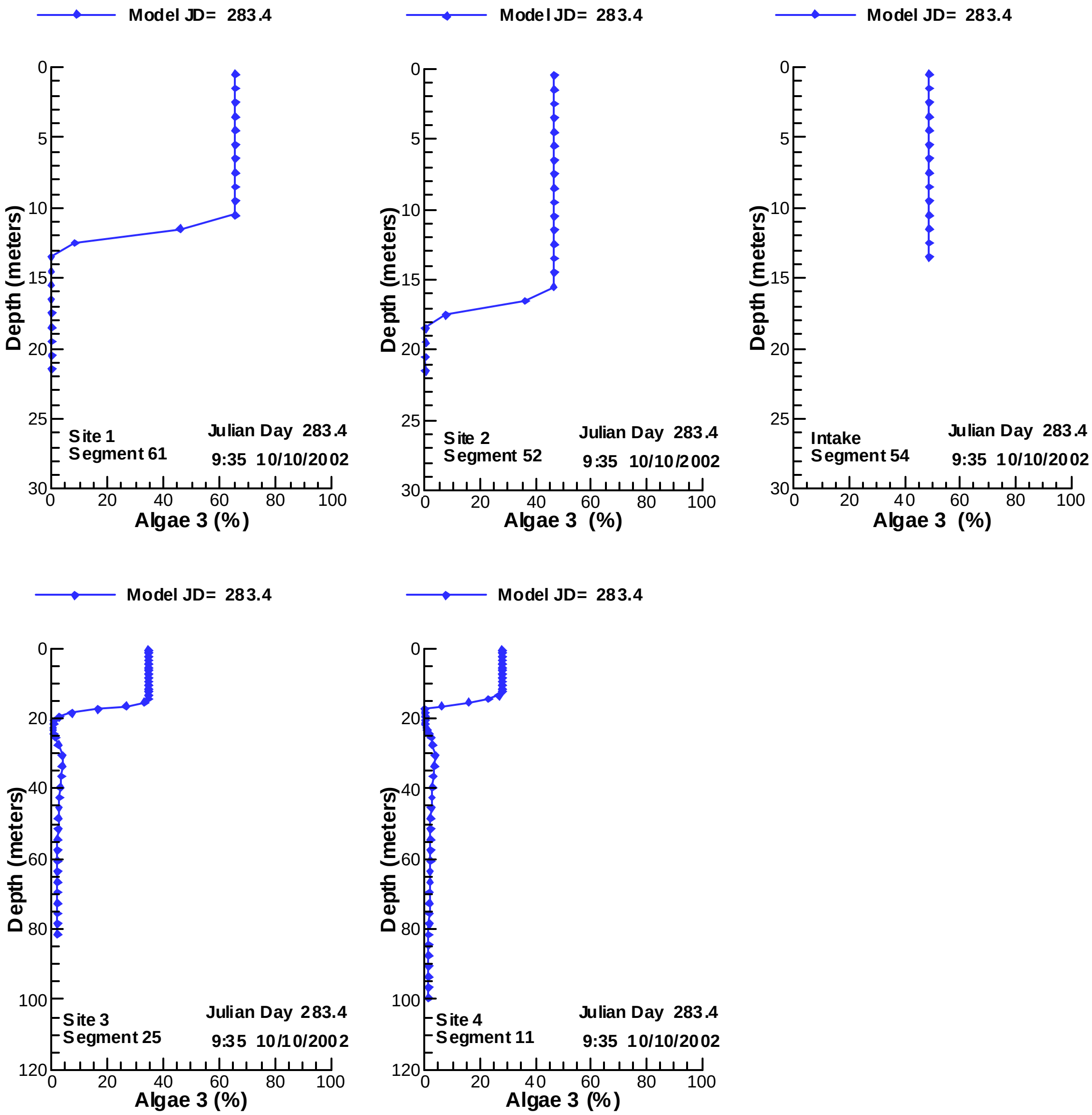

Figure 747. Vertical profiles of ALGAE 3 compared with data for 10/10/2002.

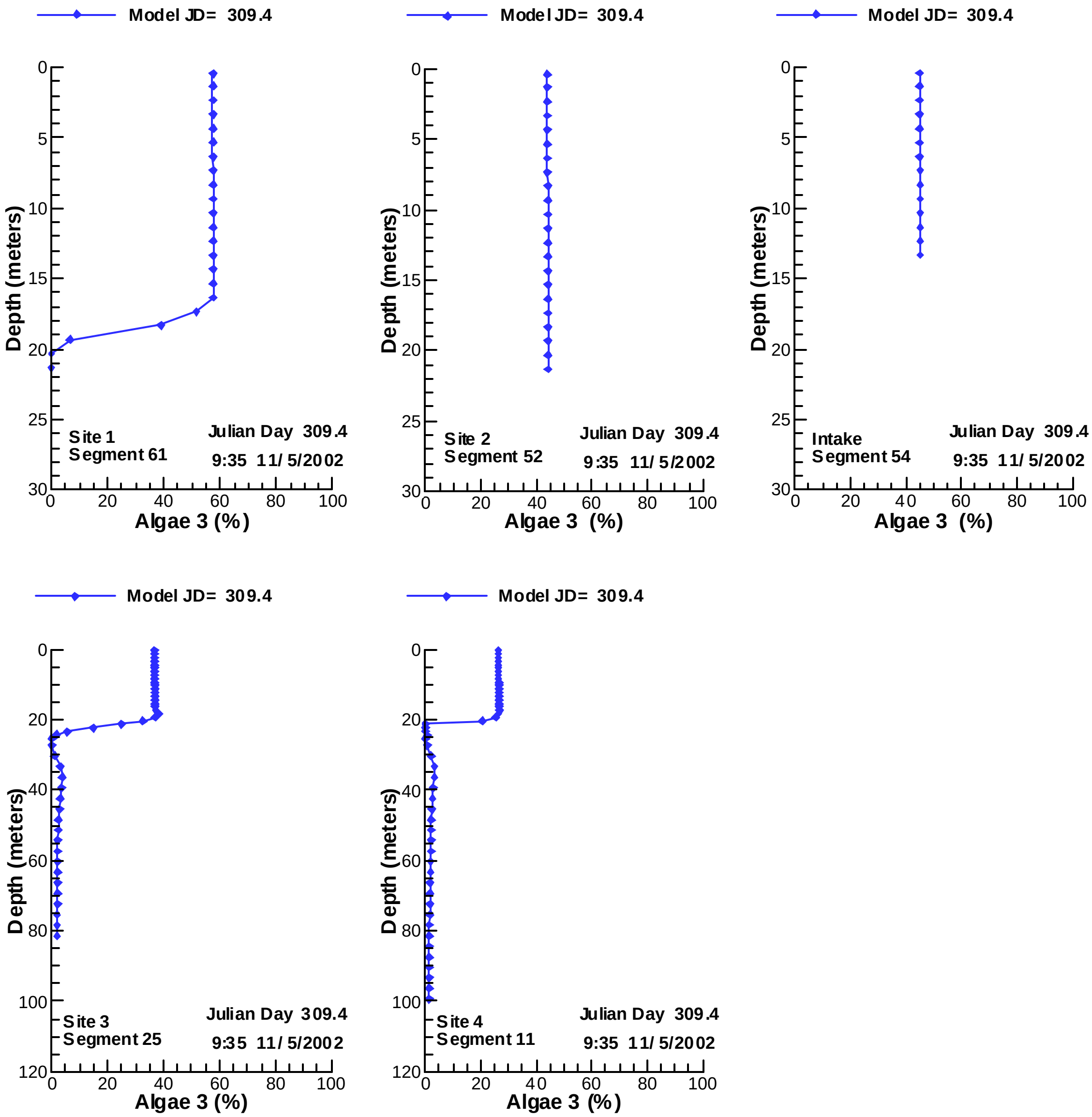

Figure 748. Vertical profiles of ALGAE 3 compared with data for 11/ 5/2002.

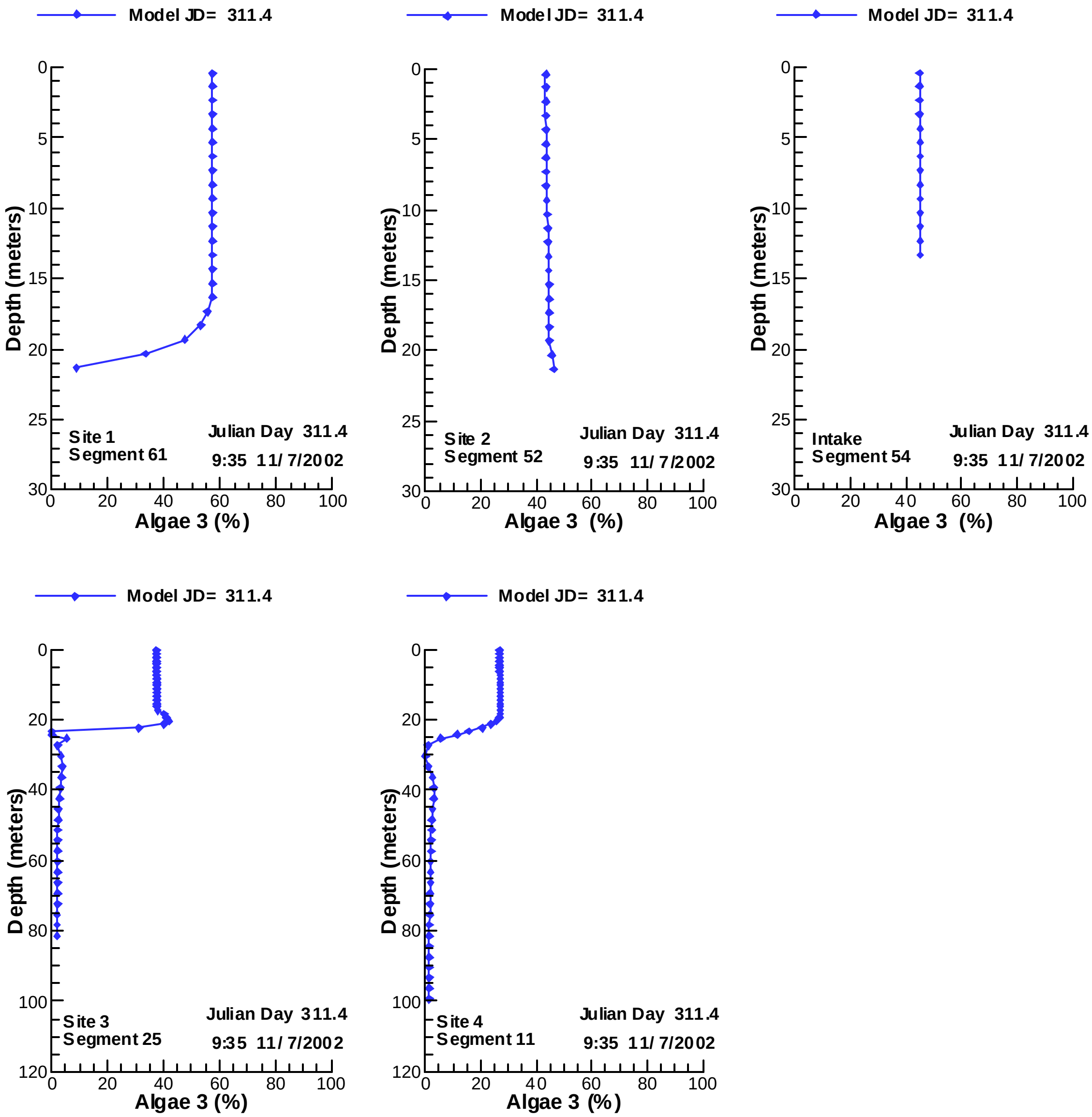

Figure 749. Vertical profiles of ALGAE 3 compared with data for 11/ 7/2002.

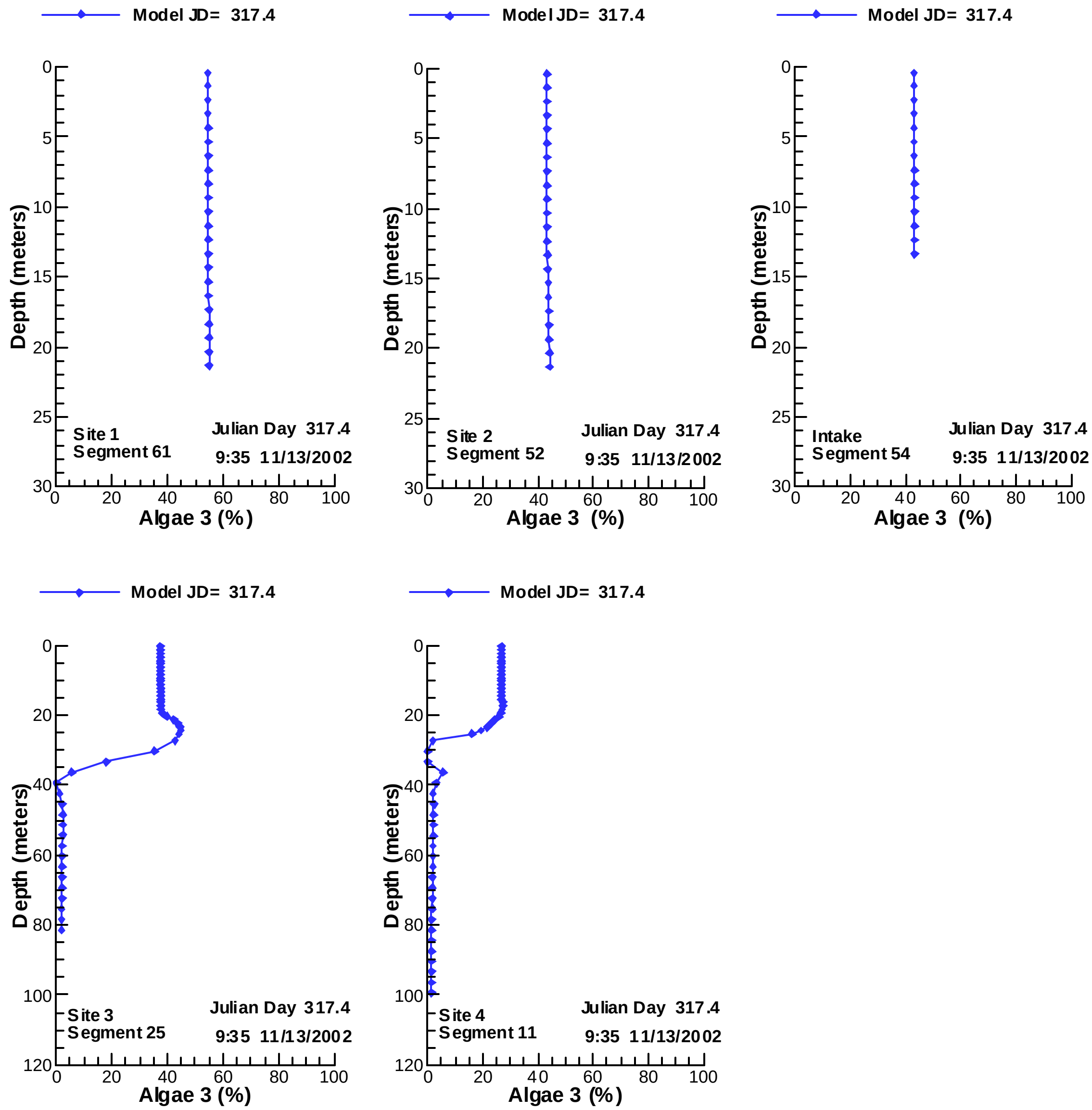

Figure 750. Vertical profiles of ALGAE 3 compared with data for 11/13/2002.

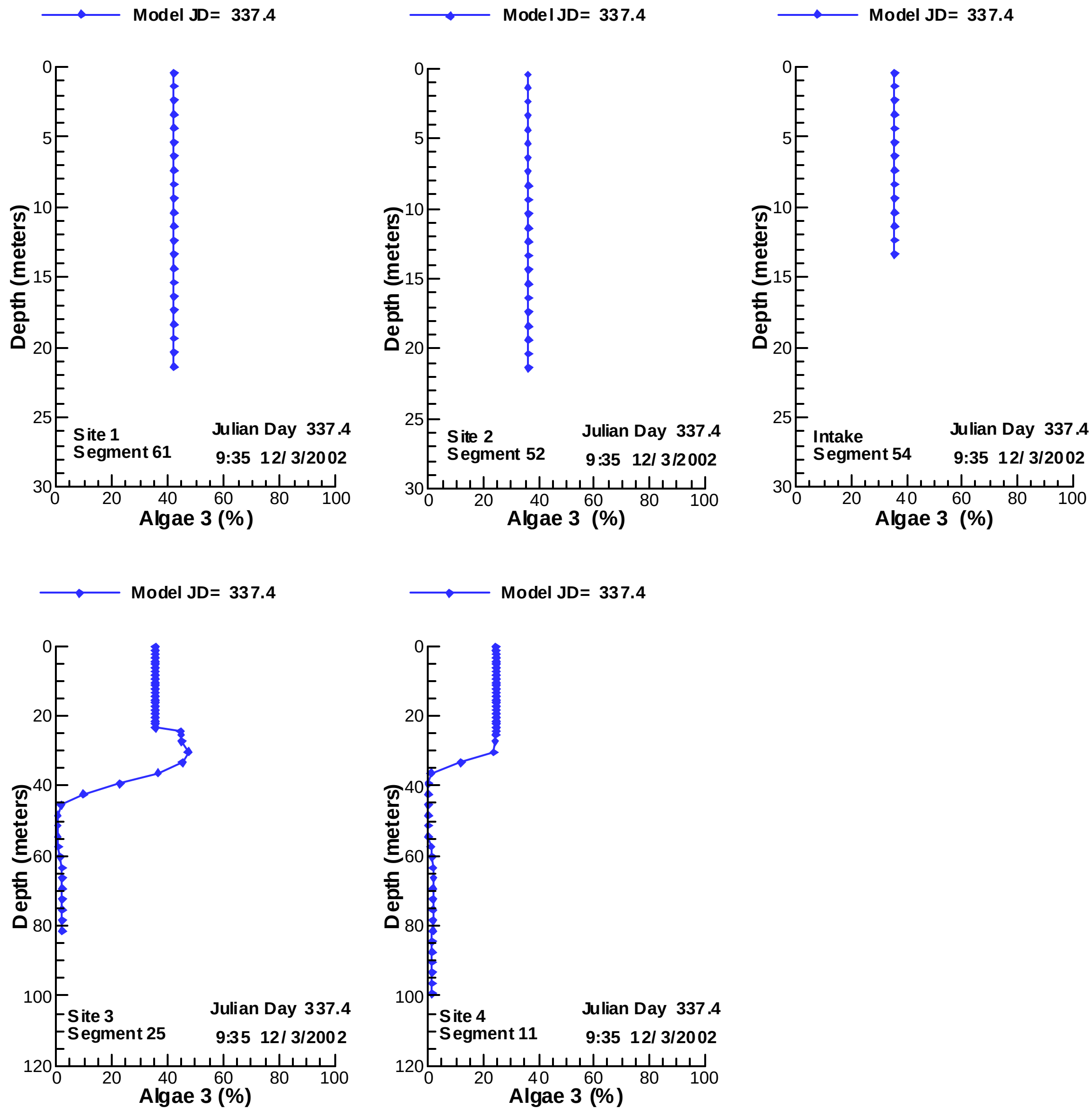

Figure 751. Vertical profiles of ALGAE 3 compared with data for 12/ 3/2002.

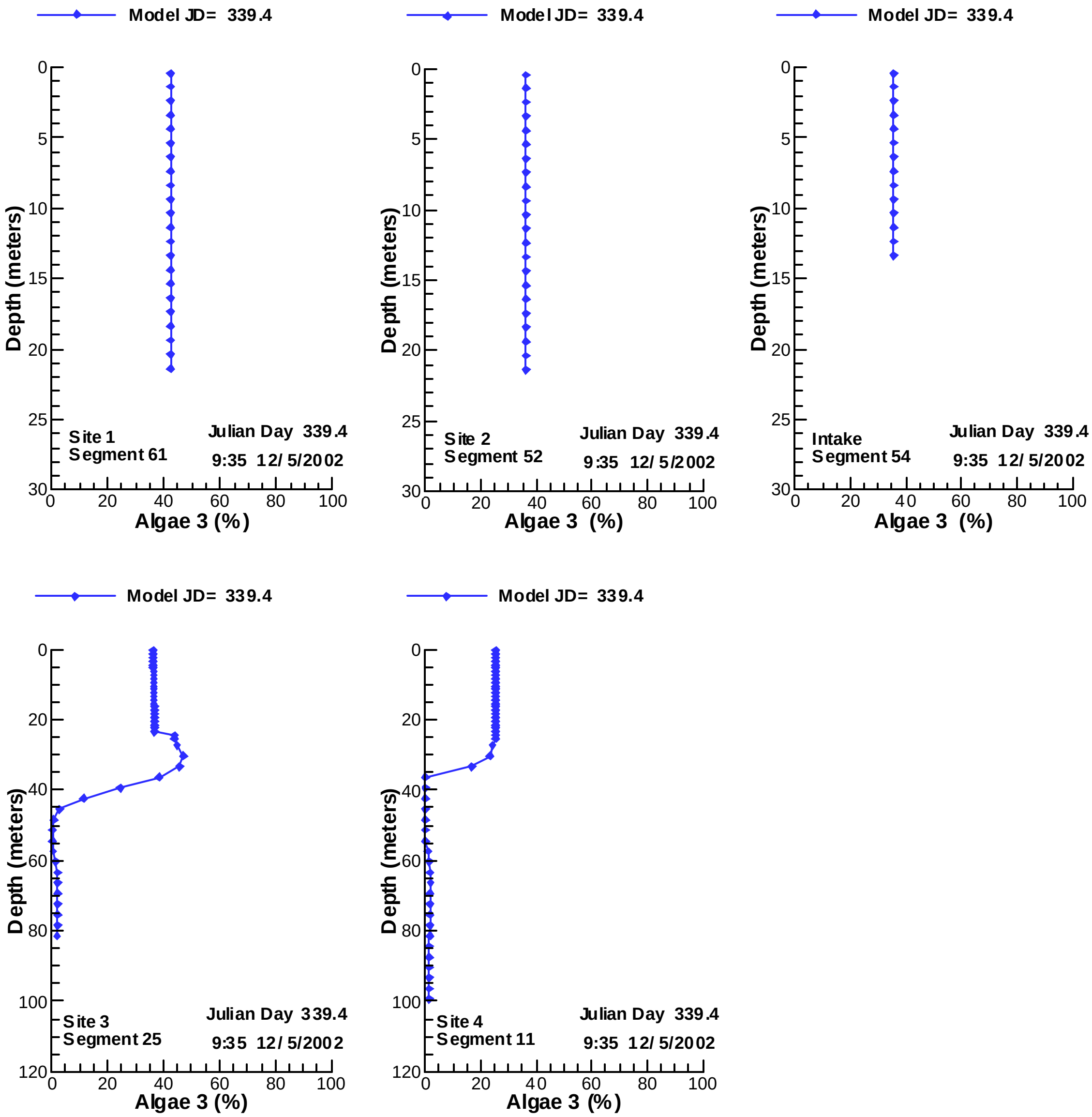

Figure 752. Vertical profiles of ALGAE 3 compared with data for 12/ 5/2002.

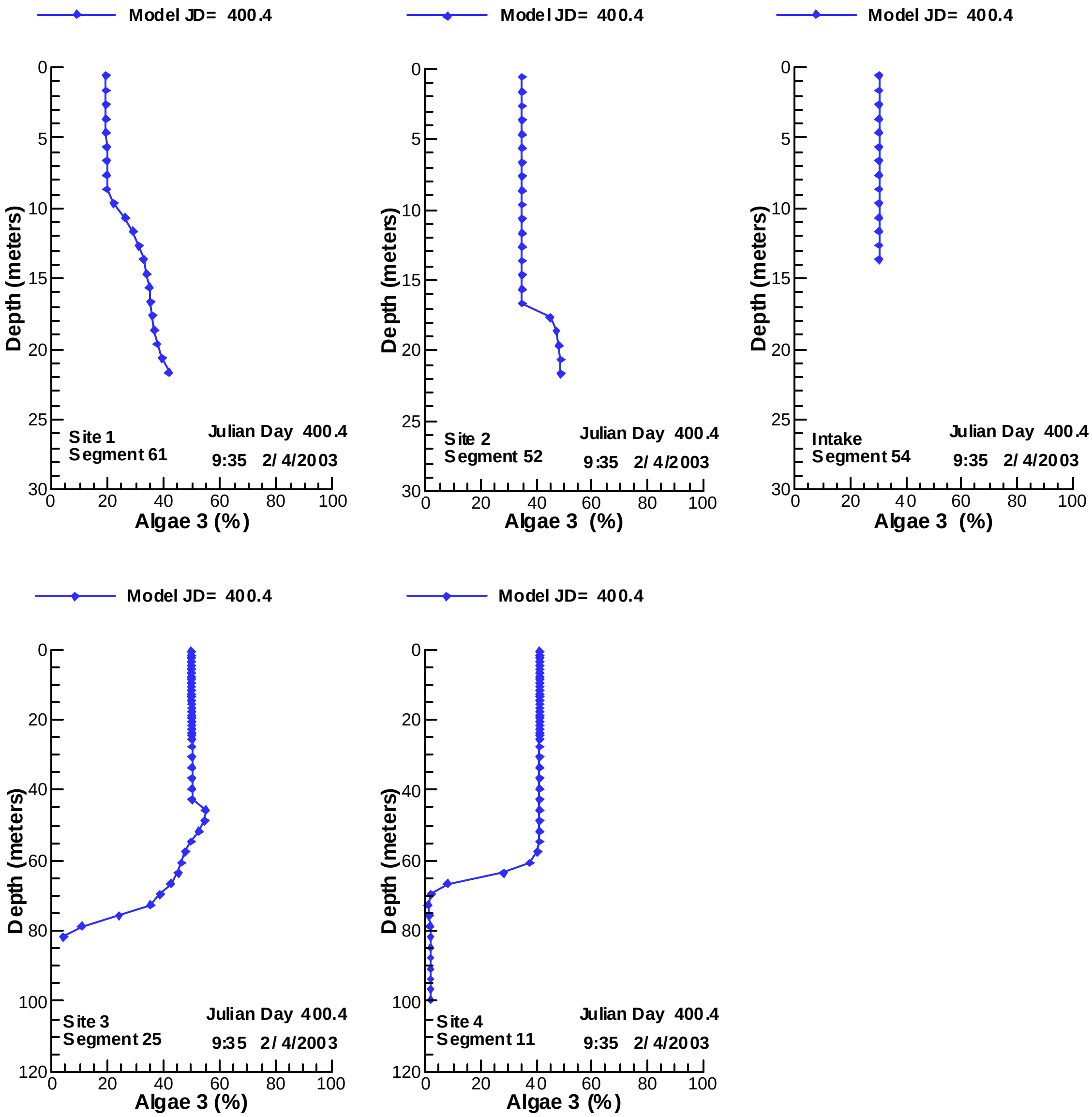

Figure 753. Vertical profiles of ALGAE 3 compared with data for 2/ 4/2003.

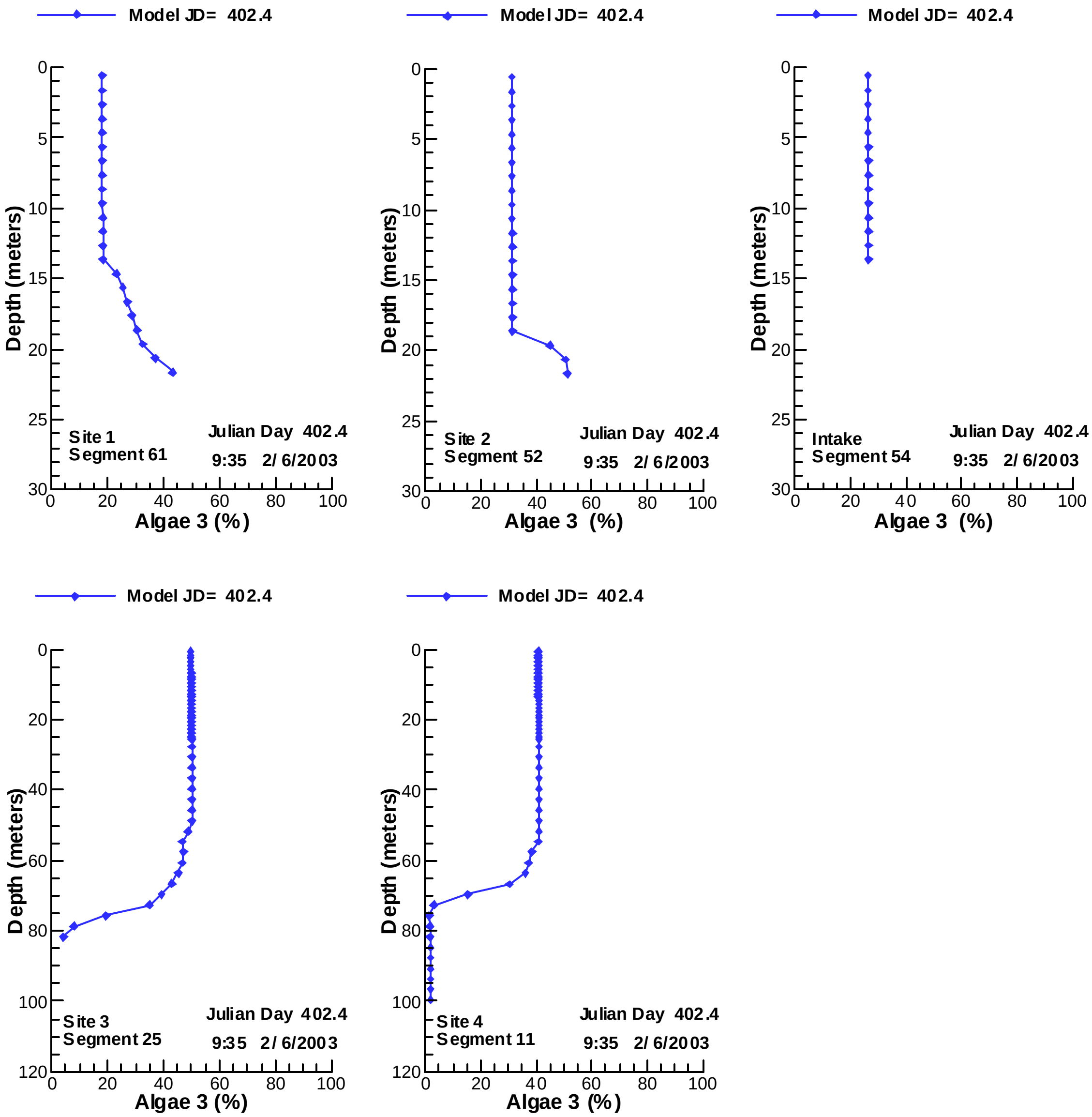

Figure 754. Vertical profiles of ALGAE 3 compared with data for 2/ 6/2003.

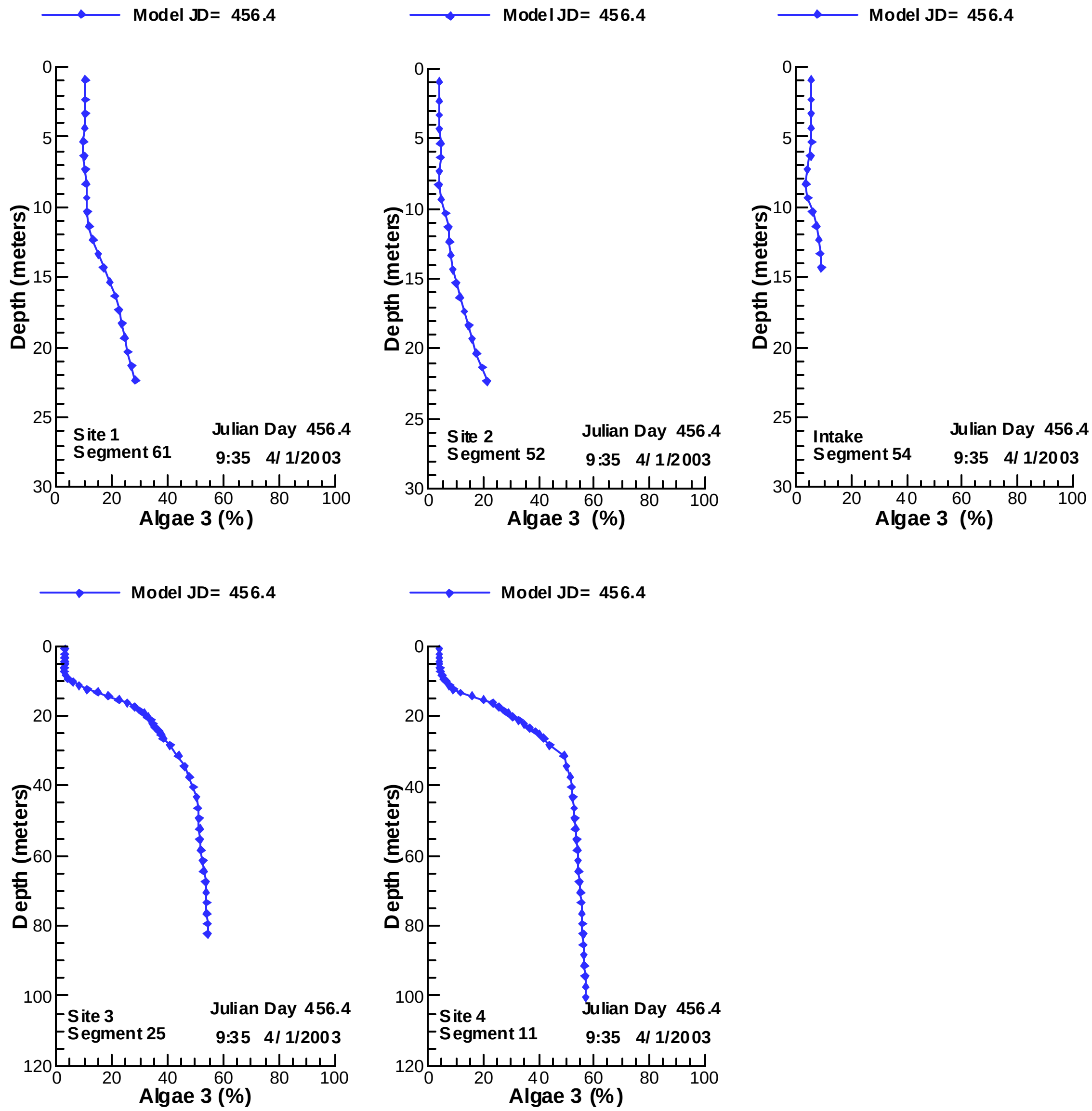

Figure 755. Vertical profiles of ALGAE 3 compared with data for 4/ 1/2003.

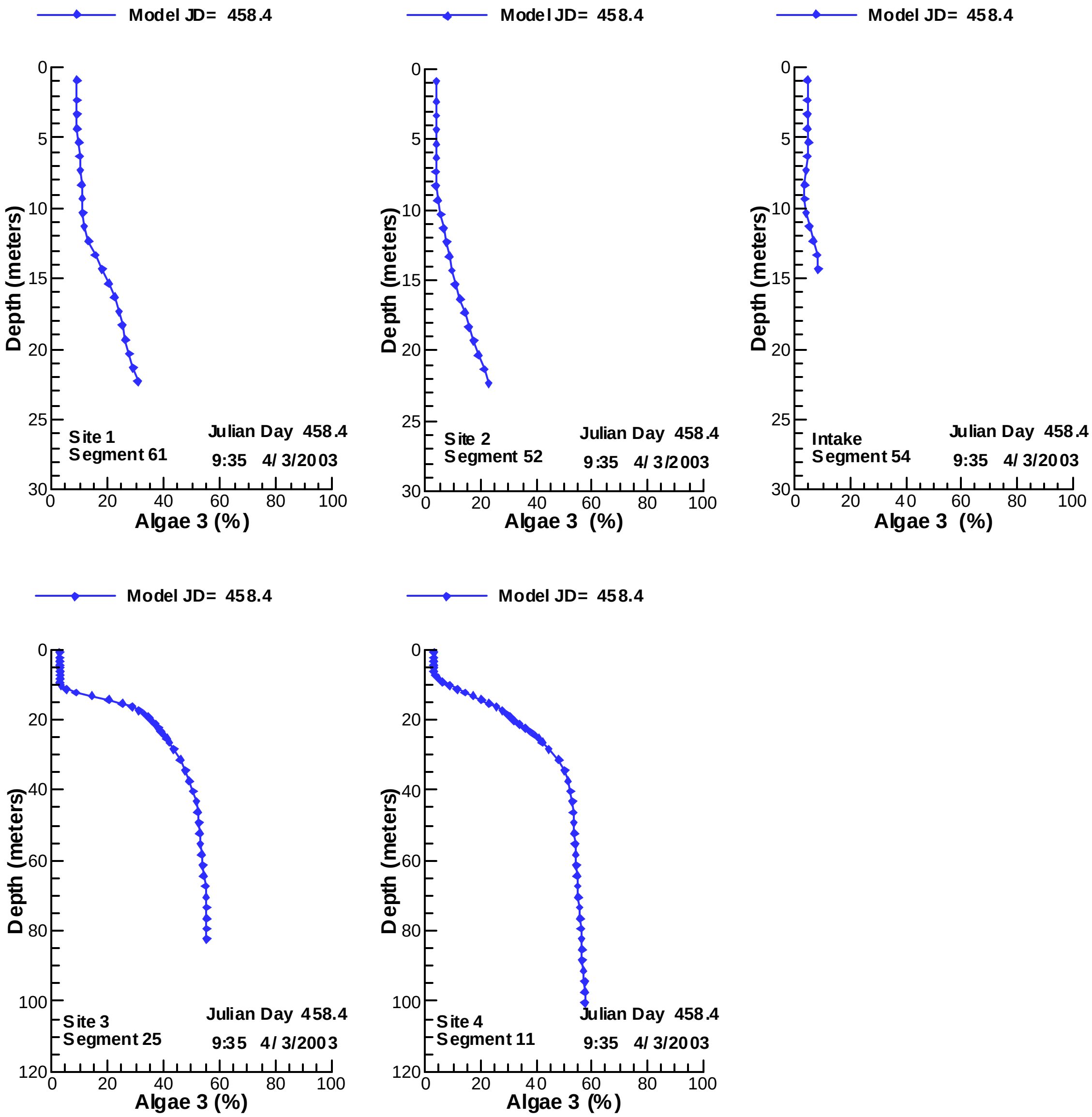

Figure 756. Vertical profiles of ALGAE 3 compared with data for 4/ 3/2003.

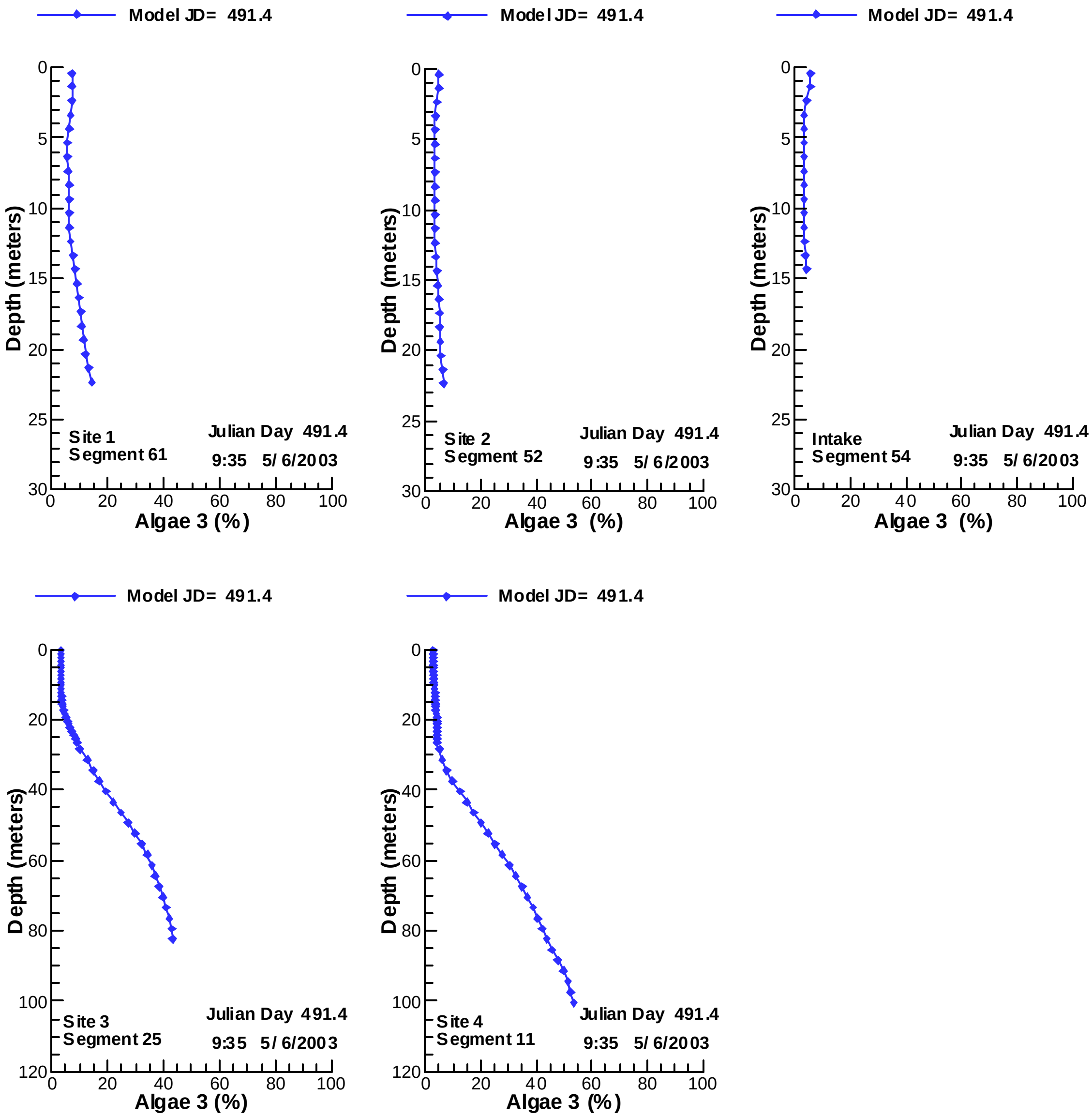

Figure 757. Vertical profiles of ALGAE 3 compared with data for 5/ 6/2003.

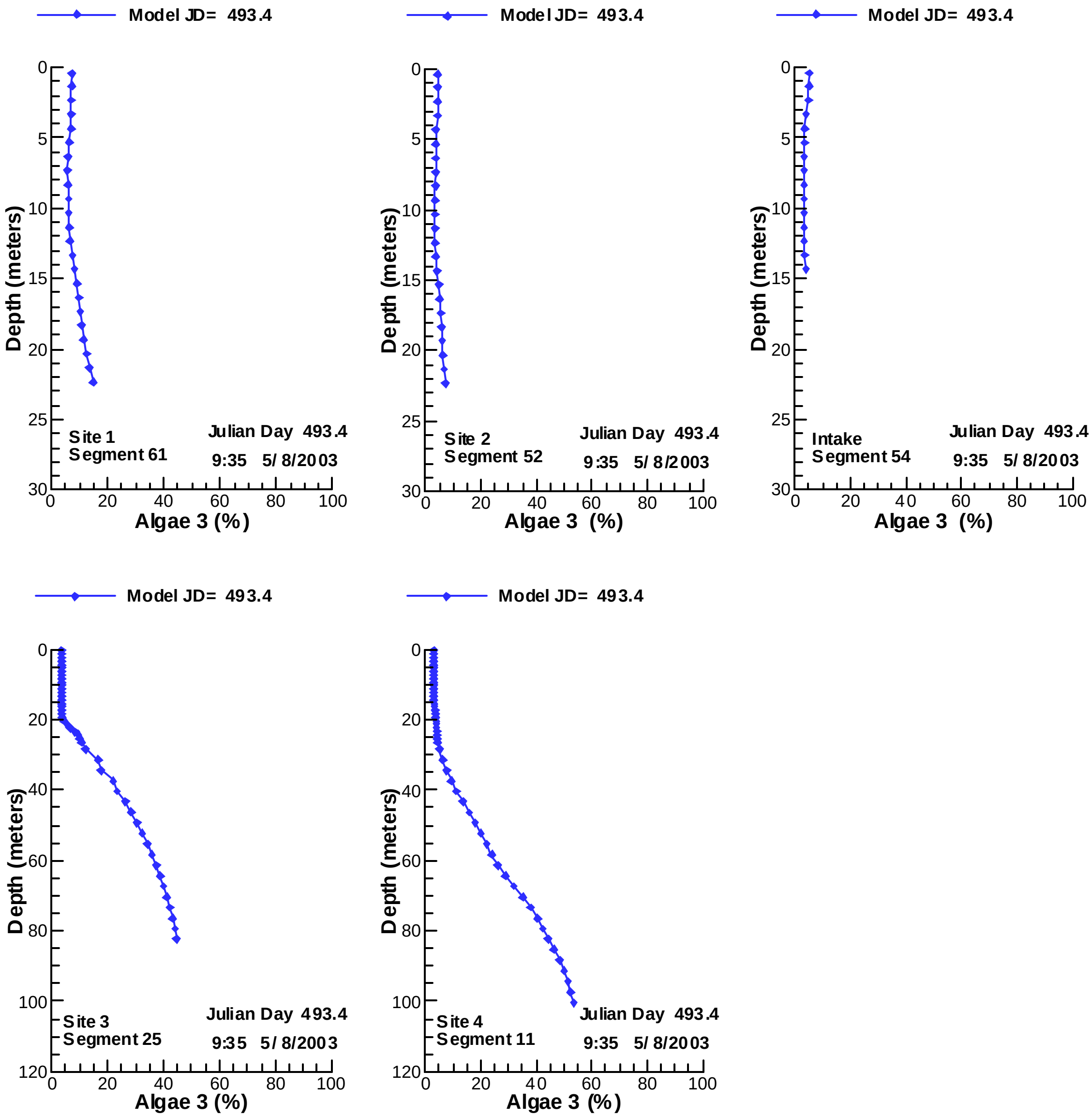

Figure 758. Vertical profiles of ALGAE 3 compared with data for 5/ 8/2003.

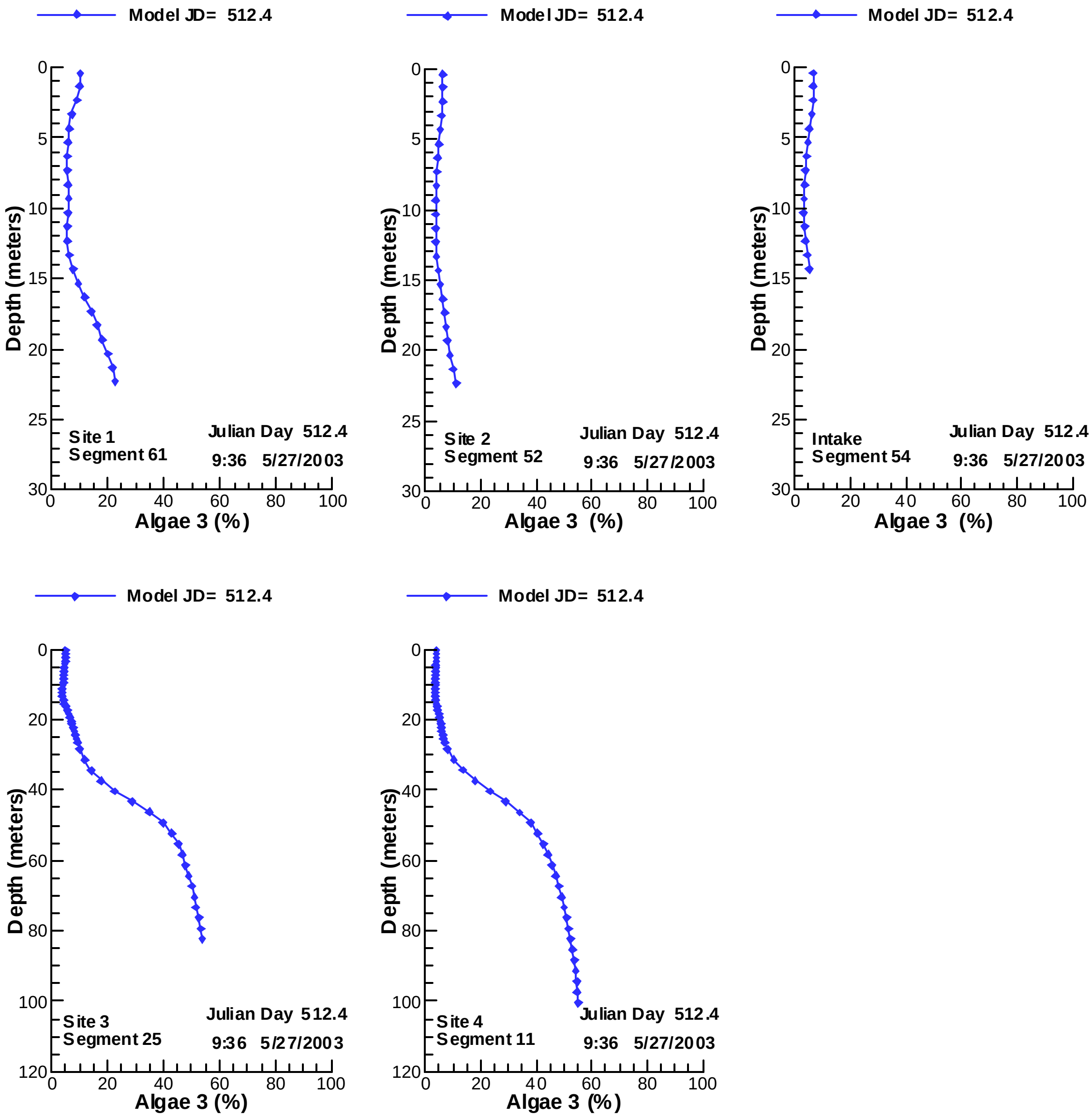

Figure 759. Vertical profiles of ALGAE 3 compared with data for 5/27/2003.

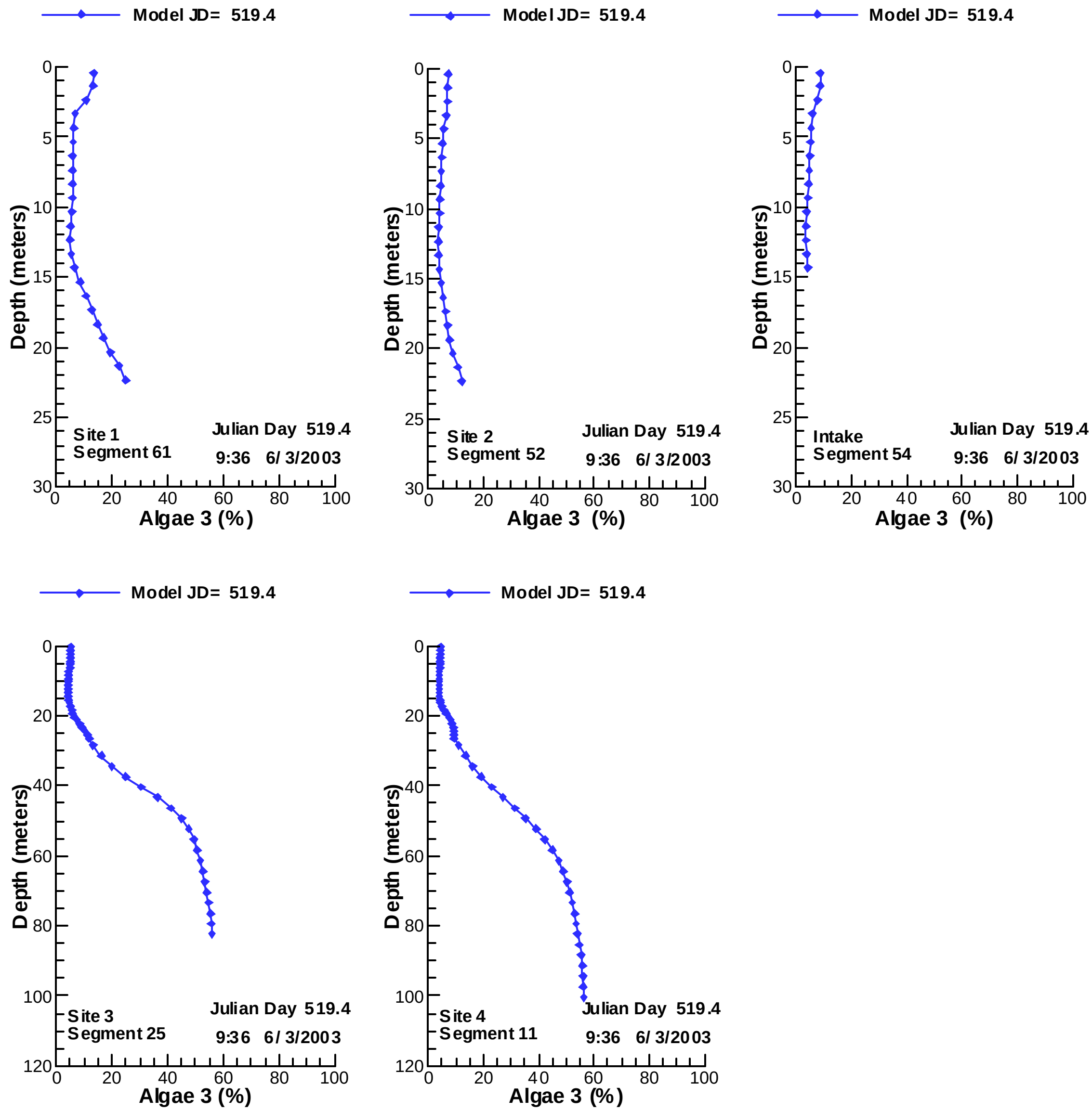

Figure 760. Vertical profiles of ALGAE 3 compared with data for 6/ 3/2003.

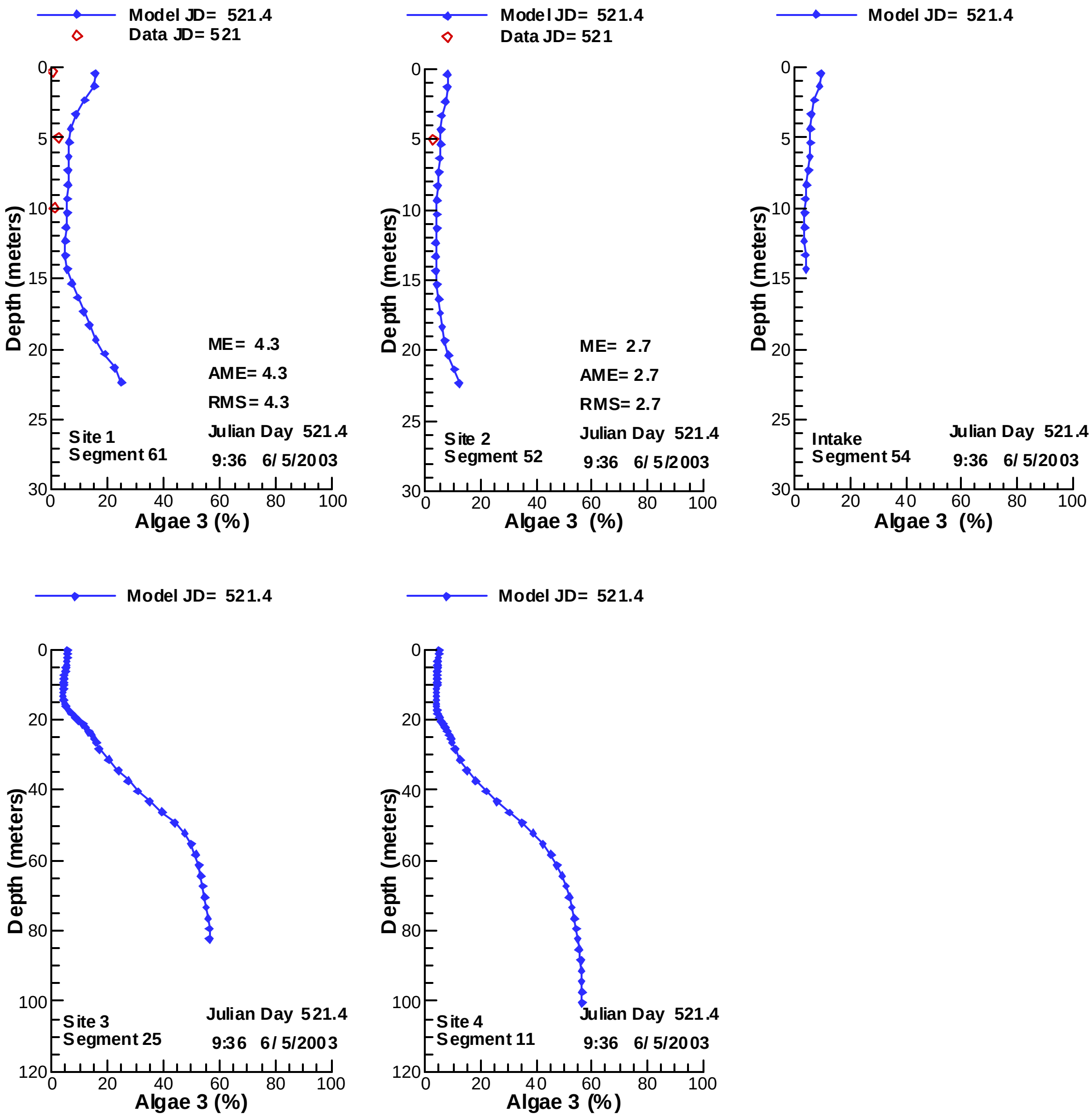

Figure 761. Vertical profiles of ALGAE 3 compared with data for 6/ 5/2003.

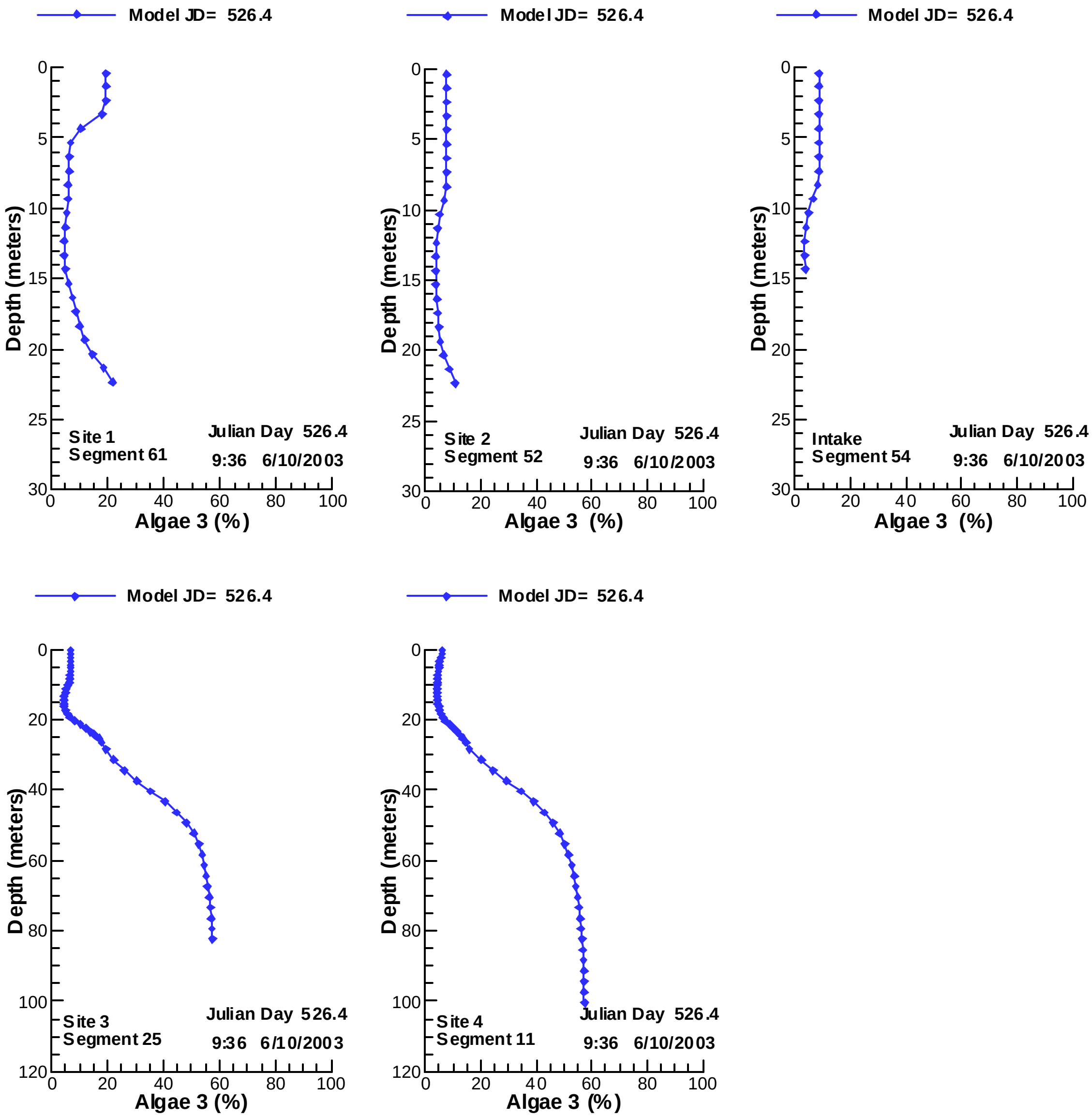

Figure 762. Vertical profiles of ALGAE 3 compared with data for 6/10/2003.

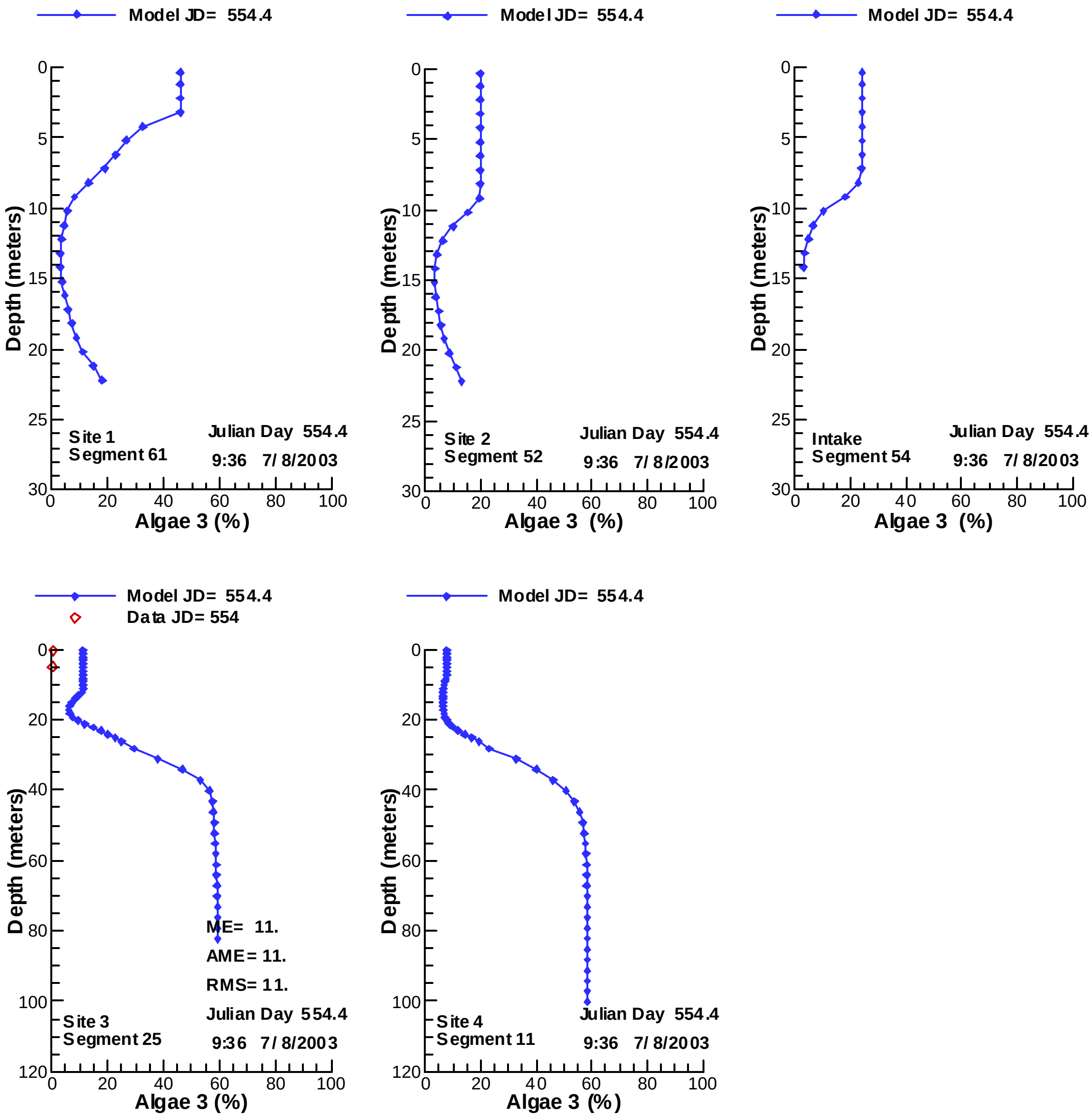

Figure 763. Vertical profiles of ALGAE 3 compared with data for 7/ 8/2003.

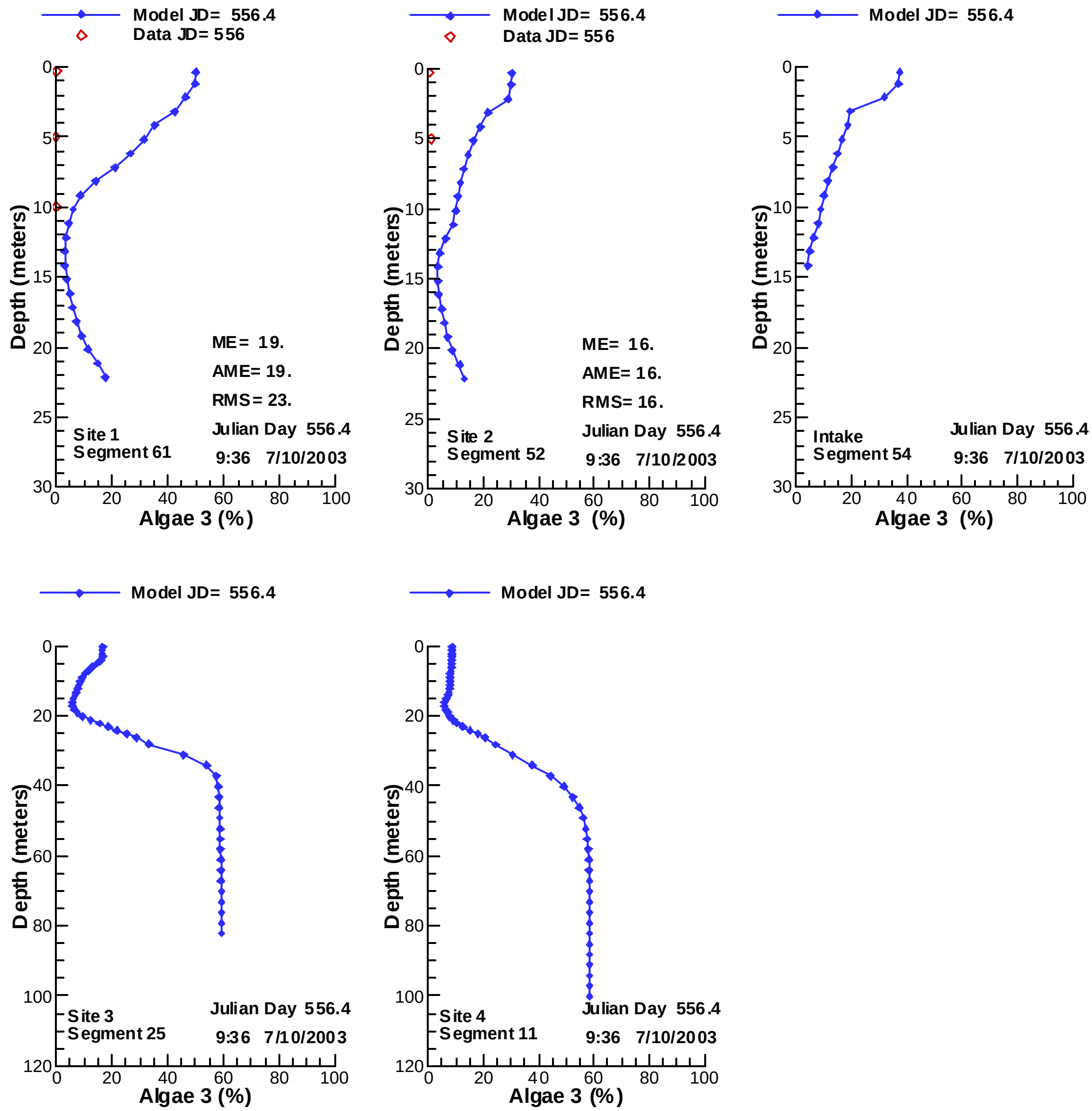

Figure 764. Vertical profiles of ALGAE 3 compared with data for 7/10/2003.

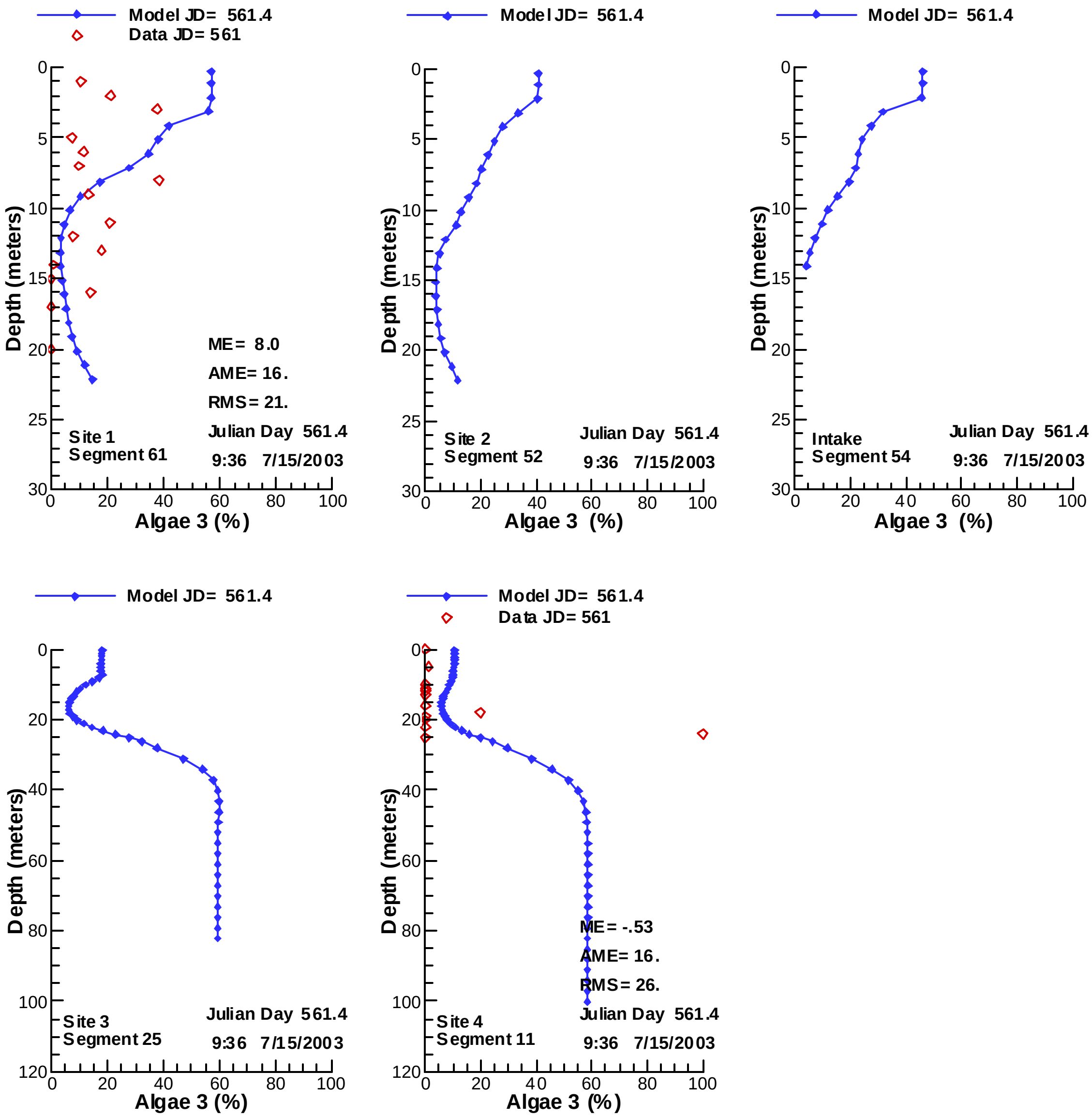

Figure 765. Vertical profiles of ALGAE 3 compared with data for 7/15/2003.

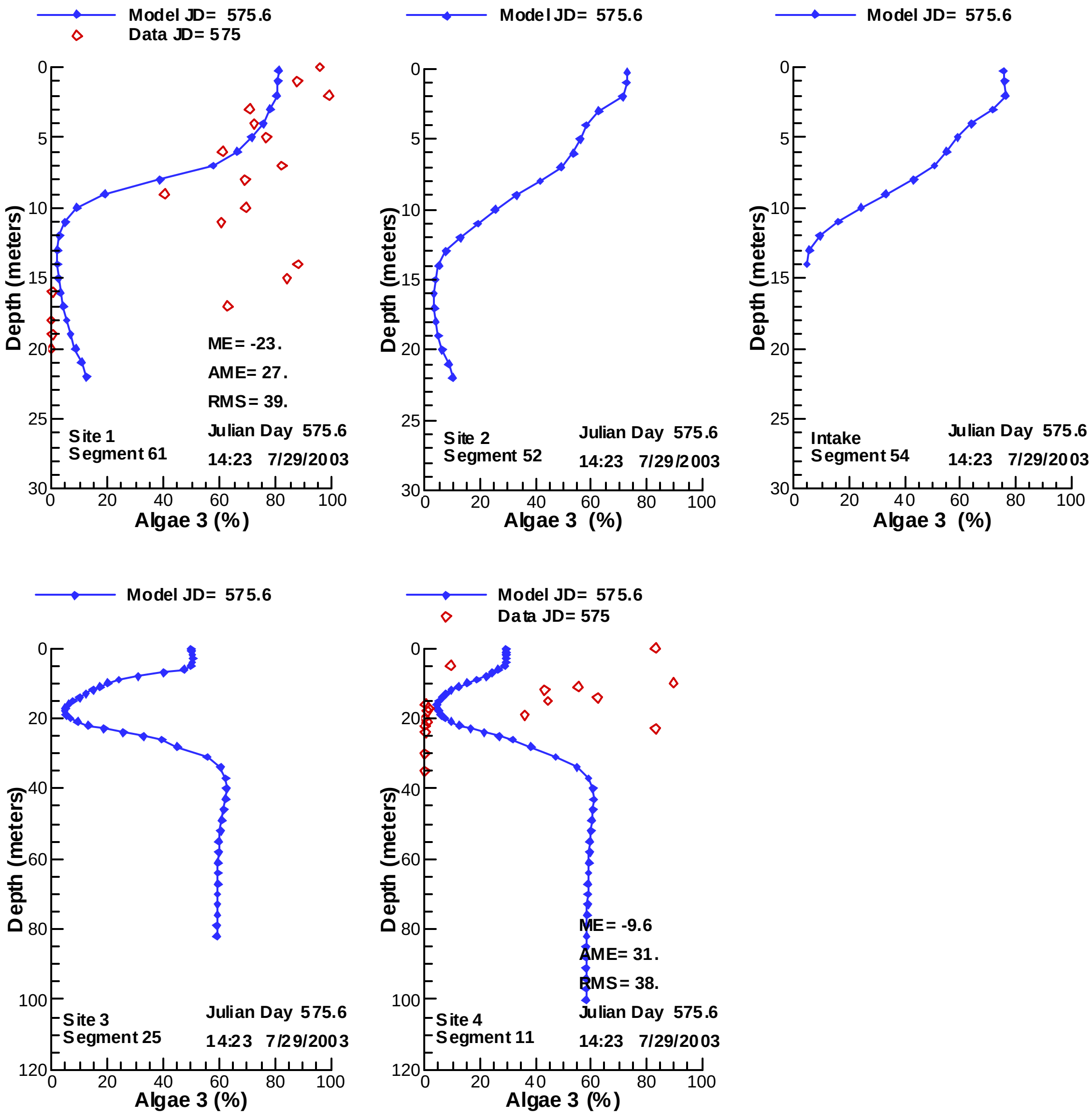

Figure 766. Vertical profiles of ALGAE 3 compared with data for 7/29/2003.

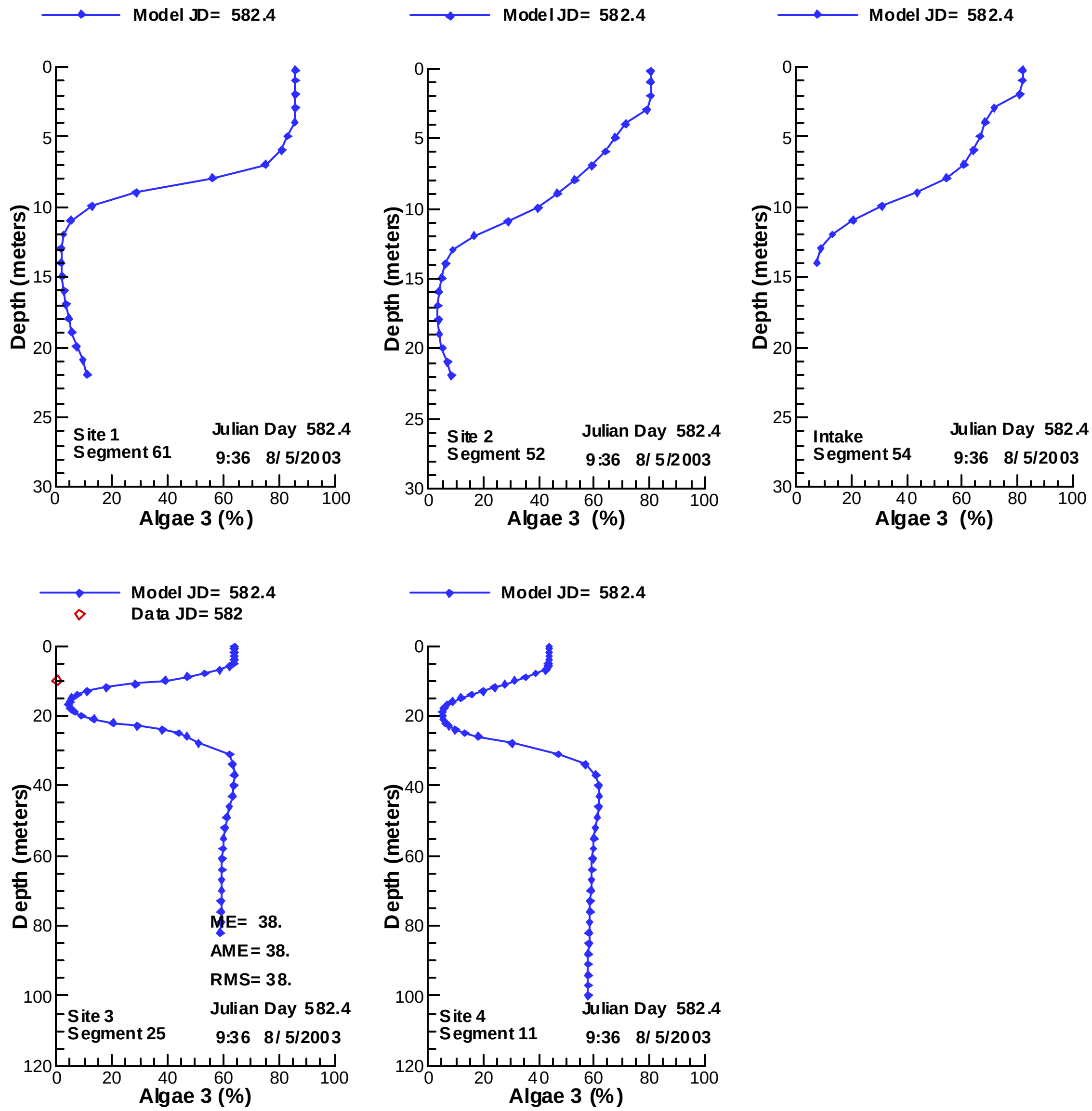

Figure 767. Vertical profiles of ALGAE 3 compared with data for 8/ 5/2003.

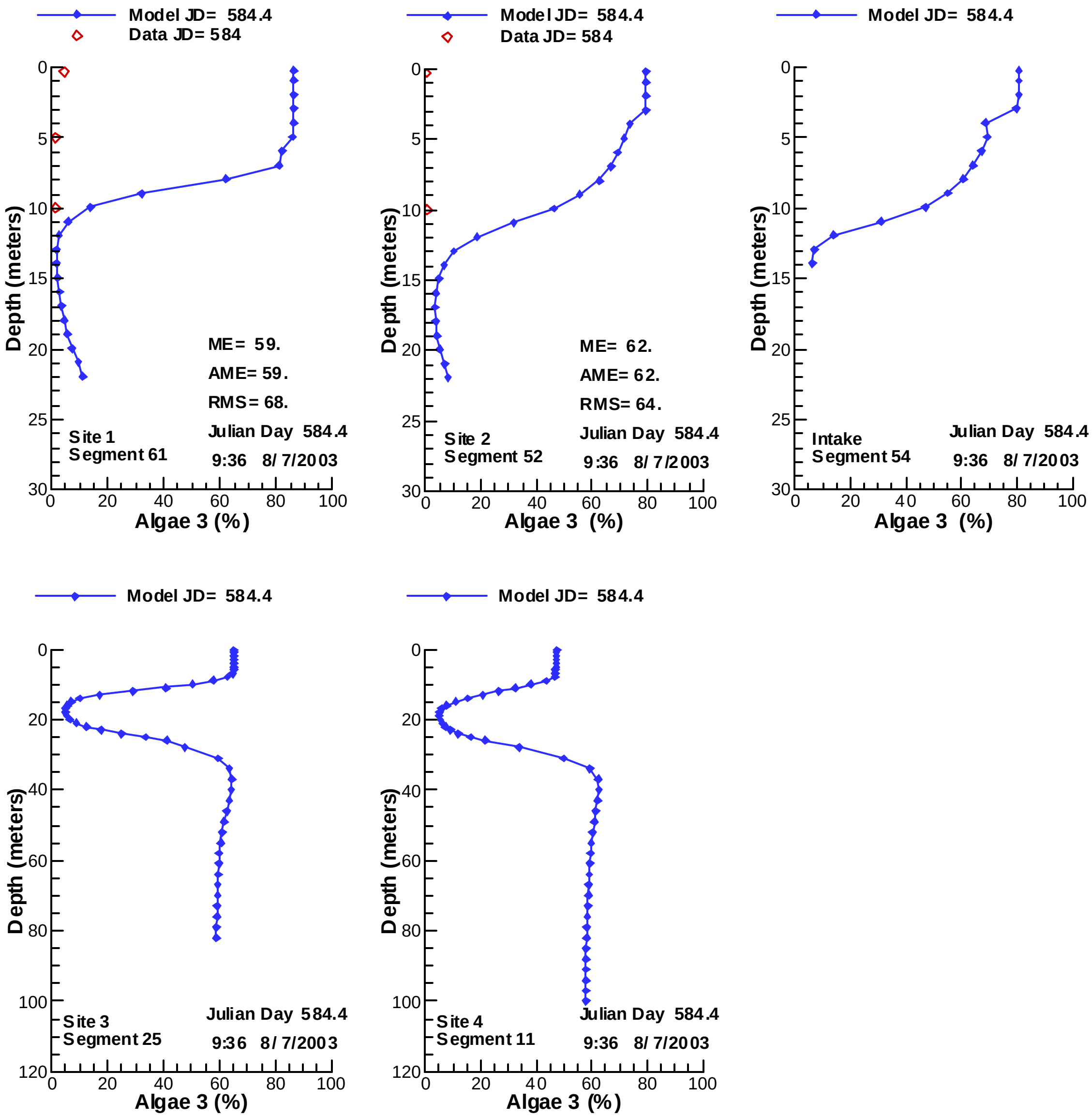

Figure 768. Vertical profiles of ALGAE 3 compared with data for 8/ 7/2003.

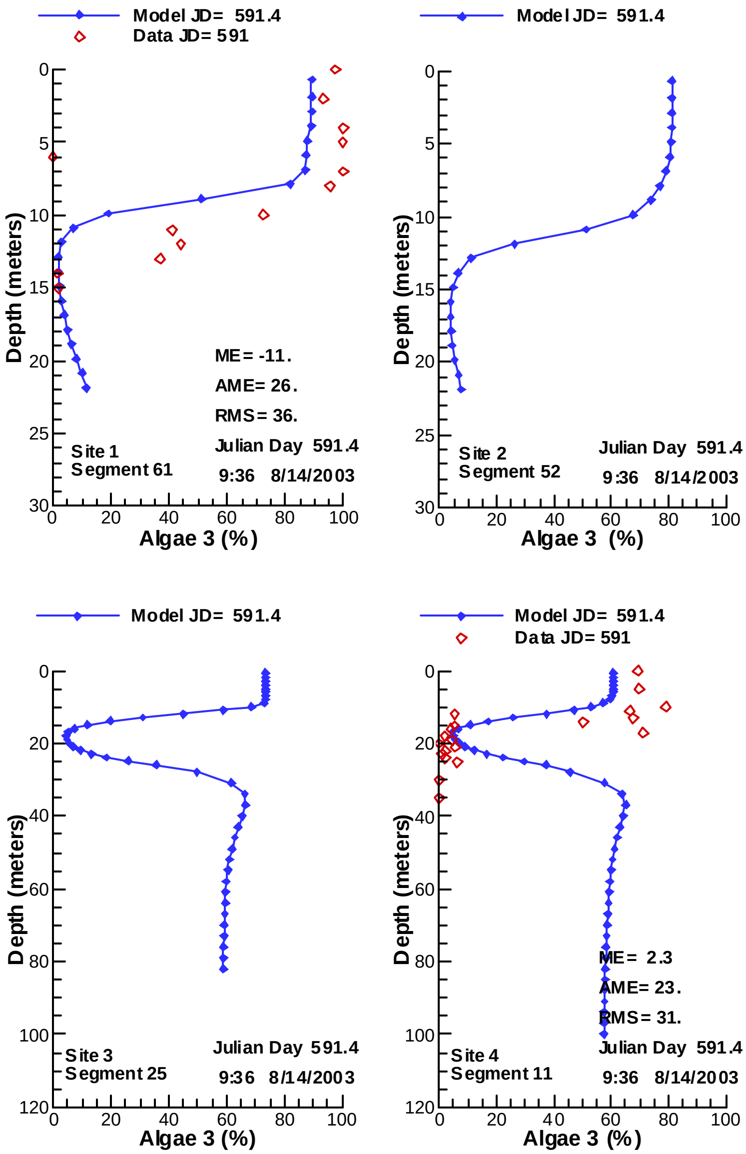

Figure 769. Vertical profiles of ALGAE 3 compared with data for 8/14/2003.

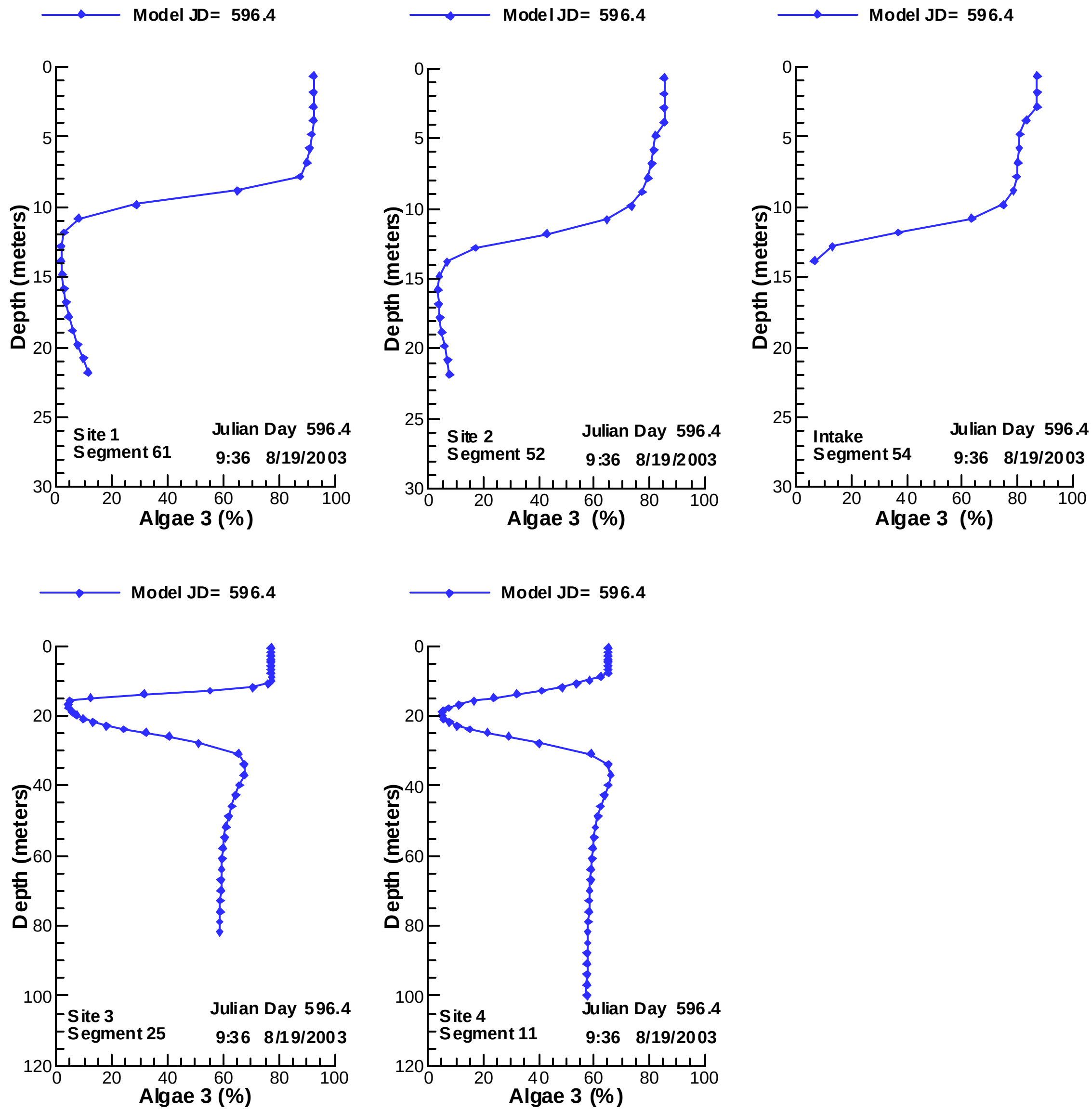

Figure 770. Vertical profiles of ALGAE 3 compared with data for 8/19/2003.

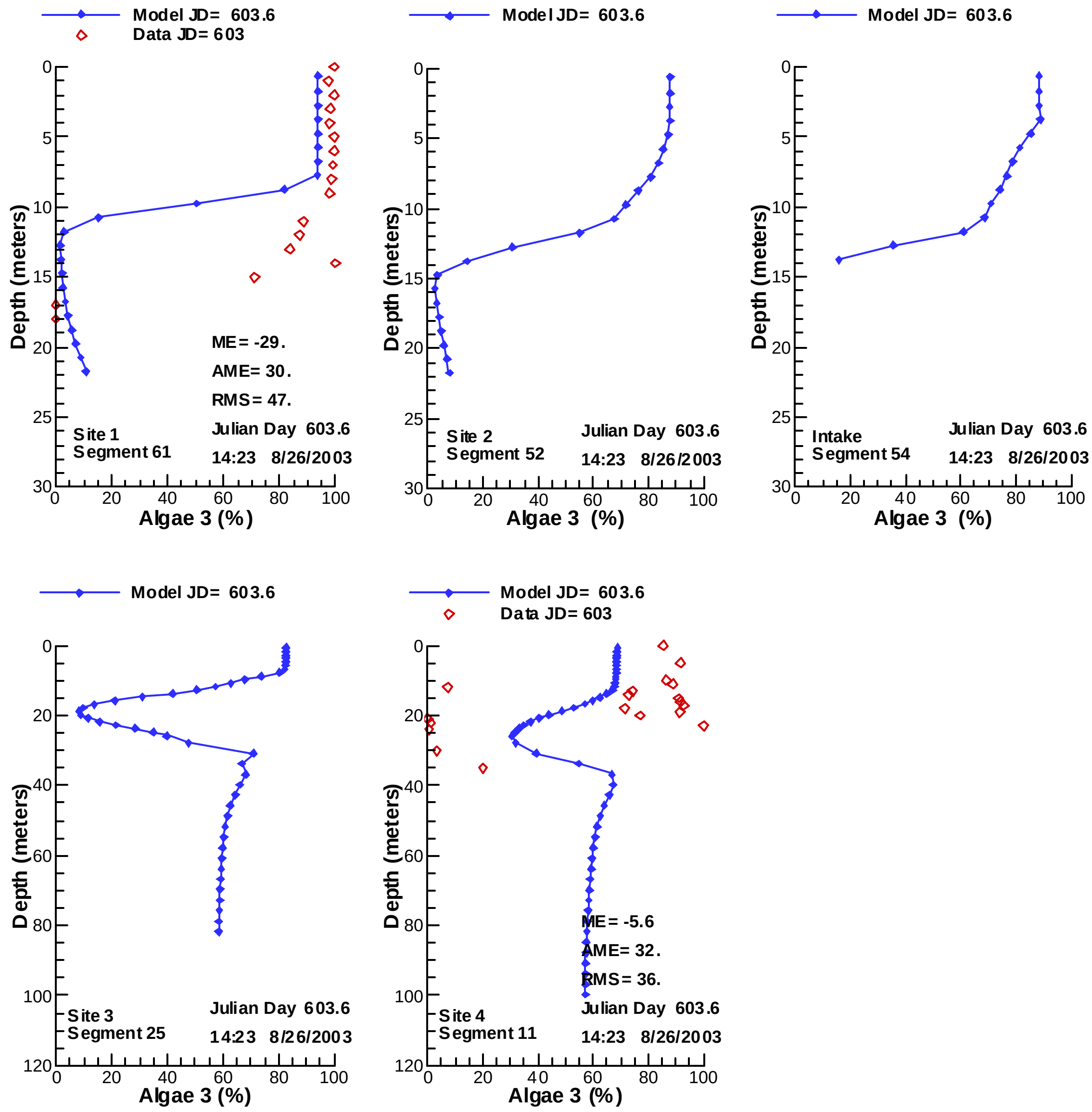

Figure 771. Vertical profiles of ALGAE 3 compared with data for 8/26/2003.

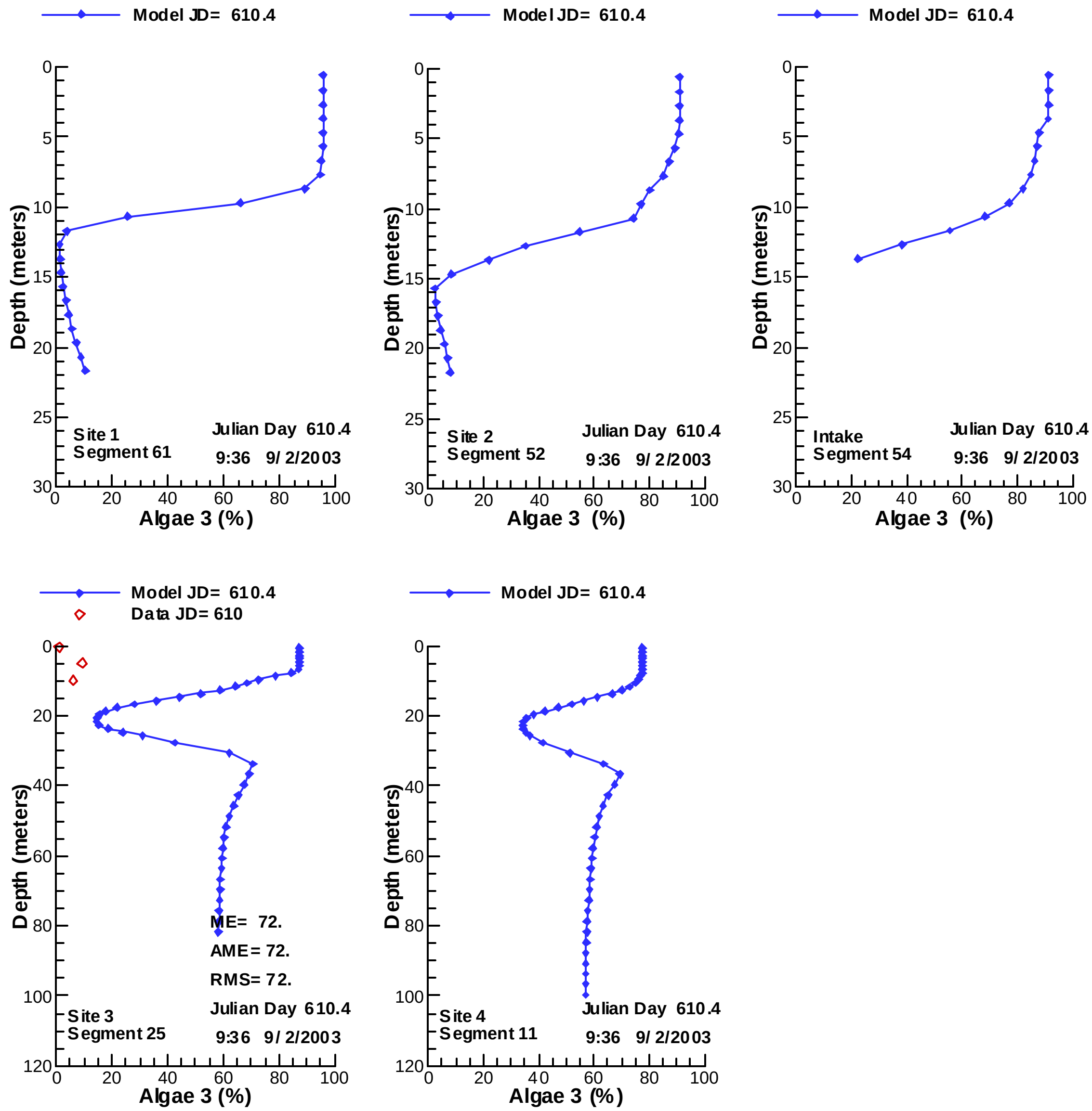

Figure 772. Vertical profiles of ALGAE 3 compared with data for 9/ 2/2003.

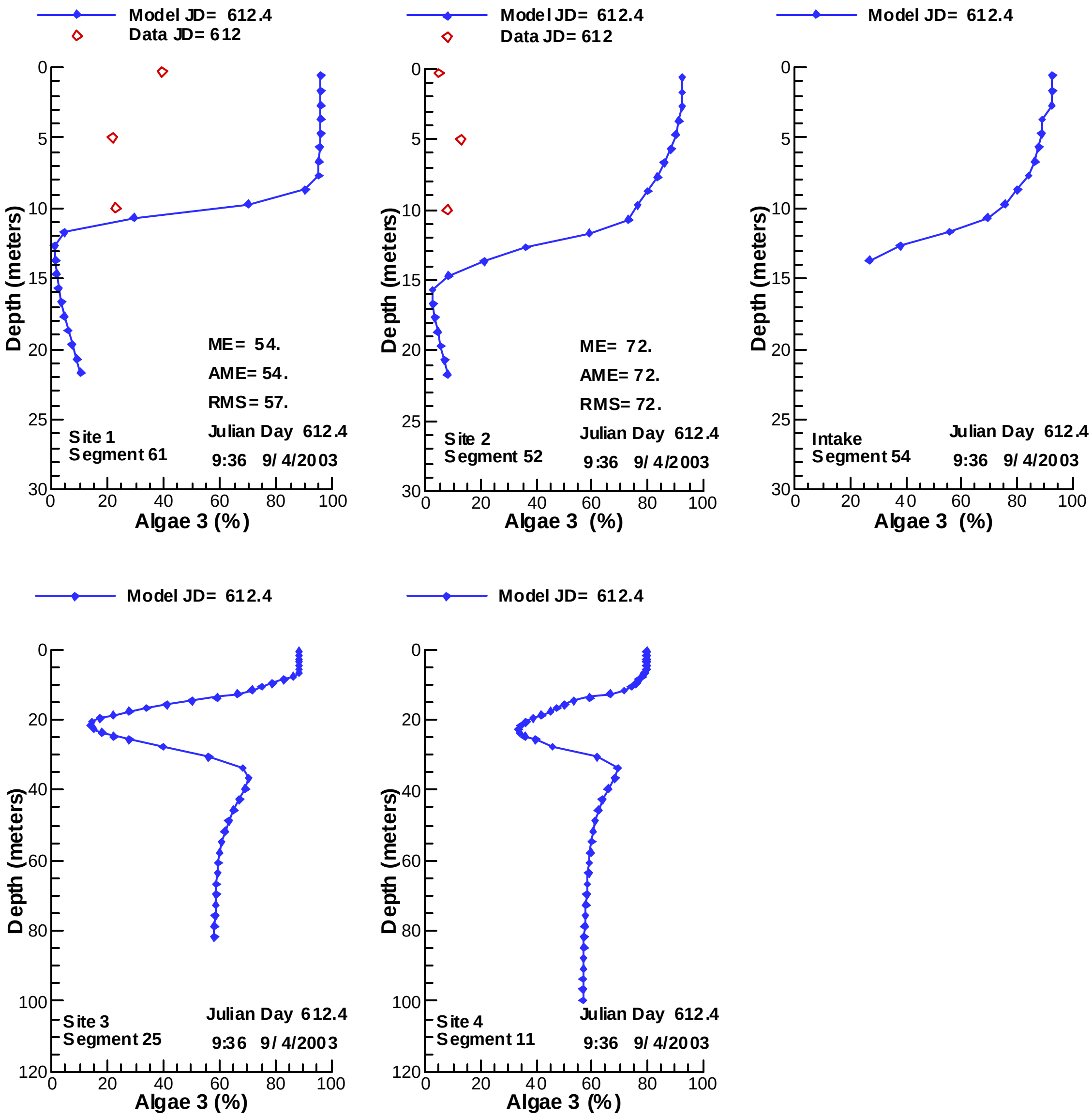

Figure 773. Vertical profiles of ALGAE 3 compared with data for 9/ 4/2003.

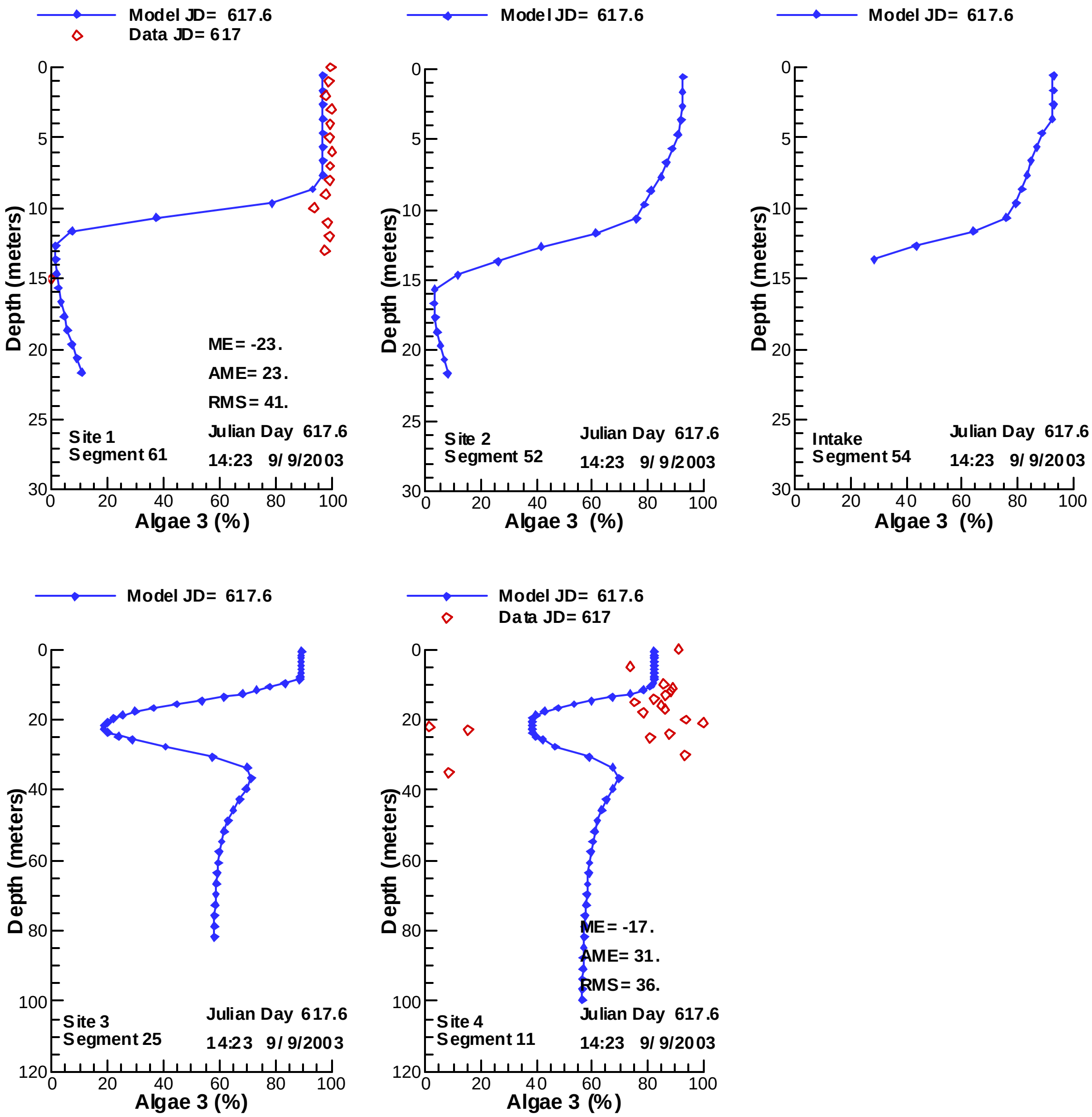

Figure 774. Vertical profiles of ALGAE 3 compared with data for 9/ 9/2003.

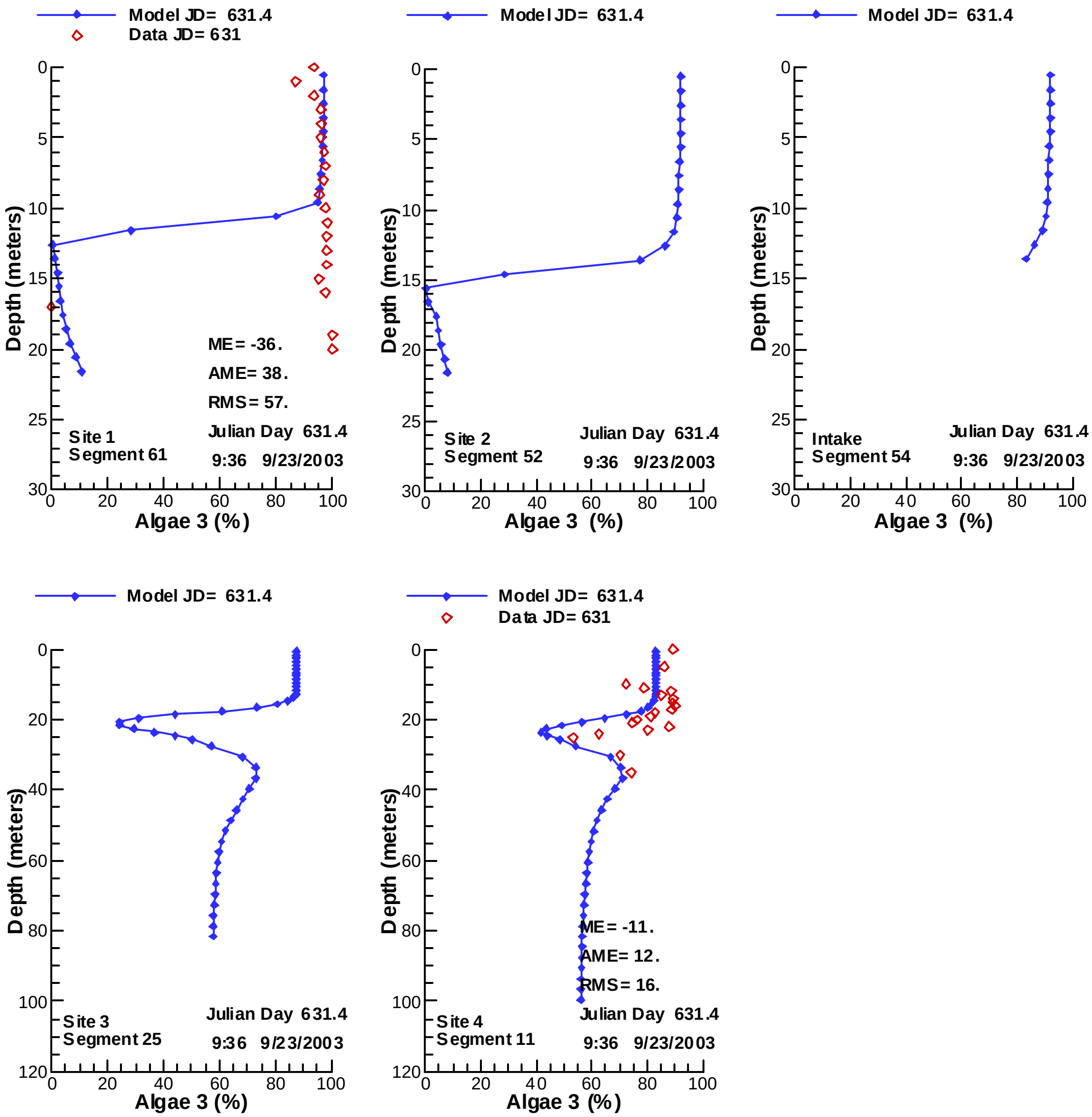

Figure 775. Vertical profiles of ALGAE 3 compared with data for 9/23/2003.

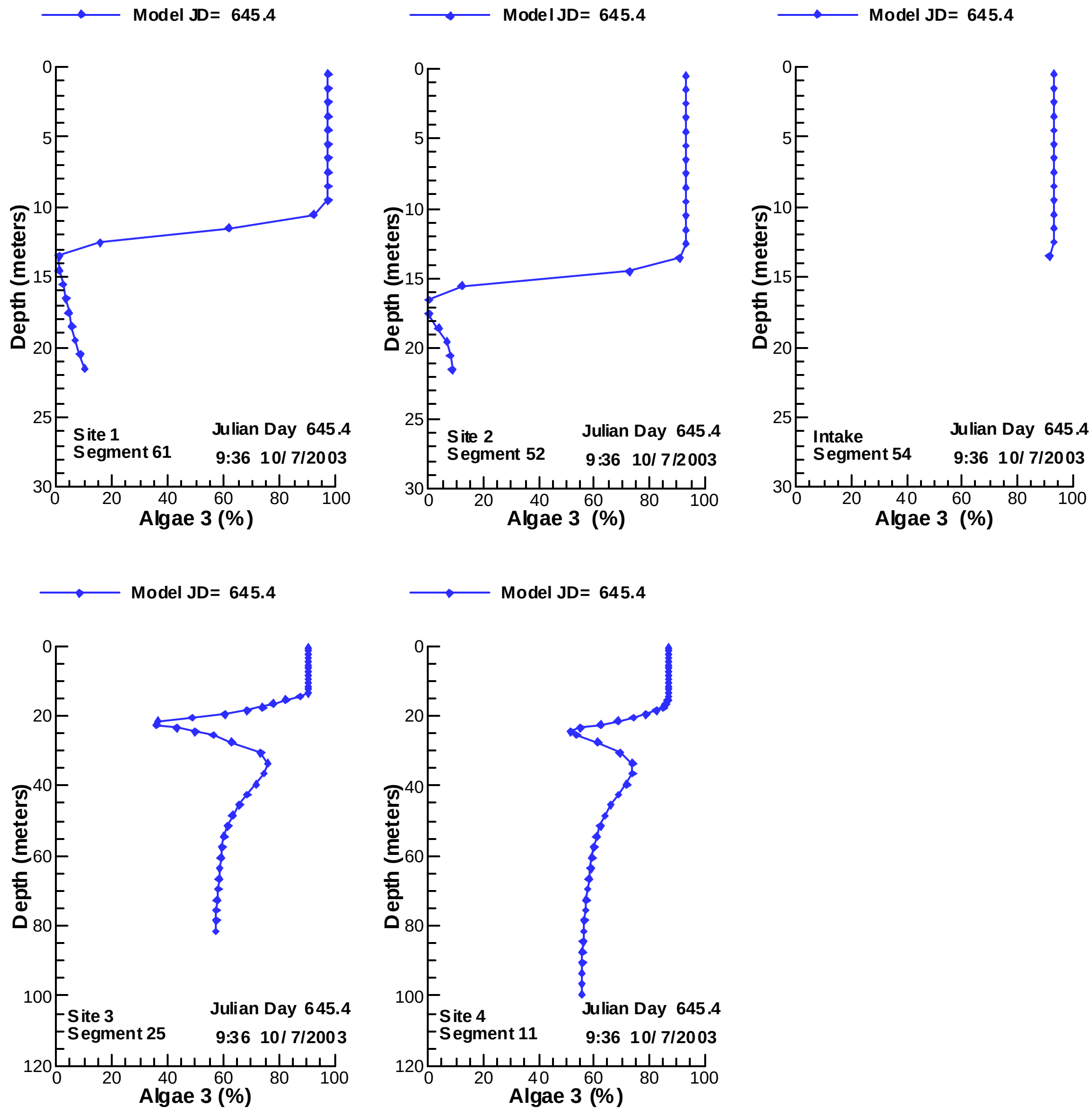

Figure 776. Vertical profiles of ALGAE 3 compared with data for 10/ 7/2003.

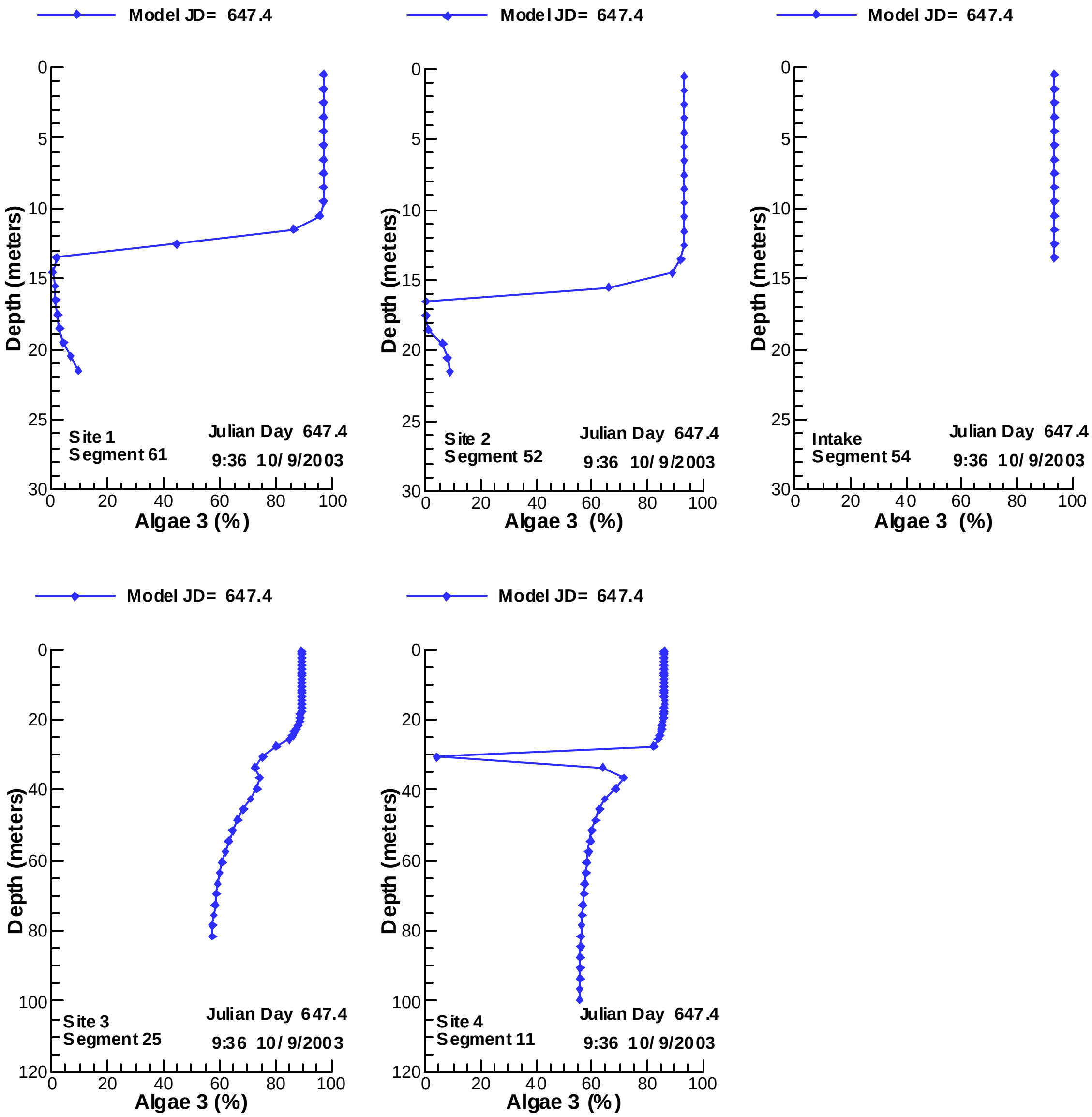

Figure 777. Vertical profiles of ALGAE 3 compared with data for 10/ 9/2003.

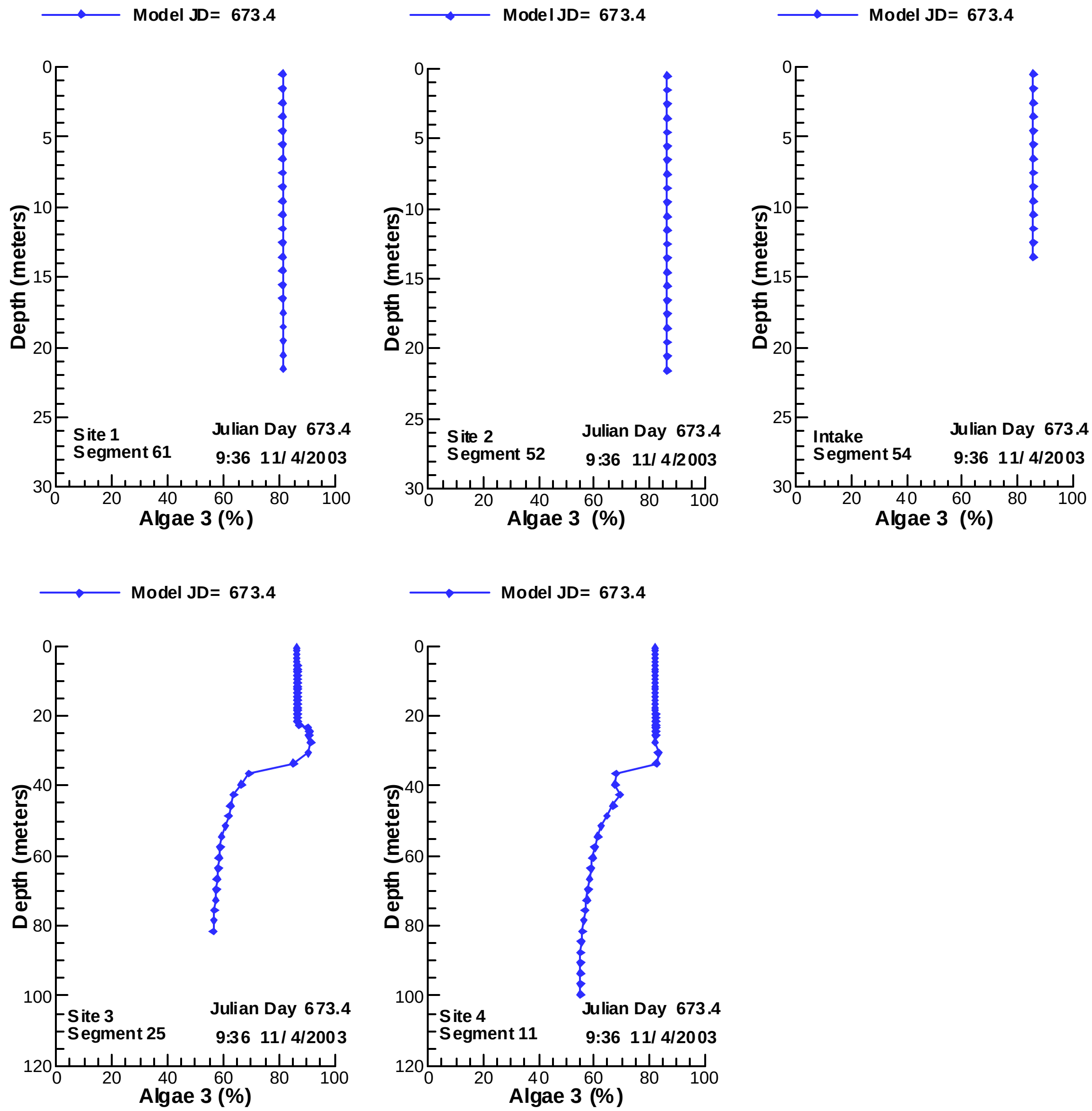

Figure 778. Vertical profiles of ALGAE 3 compared with data for 11/ 4/2003.

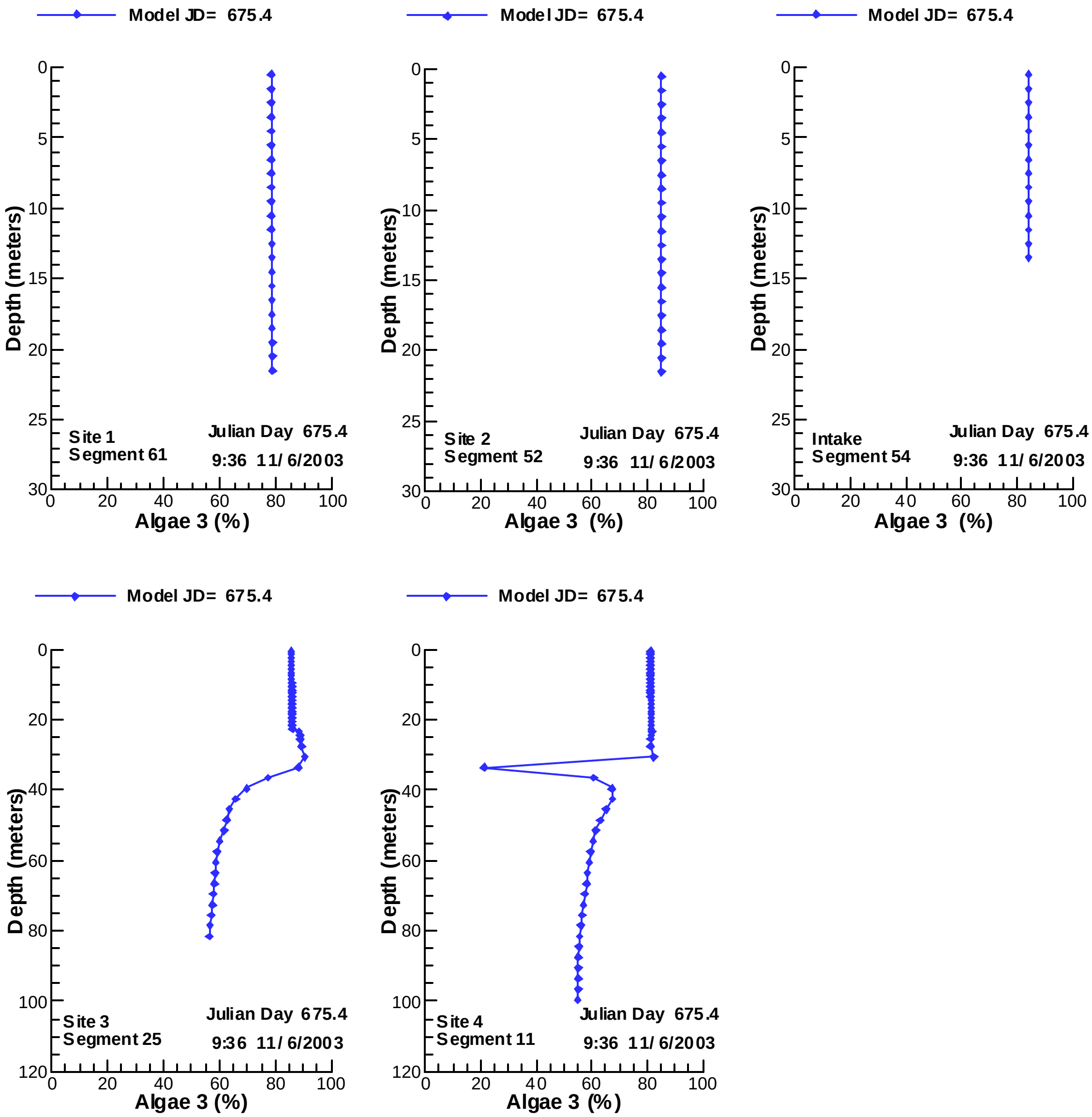

Figure 779. Vertical profiles of ALGAE 3 compared with data for 11/ 6/2003.

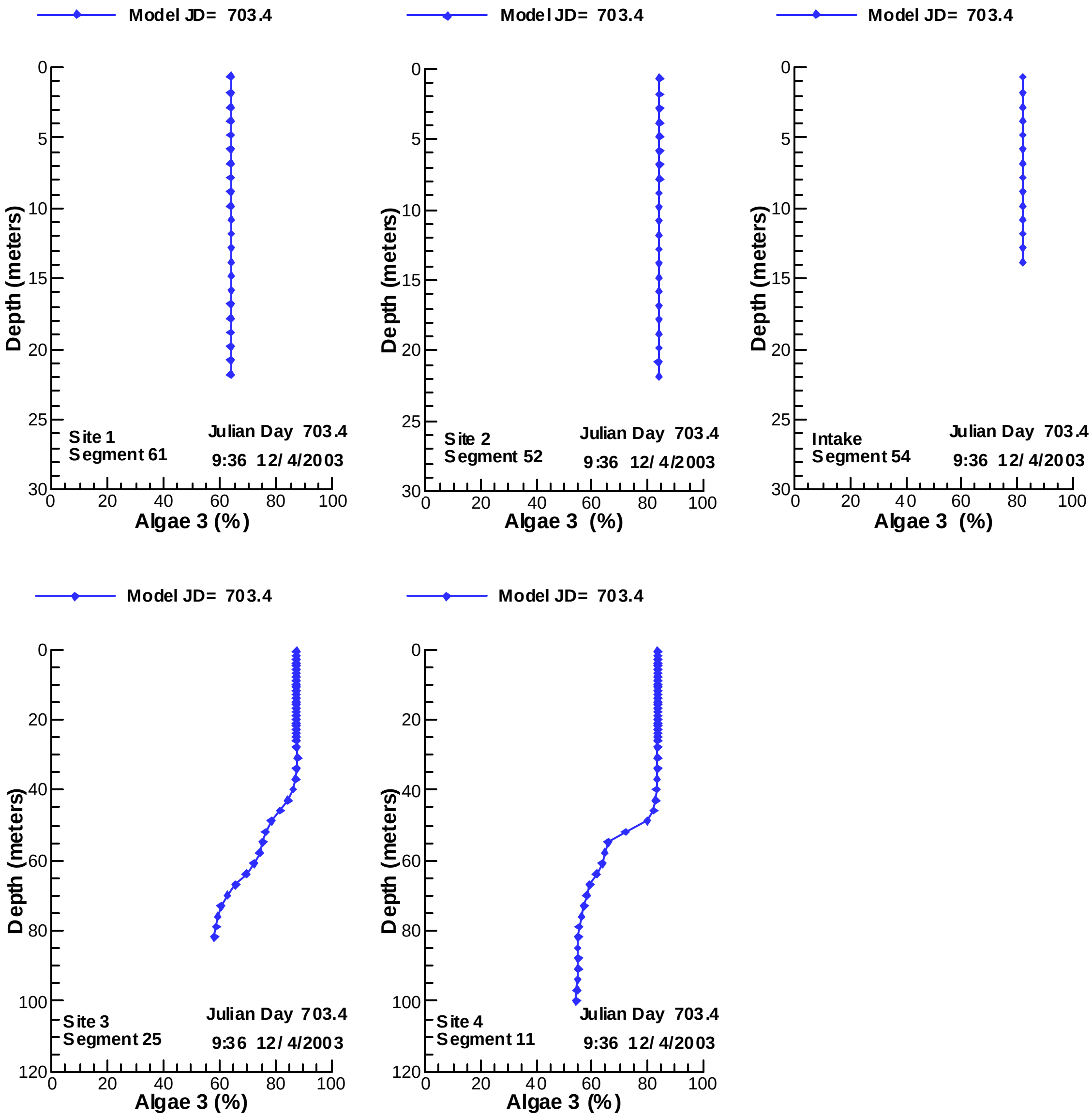

Figure 780. Vertical profiles of ALGAE 3 compared with data for 12/ 4/2003.

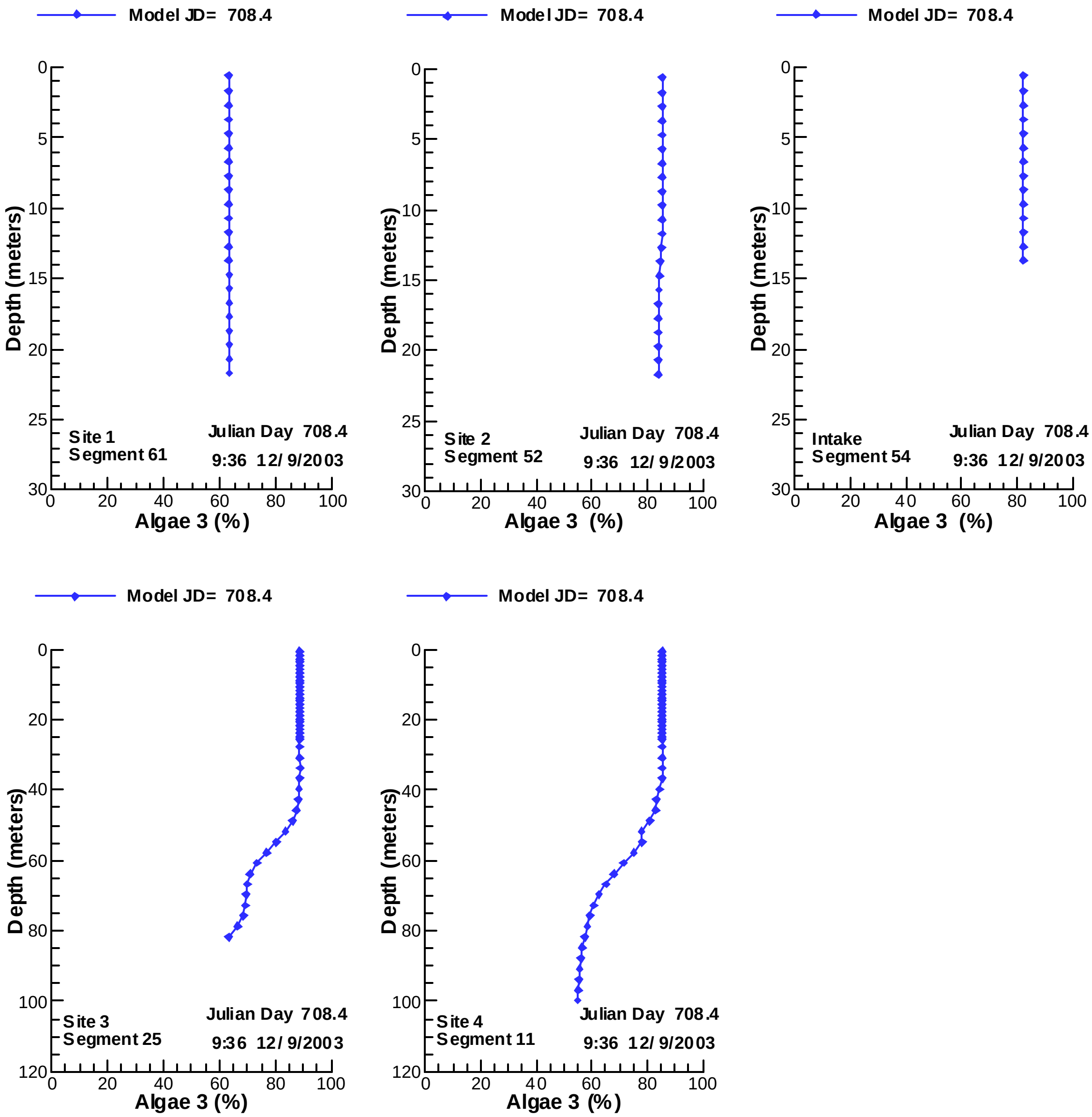

Figure 781. Vertical profiles of ALGAE 3 compared with data for 12/ 9/2003.

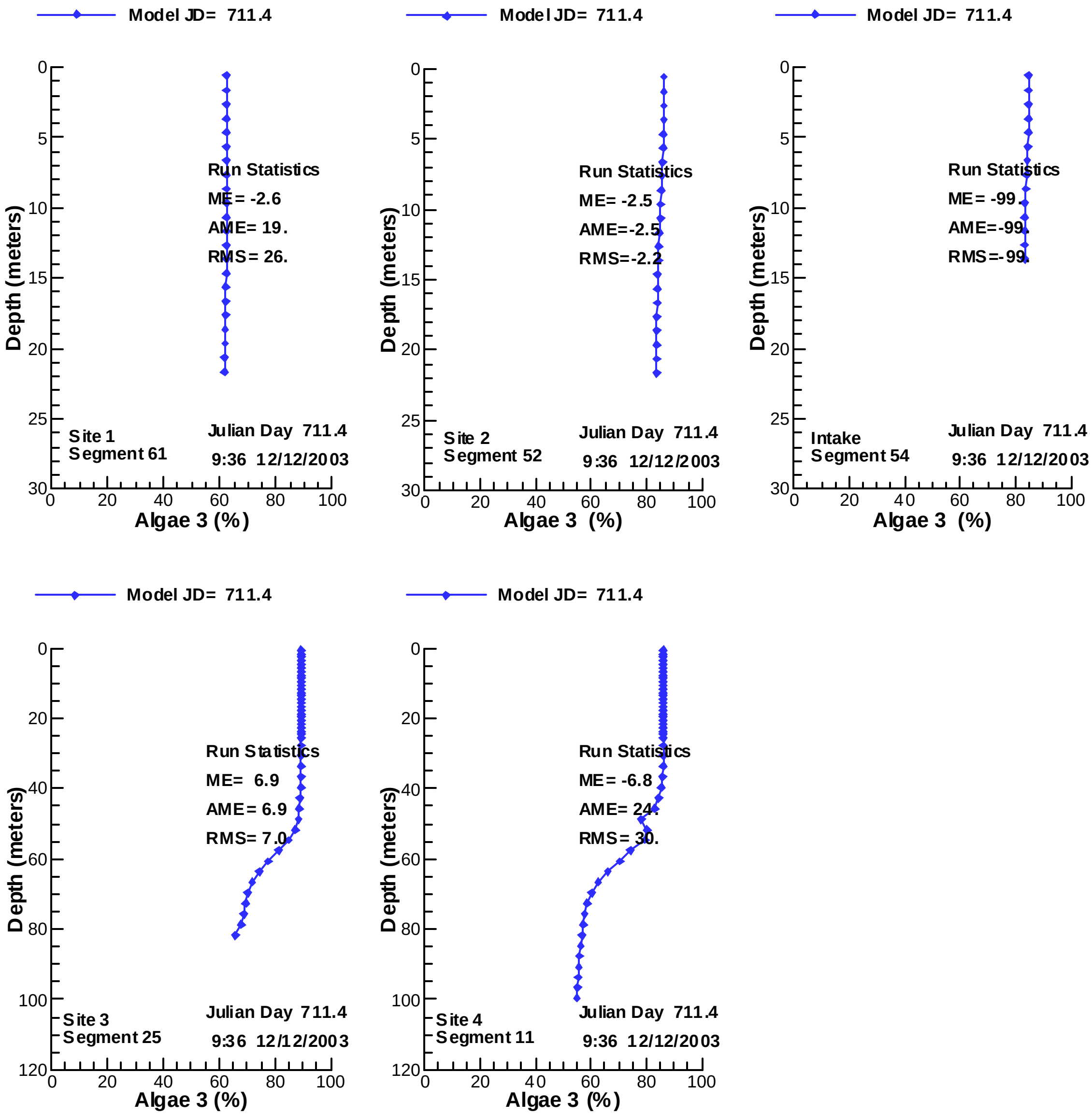

Figure 782. Vertical profiles of ALGAE 3 compared with data for 12/12/2003.